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Role of eco-towns in advancing 3R and circular economy – International cases and experiences

(Background Paper for Webinar I)

Final Draft

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10th Regional 3R and Circular Economy Forum in Asia and the Pacific

Webinar I

Background Paper

Role of eco-towns in advancing 3R and circular economy – International cases and experiences

Key Words; industrial symbiosis, eco-industrial park, eco-town, circular economy waste circulation, urban symbiosis, SDGs

1 Resource circulation through industrial symbiosis

Industrial and Urban Symbiosis are widely considered as among the most effective policies and business concepts in Asian metropolises to realize sustainable resource circulation through collaborative networks among industries as well as those between industries and urban groups including households, offices and retail shops (e.g. Van Berkel, 2006; Fang, Cote, et al, 2007; Chertow, 2007: Van Berkel, Fujita et al, 2009a). This reduces local and global environmental emission while offering attractive profits and motivations for business sectors, municipalities and citizen groups (e.g. Chertow and Lomardi, 2005; Van Berkel, Fujita et al, 2009b). Kalundborg is arguably the most publicized example of the implementation of Industrial Symbiosis (IS) which materialized over a period of several decades (e.g. Jacobsen, 2006; Chertow 2007). A number of Eco-Industrial Parks (EIPs) or Eco-Industrial Developments (EIDs) are planned and developed in various parts of the world (e,g. Deutz, 2004; Van Berkel, 2006; Chertow, 2007) Asian governments particularly got strong interests in practical application of EIDs (e.g. Fujita, 2006; Geng, Zhang et al, 2009). Various types of Eco Industrial Parks were planned as one of key policy solutions to keep their sustainable industrialization with local and global environmental limitation. A number of demonstration EIPs are planned and developed in many Asian countries and regions from late 1990s, while most of pursuing projects are based more on single stream industries or material flows, unlike preceding Kalundborg case.

One of a particular features of Asian EIPs are urban and industrial symbiosis, where new symbiotic opportunities have been generated from the geographic proximity of urban and industrial areas by linking Municipal Solid Waste Management (MSWM) with local industries (Van Berkel, Fujita et al, 2009a),. This provides environmental and economic efficiencies in sustainable resource circulation in Asian cities by transferring physical resources from urban refuse directly to industrial applications, and thereby improving the overall eco-efficiency of the city and the region as a whole. Sustainable MSWM has already been accepted and practiced by city managers for some time in several Asian countries, most prominently in the Japanese Eco-Town scheme (GEC, 2005; Fujita, 2006). However, with different social and economic realities, consumption patterns, and technological development levels, municipalities in different countries have adopted varying approaches. These mainly involve the use of landfill levies and restrictions and incentives for recycling and recovery. Due to increasing environmental pressure and decreasing landfill capacity, prevention of MSW and promoting reuse, recycling and recovery have become priorities for policy makers and city administrators alike.

This section summarizes the results and experiences of Japan's waste circulation through industrial symbiosis, namely its Eco-Town Program. This program 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. The term *Urban Symbiosis* was therefore introduced elsewhere (Van Berkel, Fujita et al, 2009a) as an extension for industrial symbiosis. It refers specifically to the use of by-products (wastes) from cities (or urban areas) as alternative raw materials or energy source for industrial operations. This section also provides an evaluation of an innovative waste management initiative by an LCA based scenario simulation model. Results show that obvious environmental and social benefits can be gained through urban symbiosis, helping to realize the goal of establishing a low carbon city.

2. Conceptual theories of resource circulation as 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 (van Berkel 2007b). One of its principal application is Industrial Symbiosis. (IS) At its core IS is concerned with ways for closing materials cycles by using the wastes from one facility as an alternative input for another facility. Industrial symbiosis is defined as encouraging traditionally separate industries to adopt a collective approach with competitive advantage involving physical exchange of materials, energy, water and byproducts (Chertow, 200; Liamsanguan 2008). The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity (Chertow 2007). Through industrial symbiosis, firms in diverse urban areas can benefit from concentrated intermediate inputs that are not specific to any particular industry, such as reuse and recycling of Municipal Solid Waste (MSW) and shared public infrastructure, accounting services and labor market. Municipal governments can receive both economic and environmental benefits from exchange of byproducts between firms and between some industries and municipalities. This means that industrial symbiosis need not occur within the strict boundaries of an industrial park or zone, despite the popular usage of the term eco-industrial park to describe the cluster of organizations that are engaged in exchanges of waste materials, water and/or heat. Urban *s*ymbiosis is an extension for industrial symbiosis. It has been defined as "*the use of byproducts (waste) from cities (or urban areas) as alternative raw materials or energy sources for industrial operations"* (van Berkel, Fujita, et al 2009a). 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 refuse to industrial applications. This is of particular relevance in Japan where the proximity principle, namely, management of waste close to source, has been a central value in MSWM for over thirty years (Okuda 2007).

The Presidential Council for Sustainable Development (PCSD) launched a national pilot program in the USA on eco-industrial parks in 1997 (PCSD 1997). The Netherlands (van Leeuwen, Vermeulen *et al.* 2003) and United Kingdom (Mirata 2004) launched similar demonstration programs respectively on eco-industrial parks and industrial symbiosis. China also established demonstration sites for eco-industrial parks under its circular economy policy (Fang, Cote *et al.* 2006), and has recently launched a standard for eco-industrial parks (Geng, Zhang *et al.* 2009). While good progress has been achieved in improving environmental amenity of existing industrial areas, the success of government programs in achieving actual resource exchanges or synergies between industries has been modest at best (e.g. Deutz and Gibbs 2004; Heeres, Vermeulen *et al.* 2004; van Berkel 2006; Chertow 2007). Generally, the EIPs in Europe have been more successful that their US counterparts. After reviewing the establishment and development of 61 EIPs in the US and Europe, Gibbs *et al.* (2005) found that only 6 out of 35 EIPs in the US and 16 out of 26 in Europe were actually in operation, whereas 16 EIPs in the US and 3 in Europe has never emerged as a real project in operation (Table 1).

A relatively small, but compelling set of practical examples of industrial symbiosis has been described in the international literature as reviewed by for example, Bossilkov, van Berkel *et al.* (2005), van Berkel (2006), and Chertow (2007). More detailed case studies can be found in the literature on Denmark (Kalundborg, e.g. (Jacobsen 2006)), The Netherlands (Rotterdam Harbour and Industrial Complex, e.g. (Baas and Boons 2007)), United Kingdom (e.g. (Harris and Pritchard 2004; Mirata 2004)), Australia (Kwinana and Gladstone, e.g (van Beers, Corder *et al.* 2007)), USA (e.g. Texas (Mangan 1998)), Puerto Rico (Chertow and Lombardi 2005) and China (e.g. Guigang (Fang, Cote *et al.* 2006)). The Japanese government initiated eco-town projects in 1997 and these projects have had a positive impact in promoting industrial symbiosis at the city level. Most Japanese municipalities have established well-designed source separation systems for their MSW. With proactive planning, valuable MSW can be efficiently collected and delivered to the appropriate sites for reuse and recycling (Fujita 2007).

Several quantitative studies have been conducted to assess the environmental benefits of industrial and urban symbioses in selected industrial areas. Several such studies were reviewed elsewhere (Van Berkel, Fujita et al, 2009b) and confirmed reductions in the demands for water, raw materials, and energy and the emissions of various air pollutants and greenhouse gases are found to be among the major benefits (Table 2).

