Summary and Proceedings of the Asia-Pacific International Workshop on Industrial Ecology

Sustainable Management with Environmental Innovation, Symbiosis between Theory and Practice

**DATE**: December 8th (Mon.) - 9th (Tue.), 2008

**VENUE**: Institute of Industrial Promotion Kawasaki
(66-20 Horikawa-cho, Saiwai-ku, Kawasaki City, JAPAN)

**Organized by**: International Society for Industrial Ecology
Tsinghua University, China
National Institute for Environmental Studies, Japan (NIES)
Kawasaki City, Japan

**Supported by**: China Ministry of Environmental Protection Key Laboratory of Eco-industry, China
Chinese Research Academy of Environmental Sciences, China
Institute for Global Environmental Strategies (IGES), Japan
Ministry of the Environment, Japan
Center for Regional Industrial Symbiosis Research, Toyo University (CRIS), Japan
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PROGRAM

December 7th, 2008

SESSION 1: Progress of Industrial Ecology in the Asia Pacific Region

Industrial ecology, industrial symbiosis and eco-industrial parks
Prof. Raymond COTE (Dalhousie University)

Progress in industrial ecology studies, networks and policy applications · Experiences of material flow analysis in Japan and beyond –
Dr. Yuichi MORIGUCHI (NIES)

Panel Discussion
Chair: Prof. Keisuke. HANAKI (The University of Tokyo)
Panelists:
Prof. Raymond COTE (Dalhousie University)
Prof. Sangwon SUH (University of Minnesota)
Prof. Dr. Yuichi MORIGUCHI (NIES)
Prof. GENG, Yong (CAS)
Moderator: Prof. Tsuyoshi FUJITA (NIES, Toyo University)

SESSION 2: Material and Energy Flow Analysis and Industrial Ecology

The Study of Metal Cycles in China
Prof. LU, Zhongwu (Northeastern University)

WIO-MFA and its application to measure the weight and composition of industrial capital stock
Prof. Yasushi KONDO (Waseda University)

Material flow and management of E-waste in Japan and other Asia
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Experiences from a decade of material flow research in the Asia-Pacific region
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SESSION 3: Circular Economy Policy and Socio-economic Systems of Industrial Ecology

Industrial Waste Water Treatment by A Sewerage System · An Experience of Osaka City ·
Prof. Ryo FUJIKURA (Hosei University)

Circular Economy in China – Characteristics, Legislation & Policy System and the Pilot Implementing Scheme in Tianjin
Prof. SHI, Lei (Tsinghua University)

Eco-industrial clusters: Enhancing regional economic development through environmental linkages
Dr. Venkatachalam ANBUMOZHI (IGES)

Urban simulation system to integrate circular economy and low-carbon city
Prof. Tsuyoshi FUJITA (NIES, Toyo University)

December 8th, 2008

SESSION 4: Eco Industrial Parks as an Emerging Practice in Industrial Ecology

Comparative Assessment of Industrial Symbioses in Practice
Dr. Rene Van Berkel (IAS/United Nations University)

Environmental Problems and Eco-industry Approach in Industrial Parks in China
Prof. SUN, Qihong (CRAES)

Progress and Evaluation of Kitakyushu EIP as a Resource Recovery Model
Prof. Toru MATSUMOTO (Kitakyushu University)

Industrial symbiotic practices and analysis in Kwinana EIP, Australia
Dr. Michele John (Curtin University)

SESSION 5: Closing Session
Workshop Summary

The Asia-Pacific International Workshop on Industrial Ecology was held on December 8th and 9th, 2008, in Kawasaki, Japan. The workshop included discussions on the development of theories and practices of industrial ecology (IE), mainly focusing on the Asia-Pacific region. The workshop was the first regional meeting organized for the International Society for Industrial Ecology following a proposal put forward during the ISIE 2007 Conference in Toronto. The workshop was attended by more than 100 international participants and included researchers, experts and practitioners in both the public and private sectors.

The workshop commenced with opening remarks by the representatives from the organizing institutions: the International Society for Industrial Ecology, Tsinghua University of China, the National Institute for Environmental Studies of Japan, and the City of Kawasaki. Keynote speeches were delivered by Prof. Raymond Cote, *Industrial ecology, industrial symbiosis and eco-industrial parks* and Dr. Yuichi Moriguchi, *Progress in industrial ecology studies, networks and policy applications - Experiences of material flow analysis in Japan and beyond*. The two keynote speeches were followed by a panel discussion on the progress and challenges of IE in the Asia-Pacific region. The panel discussion highlighted the importance of the Asia-Pacific region as being an arena in which IE would play central roles in improving existing industrial and social systems. It also identified challenges such as an unstable financial situation, limited available information and changing regulation that could hamper IE applications.

In Sessions 2, 3 and 4, twelve speakers who have been engaged in research or in the practices of IE in the Asia Pacific region delivered presentations and four discussants made comments on these presentations. Session 2 “*Material and Energy Flow Analysis and Industrial Ecology*” focused on macroscopic approaches, theories, methodologies and practices of IE. In this session, the characteristics of dynamic modeling such as differential equations, and static analysis such as MFA, were discussed as a means of describing the flow of materials. Future development of material flow modeling envisaged in this session included 1) linking material accounting to stock accounting, 2) combination of MFA, IOA and LCA. International trade of recyclables vs. relocation of Eco-towns or transfer of recycling technology was also an issue that would need to be dealt with in the Asia-Pacific region. Session 3 “*Circular Economy Policy and Socio-economic Systems of Industrial Ecology*” focused on socio-economic methodologies and policy applications of IE. This session clarified that differences in environmental regulations and dynamics among the various jurisdictions were uncertainties for EIP/EIC planning; these might be dealt with by utilizing a scientific database and models if properly disaggregated. The role of government and markets for location/relocation of eco-industrial park (EIP)/clusters (EIC) were also discussed in this session based on experiences in China, India and Japan. In Session 4 “*Eco Industrial Parks as an Emerging Practice in Industrial Ecology*”, case studies from Australia, China and Japan revealed the complexities of exchange networks for materials, energy and water, which too often make comparative assessment of performance of EIPs difficult. Participants agreed on the importance of assessment, for example of the economic benefits and efficiency indicators, of different EIPs.
The final session summarized the discussions and opinions exchanged during the workshop. As well, actions anticipated for further developments of IE research and for applications in the region were explored. There was shared anticipation for actions such as the development of a firmer societal basis for knowledge platforms, networks and systems for the institutionalization of IE. Organizing a regional chapter of ISIE that would involve researchers and practitioners from many Asia-Pacific countries was a strategy expected to encourage such actions. Given the growing importance of the Asia-Pacific region in the field of IE, this workshop might be a watershed meeting in the history of ISIE for future developments of networks of researchers and practitioners in the Asia-Pacific region.
Industrial ecology, industrial symbiosis and eco-industrial parks

Raymond P. Cote
Professor Emeritus and Senior Fellow
Eco-Efficiency Centre, Faculty of Management
Dalhousie University
Halifax, Canada

Keywords: Industrial ecology, ecological concepts, industrial symbiosis, eco-industrial parks

ABSTRACT

Industrial ecology, as a scientific field, is still in a developmental stage but is growing rapidly and beginning to influence thinking about industrialization. The key subject matter encompassed by the field has been identified in the Journal of Industrial Ecology, among other sources. Two of these subjects are industrial symbiosis and eco-industrial parks. The presentation emphasizes that these are not synonymous concepts although symbioses are important functions in creating eco-industrial parks. The latter, in the view of the author, takes a systemic approach involving site design, sustainable infrastructure, green buildings, eco-efficient production as well as industrial symbiosis with by-products. The paper concludes with a call to reach agreement on terminology.

This presentation will provide some background on the field of ecology as a preamble to a discussion of industrial symbiosis and eco-industrial parks. The presentation begins with some definitions of industrial ecology taken from the literature. These definitions reflect the different perspective on this new field. It then discusses the relevance to ecology and the importance of an ecological perspective.

The presentation argues that the state of the planet resulting from the first industrial revolution provides evidence of the need for a new industrial revolution as proposed by McDonough and Braungart (2002) among others. Industrial ecology has been proposed as one approach to the study of an ecologically sustainable industrial system. The point is made that in fact, the concepts that underlie the field have been with us for a long time. The attributes of the field of industrial ecology and some of the central topics covered by the Journal during the past ten years are presented.

Industrial symbiosis, as one of the main strategies and areas of study, is then discussed, in part to differentiate it from eco-industrial parks. The significance of the quote from Frosch and Gallopoulos (1989)

“an industrial system...where the consumption of energy and materials is optimized and the effluents of one process... serve as the raw materials for another process”

as part of the reason for the current confusion is noted. Some of the important examples including Kalundborg, Denmark and Kwinana, Australia are briefly presented so that participants are made aware of different models.

The presentation makes the case that industrial symbiosis is only one of many strategies available to optimize the consumption of materials and energy. Furthermore, industrial symbiosis is only of several strategies for creating eco-industrial parks. Paraphrasing a quote from Senge et al (2008) in a new book The Necessary Revolution, I argue that the mere use of wastes from one industry as inputs for another would not be enough to consider that the various symbiotic exchanges are an eco-industrial park. One has to think about the whole system: the land, the water, the energy, the infrastructure, the buildings, the processes, etc. “The systems view is vital and very different from simply reducing adverse environmental impacts.”

Other strategies discussed include:

• Encouraging resource recovery in which wastes are segregated for ease of recovery and recycled into other materials or products;
• fostering scavenger and decomposer businesses which can take advantage of varying quantities and values of materials and create re-use, recovery, rental, repair, remanufacturing, reclamation and recycling businesses;
• encouraging ‘food webs” in which materials are recovered, re-used or recycled at different levels of consumption in an industrial park.

But, in my view, eco-industrial parks are more than this. It is not only about recovering, re-using and recycling material through symbioses. As mentioned earlier, the whole system has to be designed to reduce the ecological footprint of the park and conserve valuable natural resources. Therefore other strategies must address the site; the infrastructure for energy, water, wastewater and transportation; the buildings; the production and manufacturing processes; the products themselves and finally the recovery and re-use of by-products or wastes.

The paper notes that there are a variety of tools and
techniques for assisting in the design and operation of eco-industrial parks including industrial symbiosis; industrial metabolism; supply chain and web management; flexible manufacturing networks; service rather than product; ecological planning; ecological design; eco-efficiency and social networking. However, not all of these are usually considered within the realm of industrial ecology.

The field of industrial ecology is still somewhat in a developmental phase. It is still looking for a solid philosophical foundation. Two of the key questions are whether
1) it is a sub-field of the science of ecology, scientific in nature and attempting to understand and describe the relationship between industrial and natural systems or
2) it also encompasses research into ways of controlling and managing that relationship, involving political, economic, legal and other disciplines?

Finally it is critical that we have a common terminology.

References


Author’s information:
Raymond Cote is Professor Emeritus in the Faculty of Management and Senior Fellow of the Eco-Efficiency Centre at Dalhousie University. He is a pioneer in the development of eco-industrial parks having led a multi-disciplinary to publish the first report on Designing and Operating Industrial Parks as Ecosystems in 1994. He has also served as an advisor to UNEP on environmental management of industrial parks.
Progress in industrial ecology studies, networks and policy applications
- Experiences of material flow analysis in Japan and beyond -

Yuichi Moriguchi
Director, Research Center for Material Cycles and Waste Management
National Institute for Environmental Studies
16-2 Onogawa Tsukuba Ibaraki, 305-8506, Japan
moriguti@nies.go.jp

Keywords: Industrial ecology, Material flow analysis, Indicator, 3R (Reduce, Reuse, Recycle)

ABSTRACT
Though the term industrial ecology is not widely used in Japan, a lot of studies and practical efforts have been undertaken in Japan. This presentation focuses on Material Flow Analysis, one of the key tools of industrial ecology, and reviews progress in MFA studies and its application to waste management and 3R (Reduce, Reuse, Recycle) policies. Economy-wide material flow studies have been undertaken by international joint effort since late 1990s and they led to the adoption of material flow indicators with their numerical target in Japanese Fundamental Plan for Establishing a Sound Material-Cycle Society. Inside structure can be analyzed by decomposing national economy into economic sectors applying economic input-output analysis. Remarkable progress in MFA has been made during the last decade, and institutionalization of experts was successful. Two-way interaction between methodological progress and policy needs is essential.