Table 1. Eco-industrial parks in USA and Europe

Park and location	Operational	Pre-operational[a]	Planned	Attempted[b]
USA				
Anacostia Ecogarden Project, Prince Georges County, Maryland				×
Avtex Redevelopment Project, Front Royal, Virginia			×	
Bassett Creek, Minnesota			×	
Brownsville Eco-Industrial Park, Brownsville, Texas				×
Buffalo, New York			×	
Cabazon Resource Recovery Park, California	×			
Civano Industrial Eco Park, Tucson, Arizona				×
Coffee Creek Centre, Chesterton, Indiana			×	
Computer and Electronics Disposition Eco-Industrial Park, Austin, Texas			×	
Eco-industrial Park, Cowpens, South Carolina				×
Devens Planned Community, Massachusetts	×			
Dallas Ecopark, Dallas, Texas		×		
Alameda County Eco-Industrial Park, San Francisco, California			×	
Eco-industrial Park, Cheney, Washington State				×
Fairfield Ecological Industrial Park, Baltimore, Maryland	×			
Franklin County Eco-Industrial Park, Youngsville, North Carolina				×
Hyder Enterprise Zone, Hyder, Alaska				×
Intervale Community Food Enterprise Center, Burlington, Vermont		×		
Londonderry Eco-Industrial Park, Londonderry, New Hampshire		×		
Menomonee Valley, Wisconsin			×	
Northwest Louisiana Commerce Center, Shreveport, Louisiana				×
Phillips Eco-enterprise Centre, Minneapolis, Minnesota	×			
Plattsburgh Eco-Industrial Park, New York				×
Port of Cape Charles Sustainable Technologies Industrial Park, Northampton County, Virginia	×			
Raymond Green Eco-Industrial Park, Raymond, Washington				×
Red Hills Ecoplex, Choctaw County, Mississippi		×		
Renova EIP, Puerto Rico			×	
River City Park, Newburgh, New York				×
St Peter, Minnesota				×
Skagitt County Environmental Industrial Park, Skagitt County, Washington				×
Shady Side Eco-Business Park, Shady Side, Maryland				×
Springfield, Massachusetts			×	
Trenton Eco-Industrial Complex, Trenton, New Jersey				×
Triangle J Council of Governments regional IS project	×			
Volunteer Site, Chattanooga, Tennessee				×
Europe				
BCSD-NSR, National Industrial Symbiosis Programme, UK (various sites)		×		
Closed Project, Tuscany, Italy	×			
Crewe Green Business Park, UK	×			
Dagenham Sustainable Industrial Park, UK		×		
Dyfi Eco-Park, UK	×			
Ecopark Oulu, Finland	×			
Ecosite du Pays de Thau, France	×			
Ecotech, Swaffham, UK		×		
Emscher Park, Germany	×			
Green Park, Cornwall, UK				×
Hartberg Okopark, Austria	×			
Herning-Ikast Industrial Park, Denmark				×
Kalundborg, Denmark	×			
London Remade eco-industrial sites, UK	×			
Montagna-Energia Valle di Non, Italy	×			
Parc Industriel Plaine de l'Ain (PIPA), Lyon	×			
Righead Sustainable Industrial Estate, UK		×		
Rotterdam Harbour Industrial Ecosystems Programme			×	
Selkirk Eco-Industrial Project, UK				×
Sphere EcoIndustrie d'Alsace, France	×			
Stockholm, Environmental Science Park, Sweden			×	
Styrian recycling network, Austria	×			
Sustainable Growth Park, Yorkshire, UK			×	
Turin Environment Park, Italy	×			
ValuePark®, Schkopau, Germany	×			
Vreten, Sweden	×			

Notes: [a]Includes both existing industrial parks developing 'green' practices and new EIPs under construction and/or recruiting tenants.
[b]Sites range from those that failed in the planning stages to those that are now fully operational but have abandoned the 'eco' and/or 'industrial' themes.

source: (Gibbs et al. 2005)

Table 2. Major environmental benefits documented in literature

Case studied	Environmental benefit	Quantity	Note	Reference
Kawasaki	Landfill avoidance	565 kt/yr	Five by-product exchanges and two recycling industries	(van Berkel, Fujita et al., 2009 b)
	Raw material saving	490 kt/yr		
Guayama	Reduction in SO_2	1978 t/yr	Exchange of steam	(Chertow & Lombardi, 2005)
	Reduction in NO_x	211 t/yr		
	Reduction in PM_{10}	123 t/yr		
	Reduction in CO	-15 t/yr		
	Reduction in CO_2	51000 t/yr		
Kalundborg	Conservation of surface water	500,000 m^3/yr	Using cooling water for steam production	(Jacobsen, 2006)
	Reduction in CO_2	154788 t/yr	Steam and heat cogeneration	
	Reduction in SO_2	-304 t/yr		
	Reduction in NOx	389 t/yr		

3. Resource circulation policies and eco-town programs in Japan

In the late 1990s and early 2000s, various recycling laws were enacted in Japan, including the "Containers and Packaging Law", the "Electric and Household Appliances Recycling Law", the "Food Recycling Law", the "Automobile Recycling Act", and the "Construction Material Recycling Act" (Okuda 2007). This legal system forms a solid foundation for material recovery. Despite this, incineration remains the dominant management method of MSW in Japan. This is because it saves landfill space and generates power or heat which, if produced by conventional energy sources such as fossil fuels would have caused emissions of greenhouse gases (Yoshida 2005). The main concern is that incineration cannot realize the material recovery potential of MSW as resources (Nakanishi 2004). Urban communities often consider incineration facilities as sources of pollution and oppose local placement of new plants. As a result, new incineration plants are often located in less populated areas. Because demand for heat in such areas is limited, a large amount of the heat generated these incinerators is not efficiently recovered and used (Sakai 1996). Incineration impedes the reuse and recycling of many valuable solid wastes that can substitute virgin raw materials. Therefore, the national government decided to adopt another approach, namely, to replace natural resources by MSW for energy generation and material processing. This new approach can reduce both total greenhouse gas emissions and the total amount of waste destined for landfill.

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 (METI 2004; Morioka, Tsunemi *et al.* 2005). It was developed under the *Basic Environment Law*, and provides quantitative targets for recycling and dematerialization of Japanese society. 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). Two complementary laws were enacted under this *Basic Law for Establishing a*

Recycling Based Society (METI 2004; MoE 2007). The *Waste Management Law* (2003 amendments) sets aims and objectives for waste management and defines roles and responsibilities in regards to waste prevention and management for waste generators (for commercial, industrial and construction wastes) and prefectures (for garbage collection and intermediate treatment/incineration and final disposal within the local government boundaries). *The Law for Promotion of Effective Utilization of Resources* (2001) has designated key products and industries for resource saving, and has since been implemented with product specific laws which set specific recycling targets for categories of wastes, to be realized through product stewardship schemes, levies and voluntary initiatives of government, producers and consumers.

A comprehensive system of recycling targets is now in place (METI 2004; MoE 2007), both by product group/waste category (ISC 2001b) as well as by industry sector (ISC 2001a). A key program in Japan's effort to become a recycling oriented society is the *Eco-Town Program* (GEC, 2005; Fujita, 2006). Launched some five years before the formal enactment of the *Basic Law for Recycling Oriented Society*, the Eco-Town program aimed to develop innovative recycling industries in particular in towns with ageing industrial infrastructure through voluntary initiatives and financial support from the national government. The status of the Eco-Town program was evaluated in 2006, on behalf of the Ministry of Economy, Trade and Industry (METI), which also provided the main share of the program funding (Fujita 2006; 2008). The main findings from this evaluation were analyzed elsewhere (Van Berkel, Fujita et al, 2009a) to provide insight into the diversity of results and experiences gained in the Eco-Towns since the program launch in 1997.

4 Characteristic analysis of Eco-town programs

Eco-Towns in Japan have been developed through a national initiative, which was inaugurated by the Ministry of Health, Labor and Welfare (responsibility over waste management was taken over by MoE: Ministry of Environment, in 2001) and Ministry of International Trade and Industry (present METI: Ministry of Economy, Trade and Industry) in 1997. The aim was twofold: to extend the life of existing landfill sites and to revitalize local industries. Japan faced in the late 1990s a serious shortage of landfill sites. In 1997, existing landfill sites for industrial wastes were estimated to be filled up in 3.1 years if no measures would be taken, and in the Tokyo Metropolitan Area, this would only take 0.7 years. At the same time, local industries experienced economic stagnation triggered by the burst of the Japanese bubble economy after 1991. Eco-Town program aimed to tackle these two challenges at the same time under the slogan of "*Zero Emissions*". This is a concept of alternative industrial system in which, in principle, all the wastes generated from one industry are usefully applied elsewhere. This concept has been promoted by the United Nations University's

Zero Emissions Research Initiative with support from the Government of Japan (Kuehr 2007).

The operation of the Program is illustrated in Figure 1 (Van Berkel, Fujita et al, 2009a) Under the Eco-Town Program, local governments (city or prefecture level) formulated Eco-Town Programs in consultation with local stakeholders from private sector, research institutes, community groups and citizens. Upon their submission the Eco-Town plans were reviewed by the national government, and, if considered appropriate, jointly endorsed by METI and MoE. The Eco-Town Plan would typically be a combination of town planning, community recycling and outreach activities (jointly referred to as the '*software'* project) and proposals for specific innovative recycling plants (commonly referred to as the '*hardware*' project).

Upon approval of the Eco-Town Plan MoE provided a grant to the local authority to execute the town planning, community recycling and promotion and outreach activities, in collaboration with citizens and non-profit organizations (NPOs). The grant was limited to maximum of 50% of the project costs, typically in the range of 3 to 5 million JPY/year (30-50,000 USD/yr) for a 3 to 5 year period (GEC 2005). Simultaneously, METI would provide investment subsidies in the range of 100 to 7,000 million JPY (up to ~ 70 million USD) to private enterprises willing to invest in the innovative recycling projects included the Eco-Town plans (Fujita 2006; Van Berkel, Fujita et al, 2009a)). The METI grant would be matched by an investment subsidy from the local government, typically in the range of 1-10% of the METI grant (GEC 2005; (Van Berkel, Fujita et al, 2009a)).