INTRODUCTION
The term Industrial Ecology itself is not very widely used, nor precisely understood in Japan. Nevertheless, a lot of studies and practical efforts have been undertaken in related fields not only by researchers in universities and public research institutes but also by practitioners in industries, and these activities have been expanded rapidly. The International Conference on EcoBalance held in Japan biennially since 1994 is one of the key events to build a network of researchers, experts and practitioners in the field of life cycle approaches. “Symbiosis” with other events such as those for eco-products and eco-design is being attempted. Japanese initiatives such as Eco-town and Zero-emission are closely related to industrial ecology, in particular to eco-industrial parks. Education and research in Japan under the title “environmental system research” often cover topics of industrial ecology. This presentation focuses on the recent progress of studies in Material Flow Analysis (MFA), which is one of the key topics of industrial ecology, with particular attention to its relevance to waste management and 3R (Reduce, Reuse Recycle) policies[1].

BACKGROUND OF MATERIAL FLOW STUDIES
Nowadays, industrialized economies extract huge amount of natural resources from the earth to produce various goods and services and to build infrastructure. Thus they support our wealthy and convenient life. On the other hand, materials after use are dumped not only as solid waste and wastewater, but also as gaseous wastes, typically CO₂ emitted to the atmosphere. The global environment is finite both as recipient of waste and as supplier of resources. Development of mass production and mass consumption has led to increasing volume and diversified quality of solid wastes, which caused various problems. We suffered from the shortage of landfill, and it became more difficult to locate waste treatment facilities. Large-scale illegal dumping episodes also took place. Such situation made waste management cost higher. We recognized the importance of the prevention of environmental pollution by waste treatment, and the needs for the prevention of waste generation itself.

By taking policy measures, remarkable emission reduction of harmful pollutant such as Dioxins and significant reduction of landfill were accomplished. However, total amount of solid waste has not yet been reduced. We should be aware that extraction of resources, which support mass production of products also gives environmental impacts. In particular, Japan depends highly on imported natural resources, which potentially and indirectly affect to ecosystem of other countries far away. Moreover, throughout the whole lifecycle of products, we consume energy and material resources and emit environmental burdens. It is important to improve energy and resource efficiency to reduce environmental burdens over the entire lifecycle. To react to such situation, we are trying to make a transition from socio-economic system characterized by mass-production, mass-consumption and mass-disposal, to a sound material-cycle society, by taking 3Rs action. The concept behind 3Rs such as closing loop and circular use is often used with a metaphor to eco-system, which is essential in industrial ecology.
INTERACTIONS; RESEARCH AND POLICY, JAPANESE AND INTERNATIONAL ACTIVITIES

Economy-wide material balance of Japan has been published on White Paper since 1992 and its English translation attracted the attention of European researchers. A workshop of sustainable development indicators organized at Wuppertal Institute in 1995 was the trigger to initiate international joint study on nation-wide material flows. Results from the joint study were published by the World Resources Institute (WRI) in 1997 and in 2000. In the latter half of 1990’s, research networks of MFA have expanded mainly by ConAccount meetings. A few years later, the first Gordon Research Conference on Industrial Ecology was organized and this led to the establishment of International Society for Industrial Ecology (ISIE).

In the year 2000, Fundamental Law for establishing a sound material cycle society was enacted in Japan. Since then, policy application of material flow analysis has become active. In-parallel, inter-governmental organizations in the field of environmental policy and environmental statistics such as OECD and EUROSTAT have also strengthened their activities for MFA. OECD adopted council recommendations on material flows and resource productivity twice in 2004 and 2008. Two-ways interactions between research and policy, and between Japan and international activities were successful. Industrial ecologists have significantly contributed to this process.

TARGET SETTING USING ECONOMY-WIDE MATERIAL FLOW INDICATORS

First trial by WRI’s joint study was to quantify overall physical size of our economy, by measuring all inputs of resources to the economy and all outputs of wastes and pollutants from the economy. Even such a very basic framework is useful to capture overall picture of our economy. Comparison of material balance of Japan in 2000 and 2005 indicates that domestic extraction of resources have significantly decreased and our dependency on imported natural resources is about half in physical weight. Such economy-wide material flow indicators have been used in policy performance review. The Fundamental Plan for Establishing a Sound Material-cycle Society was adopted by Cabinet decision in March 2003, and this plan adopted indicators and numerical targets of macroscopic material flows. Material flows are captured at three cross sections, first, input of new resources, second, cyclical use of resources, and third, output of solid wastes going to landfill. Quantitative targets were set for 2010 as compared to 2000, and good trends towards these targets have been observed. In April 2008, the government revised the plan and a new set of targets for the year 2015 was adopted.

TOOLS FOR FURTHER ANALYSIS

However, these economy-wide indicators tell little about why these numbers have changed and how to improve these indicators. In this context, analysis of inside structure of our national economy is essential. Inside structure can be analyzed by decomposing national economy into economic sectors or putting focus on specific regions and municipalities. For this purpose, application of economic Input-Output analysis is quite useful and powerful. Usual economy I-O tables account for inputs and outputs of each sector by monetary unit, but this does not cover valueless output of residues such as emissions and solid wastes. Physical description of inflows and outflows ensuring mass balance is ultimate goal of this kind of analysis. OECD recently compiled guidance documents of MFA, which include a chart which showed positioning and role of different tools of MFA, from macro economy-wide MF analysis to microscopic tools such as Life Cycle Assessment.

Needless to say, material cycles within our socio-economic system should be understood as a sub-system of larger material cycle of natural environment. Positioning of industrial material cycle into natural ecosystem is the fundamental viewpoint of industrial ecology. How material flows between socio-economic system and natural environmental system cause the environmental damages is main focus of environmental science. Traditionally in environmental issues, we have been eliminating the use and emission of specific harmful substances. This scheme, what we call de-toxification is very important. But, in addition to that, we have to accomplish dematerialization. The issue of solid waste management is directly linked to both of these schemes.

CONCLUSION

Remarkable progress in MFA studies has been made during the last decade, and institutionalization of experts was successful. Two-ways interaction between methodological progress and policy needs is essential. Further international joint efforts are necessary, in particular, outside of OECD countries, e.g., with China and other BRICS countries. The follwing is a phrase of chair’s conclusion from OECD-UNEP conference for resource efficiency in April 2008, which reads that; The different concepts and approaches are converging: 3R, Sound material-cycle society, Circular economy, Integrated or sustainable waste management, Sustainable consumption & production, Life-cycle management, Sustainable materials or resource management all aim at similar objectives and require similar action by the various stakeholders. Definitely, contribution of industrial ecology studies is increasingly anticipated.

Reference

The Study of Metal Cycles in China

LU Zhongwu, YUE Qiang
SEPA Key Laboratory on Industrial Ecology, School of Materials and Metallurgy
Northeastern University, Shenyang, Liaoning, China 110004

Keywords: model of Fe-flow in the life cycle of steel product, steel scrap index, iron ore index, iron loss index, variation of steel output

ABSTRACT

A model of Fe-flow in the life cycle of steel product was put forward and analyzed. Three important resource and environmental indicators for Fe-flow analysis, that is, steel scrap index, iron ore index and iron loss index were derived from this model. Illustrative examples, demonstrating the influence of the variation of steel output on steel scrap index and iron ore index, were given. Case studies for estimating the values of steel scrap index of Japan, China and USA in the period of 1988-1997 were carried out. It was clarified that the main reason of severe deficiency in steel scraps for China’s steel industry was its continued rapid growth. The study of iron, copper and lead cycles in China was carried out successfully according to this model.

EXPLORATION OF THE MODEL AND INDICATORS FOR FE-FLOW ANALYSIS

The model of Fe-flow in the life cycle of steel product

Fig. 1 shows the model of Fe-flow in the life cycle of steel product in a nation, which we explored for studying the scrap resource problem of steel industry.

The year of interest is designated as the year \( \tau \), during which the annual output of steel of the nation is \( P_\tau \), t/a. The span of a product life cycle is assumed to be \( \Delta \tau \) years. In the year \((\tau - \Delta \tau)\), the annual output of steel of the nation is \( P_{\tau - \Delta \tau} \), t/a. The import and export of steel scraps, products and goods are not taken into consideration in the model.

Resource and environmental indicators for Fe-flow analysis

Steel scrap index

\[
S_\tau = \alpha \frac{P_\tau - P_{\tau - \Delta \tau}}{P_\tau} + \beta
\]  

Iron ore index

\[
R_\tau = 1 - \alpha \frac{P_{\tau - \Delta \tau}}{P_\tau} - \beta + \gamma
\]  

Iron loss index

\[
Q = 1 - \alpha - \beta + \gamma
\]  

STUDY OF SCRAP RESOURCES FOR STEEL INDUSTRY

(1) In case of increasing steel production, the scrap resource for steel industry is relatively deficient, and the more rapid the increase, the more is the deficiency.

In case of decreasing steel production, the scrap resource for steel industry is relatively rich, and the more rapid the decrease, the more is the richness.

The case of constant steel production is situated between the above two cases.

(2) The continued rapid growth of China’s steel output is the main reason of severe deficiency in scrap resources for its steel industry. It is inadvisable and unfeasible for China to lay stress on scrap-based steelmaking process, so long as its steel production is increasing rapidly (Tab. 1).
CONCLUDING REMARKS

(1) Continued rapid growth of metal production has been one of the most important characteristics of China’s metal industry, to which attention should be paid in studying the resource and environmental issues of China’s metal industry and metal system.

(2) The model of Fe-flow in the life cycle of steel product (Fig.1) clearly shows the variation of steel output with time. Therefore, the scrap resource issues for steel industry were studied successfully by using the model.

(3) The study of iron, copper, zinc and lead cycles in China was carried out according to the model shown in Fig.1. Thus, an alternative method of SFA was put forward and formulated.

Tab.1 Estimated values of steel scrap indexes for Japan, PR China and USA

<table>
<thead>
<tr>
<th>year</th>
<th>Japan</th>
<th>PR China</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1988</td>
<td>0.3400</td>
<td>0.1820</td>
<td>0.7514</td>
</tr>
<tr>
<td>1989</td>
<td>0.3638</td>
<td>0.1996</td>
<td>0.7580</td>
</tr>
<tr>
<td>1990</td>
<td>0.3793</td>
<td>0.2039</td>
<td>0.7346</td>
</tr>
<tr>
<td>1991</td>
<td>0.3766</td>
<td>0.1976</td>
<td>0.7823</td>
</tr>
<tr>
<td>1992</td>
<td>0.3980</td>
<td>0.1924</td>
<td>0.7390</td>
</tr>
<tr>
<td>1993</td>
<td>0.3838</td>
<td>0.1895</td>
<td>0.7472</td>
</tr>
<tr>
<td>1994</td>
<td>0.3852</td>
<td>0.1922</td>
<td>0.7298</td>
</tr>
<tr>
<td>1995</td>
<td>0.3763</td>
<td>0.1080</td>
<td>0.6321</td>
</tr>
<tr>
<td>1996</td>
<td>0.3967</td>
<td>0.0970</td>
<td>0.5627</td>
</tr>
<tr>
<td>1997</td>
<td>0.4133</td>
<td>0.0830</td>
<td>0.5767</td>
</tr>
</tbody>
</table>

STUDY OF COPPER CYCLE IN CHINA

The result of copper cycle based on the model described in this paper will be given below.

Fig.2 shows the copper cycle in China in 2005.