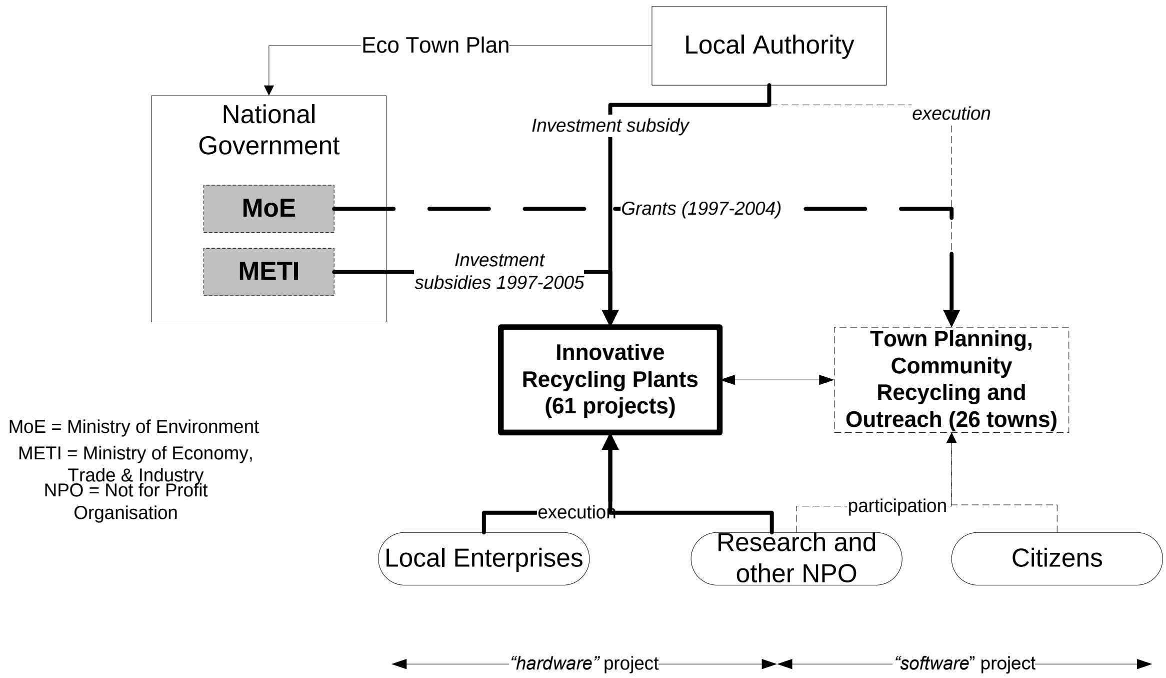


Figure 1: Operation of the National Eco-Town Program

Source: (Van Berkel, Fujita et al, 2009a)

During its 10 years of operation, 26 Eco-Town Plans were approved and endorsed for implementation by the responsible local government authority. Figure 2 contains a map with the geographic locations of these 26 Eco-Towns. The map proofs extensive coverage of all key regions of Japan by the Eco-Town Program.

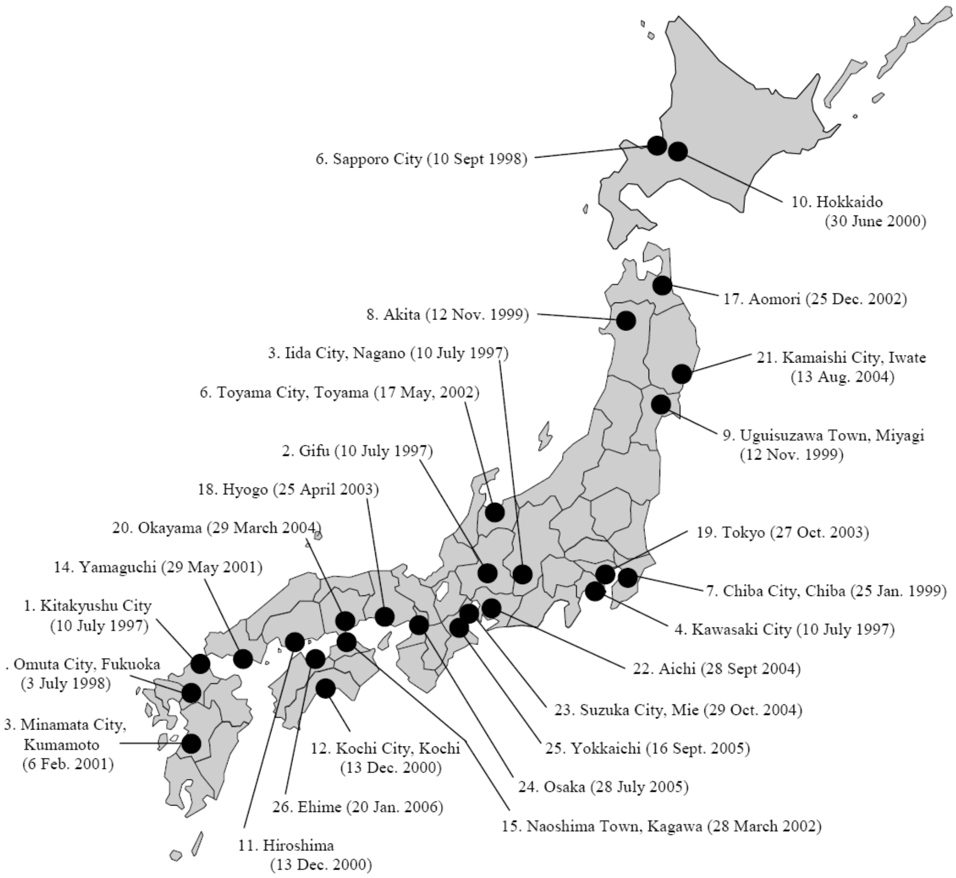


Figure 2: Map of Eco-Town Locations
Source: http://www.env.go.jp/en/press/2006/0120a-01.pdf, last accessed 14 March 2008.

Half of the Eco-Towns were approved and established in the first four years of the program, respectively four in its first year (1997) and three each in the following years (1998, 1999 and 2000). The other half of the Eco-Towns was approved and established between 2001-2006, four in 2003, three in 2002, two each in 2001 and 2005 and one each in 2004 and 2006. The *administrative responsibility* for half of the Eco-Towns rests with a municipality and the other half with a prefecture (each 13 Eco-Towns). There is considerable differentiation in the *geographic target area* of the respective Eco-Town Programs, as we analyzed before (Van Berkel, Fujita et al, 2009a). Six plans cover a metropolitan area (Chiba, Kawasaki, Kitakyushu, Osaka, Sapporo and Tokyo). These are all focused on setting up recycling infrastructure for different parts of the urban waste streams, including household recyclables, commercial and construction and demolition waste etc. Six plans cover a region including several towns and/or villages. These are: Aichi, Akita, Ehime, Gifu, Hyogo and Omuta. A common objective for these Eco-Towns is coordination of waste handling and recycling at the regional level to achieve economies of scale. A comparable group of two Eco-Towns covers an island (respectively Hokkaido (large) and Naoshima (small)). The largest group of 10 Eco-Towns has a city, or part thereof, as its target region. Their Eco-Town plans are quite diverse, and typically include a combination of community based initiatives for improved recycling, environmentally conscious town planning and creating of clusters of recycling businesses. The final group of two Eco-Towns has an industrial or port area as its target region (Kamaishi and Okayama). These Eco-Towns have been set up to establish new recycling oriented businesses in existing industrial complexes for rejuvenation and diversification among established heavy industries.

Elsewhere (Sato *et al.* 2004) it had been proposed to categorize Eco-Towns in three *types*, respectively: promotion of environmental industries (Type 1), treatment of wastes (Type 2) and community development (Type 3). We expanded and revised this categorization, on basis of information available in 2006. Table 3 categories all 26 current Eco-Towns (van Berkel, Fujita et al, 2009a). Just over half (14 of 26) of the Eco-Towns are of Type 1. All of these have a strong emphasis on environmental innovation in existing industries by applying their core technology and competencies for environmental purposes and/or establishing niche operators that can process wastes that are available in the region into valuable alternative raw materials for the existing industries. The other Eco-Towns are almost evenly split between Type 2 (waste processing in seven Eco-Towns) and Type 3 (community development and engagement of citizens and businesses in five Eco-Towns).

Table 3: Categorization of Eco-Towns (source: Van Berkel, Fujita et al, 2009a).

Type [number of Eco-Towns] (based on (Sato *et al.* 2004))	**Eco-Towns**
1. Promotion of environmental industries [14]	Aichi, Akita, *Aomori,* Bingo, Ehime, Kawasaki, Kitakyushu, Kurihara, Okyama, Omatu, Osaka, Toyama, Yamaguchi and Yokkaichi
2. Treatment of wastes [7]	Chiba, *Hokkaido,* Kochi, Naoshima, Suzuka, Sapporo and Tokyo
3. Community development [5]	*Gifu*, Hyogo, Iida, Kamaishi and Minamata

Eco-Towns that are underlined were not included in (Sato *et al.* 2004). Eco-Towns in *italics* have been assigned to different categories on basis of additional information in (Fujita 2008).

Designation as an Eco-Town provided access to investment subsidies for priority innovative recycling projects in the respective towns. The total governmental subsidies were provided to private sector parties who invested in the establishment of the facilities and own and operate these recycling facilities upon completion. The total investment for these plants were reported by Fujita (2008) to be 165 billion JPY (Figure 3). Governmental public initiatives of a series of recycling laws and national subsidiesof 59 billion JPY induced as many as 2.8 times more private investment.

The investment per plant ranged between 63 and 20,328 million JPY with an average of 2.71 billion JPY per project (Van Berkel, Fujita et al, 2009a). The total investment in subsidized recycling plants in each Eco-Town ranged between 75 and 43,372 million JPY, with an average of 6.6 billion JPY per Eco-Town. The investment was unevenly spread among the Eco-Towns (Figure 3). Over a quarter of the total was invested in one Eco-Town (Chiba), and collectively four Eco-Towns (Chiba, Kawasaki, Omuta and Bingo) absorbed 2/3 of the total investment.

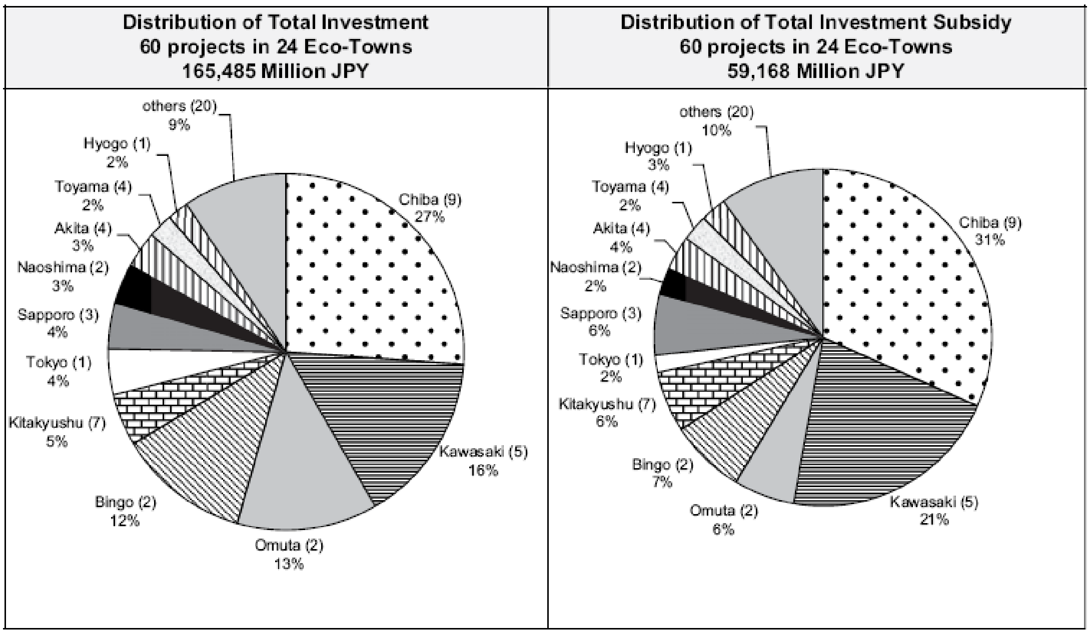


Figure 3: Levels of subsidies and total investments by Eco-Towns
Source: (ven Berkel, Fujita et al. 2009a)

The level of subsidy by the national government ranged between 14 and 50% of the total investment with an average of 36% (Van Berkel, Fujita et al, 2009a). The national government provided a total subsidy of 59 billion JPY (approximately 590 million USD) (Figure 3), on average just under one billion JPY per recycling plant. This excludes data on subsidy for one relatively small plant, which had only a small total investment (300 million JPY) in Kamaishi. The subsidy was provided by METI (87%) and MoE (13%). The national subsidies were matched by local government subsidies, reported to be in the range of 1 to 10% of the national government subsidies (GEC 2005). However, no detailed data were available. It is thus likely that the average subsidy percentage for the subsidized plants might have been slightly higher, in the range of 36 to 40% (Van Berkel, Fujita et al, 2009a). The subsidies followed the investment pattern, and were therefore also not evenly spread over the Eco-Towns (as illustrated in the right side pie chart in Figure 3). The total subsidy per Eco-Town varied between 25 and 18,816 million JPY, with an average of 2.37 billion JPY per Eco-Town (averaged over the 24 Eco-Towns for which subsidy data are available). Of the total subsidy, over a quarter was spent in Chiba only and collectively four Eco-Towns (Chiba, Kawasaki, Omuta and Bingo) received 2/3 of the total government subsidy.

The 2006 summary profiles of the Eco-Towns presented in Fujita (2008) revealed that the motivation for the local governments to develop an Eco-Town program had been quite divergent between the various Eco-Towns. Five categories of motivation emerged from the analysis of the 26 Eco-Town programs (Van Berkel, Fujita et al, 2009a) These were:

1) *Waste management* and in particular the growing concerns about the availability of landfill space (and/or other treatment and disposal options) to deal with the growing volumes of urban and industrial wastes. This is a shared concern of local government (responsible for garbage collection and disposal) and waste generating businesses (responsible for collection and disposal of commercial, industrial, construction and other wastes). Waste management is based on the proximity principle, which essentially states that waste generated within one local government area, should be

disposed off within the boundaries of the jurisdiction, or in other words, wastes cannot be transferred from one town to another town for treatment and disposal.

2) *Development of recycling industry*: in particular the need to create infrastructure and facilities to reach the mandatory recycling targets set for various product categories under the umbrella of the '*Basic Law for Establishing a Recycling Based Society'*.

3) *Industry modernization*: many heavy process industrial areas in Japan have experienced downturns over the past two decades, for example due to deregulation and opening of the economy (leading to greater international competition (for example from China), ageing of industrial facilities, changes in production and consumption patterns (e.g. greater material competition between metals and with plastics) and depletion of local mines (for industries relying on mining activities). Some Eco-Town projects have been established to counter these trends and develop environmental businesses that utilize technological resources available to existing industries for new environmental applications;

4) *Environmental remediation*: the presence of an environmental black spot, like a polluted river or abandoned hazardous waste sites, has encouraged local governments to develop Eco-Town plans, as a practical way to regain confidence from the residents and improve their quality of life; and

5) *Town planning and community development and engagement*: launching environmental initiatives which involve local residents can strengthen their sense of place in and belonging to the Town and gradually improve credibility for the local governments involved.

The 2006 survey (Fujita 2008) also established that the Eco-Town Program had also triggered investments in at least another 147 additional recycling plants. This analysis was however bound by limitations (Van Berkel, Fujita et al, 2009a). Firstly, the inventory of additional recycling facilities may not have been complete, as it relied essentially on knowledge and readily available information from local government representatives. For some Eco-Towns it is for example known that more recycling projects have been implemented, for example the use of a range of alternative fuels and raw materials for cement production in Kawasaki.

An analysis was also made of the total set of 207 recycling projects reported for the 26 Eco-Towns, based on the type of waste materials and/or processing involved (Van Berkel, Fujita et al, 2009a). To this end, a division in 12 categories was made:

a. *Alternative Fuels and Raw Materials (AF&R):* use of alternative fuels (organics, plastics, wood, etc.) and alternative raw materials (e.g. shells, ash and slags) in cement making;

b. *Construction and Demolition Waste (C&DW):* recycling of inert waste from construction sector, including from roads and infrastructure, most commonly for reuse as coarse aggregate;

c. *End-of-Life Vehicles (ELVs):* dismantling and recycling of automobiles, including their components, in particular tires and batteries;

d. *Glass*: reuse and/or recycling of glass, mainly as bottles;

e. *Industrial waste*: advanced treatment of wastes from industrial operations (e.g. slags, ash, etc.) including treatment of residues from recycling or incineration operations;

f. *Metal recovery*: advanced processes for recovery of precious and/or hazardous metals from complex wastes, such as for example shredder residue from ELVs and/or WEE;

g. *Municipal Solid Waste (MSW):* intermediate treatment of garbage collected by municipality, typically involving sorting with metal recovery and incineration with heat recovery for power generation, or production of an intermediate fuel (e.g. Refuse Derived Fuel);

h. *Organics:* recycling of organic matter (e.g. food waste, fishery processing waste from fishery industry) through anaerobic digestion (production of biogas) and/or composting (for soil improvement);

i. *Paper:* recycling of paper, cardboard and related products, for reuse of fibre and manufacture of recycled paper or paperboard;

j. *Plastics:* recycling of various sorted and/or unsorted plastics, in particular from packaging applications, either for direct reuse (down-cycling of mixed plastics) or for recovery of original plastic or for production of intermediate synthesis or fuel gas (for example as alternative reductant in chemical or metallurgical applications) [(1)];

k. *Waste Electric and Electronic Goods (WEE):* dismantling of electric and electronic appliances (including home, office and medical appliances and amusement machines) for recovery of bulk materials. Also includes recycling facilities for fluorescent tubes (glass, aluminum and mercury recovery) and dry cell batteries; and

l. *Wood:* recovery of waste wood, for chipping and reuse in wood products.