The calculated values of copper ore index R and copper scrap index S were 0.77 t/t and 0.29 t/t (including 0.60 Mt of imported copper scraps) in China in 2005, respectively. It means that the dependence of copper industry on copper ore was very high. It is the consequence of continued rapid growth of copper output. China’s copper industry was obliged to operate mainly on copper ore. In addition, the value of copper loss index Q was high (0.63 t/t), which was closely related to the high dependence of copper industry on copper ore.

The problems and challenges in iron, zinc and lead cycles were similar to that in copper cycle as just mentioned.

Fig.2 The copper cycle in China in 2005 (unit: Mt)

I — Production ; II — Fabrication & Manufacture ; III — Use ; IV — Waste Recovery
WIO-MFA and Its Application to Measure the Weight and Composition of Industrial Capital Stock

Yasushi Kondo*1, Kenichi Nakajima2, Kazuyo Matsubae-Yokoyama3, Shinichiro Nakamura1
1Faculty of Political Science and Economics, Waseda University
1-6-1 Nishi-waseda, Shinjuku-ku, Tokyo, 169-8050 Japan
2Research Center for Material Cycles and Waste Management, National Institute for Environmental Studies
16-2 Onogawa, Tsukuba, Ibaraki, 305-8506 Japan
3Graduate School of Environmental Studies, Tohoku University
6-6-11-1004 Aoba, Aramaki, Aoba-ku, Sendai, Miyagi, 980-8579 Japan
*Corresponding author: ykondo@waseda.jp

Keywords: Waste input-output, Material flow analysis, Capital stock, Material composition

ABSTRACT

The operation of an economy is supported by the stock of materials in the form of durables and infrastructure such as machinery, equipment, buildings, and structures. This paper proposes a new method for measuring the stock of long-lived durables and infrastructure in terms of the mass of its materials based on the WIO-MFA method and the capital formation matrix, which is a supplementary table of the input-output table. The method is applied to the Japanese input-output data with 400 sectors, 9 types of metals and 8 types of plastics occurring as materials. It was found that substantial variations exist among sectors while fixed capital formation in year 2000 weighs 518kg per million Japanese yen on average in metals and plastics.

OBJECTIVE

The operation of an economy is supported by the stock of materials in the form of durables and infrastructure such as machinery, equipment, buildings, and structures. In the literature of economics, the amount of durables and infrastructure or “capital stock” in the economy at time $t$, say $K(t)$, is usually measured in monetary terms based on the data on capital expenditure, say, \(\{I(t), I(t-1), I(t-2), K, \ldots\}\), some estimates of the rate of depreciation $d$, and the initial value $K(0)$:

$$K(t) = I(t) + (1 - d)K(t - 1).$$

In spite of its wide use by economists, this measure of “capital stock” is of very limited use for sustainable management of material stock because of its neglect of physical properties such as the mass and material composition. For the purpose of sustainable management of physical stocks in the economy, the traditional measure based on monetary terms used by economists will not be adequate.

This paper proposes a new method for measuring the stock of long-lived durables and infrastructure in terms of the mass of its materials. This method is based on the WIO-MFA (waste input-output material flow analysis) method [1, 2]. Different industry sectors will be characterized by different configuration of durables. In addition, while capital stock in monetary terms is not able to consider physical differences among its vintages due to differences in the technologies embodied, a simple mass of capital stock neglecting its composition will suffer from a similar problem. We therefore distinguish $I(t)$ by sectors and by its composition, as well. This is facilitated by use of the capital formation matrix that is one of the supplementary tables of the input-output table (IOT) [3].

The method is applied to the Japanese input-output data with 400 sectors, 9 types of metals and 8 types of plastics occurring as materials. It was found that substantial variations exist among sectors while fixed capital formation in year 2000 weighs 518kg per million Japanese yen on average in metals and plastics.

THE METHOD

Waste Input-Output Material Flow Analysis

WIO-MFA provides a framework to analyze how much amount of material exists, and flows in what form, and to which destination. By using the WIO-MFA model, a monetary input-output table (MIOT) can easily be converted into a physical input-output table (PIOT), or a physical material flow account of an arbitrary number of materials, and the material composition of a product can be decomposed into its origin. The material composition matrix at time $t$, say $C(t)$, that is one of key components of WIO-MFA is derived by exploiting the triangular nature of the matrix of input coefficients, which is obtained by rearranging the ordering of sectors according to degrees of fabrication (See Fukui [4] and references therein for details of triangularization of IOTs).

The $(i,j)$-component $C_{ij}(t)$ of the material
composition matrix \( C(t) \) gives the amount of material \( i \) that is contained in a unit of product \( j \). If all the materials are measured in a common mass unit, say kilograms, then \( c_{ij}(t) = \sum C_{ij}(t) \) gives the weight of a unit of product \( j \) in kilogram, that is, the sum of all the materials that are contained in a product, where the unit of \( j \) can be physical or monetary.

**Capital Formation Matrix**

A capital formation matrix at time \( t \), say \( B(t) \), which is one of the supplementary tables of IOT, gives the monetary amount of capital formation, or investment, distinguished by sectors and by its composition. The \((i, j)\)-component \( B_{ij}(t) \) of the capital formation matrix \( B(t) \) gives the amount of expenditure that industry \( j \) invests in durable goods \( i \). A summary of the Japanese capital formation matrix for year 2000 is shown in Fig. 1, where the original matrix with 517 goods and 109 industry sectors is consolidated to the one with 10 goods and 17 industry sectors. Substantial differences in the content of capital formation exist among investing sectors. In ‘Financial, insurance and real estate’, the overwhelming part goes to ‘Building construction’. ‘Public construction’ occupies the largest share in ‘Agriculture, forestry and fishery’, ‘Electricity, gas, heat and water supply and waste management services’ (hereafter, ‘EGHW supply and WM services’) and ‘Transport’. ‘Precision instruments’ goes mostly to ‘Medical service and social security’.

**RESULTS**

The method explained in the previous section is applied to the Japanese input-output data with 400 sectors, 9 types of metals (iron, ferroalloy, copper, zinc, lead, tin, aluminum, silver, and gold) and 8 types of plastics (thermo-setting resins, PE (low), PE (high), PS, PP, PVC, high-performance resins, and other resins) occurring as materials. The material composition \( C(t)B(t) \) of capital formation is shown in Fig. 2. Of the materials considered, iron occupies the largest share, 89%. Sectors with large investment expenditure tend to be a large investor in terms of mass as well. There are exceptions, however. For instance, ‘Transport’ invests less than ‘EGHW supply and WM services’ in money terms, but more in mass; ‘Medical service and social security’ invests more than ‘Education and research’ in money terms, but less in mass.

These reverse relationships can be explained by investigating the mass of capital formation per investment expenditure. It was found that one million Japanese yen (JPY) of ‘Transport’ is heavier than ‘EGHW supply and WM services’ by 37% and ‘Medical service and social security’ is lighter than ‘Education and research’ by 17%. Substantial variations exist among sectors. It was found that ‘Transport’ is the heaviest with 687kg per million JPY, and ‘Communication and broadcasting’ is the lightest with 374kg per million JPY while capital formation weighs 518kg in metals and plastics per million JPY on average in metals and plastics.

**REFERENCE**


Material flow and management of E-waste in Japan and other Asia

Atsushi Terazono
National Institute for Environmental Studies, Japan
16-2 Onogawa, Tsukuba, Japan
Email: terazono@nies.go.jp

Keywords: secondhand home appliances, material flow, export, invisible flow

ABSTRACT

The domestic generation of end-of-life electrical and electronic equipment (EEE), such as end-of-life home appliances and personal computers (PCs), is increasing in most Asian countries. We estimated the number of home appliances (CRT-TVs, air conditioners, refrigerators, washing machines) exported from Japan, using domestic material flow and trade statistics. Based on the domestic flow analysis, secondhand exports were estimated to be 4.6 million units in FY2005. Among four items, TV is the largest item with more than 2 million units. For other three items, trade statistics is considered to give underestimation. Hong Kong has been the major destination of secondhand TVs until 2006. Due to Hong Kong’s import control, however, the destination has been changed to other countries such as Vietnam. Inappropriate reuse and recycling of E-waste by informal sectors can easily occur in the “invisible flow”. To promote environmentally sound reuse and recycling procedures beyond the countries, international cooperation is needed to better understand material flow and to control inappropriate trade of secondhand EEE.

INTRODUCTION

The amount of domestic generation of end-of-life EEE, such as home appliances and PCs, is increasing in most Asian countries. International trade of secondhand products, parts, and other materials related to EEE is also expanding. Since E-waste is potentially economically valuable but also includes hazardous materials, it needs to be reused and recycled in an appropriate manner.

It is not easy to estimate and control the export of secondhand home appliances from developed countries. In this paper we tried to estimate the number of end-of-life EEE from Japan to other countries and discuss the current issues for environmentally sound management of E-waste.

ESTIMATION OF SECONDHAND HOME APPLIANCES EXPORT

Estimation from domestic flow in Japan

According to Japan’s Ministry of Economy, Trade, and Industry (METI) and Ministry of the Environment (MOE) [1], the number of end-of-life home appliances generated in FY2005 was estimated to be 22.87 million units, and about 50% of these were recovered and recycled by producers. The remaining flow is called “invisible flow,” which can be difficult to understand, but METI and MOE provide an overview of this invisible flow. Secondhand export for reuse accounts for the largest part of invisible flow—an estimated 5.94 million units (26%).

Taking the number of stored items into consideration, I adjusted the estimate from 22.87 million units to 21.29 million. I also reviewed the transaction route at the generation stage and took business users into consideration as well and recalculated the material flows (Fig. 1). With these changes, the estimated amount of secondhand home appliances exported decreased from 5.94 million units to 4.60 million units in FY2005, including 2.23 million TVs.

Estimation from trade statistics

In Japanese trade statistics, brand-new and secondhand EEE have not been differentiated until 2007.
(Since January 2008, the four home appliances is differentiated, according to whether packaging for retail sales exists.) We used the unit price method to estimate secondhand exports from the trade statistics, referring detailed unit price data by months and customs. In this method, a low-price item (tentatively, less than 7,000 JPY for each item) is defined as secondhand, and a higher-priced item are classified as brand new.

RESULT

The number of exported home appliances estimated using domestic flow (5.94 million units by METI and MOE, 4.60 million here) were larger than that from trade statistics (2.82 million units in FY 2006). Among the four appliances, the number of exported secondhand TVs was the greatest, with 2.19 million units in 2006. The estimation of secondhand TVs export, using the domestic flow and trade statistics methods, were relatively similar. But the estimation result using the trade statistics method were far lower than those from the domestic flow for the other three appliances. This difference may have resulted from the fact that trade statistics do not cover low-value cargo (less than 200,000 JPY for each HS code); this is probably true for the three items other than TVs.

DISCUSSION

Comparing two estimations methods for the number of secondhand home appliances exported, the results give similar figures for TVs. For other three items, the domestic flow analysis would be the probable result.

On the other hand, trade statistics is useful for identifying the destinations. Fig. 2 is a material flow of secondhand TVs from Japan for 2006 and 2007, estimated from trade statistics method. Japan’s exports of secondhand TVs have remained stable until 2006. The number of secondhand TVs exported from Japan to Hong Kong was 1.54 million units, or 70.2% of total exports from Japan in 2006.

According to the April 2006 “Advice on Import and Export of Used Electrical and Electronic Appliances Having Hazardous Components and Constituents” of Hong Kong, it stated that “In any case, it is advisable to avoid any unit with over 5 years from the date of manufacturing.”, and required sufficient individual protective packaging. Since there have been many cases of ships that have been sent back to Japan from Hong Kong containing secondhand TVs not in compliance with the above conditions, Japan’s METI and MOE strengthened the export controls in June 2007, providing notice to dealers of EEE and secondhand goods [2].

Consequently, exports of CRT TVs to Hong Kong decreased to 369,000 units in 2007, while it increased to 838,000 for Vietnam, 468,000 for the Philippines and 311,000 for China.

CONCLUSION

There are many invisible flows not only in domestic flow in Japan but also in the international trade of secondhand EEE in Asia. Inappropriate reuse and recycling of E-waste by informal sectors can easily occur in such “invisible flow”. To promote environmentally sound reuse and recycling procedures beyond the countries, international cooperation is needed to better understand material flow and to control inappropriate trade of secondhand EEE.

REFERENCES

Experiences from a Decade of Material Flow Research in the Asia-Pacific Region

Heinz Schandl
CSIRO Sustainable Ecosystems
GPO Box 284, ACT 2601, Canberra, Australia
heinz.schandl@csiro.au

ABSTRACT
Asian economies have become the main driver in global resource use because of the new growth dynamics of China, India and Russia. This has led to a new geography of production and consumption and has increased the pressure on resource endowments, ecosystems and the global climate. Information on the biophysical dimensions of Asian economic growth will be crucial to enable good governance and to guide a transition toward more sustainable Asian and global economic activities to establish low-carbon and environmentally friendly economies. Satellite accounts for material and energy flows to the System of National Accounts (SNA) have been established for some countries to provide aggregate indicators and detailed sectoral information to inform integrated economic-environmental policies. Research in Japan has been at the forefront of providing material flow data and indicators for use in policy planning, and has been instrumental for driving the international discussion around material flows and resource productivity measures at OECD and UNEP level. There has been some similar research in Australia but as yet it has led to very little political uptake. Most recently, material flow research has become important in the Chinese research community with increasing numbers of contributions to the international literature. The political recognition for this kind of research is also growing. This presentation discusses the role of Asia-Pacific economies in global resource use patterns and especially the growth dynamics of developing Asian economies and their resource use implications. It looks at how the growing importance of the Asia-Pacific region in global resource use has been reflected in material flow and resource productivity research.

INTRODUCTION
Natural resource use is now on the political agenda, and heatedly discussed among the wider public because pressure points including climate change, water and food availability, price surges for strategic raw materials, and peaking global oil supply are converging rapidly in an unprecedented manner. The current global patterns of production and consumption are hitting the real limits of global ecosystems. The global economy seems to be at a turning point where decisions are urgent while information is incomplete. For quite some time global resource use was driven by wealthy OECD economies. Today’s main drivers of resource use, however, are the rapidly developing economies, above all China and India. These countries, although still having a standard of living way below that of OECD countries, determine the global dynamic through their sheer size and the speed of their industrialization process. That has led to changing international markets for materials, volatile market prices and risks of supply disruptions. A new geography of supply and demand has emerged within only a decade.

In a recent study on global resource use Schandl and Eisenmenger (2006) showed that about half of the 50 thousand million tons of resources used on a global scale in the year 1999 have been extracted in the Asia-Pacific region. At the same time, the Asia-Pacific region is particularly diverse with regard to its resource use patterns and dynamics. It includes the rapid developing economies of China and India, industrialised OECD countries like Japan which are dependent on resource inputs, and Australia and New Zealand being resource exporting economies. The region includes oil exporting economies in central Asia, the transition economy of the Russian Federation, and small Pacific Island states. The metabolic profiles found in the region differ widely, ranging from Domestic Material Consumption of between 30-40 tonnes per capita in Australia and New Zealand, to less than 5 tonnes per capita in India and Indonesia.

THE OPPORTUNITY OF SUSTAINABLE PRODUCTION AND CONSUMPTION
As is known from other world regions, the industrial transition of developing economies in Asia will involve a major increase in material and energy flows, corresponding to a 2-4 fold increase in the demand for raw materials and energy (Schandl et al. 2008). There may be an opportunity to avoid some of the growth related resource impacts when the major economies of Asia transition to an industrial metabolism. Such potential success has to be accompanied by a more efficient use of resources in the OECD countries in the Asia-Pacific. If policy measures are well set there may be a triple dividend of greater wellbeing, cost savings
and greater competitiveness, and reduced environmental impacts. Information will play a crucial role in policy planning and the evaluation of successful policy implementation. There are at least four related areas of focus for supporting a dematerialization of economic activities in Asia-Pacific. The first is related to the production of goods and services, the role of technology to mediate between economic activities and resource use dynamics, and the potential for increased eco-efficiency of production processes and the dematerialization of aggregate economic activity.

The second focus is on changing consumption behaviours and the role of lifestyles for mediating between consumption activities and resource use, and the potential for sustainable consumption patterns. Thirdly, infrastructure, and the way that large supply systems of transport, housing, water, energy, nutrition are organized and how these services are provided play an important role for enabling sustainable consumption. These systems have been referred to as socio-technical regimes and change could address by systems innovation, sustainability experiments, regime transition and strategic niche development (Elzen et al. 2005). Finally, the role of employment, know-how and skills, as well as the need to improve education and training to grow green skills has been addressed more recently (UNEP 2008). There is the need for a ‘skills revolution’ to underpin a sustainability transition.

Fischer-Kowalski and Haberl (2007) in their new book ‘Socioecological Transitions and Global Change’, discussed the fundamental changes in our relationship with the environment that would be required to achieve a sustainability transition. They introduced the concept of socio-ecological regimes and metabolic profiles to shape the discussion around the idea of guiding social change towards sustainability.

**A SUSTAINABILITY TRANSITION FOR ASIA-PACIFIC ECONOMIES**

To better understand the fundamental character of a sustainability transition, the concept of socio-ecological regimes is a very useful starting point. The term socio-ecological regime designates a specific set of rules that regulate the operation of a social system and its institutions, the corresponding biophysical properties of the social system and the related patterns of society-nature interaction. They are complex dynamic systems that are integrated across scales and allow for certain change and growth processes. They feature specific environmental impacts and are characterized by institutional arrangements, demographic features, spatial patterns of land-use and of socio-economic organisation, infrastructure, networks and technology clusters (Krausmann et al. 2008). More importantly, a socio-ecological regime shows a distinct structure and level of material and energy use (metabolic profile) and typical patterns of use of human time and labour (time allocation profile). Transitions between socio-ecological regimes imply major change and are often referred to as ‘revolutions’ (such as the industrial revolution). The important question is whether there is enough research capacity in the region to inform policies for guiding a resource use transition and to evaluate its outcomes. A first look at the literature suggests that beside the important research contributions from especially Japan and Australia, there is an emerging body of international literature coming from China and Southeast Asia. There is very little information, however, on national material flows and resource productivity indicators for Asia-Pacific economies.

**INUSTRIAL ECOCLOGY RESEACH ON MATERIAL FLOWS TO INFORM POLICIES FOR A SUSTAINABILITY TRANSITION**

We classify the emerging literature on resource flows for the Asia-Pacific region using the classification schemes proposed by Fischer-Kowalski and Huettler (1999) and Moriguchi (2007). We differentiate between the resource flow focus on substances, materials and products and the geographical, functional/economic boundaries for the studies. There have been numerous conceptual and methodological contributions focusing on environmental accounting in general terms, the potential of industrial ecology and material flow research in the Asia-Pacific region and policy implications of this body of research. There is a growing body of literature on substance flows (SFA), material flows (MFA) and products (LCA) covering a geographical range from global, to continent, to national, sub-national, district/city and local. There are also important contributions for SFA, MFA and LCA with regard to functional or economic criteria for whole economic sectors or firms. National level MFA studies for Asia-Pacific economies are only available for a minority of countries such as Japan, China, Australia, New Zealand, the Philippines, Singapore and the Republic of Korea. There is, however, increasing interest in material flow studies in the Asia-Pacific region from national research institutions and policy departments and also from international organisations such as UNEP and UNESCAP, which will speed up research activities considerably in the near future.

**Author’s information:**

Dr Heinz Schandl is a sociologist and senior scientist at the CSIRO Sustainable Ecosystems Division in Canberra, Australia where he leads a research area on sustainable use of natural resources.
Industrial Waste Water Treatment by A Sewerage System
- An Experience of Osaka City -

Ryo Fujikura
Faculty of Humanity and Environment, Hosei University
Fujimi 2-17-1, Chiyodaku, Tokyo, 102-8160 Japan
fujikura@hosei.ac.jp

**Keywords:** industrial waste water, sewerage, Osaka City,

**ABSTRACT**

In Osaka City, half of the total factories and houses were already connected sewer by 1968. Quality standard of waste water discharged from factories to the sewerage system was already established in 1960, but waste water was not actually monitored. Untreated industrial waste water often damaged or clogged sewers. In 1972, the Municipal Government began periodical inspection, and exposed violations in collaboration with the Osaka Police Office. The share of the factories actually installed waste water treatment facilities of the whole required to install them increased from 47.5% in 1972 to 95.4% in 1978. In 2005, there were approximately 3,000 facilities subjected to a site inspection. The Municipal Government conducted 8,600 inspections in the year. It introduced gradual increase of unit price of waste water fee in 1972 and "Water quality fee" in 1973. The new tariff decreased industrial waste water of 59.8% during 1974 - 1983. There were only 2 facilities equipped with activated sludge process in 1967. Around 1970, BOD of river water in the downtown sometime exceeded 200 mg/L. After adoption of activated sludge process at 12 facilities in 1972, water quality rapidly improved to an acceptable level.

**Sewerage Law**

The Sewerage Law was established by the Japanese Imperial Government in 1900. The Law obliged every facility located within an area where a sewerage system was ready to discharge its waste water into a sewer. The stipulation has been still effective until today.

The objectives of the law did not included water quality conservation but removal of rain water and waste water. Inadequate treatment of sewage was a major factor of water pollution in the urban area. In 1970, the law was totally amended. Water quality conservation was included in the objectives, and sewage must be treated before discharge to the water for public use. Since then, sewerage systems have substantially contributed water quality conservation in Japan.

**Development of Sewerage System in Osaka**

Osaka's history of the sewerage system has begun as early as in 17th century. Osaka City is located at delta plains facing Osaka Bay, and removal of rain water was crucial issue. Drainage ways were constructed along the streets in the downtown. Some of them were utilized as sewers until 20th century.

During the 1960s and the 1970s, the Municipal Government rapidly developed the sewerage systems. Coverage of sewerage system increased from 19.2% in 1960 to 55.6% in 1968. It reached 95.1% by 1978, while that of the Japan was 27% in the same year. Presently about 3,000 facilities in Osaka City discharges the waste water into sewerage, while only 71 facilities discharges waste water directly to a river or the sea in 2006 [1].

**Inspections**

In 1960, the Municipal Government established quality standards of waste water discharged to a sewerage system. However, the quality had not been routinely monitored. The sewerage system was often damaged by wicked waste water. Significant cases included damages of pump facilities by strong acidic waste water in 1960 and 1970, explosion of a sewer by unknown origin in 1967, and sewer clogging by discharged oil in 1969.

In 1972, the Municipal Government amended the local ordinance of sewerage and started periodical monitoring. It exposed violations in collaboration with the Osaka Police Office. The government posted 45 officers to the Water Quality Monitoring Division in 1973 and increased the number of the officers to 57 by 1978. During the same period, number of inspections increased from 3,165 to
The share of factories actually installed waste water treatment facilities of the whole required to install them increased from 47.5% in 1972 up to 95.4% in 1978 [2]. The administrative cost is high. There were about 3,000 facilities subject to an inspection based on the law or the local ordinance. In 2002, 38 inspection officers conducted a total of 8,600 inspections. Each facility was inspected on average 2.9 times in a year. Number of violations reduced to 60% compared to that during the early 1980s [3].

The inspection provides also an opportunity of technical assistance for small and medium enterprises. Some of them do not know how to treat their waste water, and sometime install an excessively large treatment facility believing a suggestion of a plant manufacturer. In such a case, the enterprise, the inspector and the plant manufacturer discuss and decide an appropriate technology for the factory.