The classification of recycling projects is displayed in Figure 4 (Van Berkel, Fujita et al, 2009a). By far the largest group was the plastics recycling projects, with 35 implemented projects (of which 20 were subsidized) and 11 planned projects. This was also the most diverse group, in terms of complexity and innovativeness. It included novel chemical separation and recycling processes (e.g. for PET-to-PET recycling, oil liquefaction) as well as relatively simple grinding and pelletization projects for mixed plastics. The next largest groups were organics and MSW, both with 23 implemented projects, followed by WEE (with 19 implemented projects) and industrial waste (with 13 implemented projects).

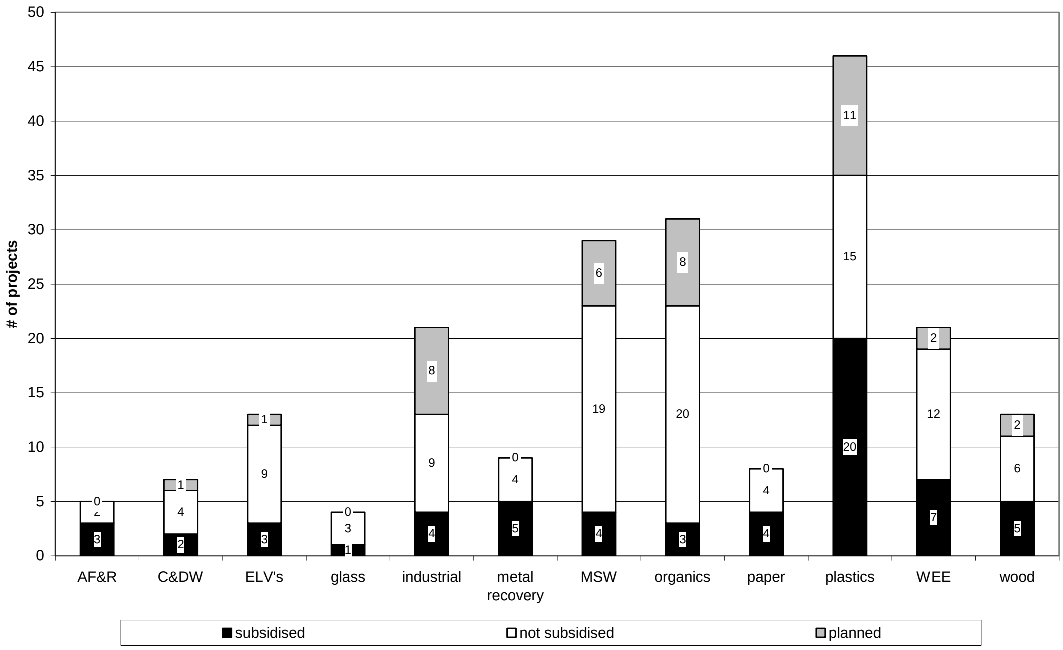


Figure 4: Recycling projects in Eco-Towns by category (total of 61 subsidised projects, 107 unsubsidised projects and 39 planned projects)

Source: (Van Berkel, Fujita et al, 2009a).

We also provided a conceptual impact diagram to illustrate the diversity of the 26 Eco-Town Programmes in Japan (Van Berkel, Fujita et al, 2009a). The four quadrants in the impact diagram (Figure 5) cover different aspects of the environmental and sustainability agendas for government, business and society at large (see e.g. WBCSD 2001; Dunphy, Griffiths *et al.* 2003; Hargroves and

Smith 2005). These have been characterized in Figure 5, by means of the four circles, respectively:

- *Eco-Efficiency:* producing less waste and using less materials in productive activities (see e.g. van Berkel 2007a);
- *Corporate Social Responsibility*: improving the well being of employees, their families and communities (see e.g. WBCSD 2000);
- *Environmental Restoration:* reversing environmental damage from past activities to levels that are no longer harmful to humans and ecosystems; and
- *Environmental Innovation*: using environmental issues as a driver for developing new technologies, products and services (see e.g. WBCSD 2002).

Figure 5 also illustrates that the top right hand triangle is the working area for *industrial symbiosis* (Chertow 2000) and the bottom left hand triangle could then be considered as the working area for *urban symbiosis*.

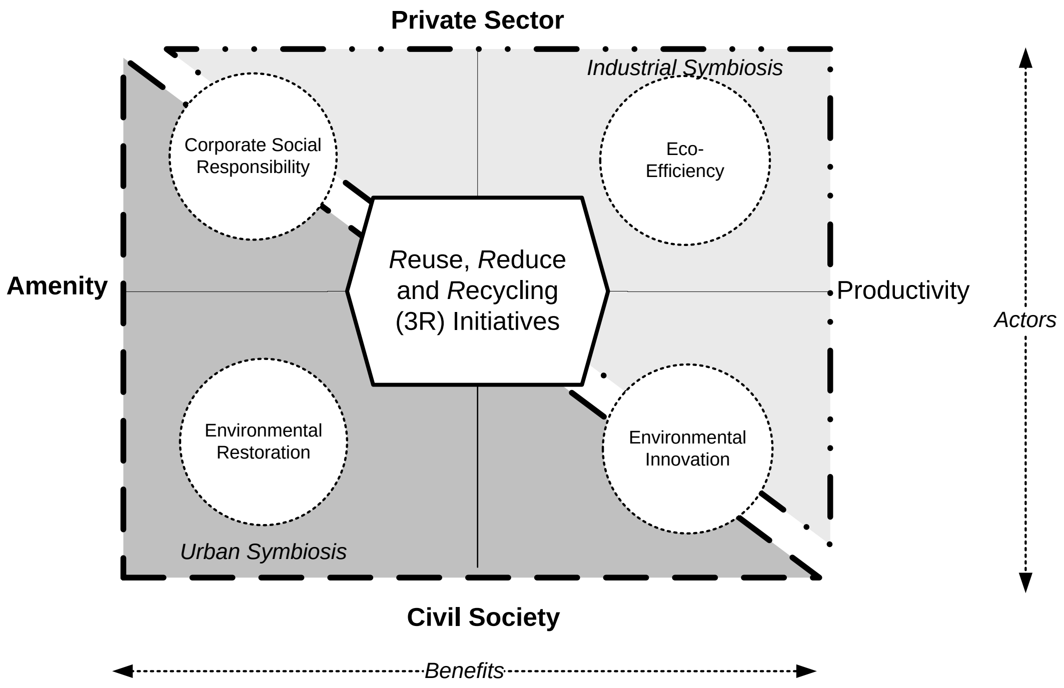


Figure 5: Contribution of Eco-Towns to sustainable industrial development

Source: (Van Berkel, Fujita et al, 2009 a)

Using the pseudo-quantitative axes, all 26 Eco-Towns have been characterized on this conceptual impact map, as in Figure 6 (Van Berkel, Fujita et al, 2009a). The largest group is in the Eco-Efficiency quadrant (twelve Eco-Towns), followed by the Environmental Restoration quadrant (seven Eco-Towns) and the Environmental Innovation Corporate Social Responsibility quadrants (two Eco-Towns each). A rest group of three Eco-Towns does not fit comfortably in either of the quadrants, due to more or less balanced involvement of civil society and private sector (Eco-Town on the horizontal axis) and/or a balanced focus between amenity and productivity (Eco-Towns on the vertical axis). The figure also shows that in 16 Eco-Towns the private sector is more a more important actor than civil society and that in total for 14 Eco-Towns productivity benefits are more important than amenity benefits. The impact map thus confirmed that overall the Eco-Town program had provided a platform for the private sector to innovate using 3R as the guiding paradigm and thereby contributed to maintaining and where possible improving its competiveness and productivity under tightening environmental regulations.

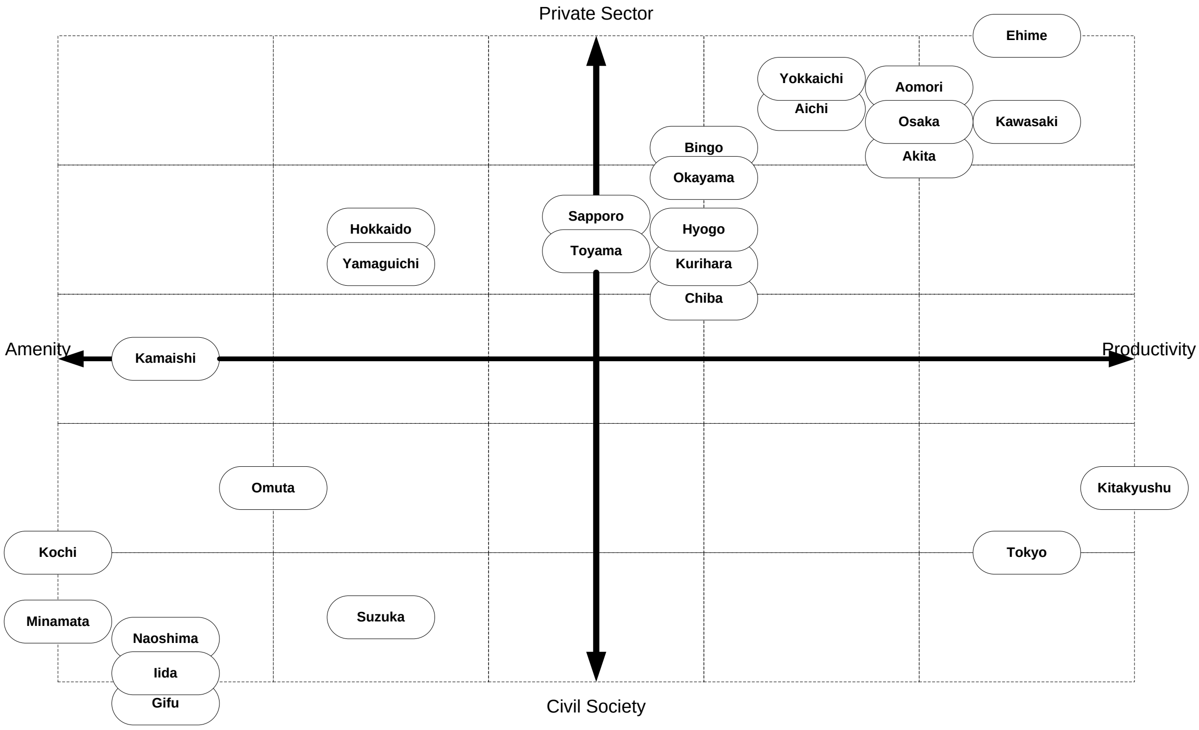


Figure 6: Qualitative characterization of 26 Eco-Towns Source: (Van Berkel, Fujita et al, 2009a).

5 Linking MSWM with Local Industry in Kawasaki Eco-town

Eco-Town programs are typically a combination of town planning, community recycling and outreach activities (jointly referred to as the ‘software’ project) and proposals for specific innovative recycling plants (commonly referred to as the ‘hardware’ project). The selected city governments formulate their own eco-town program in consultation with local stakeholders from private sectors, research institutes, community groups and citizens.

Kawasaki was one of the first Japanese cities to initiate an eco-town project (e.g. Van Berkel, Fujita et al, 2009 b). Their project was approved in 1997, with a total investment of 25 billion yen from government. Five facilities were subsidized. These included a waste plastic recycling system utilizing waste plastics as an input to the blast furnace; a paper recycling facility; a PET-to-PET recycling facility; a waste plastic recycling system for utilizing waste plastic as a raw material to make ammonia; and a facility to transfer waste plastics into concrete-setting frames (wall board) (GEC 2005). Other key recycling facilities which were not subsidized include a home appliance recycling facility and a cement plant with recycling processes. The main mission of the project was to encourage industrial and urban symbiosis activities and improve the overall eco-efficiency of the coastal industrial area, aiming to develop a zero-emission park.

The city government has not limited their eco-town project to within the coastal industrial area. In order to further promote the concept of eco-industrial development, the city government was investigating the possibility of extending their efforts at a larger level, namely linking MSWM with the local industries. With planning and coordination, several urban-industrial symbiosis activities have taken place between local industries and the city government. Figure 7 shows current urban-industrial symbiosis in Kawasaki (van Berkel, Fujita et al., 2009 b). For instance, the cement company is currently recycling sewage sludge from urban areas as a substitute for clay; and waste wood, plastic, tires and oil as substitutes for coal. The blast furnace slags from the steel manufacturing company that is located within Kawasaki Eco-town are utilized as a raw material for making cement. The steel company is currently receiving iron and non-ferrous metals from the home appliance recycling facility as a substitute for raw iron material. In addition, waste plastic collected from the home appliance recycling facility and urban area are utilized as deoxidization matter for making steel products. The paper recycling plant named as Corelex Papers is the first paper recycling facility in the world that has succeeded in achieving zero emissions. This facility can treat almost all kinds of waste paper, such as magnetic train tickets, printing paper for photographs, paper containers with aluminum and laminate layers, and used paper with mixed plastic and staples. Contaminated metals, films, plastic and paper sludge, fluorescent and other ink can be removed from paper sources by using innovative technology. Paper sludge and plastic separated in the process are used as fuel for operating their boilers.

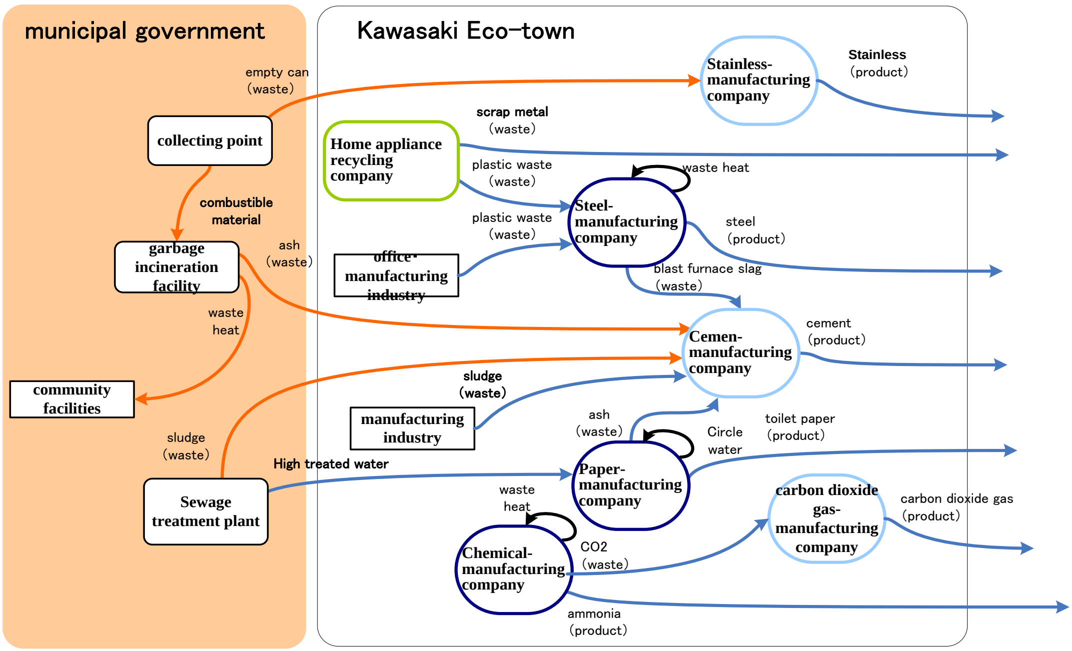


Figure 7: Current urban-industrial symbiosis in Kawasaki

Source: (Geng et al., *forthcoming*)

6 Scenario Design and Analysis

With the establishment and operation of recycling facilities for treating MSW, particularly replacing raw materials with MSW, both economic and environmental benefits can be gained. These include reduction of natural resource consumption, reduction of the total solid waste volume, reducing the burden on local landfill, reduction of resource costs and solid waste treatment costs, as well as environmental liability and insurance costs relative to solid waste issues. Despite this, public controversy on the appropriateness of such an approach remains. Therefore, a quantitative evaluation of different policy scenarios is required. Such an evaluation should be able to test the overall eco-efficiency of different policy options, including the potential of reduced MSW amount to landfills, reduced CO_2 emission, and total cost.

Several evaluation methods have been developed. Life Cycle Assessment (LCA) is a common methodology for the impact assessment of MSWM at the city level. Eriksson *et al*., (Eriksson 2005) used a sophisticated LCA based model, ORWARE, to evaluate waste treatment policy scenarios with different combinations of technology applications in Uppsala, Stockholm and Alvdalen, Sweden. Finnveden *et al*., (Finnveden 2005) used LCA to examine the effectiveness of waste management hierarchy, in which they proved that recycling is preferable to incineration, and incineration preferable to landfill. Habara *et al*., (Habara 2002) evaluated the environmental impact of energy consumption and cost of the collection and transportation process for a regional solid waste management system, in which several municipalities share one centralized treatment facility so as to reduce the total cost. Thus, we adopted the LCA approach for our scenario design and evaluation. As defined by the Society of Environmental Toxicology and Chemistry, “the (life cycle) assessment includes the entire life cycle of the product, process or activity, encompassing extracting and processing raw materials; manufacturing, transportation, and distribution; use/re-use/maintenance; recycling; and final disposal (Gradel 1995) (pp.108)." One of the features of our model in this paper is to apply this life cycle approach to assessing environmental and economic effects of urban symbiosis. Urban symbiosis pertains to multiple life cycle stages of various products. It also concerns multiple stakeholders from residential, business, and industrial sectors who generate recyclable wastes, and manufacturers who take recyclable wastes as input to production by innovative symbiotic technologies. The assessment boundary of the model in this paper includes both the processes of waste management and production. First, by surveying manufacturers that accept recyclable wastes, we compared the differences between the conventional production process and the process designed to utilize wastes as inputs, and further calculated the difference of CO_2 emissions between the two processes. The comparison and calculation included the embedded CO_2 emissions of relevant raw materials and utilities.