**Water Quality Fee**

In 1973, the Municipal Government began to charge a water quality fee on the factories discharging waste water of more than 1,250 cubic meters, if BOD, COD or SS (suspended solids) of the water exceed 201mg/L. In 1978, 165 factories were subject to the fee, and every factory paid about 5 million yen in average. The introduction of the fee forced them to reduce the water consumption, and the amount of the waste water subjected to the fee reduced to one fifth in ten years after the introduction.

While the number of factories decreased 5.1% from 1974 until 1983, the total amount of the waste water reduced 59.8% during the same period. It can be attributed to the introduction of water quality charge and that of gradual increase of unit price of waste water fee in 1972 [2].

**Improvement of Water Quality**

Osaka was known as a "Water City", because a number of canals were developed since centuries ago. The water quality was deteriorated since the beginning of 20th century. An investigation carried out in 1936 estimated that 20% and 30% of river water in downstream of Neyagawa River was industrial and domestic waste water, respectively. The pollution worsened as the national economy rapidly developed during the 1960s. Around 1970, BOD of Neyagawa River reached 65mg/L, and that of Hiran River often exceeded 200mg/L [2].

It was the establishment of sewage treatment facilities that improved the water quality. There were only 2 facilities equipped with activated sludge process in 1967. All other facilities adopted only a sedimentation process. After adoption of activated sludge process at 12 facilities in 1972, water quality rapidly improved. At 24 of 38 river water monitoring stations, BOD met the national environmental standards (3 or 5 mg/L) in 2006 [4].

**Implications of Osaka’s Experience**

There are arguments whether industrial waste water should be accepted by public sewerage or not. It contradicts polluter pays principle because the waste water fee does not cover the construction cost of the system. It is inefficient to treat water after mixing the industrial waste water of high BOD with the domestic waste water of low BOD.

Nonetheless, Osaka's experience implies a possibility to deal with industrial water pollution presently occurred in developing countries. One of the major pollutants is food processing industry, and the waste water does not contain toxic substances such as heavy metals. Many of the factories are small or medium and have little fund to install water treatment facilities by themselves. Accepting the waste water into a sewerage system is one option, because the factories need not treat the waste water but just need to pay the waste water fee. Then, the fee gives a factory a strong incentive to reduce and recycle waste.

The Osaka's experience suggests high administrative cost of operation at the same time. Inspections are definitely needed in particular for the places where factories likely discharge toxic waste water.

**Acknowledgement**

This paper was principally based on an author's previous article [5].

**Reference**

3. Interview with a Municipal Officer in September 6, 2004

**Author's information:**

Ryo Fujikura is a Professor of Hosei University, Japan. He received his B.A. (1978) and M.Sc. (1980) from the University of Tokyo, and Doctor of Natural Science (1982) from Innsbruck University, Austria. He served as an officer in the Environment Agency (presently, Ministry of the Environment) of the Japanese Government between 1984 and 1995. He was an Associate Professor of the Kyushu University, and later a Professor of Ritsumeikan University from 1995 until 2003.
CHINA CIRCULAR ECONOMY PROMOTION LAW

In the face of the challenge for changing the traditional economic development model and the long-term development strategy for constructing a resource conservation and environmental friendly society, China formulates and issues the Circular Economy Promotion Law (the Law for short) which will come into force on January 1, 2009.

According to the article 2 of the law, circular economy is referred to the reducing, reusing and recycling measures conducted in the process of production, circulation and consumption. Only from the wording, the Law is very similar with the Japan’s recycling-based society promotion law. However, there are two major differences between them.

1) China’s circular economy conception puts more stresses on production stages. Compared with developed countries whose circular economy legislative objective is resolution of the problem on waste treatment and disposal, China presents a broader definition on circular economy by integrating cleaner production, sustainable consumption and waste management. That is to say, China should establish its circular economy legal system on the basis of the localized 3R (reduce, reuse and recycling) principles, in accordance with the strict hierarchy of reduction, reuse and recycling, and with stress on resource conservation and the preventing principle.

2) China circular economy promotion law is a more specific and concrete law. Compared with Japan’s Recycling-based Society Promotion Law, the Law only serves as a piece of basic and leading circular economy legislation addressing general issues such as policy targets and guiding principles, but also provides more specific and concrete legal systems and mechanism for enhancement of operability. The reason lies in that China’s existing circular economy-related provisions are too abstract, lacking operability and cannot as effectively undertake the tasks of circular economy promotion as Japan’s individual circular economy legislation does.

In the Law, the 3R principle of reduction, reuse and recycling is divided into two basic aspects including the aspect of reduction and the other aspect of reuse and recycling. For the two aspects, various policy measures are designed to enhance the operability of the Law. The basic managerial systems and measures established in the Law include:

1) comprehensive systems and measures such as the circular economy planning and target-based accountability system, circular economy evaluation indicator system and statistic information system, circular economy standardization and labeling system, circular economy market access control system, the system of circular economy catalog and elimination of outdated techniques, circular economy statistic and information dissemination system, extended producers’ responsibility (EPR) system, etc.

2) Managerial measures and measures regarding reduction,
such as the eco-design system, disposable products system, packaging system, etc.

3) Managerial systems and measures regarding reuse and recycle, such as the system of assorted management of waste, recovery, deposit, assortment of domestic garbage, green purchasing system, green consumption system, etc.

4) Economic measures of taxation and pricing supportive to circular economy.

PILOT IMPLEMENTATION OF CIRCULAR ECONOMY IN TIANJIN CITY

To promote and implement circular economy, China started two batches of national-wide pilot demonstration projects with four hierarchies: energy-intensive and/or resource-intensive key industrial sectors, industrial parks, waste recycling park (like Japan’s eco-towns), and regional economy at provincial and municipal levels.

Being one of pilot cities, Tianjin promotes circular economy since 2000 by integrating circular economy into development planning, strengthening the leadership to form the working mechanism, optimizing policies and regulations, building personnel and technology system, and so on. Currently, Tianjin has achieved remarkable results. For example, TEDA (Tianjin Economic and Development Area), Port industrial area, Ziya industrial park, Beijiang power plant and Datong copper company were all listed into the national circular economy pilot demonstration units.

The goals and targets of Tianjin’s circular economy include: 1) to build multi-hierarchical circular economy system with “micro-cycle in enterprises, meta-cycle in the park, macro-large cycle in urban area, super-cycle internationally”; 2) to establish a co-evolutionary development pattern with eco-industry, eco-agriculture and eco-service sectors; 3) to combine ecological reconstruction of traditional industrial area and circular layout of the new industrial area; 4) to establish the development mechanism of circular economy which functions operates harmoniously with each other.

To achieve the targets above, five major tasks are taken as follows: 1) to build the resources-saving pilot city with emphasis on saving resources and energy; 2) to construct the circular industry of mutual promotion among three industries; 3) to create the dynamic-static integrated industrial system with emphasis on TEDA and Ziya national demonstration pilot park; 4) to build national first-class ecological suitable demonstration area for settlements by taking Zhongxin ecological city and Huaming demonstration town as marks; 5) to construct supporting system for circular economy with emphasis on the technological innovation and system innovation. More detailed, the following key projects are:

- To build 100 national and city level exemplary bases for circular economy;
- To build an open regional network for recycling renewable resources;
- To construct 20 higher level frameworks of circular economic industrial chain;
- To develop 5 modes of circular economy development with characteristics;
- To keep on propelling saving energy and reducing emissions;
- Overall Construction of the Economize Society;
- To build the zhongxin ecological city which has a significant meaning on demonstration;
- To build information system of circular economy;
- Greatly strengthen cultural construction of circular economy.

Reference


Author’s information:
Dr. SHI Lei, associate professor of Tsinghua University, his research interests include eco-industrial complexity, regional development strategy and circular economy. He contributed to the China’s Circular Economy Promotion Law by participating the Project “Study on Legal Framework for Promoting Circular Economy in China” as an local expert. Prof. ZHU Tan is professor of Nankai University and contributes to pilot implementation of circular economy in Tianjin.
Eco-industrial Clusters: Enhancing Regional Economic Development through Environmental Linkages

Venkatachalam Anbumozhi
Institute for Global Environmental Strategies, Kansai Research Centre, Chuo-ku, Kobe, Japan 650 003  anbu@iges.or.jp

Keywords: Industrial clusters, Inter-firm networks, Urban-rural fringe areas, Policy integration

ABSTRACT

Developing countries in Asia are struggling to cope with negative impacts of concentrated industrial activities. For countries those are looking beyond simple manufacturing, but rather for an adoption of new kind of industries, the inner regions and the fringe areas that lie as hinterlands between urban and rural areas offers an opportunity for environment friendly and equitable growth. These areas are already used as sites for clusters of new industries that want equal access to raw materials as well as to urban markets. However, rather than just co-existing, these companies could become interconnected, sharing resources and achieving economic, social and environmental success. The solution is to create Eco-Industrial Clusters (EIC). Essentially EIC aims at efficiently using local resources, discarded materials and byproducts which otherwise termed as waste, while achieving equitable development targets. The key foundations of EICs, as could be learned from four prototype cases in Asia are: inter-firm networks, enabling technologies, social capital and public policy support. It is important that these infrastructures should be created simultaneously with new industries, and not after the environmental problems already developed, as has been done in the past. Changes in policy orientation are essential to promote EIC as a new model for sustainable regional development. Joint efforts that cut across three main policy streams of industrial policy, environmental policy and regional development policy that favour co-operative, multi-stakeholder and often location specific approaches are needed to unleash the sustainability potentials of EICs.

ECO-RESTRUCTURING AND INDUSTRIAL CLUSTERS IN ASIA

Pushing eco approaches such as eco-towns is a crucial element for resource recovery in high impact manufacturing sectors and can become a good model for the countries that are still focusing on manufacturing. However, new transformation techniques are needed for countries that are looking to adopt new industries, and for regions that are still dominated by small scale industries that are lagging behind modern industrial frontiers. One of the vehicles commonly used to achieve the goals of local wealth creation, innovation and regional competitiveness is to support ‘industrial cluster’ formation in inner regions, which could optimize use of local resources to activities with higher levels of productivity (IGES, 2007). There are quantitative evidences to prove that many industries remain relatively concentrated in specific regions (Anbumozhi, 2007; Porter, 1998). Additionally, in some countries of Asia, they outnumber their counterparts located in urban centres (Kuchiki and Tsuji (2005). Clustering the new bio-resource based industries and relocating appropriate process industries to fringe areas providing equal access to both the rural and urban reduces the intensity of environmental issues in urban centres. Central to this is the conservation of environmental quality in the urban while providing equal employment and social opportunities to rural communities.

This aspect of the environmental and economic gains of eco-industrial clustering has often been ignored by development planners. Addressing these issues will accelerate the development of new eco-industries. Eco-Industrial Clusters (EIC) are defined as: a community of business; geographic concentration of interconnected companies in a specialized field that cooperate with each other and with the local community to efficiently share resources leading to improved environmental quality, economic gains, and equitable enhancement of human resources for both the business and local community. In accordance with the applications of industrial ecology principles and business competition theories, EICs can become an emergent venture of integrated environmental and economic planning. The theory behind the benefits of eco-industrial clusters is based on the economies of scale, sound resource use and the availability of human capital.

CHALLENGES IN ESTABLISHING ECO-INDUSTRIAL CLUSTERS

Communities and companies in many developing countries of Asia, still face several challenges in seeking the benefits of eco-industrial cluster development. The four prototype eco-industrial clusters in key economic sub-sectors of India, Japan, Thailand and Vietnam demonstrates the variety of drivers as well as barriers. In
each case study cluster, there seems to be several factors that play a role in developing small business into large, competitive forces. Large firms, ties with external market agents, and the presence of local support institutions have been of great significance. Industrial, environmental and regional development policies also found to have strong impact.

Successful EICs are made up of enterprises that constantly seek inter-firm networks, not only to minimise waste and reduce pollution, but also to look for all types of innovation to improve zero emission processes and develop new eco-products (IGES, 2006). Agreements based on mutual trust within a network aim to sharing by-products, wastes and physical and natural resources including labour. Such networks are found to generate new markets, logistics and cluster management. But the studied prototype clusters were also found to have the following deficits.