Second, based upon our investigation on waste collection and transportation activities, we developed a spatial database for the MSW generation and collection network in Kawasaki. This database can help determine MSW collection boundaries for different collection centers and recycling facilities, based on transportation distances. We then designed four different scenarios with individual recycling options. The baseline scenario (Scenario 0) involves the incineration of mixed waste without any recycling or recovery activities. Scenarios 1 to 4 are set to test various combinations of and trade-off between incineration and various symbiotic technologies. In Scenario 1, mixed waste paper is recycled by Corelex Papers and directly used in toilet paper production. In Scenario 2, waste packaging plastics are recycled by JFE and utilized as a reductant in steel production. In Scenario 3, organic waste from business sectors is recycled by the local bio-gas plant, and fermentation residues are further used in cement production. In Scenario 4, all three recycling options are combined. In the latter four scenarios, all mixed garbage remains are to be sent to the four incinerators in Kawasaki with electricity generation and heat recovery. In order to realize these scenarios, several new facilities need to be constructed. For instance, for Scenario 1, two new pre-treatment centers that can separate, compress and package different waste papers are required. For Scenario 2, two new pre-treatment centers that can separate, compress and package different waste plastic are required. For Scenario 3, a bio-gas plant that can produce power by using the methane from the fermentation process of organic waste is required. Thus, the construction cost and operation cost of these new facilities need to be considered for scenario analysis. Figure 8 illustrates MSW processing flow scenario analysis in Kawasaki.

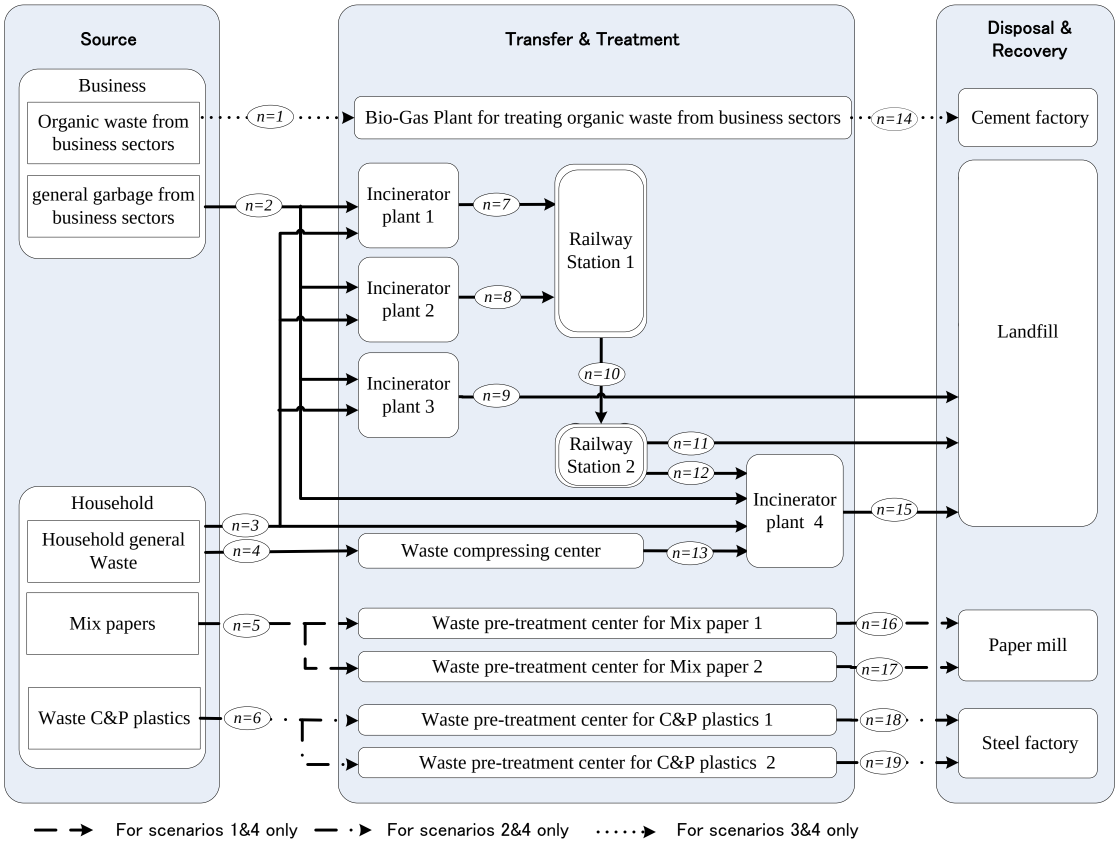


Figure 8: MSW processing flow scenario analysis in Kawasaki
Source: (Geng et al., *forthcoming*)

The next step was to calculate CO_2 emissions, the total input to local landfills, as well as the total cost of MSWM. By applying the LCA method, we could see that CO_2 emissions come from waste collection and transportation processes, construction of recycling facilities, and operation of recycling facilities. Thus, relevant formulae are required. Through interviewing local industrial engineers and checking Japanese literature, appropriate formulae were developed. We detail all calculation processes in the following section.

The total CO_2 emissions Q_i under Scenario i were calculated by the following equation:

$$Q_i = QT_i + QC_i + QO_i - QSub_i$$

where i: scenario index (i=0 to 4); QT: CO_2 emissions from waste collection and transportation; QC: CO_2 emissions from the construction of new waste treatment facilities, including two paper recycling facilities, two plastic recycling facilities, one bio-gas plant; QO: CO_2 emissions from the operation of waste treatment and disposal facilities, including four incinerators, one transportation and compressing center, two paper recycling facilities, two plastic recycling facilities, one bio-gas plant, and one landfill site; and $QSub$: reduction of CO_2 emissions due to the substitution of raw materials, including raw pulp (by waste paper), cokes (by waste plastic), and limestone and clay (by residue from the bio-gas plant).

By using the original data on waste from the Kawasaki city government (Kawasaki City 2005) and the above formulae, we calculated the total CO_2 emissions of different scenarios, as well as the total cost of each scenario. Table 4 shows the total CO_2 emissions for each scenario. Table 5 shows the total cost of each scenario. The results show that the application of urban symbiosis can significantly reduce total CO_2 emissions. This is very important for Japanese municipal governments, because the Cabinet of Japan has set up a target of 20%

reduction in CO_2 emissions from the 1990's level by 2020 (Fukuda 2008). Under the pressure from the national government in the post-Kyoto period, all cities face the challenge of reducing overall greenhouse gas emissions to meet the long-term emission target. In this study, Scenarios 2 and 4 have the lowest CO_2 emissions among the five scenarios. The diversion of plastics from incineration contributes the most to the reduction of CO_2 emissions because they are not carbon neutral in incineration and, by the symbiotic technology, can substitute cokes in steel production. Through such a process, cokes are conserved and prevented from combustion. The results of Scenarios 1 and 3 show that recycling mixed waste paper and organic wastes could not significantly reduce CO_2 emissions as recycling plastics does. This is mainly because what these two types of wastes substituted in industrial production is not as carbon intensive as cokes are. Moreover, conventional paper production considered in this study already uses residues with high heat value from paper production, such as the black liquor, as carbon neutral energy sources in production; whereas recycling hard-to-recycle paper requires more energy in pre-treatment processes.

Table 4. Total CO2 emissions from each scenario

Unit: t/yr

Emission Source	Sce. 0	Sce. 1	Sce. 2	Sce. 3	Sce. 4

Collection & Transportation of Waste	1650	1810	19430	1790	2230
Construction of New Plants	0.0	105	463	296	863
Operation	113000	97000	51900	95500	53300
Reduction Due to Substitutive Effect	0.0	126	-10700	-283	-10900
Total	114,000	99,100	43,600	97,300	45,500

Source: (Geng et al., *forthcoming*)

Table 5. Total cost of each scenario(van Berkel, Fujita et al., 2009 b)