Environmental technologies for conversion of waste to energy, wastewater treatment and use of renewable materials have to spread easily among the companies to benefit the cluster as a whole. Both Thailand and India need serious intervention in this field in order to strengthen existing inter-firm networks and enabling to share relevant technologies. Research institutes that focus some of their research within the industrial cluster are helpful in assisting with eco-innovations and the diffusion of appropriate technologies within firms of a cluster. Japanese wood industrial cluster serves as a good example, where high social capital that includes the relationships, attitudes and values governing the interactions among people, businesses and institutions, facilitated the sharing and development of ideas and pertinent market information thus reducing the transaction cost for businesses operating within the cluster. While the concept of mutual trust among competitors is not the norm among businesses, the evidence from Japanese case indicates that similar relationships can be built through progressive action by community-based cluster players like local Non-Profit Organizations (NPO).

Market differentiation for green products is another viable business strategy for eco-industrial clusters, that is being exploited by Japan and Vietnamese clusters. Eco-products like bio-ethanol, natural cosmetics, rice bran oil, green energy have different markets in the urban centres, which needs varying marketing strategies. Governments can address market failures by strengthening the micro-foundations of EICs through a coordinated system of approaches.

CONCLUSION

Comparative evaluation of four prototype clusters demonstrates that EIC formation would take place in three hierarchical steps. The interaction between the local entrepreneurial attitudes and activities and their characteristics, are an important starting point for the evolution of industrial clusters. These interactions would lead to a spatial concentration of firms that would in turn maximise the use of local resources. Policy makers may need to work with other stakeholders to properly use cluster identification techniques. Cooperation among firms and between communities is the second essential part of eco-industrial cluster development. A local industrial cluster is upgraded or transformed into an EIC through more organised cooperation or informal agreements between companies within clusters, stimulated by mutual trust, norms and community conventions. Thirdly, strong public policy support is needed at the national level to upgrade EICs into specialised eco-friendly economic zones. Government should develop integrated policies to attract more businesses into the clusters and make them effective in terms exploiting environmental linkages for regional economic growth.

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Author’s Information

V.Anbumozhi was the Manager of the Business and the Environment Project at the IGES -Kansai Research Centre. After graduating with a doctoral degree in Biological and Environmental Engineering from the University of Tokyo in 1995, he served for JICA and JBIC projects on sustainable regional development projects. Later he taught environment friendly development and its international aspects at the University of Tokyo. He has written widely on natural resource management issues, infrastructure development, institutional problems and environmental policy challenges facing the Asian countries. He sits on the editorials board of journals on environmental planning and advises Asian Productivity Organization and UNESCAP on their sustainable development projects.
Urban simulation system to integrate circular economy and low-carbon city

Tsuyoshi Fujita
National Institute for Environmental Studies
16-2 Onogawa, Tsukuba-City, Ibaraki, 305-8506 Japan
fujita77@nies.go.jp

Keywords: policy simulation, eco-town, resource circulation, circular economy, low-carbon city

ABSTRACT

This Industrial symbiosis is more concerned in Asia and Pacific region as the concept to harmonize sustainable environmental management with continuously growing economic development. This paper, firstly review the theories and practices of industrial symbiosis in Japan as the Eco town programs. The Eco-Town Program in Japan is a program to extend Industrial Symbiosis into geographic proximity of industrial areas by using previously discarded waste materials for industrial applications. A policy simulation system for integrative policy development in eco-town cities and regions is also discussed. Thirdly, an integrative policy simulation frame work for Asian industrial cities is proposed, which compile the urban environmental GIS database, quantitative inventory for circular technologies, policy evaluation procedure for decision makers. Finally, the present and potential performances of circular economy are examined by employing a case study approach and life cycle CO₂ analysis with special focus on municipal solid waste (MSW) management. As one of the first circular economy demonstration city, Dalian, China The results of our analysis implied that the introduction of a waste incineration plant would significantly reduce final landfill disposal though it would inevitably increase the total CO₂ emissions mainly due to the incineration of wastes with fossil origin.

OBJECTIVE

This Industrial symbiosis is more concerned in Asia and Pacific region as the concept to harmonize sustainable environmental management with continuously growing economic development. This paper discusses a policy simulation system for integrative policy development in eco-town cities and regions is also discussed. Thirdly, an integrative policy simulation frame work for Asian industrial cities is proposed, which compile the urban environmental GIS database, quantitative inventory for circular technologies, policy evaluation procedure for decision makers. The present and potential performances of circular economy are examined in Dalian, China, one of the first circular economy demonstration city.

ECO-TOWN PROJECTS IN JAPAN

Eco-Town Program, as Japan’s key effort to foster industrial symbiosis has been unique in expanding its focus (Fujita 2006), initially from site specific initiatives (typically Cleaner Production or Eco-Efficiency (van Berkel 2007a), to industrial symbiosis and urban-industrial interactions. A comprehensive legal framework to that effect is now in place. The foundation was laid by the Basic Law for Establishing a Recycling-Based Society, which was came into force in January 2002. It was developed under the Basic Environment Law, and provides quantitative targets for recycling and dematerialization of Japanese society.

The status of the Eco-Town program was evaluated in 2006, on behalf of the Ministry of Economy, Trade and Industry (METI), which also provides the main share of the program funding (Fujita 2006; 2008). The main findings from this evaluation are presented and analyzed here to provide insight into the diversity of results and experiences gained in the Eco Towns since the program launch in 1997.

During its 10 years of operation, 26 Eco-Town Plans were approved and endorsed for implementation by the responsible local government authority. Compared to 2000, it aims by 2010 to have improved resource productivity by about 40% (to 390,000 JPY/ton) and recycling by about 40% (to 14% of total materials use) and decrease landfill by about 50% (to 28 million tons/year).

Whilst these factors in the Eco-Town Program have worked in favor of the realization of industrial and urban symbiosis over the past decade, concerns are being expressed whether such will continue into the future. There is increasing international competition for high grade recyclable waste streams, from China and other countries in Asia. This could ultimately erode the supply of waste materials to recycling facilities in Japan. The Eco-Town investment subsidies are also no longer available, and these were an important carrot for developing and trialing new recycling technologies. In light of the above it would be reasonable to expect at least continuation of current recycling operations and possibly replication of current recycling technologies in similar facilities in other regions in Japan.

INTEGRATIVE EVALUATION SYSTEM FOR CIRCULAR CITIES

An evaluation system is developed to support the decision making of circulation policies for the implementation of conversion technology using disaggregate spatial database of organic waste.
emission. (Wong 2008) Disaggregated spatial database is developed using Geographical Information System (GIS), and the circulation policy scenarios are designed based on conversion technology inventory and environmental policy options. In order to quantitatively evaluate the effectiveness of technology, the production functions of conversion technologies are developed. By applying the evaluation system to examine circulation policy scenarios in regional and city scale, based on the findings a multi-scale decision supporting system is designed and proposed.

In order to evaluate the efficiency of conversion technologies, the production functions are developed. For example, two types of conversion technologies for organic waste matter circulation, including energy conversion technology and industrial symbiotic technology, are focused. In this dissertation, for energy conversion technology, production functions of methane fermentation systems are developed. For industrial symbiotic technology, production functions for plastic waste circulation in steel manufacturing industry are determined.

The production functions are applied for the evaluation of policy scenarios. The evaluation system is applied for circulation policy scenarios in city scale. Future policy scenarios for circulating organic wastes from municipal solid waste (MSW) in Kawasaki City are evaluated. Urban waste management policy such as renovation schedule of incineration plant is incorporated into the circulation policy scenario design, and industrial symbiotic technologies which are equipped by local heavy manufacturing industries are identified as conversion technology options to circulate municipal organic wastes including mix papers, waste container and packaging plastics, and food wastes. The scenarios are planned based on the types of circulation waste and the renovation schedule of incineration plants. Mix paper, waste C&P plastic and incineration ashes are assumed recycled by industrial symbiotic technologies including paper, steel and cement manufacturing process. Because the raw materials of paper manufacturing company are used papers, and the cement company is fully using industrial waste sludge for clay substitution, only the CO2 emission substitution effects from recycling waste C&P plastics is counted.

APPLICATION IN CHINESE CITIES

The Government of China has decided to adopt the circular economy (CE) as the national eco-industrial development model to prevent environmental degradation and resource scarcity associated with rapid economic development since 2002 (Geng et. al, 2008). The concept of CE has the same essence as the industrial symbiosis with a closed-loop of materials, energy and waste flows but with wider applications for more sustainable urban economic and industrial development. Chosen as a demonstration city, Dalian, a sub-provincial city of Liaoning province, has implemented the CE strategy as a means of conserving water, materials, energy and land. Through CE practices, the city aims to improve resource use efficiency, as well as to minimize the amount of waste produced and converting wastes into useful resources. Among them, improvements in levels of reuse, recycling and recovery of solid wastes are one of the key issues in Dalian (Dalian Municipality, 2007a). Therefore, the objective of this paper is to evaluate the potential of CE practices in Dalian by employing a case study approach and life cycle CO2 analysis for alternative CE scenarios with special focus on MSW management.

Alternative CE scenarios were designed for the city of Dalian as combinations of alternative waste management and industrial symbiosis options in order to evaluate the present and potential of MSW management practice. The results of our analysis implied that the construction and operation of a waste incineration plant would promise significant reduction of final landfill disposal though it would inevitably increase the total CO2 emissions mainly though the incineration of wastes with fossil origin. Cooperation with a single company that could utilize MSWs as raw materials might not provide readily improvements in resource efficiency since the city of Dalian seemed to have great potential of material recovery if MSW stream is properly managed. Final decisions on which strategies to choose as a circular economy policy seemed to rest on the priority order of existing issues.

CONCLUSION

Schemes for Eco-Towns are expected to function as demonstrative model for Asian circular cities. The results to apply evaluatin methodology of circular technologies and policies in Dalian implied cooperation among MSW and companies would have great potential of material recovery if MSW stream is properly managed. Final decisions on choosing strategies for CE policy should be supported scientific evaluation and the priority order of existing issues.

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Comparative Assessment of Industrial Symbioses in Practice in Asia

Rene VAN BERKEL
Visiting Senior Fellow, United Nations University – Institute of Advanced Studies
1-1-1 Minato Mirai, Nishi-ku, Yokohama 220-8502, Japan, ecoinnovation.vanberkel@gmail.com

Keywords: Industrial Symbiosis, Urban Symbiosis, Eco-Industrial Parks

Abstract
Industrial Symbiosis is concerned with the recovery and reuse of wastes from one facility as alternative input in neighboring facilities. It is an iconic application of industrial ecology, and regularly combined with other collective environmental management initiatives into eco-industrial parks, or with utilization of urban wastes in industrial applications (‘Urban Symbiosis’). A growing number of practical examples are now documented covering different parts of Asia and elsewhere, raising interest to compare and possibly rank such Industrial Symbioses. Alternative assessment methods are demonstrated and reviewed here. Whilst useful to demonstrate the development over time and significance of symbiosis in a particular region, none is suited for inter-regional comparison as fundamentally each symbiosis is location specific. This justifies further research to focus on understanding framework conditions and collaboration mechanisms for development of Industrial Symbioses.

Objective
Over the past decade there has been a steep increase in awareness of the concept and practice of Industrial Symbiosis, which has encouraged governments, private sector and academia to launch policies and projects for its realization, including in several countries in the Asia Pacific Region (e.g. Japan, China, Australia, Republic of Korea and India). Whilst environmental, economic and, to a slightly lesser extent, social benefits have been intuitively convincing, their quantification has not yet been sufficient to provide a compelling case that Industrial Symbiosis is relevant and significant. The objective of this paper is to review different applications of Industrial Symbioses and the approaches taken to assess their relative maturity and benefits.

Industrial Symbiosis
Industrial Ecology uses an ecosystem metaphor and natural analogy to study and improve the resource productivity and reduce the environmental burden of industrial and consumer products and their production and consumption systems [1]. It applies the notion that ‘in nature nothing is being wasted’ as the waste from one species becomes the food for another species, and therefore industrial systems can also be studied in terms of industrial food webs (that is the ecosystem metaphor with closed materials cycles, powered by solar radiation). It also seeks to mimic in manufactured products and processes, the materials, processes and forms that have proved to be efficient and resilient in nature, such as for example the self cleaning surface of the Lotus flower (that is the natural analogy).

Industrial Symbiosis is one of the iconic applications in the field of Industrial Ecology. At its core Industrial Symbiosis is concerned with ways to close materials cycles by using the wastes from one facility as an alternative input for another facility. Chertow provided the definition that is commonly quoted “Industrial Symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products. The keys to Industrial Symbiosis are collaboration and the synergistic possibilities offered by geographic proximity” [2].

Comparable terms are in widespread use. The two key pairs are: Industrial Symbiosis and industrial ecosystem, respectively the process and outcome of exchanging by-products and other resources between firms, and eco-industrial development and eco-industrial parks, respectively the process and outcome of applying best environmental management practices for industrial parks, including, but not limited to, material exchanges between firms [3]. The notion of ‘eco-cooperation options’ is useful to structure Industrial Symbiosis. Three options are considered: symbiosis or by-product exchanges (based on physical exchanges of materials or by-products); utility sharing (shared use of utility infrastructure) and planning and management of the open space and park management facilities. Each of these has its specific profile of business opportunities and risks, and potential triple bottom line rewards which is illustrated in Figure 1 [3].

![Figure 1: Schematic illustration of eco-cooperation options (source: [3]).](image)

A further extension is possible through inclusion of urban-industrial interactions. The term Urban Symbiosis specifically refers to the use of by-products (wastes) from cities (or urban areas) as alternative raw materials or energy source for industrial operations [4]. Similar to Industrial Symbiosis, Urban Symbiosis is based on the synergistic opportunity arising from the geographic proximity through the transfer of physical resources (‘waste materials’) for
environmental and economic benefit. Urban Symbiosis is a specific opportunity arising from the geographic proximity of urban and industrial areas and transfers the physical resources from urban sources to industrial applications [4]. The benefits of combining industrial and Urban Symbiosis have been demonstrated in the Eco-Town Program in Japan.

Practical Applications
Earlier global inventories [3, 5] with particular focus on heavy process industries described a total of 31 regions on four continents (Europe, North America, Asia and Australia). Since then further applications have been documented, including several in Asia, for example Naroda and Ankleshwar (India), Ulsan (Rep of Korea), Guitang (PR of China) and all 26 Japanese Eco-Towns. The cooperation structures of the Industrial Symbioses are quite different, including for example a base of 2 or 3 anchor companies (for example oil refinery and power station in Kalundborg, Denmark), integration of novel recycling technologies in existing materials processing centres (e.g. Kawasaki, Japan) and comprehensive integration along and between different value and supply chains (e.g. Kwinana, Australia).

Assessment
In a first attempt to characterize and compare different Industrial Symbioses, several authors have relied on an index of connectedness or symbiotic intensity, typically based on the combination of the number of firms involved and either the number of synergistic projects or the number of symbiotic resource flows (the latter typically being higher as the number of projects, due to the fact that specific symbiotic projects (such as a cogeneration facility) could involve various resource flows (e.g. process water, process steam, fuels and electricity)). The Industrial Symbiosis in Gladstone (Australia) comprises of 3 symbiotic projects between 6 firms, whilst in Kwinana (Australia) it comprises of 47 symbiotic projects between 22 firms. Similarly Guitang (PR of China) is an Industrial Symbiosis with 5 symbiotic projects between 5 firms, and in Ulsan (Rep of Korea) it is based on 9 symbiotic projects among 12 firms [6]. Chertow proposed a stricter interpretation to include only companies that have symbiotic resource flows but are not primarily recycling businesses [7]. In its practical application, Kawasaki would then be a 3-4 type symbiosis involving three companies (steel, cement and paper works) and 4 resource flows (scrap metal, electricity, sludge and slag) [6]. Indicators for symbiotic intensity reflect on the organizational complexity of the industrial ecosystem. They are however dependent on the level of knowledge and understanding of the industrial system and the industrial organization and firm boundaries. They are useful to monitor the maturing of symbioses in any particular industrial system over time, but are inadequate to assess the environmental, economic and other benefits [6].

Quantitative assessments have been performed on the basis of comparison of material and energy flows in the symbiotic system, compared to a reference system, assumed to have no symbiotic exchanges. A recent study confirmed for example the material flow benefits of seven symbiotic projects in Kawasaki (total waste diversion approximately 565,000 ton per annum) whilst economic benefits could be estimated only for four of these (totaling 13 billion JPY annually (approximately 130 million USD)) [6]. Such quantitative assessments demonstrate the significance of Industrial Symbiosis at the regional scale. However, there are methodological issues, pertaining in particular to the uncertainty of the reference non-symbiotic scenario and exclusion of resource use and environmental impacts of the symbiotic activities itself [6]. Moreover, data are generally incomplete and/or considered commercially sensitive, whilst also potential trade offs between alternative uses of by-products need to be considered (e.g. in the case of blast furnace slag its use as cement replacement or for heat recovery) [6].

Closing Remark
The past decade revealed that Industrial Symbiosis is a more common feature of in particular heavy process industrial areas than initially assumed. Whilst similar technology combinations may be present in Industrial Symbioses in different locations, each Industrial Symbiosis takes on location specific forms, leading to non-comparability of the resulting eco-industrial systems. This would warrant greater focus on the processes driving and delivering symbiotic exchanges, which could include legislation, industry leadership, business case, resource scarcity, technology opportunity and societal pressure.

Author
Rene Van Berkel (PhD) is a Visiting Senior Research Fellow of the United Nations University-Institute for Advanced Studies. He has 20 years professional experience in applied research, training and advocacy in the areas of industrial ecology, eco-efficiency, and corporate sustainability, including several countries in the Asia Pacific Region.

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Eco-industrial Development as Policy Approach to Environmental Problems in Industrial Parks in China

SUN Qihong, QIAO Qi, LI Yanping
MEP Key Laboratory of Eco-industry, Chinese Research Academy of Environmental Sciences
Dayangfang 8, Anwai, Chaoyang District, Beijing 10012, China
sunqh@craes.org.cn

Keywords: Eco-industrial development, Eco-industrial park, Policy approach, China

ABSTRACT
The environmental problems in industrial parks have become outstanding in recent decade in China. Compared with traditional command & control policy, integrated measures should be adopted. Eco-industrial development is exactly a right policy choice. The development, challenge and environmental problems in some IPs in China were reviewed. The early introduction of eco-industrial development concept with the effort of solving structural and regional environmental problems was analyzed. Managerial development of EIP promotion at national level, such as establishment of regulations and standards, was introduced. Trends of EIP development were analyzed and several suggestions for further promotion put forward.

In terms of circular economy policies, SUN, et al. [1] proposed a policy regime based on the World Bank’s policy matrix [2]. Traditionally, the environmental policies are command & control ones, such as EIA system. However there are also other policies, such as market-oriented policies, public participation and information disclosure, etc. These new policies have formed a new trend in China’s environmental policies. However, there is still a debate on the basic environmental policy orientation facing current serious environmental problems, i.e., while we highlight stricter environmental law enforcement, can the incentive measures such as eco-industrial parks demonstrations still play their due roles?

DEVELOPMENT AND PROBLEMS
Major developments of IPs in China
Since 1984, China’s industrial parks (IPs) have experienced 3 phases. In Start-up and Exploration Phase (1984-1991), the development speed was slow, gross economy small and hi-tech lacked. In Rapid Growth Phase (1992-1998), there was a great increase in foreign capital absorption, and many IPs became growth points of local economies. In Adjustment and Stable Development Phase (1999-present), many IPs encountered problems and challenges, such as unreasonable industrial layout, lack of management mechanism innovation, urgent land resource conservation, and resource constraints and environmental pollution, etc., and the Central Government exerted an adjustment policy on IPs to enhance their development efficiency. The basic idea to tackle these problems is to implement the view of scientific development and to construct harmonized development zones, e.g. developing hi-tech industries, and phasing-out disadvantage enterprises to improve land productivity.

Main environmental problems of IPs
Currently, some IPs have serious environmental problems: (1) Lack of perfect environmental management institutions and instruments in some IPs. Local protectionisms lead to giving-up of the environment quality in order to earn economic profits. EIA procedure for polluting construction projects is not strict in some IPs. (2) Lack of environmental planning and pollution prevention measures. The functional zones are unclear due to lack of regulatory detailed planning and environmental planning. Most IPs have not performed regional EIA for development plans, some leaving outstanding structured pollution. (3) Low awareness of environment of enterprises and frequent illegal discharge of pollutants. Based on survey data of former SEPA in 2007, in the surveyed IPs, 24% enterprises had illegal discharge behaviors.

ECO-INDUSTRIAL DEVELOPMENT POLICY
Early introduction of EID concept to IPs in China
The EIP demonstrative construction embodies integrated instruments for environmental management. The start point of EIP promotion is to solve regional and structural environmental pollution. Put Guangxi Guigang EIP for instance. The first national demonstrative EIP in China was approved to be established in 2001 by former SEPA. The core company, Guitang Group Company, is located in South China. The main product is sugar. It also uses sugarcane bagasse waste sugar molasses to produce paper and alcohol. Sugar-making, paper-making and alcohol-making are 3 typical water-consuming and polluting industries. What if there are together? In Traditional Model, simply sum up them and result in a sum of three big polluters. The enterprises face pressure of low economic benefit and serious environmental pollution. In
Eco-industry Model, The three polluters form an eco-industrial chain, using wastes of others as raw materials, thus obtaining win-win by maximizing resource utilization and minimizing pollutant discharge. (Fig. 1)

### Classified management of EIPs
In 2007, three ministries, SEPA, MOC and MOST, jointly issued *Circulation on Carrying out National EIP Demonstrative Construction*. The EIPs in China have three kinds: sector-specific EIPs, usually with one main industry such as steel and iron for each EIP; sector-integrated EIPs, involving national and provincial ETDZs, hi-tech zones and environmental industrial parks, etc.; and venous industry based EIP with waste recycling and treatment and disposal. By October 2008, a total of 30 national EIP demonstrations have been approved.

For promoting EIPs, the ministries have issued some regulations, standards and guidelines, including a guideline for EIP planning, standards for 3 kinds of EIPs, over 40 cleaner production standards for individual sectors. Other technical guidelines are also under development.

### OUTLOOK AND SUGGESTIONS

#### Outlook of eco-industrial development in China
Eco-industrial development in IPs has been highlighted in newly effective *Circular Economy Promotion Law*. Its Article 29 states that “The state encourages enterprises in various types of industrial parks to exchange wastes for use, adopt cascade utilization of energy, intensive use of land and classified and recycling use of water, and share infrastructure and other related facilities.”

Three trends can be identified: Firstly, construction of EIP will be an important platform of strengthening environmental protection in various IPs as well as a key measure of realizing energy saving and pollutant reduction. Secondly, the construction of EIP demonstrations at national level will greatly promote related activities at local levels. Thirdly, venous industrial based EIPs should be a new hotspot in near future.

#### Suggestions on complementary measures

Three suggestions are put forward: (1) Speed up laws and standards construction: formulating macro-control policy and finance and tax preferential/encouragement mechanism; formulating investment, tax and price policies to encourage waste recycling for individual industries; and developing management tools, technical instruments and communication platform and strengthening technical guideline to EIP construction. (2) Strengthen daily environmental supervision: consolidating institutional and system construction and strengthening EIAs for both IP plans and construction projects; strengthening source control and being strict with environmental access for relevant industries; systemizing Region-Based Limitative Ratification for new projects; and enhancing risk awareness and implementing environmental risk management. (3) Develop and promote eco-industry technologies: 3R technologies; new technologies to form eco-industrial chains for individual industries.

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SUN Qihong: Research fellow, Center of Cleaner Production and Circular Economy Research (CCP&CER), CRAES, China, sunqh@craes.org.cn, QIAO Qi: Director and Leading Expert, CCP&CER, qiaoji@craes.org.cn, LI Yanping: Assistant Research fellow, CCP&CER, leyp@craes.org.cn.
This study aimed to conduct a comprehensive assessment in order to quantitatively and fundamentally understand the role of Japanese Eco-town projects in relation to material circulation. For this objective, the contribution of Eco-town in regional and national material circulation was analyzed by using flow data for materials passing through Kitakyushu Eco-town. First, material flow in Kitakyushu Eco-town was examined. In addition, inputs into Eco-town were classified by distance from origins, and outputs from there classified by distance to destinations. As the next step, the structure of material circulation for the whole city of Kitakyushu including Eco-town was analyzed. Based on these results, four indicators were defined (resource productivity, usage rate of recycled material, rate of final disposal and recycling rate) for evaluation of the contribution of Eco-town in regional material circulation.

OBJECTIVES
This study aimed to conduct a comprehensive assessment in order to quantitatively and fundamentally understand the role of Japanese Eco-town projects in terms of material circulation. For this objective, the contribution of Eco-town in regional and national material circulation was analyzed by using flow data for materials passing through Kitakyushu Eco-town.

AN OVERVIEW OF KITAKYUSHU ECO-TOWN
The Eco-town Project was created in fiscal 1997. The Eco-Town project has two objectives: (i) to stimulate local economies by nurturing the growth of environmental industries, and (ii) to create integrated systems that are in harmony with the environment, and to involve industry, the public sector, and consumers, in creating a sound material-cycling society.

Since 1997, Kitakyushu Eco-town, Japan’s first Eco-town project, has been growing as a recycling-oriented industrial park. Now, Kitakyushu Eco-town is called one of the biggest and the most successful site in Japan, and over 20 enterprises are located there.

MATERIAL FLOW ANALYSIS (MFA)
By the end of 2006, material flow data for 18 enterprises had been compiled for MFA. Figure 1 shows the results of the accumulated data from the 18 enterprises. According to this information, it is calculated that 250 Mt is input into Eco-town as material for recycling and 216 Mt is output as recycled resources. Material flow by internal linkage in Eco-town amounts to 22 Mt, which is...
As a next step, distance ranges for material input and output at Eco-town were analyzed. Figure 2 shows material inputs into Kitakyushu Eco-town classified by distance from origins. 20 km on the X axis roughly means within the city, while 50 km indicates the prefectural range, and 300 km corresponds to a regional level such as the Kyushu area. 500 km reaches as far as Osaka, and 1,000 km includes Tokyo or the corresponding circumference. Construction waste from 50 km, iron and other inorganic materials from 300 km and 1,000 km, and plastics from 300 km and 1,000 km are present in large volume.

Figure 3 shows material outputs from Kitakyushu Eco-town classified by distance to destinations. The X axis is the same as in the previous graph. The 20 km range has a large volume and leaves the rest of ranges far behind one. In particular, transportation of construction waste and iron within 20 km is substantial. Construction waste within 20 km mainly indicates transportation for internal linkage of enterprises inside Eco-town. Iron within 30 km indicates materials moving from Eco-town to Nippon Steel Corporation in Kitakyushu. In addition, nonferrous metals to 300 km and other inorganic materials to 500 km are present in large volume.

**LIFE CYCLE ASSESSMENT (LCA)**

LCA results for 18 recycling projects are shown in Table 1. Energy, CO2, SOx, NOx and resource consumption were chosen as indicators of LCI. The increase factors are transportation processes and recycling processes. On the other hand, the decrease factor is the effect of reduction of virgin resources by recycling. The waste treatment process is not displayed because it is relatively small.

Figure 4 shows the contribution in LCCO2 reduction from recycling activities in Eco-town. The main factors of LCCO2 reduction in Eco-town are cleared in this assessment. The effects of CO2 reduction through iron and nonferrous metals recycling are large. This is because of favorable geographic and social conditions and the large number of metal industries in Kitakyushu city. In addition, generally, metal recycling has a high potential for CO2 reduction. The effects of thermal recovery from recycling residues and waste treatment reduction also offer great potential.

**INDICATORS FOR EVALUATION OF CONTRIBUTIONS IN THE OVERALL MATERIALS FLOW OF THE CITY**

Table 2 shows evaluation indicators for the contribution of Eco-town in material circulation. Four indicators for evaluation were selected: resource productivity, usage rate of recycled material, rate of final disposal, and recycling rate. As for whole city of Kitakyushu, usage rate of recycled material is 22%, the rate for final disposal is 13% and the recycling rate is 56%. On the other hand, in the Eco-town case, the usage rate for recycled materials is 96%, the rate of final disposal is 4% and the recycling rate is 93%. The contribution rate of Eco-town can be also calculated. Eco-town contributed 2.3% to the usage rate of recycled materials, 0.8% to the rate of final disposal, and 4% to the recycling rate.

**CONCLUDING REMARKS**

Resource-recovery type EIPs are being developed in various Asian countries, including China. Additionally, intercity cooperation projects are progressing such as those between Kitakyushu and Qingdao, and Kitakyushu and Tianjin. In these undertakings, it is necessary and useful to draw on the experience and lessons from Japanese cases.

**Author’s information:**

Toru Matsumoto is a professor at the University of Kitakyushu, Japan. He received his B.A. (1990), M.Eng. (1992) and D.Eng. (1999) from Kyushu University, Japan. He worked as an researcher for Nomura Research Institute (NRI), one of the biggest think tanks in Japan, between 1992 and 1995. He was a research associate of Kyushu University from 1995 until 1999 and an associate professor of Kyushu University and the University of Kitakyushu from 2000 until 2008.
Eco-Industrial Park Research: Experiences and Lessons from the Kwinana Industrial Area / Western Australia

Michele John
Centre of Excellence in Cleaner Production, Curtin University of Technology
GPO Box U 1987, Perth WA 6845, Australia
Tel. +61 (0)8 9266 1286 Fax +61 (0)8 9266 4811
Email: m.john@curtin.edu.au Internet: www.c4cs.curtin.edu.au

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ABSTRACT
The Kwinana Industrial Area (KIA) is home to the largest concentration of heavy process industries in Western Australia. Industrial symbiosis has truly taken off in Kwinana since the late 1980s, making it a leading example for eco-industrial parks around the world and providing economic, environmental and social benefits to the companies involved, the surrounding communities and the State. Industry in the area is diverse, including various minerals processing and chemical industries, energy and water utilities and fabrication and industrial service providers. This has fostered a generally favourable attitude to cooperation, facilitated by the local industry association. Over the past two decades, Kwinana operations have established up to forty-nine industrial symbiosis, or resource synergy, projects, including recovery of previously discarded by-products or shared use of water and energy infrastructure, while many more opportunities appear to exist. The Centre of Excellence in Cleaner Production at Curtin University of Technology under the auspices of the Centre for Sustainable Resource Processing designed, and now implements, an integrated research strategy to support the further development and implementation of profitable industrial symbiosis projects between Kwinana operations, and in other heavy industrial areas. This paper provides an overview of past and current developments in the KIA and places the lessons learnt in the context of international developments.

INTRODUCTION
Regional resource synergies concern the capture, recovery, and reuse of previously discarded resources (materials, energy, water) from one industrial operation by other, traditionally separate industries in close proximity (Chertow 2000). These can extend into utility synergies (shared use of utility infrastructure) and supply chain synergies.

Regional synergies are well established within the Kwinana Industrial Area (KIA). The KIA is located approximately 40 kilometres south of Perth, and was established in the 1950s to accommodate the development of heavy industries in Western Australia. There is a coexistence of diverse and non-competing industries in Kwinana.

Recognising the sustainability benefits that industries can achieve through synergies, the Kwinana Synergies Project was launched to provide practical support to the industries for further development of regional synergies. This project is commissioned by the Centre for Sustainable Resource Processing (CSRP), with strong support from the Kwinana Industries Council (KIC) and its members (Van Beers 2008).

The paper shares some of the lessons learnt by the researchers and industry partners so far, and provides insights into future directions for the collaborative project.

LESSONS LEARNT
The overarching lessons learnt from the regional synergies already in place and the new synergy opportunities currently being developed in Kwinana are summarised below (Swetman et al. 2006).

Industry Networking. The KIC engenders a high level of cooperation and trust between the operations which helps smooth the way for the development of new synergy opportunities and other joint initiatives. This is a vital factor for encouraging synergies to happen. The importance of building relationships between representatives of the companies in the region should not be underestimated and is an essential component of the development of synergies where the benefits are typically not just financial but also environmental, community or company reputation.

Business Case. The broader sustainability benefits of synergies are not often well understood. Traditionally, company decision-making for new projects is based on return-on-investment rates. A more comprehensive and inclusive approach is required to demonstrate and account for the economic, social, and environmental benefits of the life cycle of a new synergy opportunity. A novel triple-bottom-line accounting methodology is being
developed and trialled in Kwinana to help build a more comprehensive business case for new synergy projects leading to improved regional sustainability (Kurup et al. 2005).

Regulatory Barriers. Government support for the widespread implementation of regional synergies is not yet forthcoming (Harris 2007). There is a (mis)perception that by-products are, by definition, wastes (and therefore contaminated), rather than valuable alternative raw materials with characteristics similar to traditional resources. The current regulatory framework is oriented to support the established raw materials industries and not so much to enable the reuse of available by-products in different industry sectors. A more collaborative approach involving industry, government, community, and research providers would likely result in achieving the full potential of regional synergies; this is particularly the case for inorganic by-products (e.g., kiln dusts, fly-ash, bauxite residue).

Time. Significant progress has been made so far towards the development of new synergy opportunities. It must be noted, however, that the development of synergies from identification, assessments, to implementation is a time-consuming process. It involves multiple parties working together to achieve a common goal that is often not perceived as core business. It is believed that most ‘low-hanging fruit’ have been captured when it comes to the realisation of regional synergy opportunities. It is now the challenge to further develop the more challenging synergy opportunities with significant sustainability benefits.

Key Success Factors. The realisation of successful synergies is dependent on three main aspects: proven technology, convincing business case, and license to operate (van Berkel 2006). For a synergy to be successful, all involved parties must benefit. In fact, it is unlikely that a synergy would be implemented unless all involved parties at least perceived some business benefit (direct or indirect).

When developing synergy opportunities for the Kwinana Industrial Area, it is most important to maintain a focus on these three key success factors.

CONCLUSIONS & FUTURE DIRECTION
The research has confirmed the close collaboration and integration that already exists in the KIA, which has initially developed in response to perceived business opportunities and environmental and resource efficiency considerations. There are already 47 regional synergies in place in the KIA (Van Beers 2008). 32 of these are by-product synergies and 15 involve shared use of utility infrastructure. These existing synergies greatly exceed ‘business-as-usual’, and are more diverse and significant than reported for other heavy industrial areas (Bossilkov et al. 2005). This positions Kwinana among the international leading edge examples of regional synergy development.

The existing synergies provide a range of economic, environmental, and social benefits for the industries involved and KIA as a whole. Landfill diversion, increased resource security and efficiency, and lower operational costs are some illustrative benefits from existing synergies in Kwinana (Van Beers, 2008). These examples show that the benefits are not just commercial but also strategic, leading to reduced exposure to risk and better reputation with key stakeholders.

Significant progress has been made so far to further develop promising new synergies. It is believed that all ‘low hanging fruit’ have been captured when it comes to the realisation of regional synergy opportunities. It is now the challenge for all involved parties to further develop the more difficult synergy opportunities. These synergies will only come to fruition through dedicated research and hands-on support to the industries to meet their research needs. Strong commitment from industry, KIC, and the CSRP will assist in achieving this goal.

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