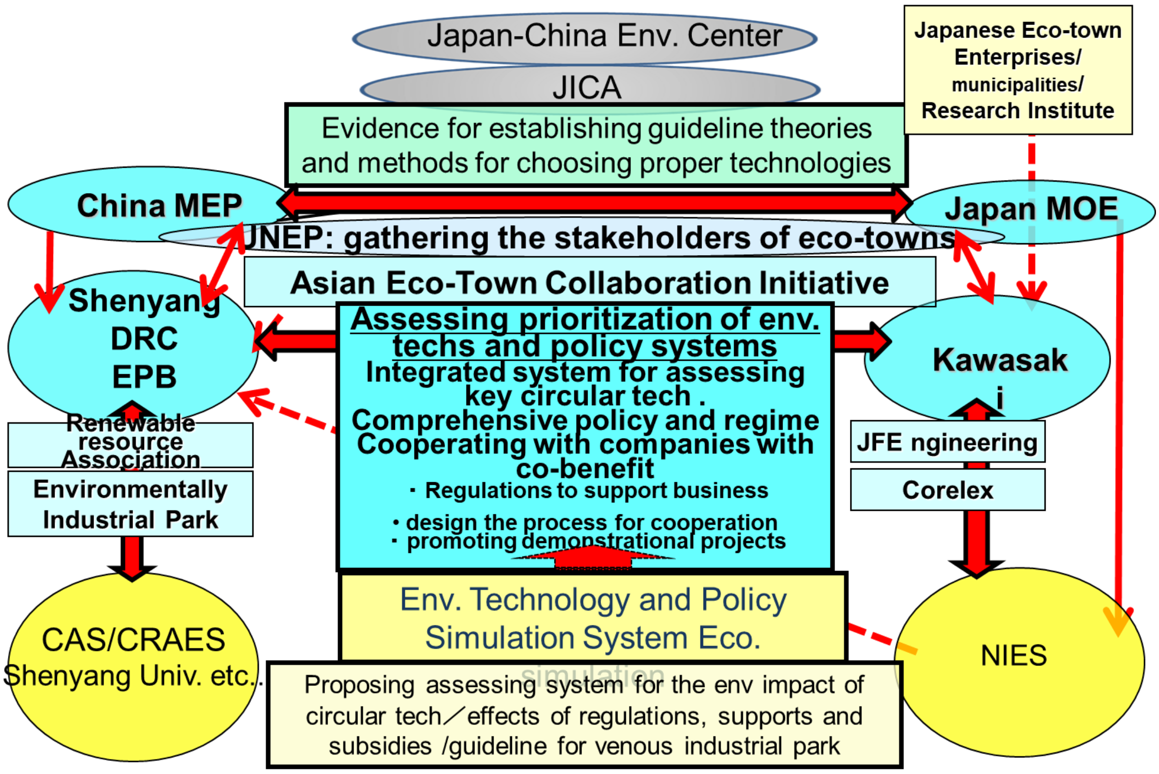
Unit: milJPY/yr

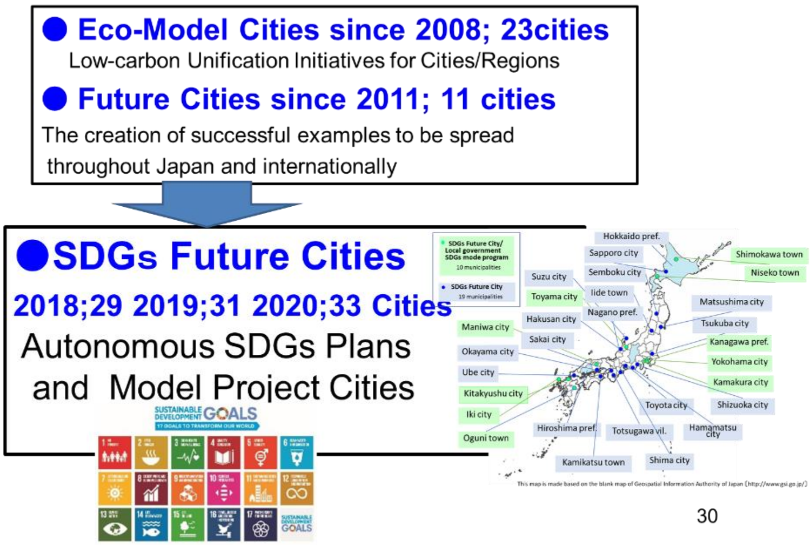
Cost Source	Sce. 0	Sce. 1	Sce. 2	Sce. 3	Sce. 4
Collection & Transportation of Waste	2,972	3,060	3,297	3,119	3,558
Construction of New Plants	842	824	911	879	929
Operation	5,037	4,930	5,200	4,936	5,371
Commission	0	105	63	51	219
Total Cost (mJPY/yr)	9	9	9,000	9	10

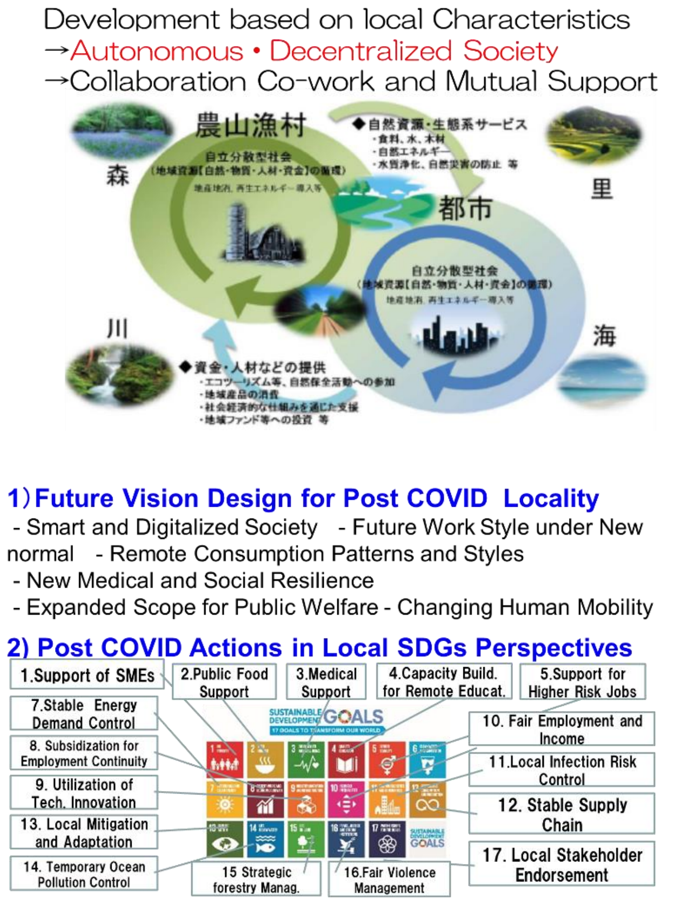
Source: (Geng et al., *forthcoming*)

The implementation of urban symbiosis will cost more money in the short-term due to the operation of waste separation programs and the construction of new storage and pre-treatment facilities. The cost of reducing CO_2 emissions through urban symbiosis as discussed here, approximately US$91/t-$CO_2$ in Scenario 2 and US$185/t-$CO_2$ in Scenario 4 (at an exchange rate of 96 JPY/US$), is also higher than the price of carbon credits in the international market. However, such an investment is worthwhile because Kawasaki can gain additional environmental benefits through urban symbiotic activities, e.g., saving landfill space and conserving non-renewable natural resources. Compared with baseline scenario, such urban symbiotic activities in Scenarios 1 to 4 would reduce waste input to landfill by 3177 ton, 2714 ton, 2278 ton, and 8161 ton, respectively. In addition, most incineration facilities require renewal after 20 to 30 years depending on operation levels. By sending less waste for incineration, renewal costs of incineration plants can be reduced in the long-term. Due to the target of reducing greenhouse gas emission and other unquantified environmental and social benefits, recycling more wastes through urban symbiosis should be an optimal future scenario for Kawasaki.

With such environmental, economic and social benefits, the Kawasaki case study findings can be applied in other Asian cities. In Asian urban development, issues concerning residential communities, commercial services, and primary/secondary industrial activities often coexist. However, a holistic approach wherein the consumption pattern of the residential community interacts with the production pattern in commercial and industrial areas rarely exists. Traditional industrialization has been characterized by urban economic growth and environmental degradation. The major means by which the industrial system is restructured to reduce the discharge of hazardous materials from the production process is to apply end-of-pipe cleaning technologies and/or cleaner production technologies. These technologies can only be employed at the firm level. Urban symbiosis presents a new model for more sustainable urban economic and industrial development at a regional level. Through adequate and appropriate policies, flexible organizational structure, and effective tools for integrated resource management, urban symbiosis aims to achieve simultaneous positive outcomes for the economy, society, and the environment. Particularly with the rapid growth of industrialization and urbanization, sustainable MSWM is of critical importance for city managers. By avoiding production of waste at source as well as turning waste into resources, innovative MSWM through urban symbiosis can reduce both the amount of waste to be disposed and resource consumption, helping reach the target of sustainable development in urban areas. The process of identifying the most appropriate urban symbiosis methods for different cities requires understanding and information exchange on background conditions, local policies and a myriad of other factors.


Japan-China Env. Center
JICA
Japanese Eco-town Enterprises/ municipalities/ Research Institute
Evidence for establishing guideline theories and methods for choosing proper technologies
China MEP
Japan MOE
UNEP: gathering the stakeholders of eco-towns
Asian Eco-Town Collaboration Initiative
Shenyang DRC EPB
Assessing prioritization of env. techs and policy systems
Integrated system for assessing key circular tech .
Comprehensive policy and regime
Cooperating with companies with co-benefit
・Regulations to support business
・design the process for cooperation
・promoting demonstrational projects
Kawasaki
Renewable resource Association
Environmentally Industrial Park
JFE ngineering
Corelex
CAS/CRAES Shenyang Univ. etc..
Env. Technology and Policy Simulation System Eco. simulation
NIES
Proposing assessing system for the env impact of circular tech／effects of regulations, supports and subsidies /guideline for venous industrial park


● Eco-Model Cities since 2008; 23cities
Low-carbon Unification Initiatives for Cities/Regions
● Future Cities since 2011; 11 cities
The creation of successful examples to be spread throughout Japan and internationally
●SDGs Future Cities
2018;29 2019;31 2020;33 Cities
Autonomous SDGs Plans and Model Project Cities
Hokkaido pref.
Sapporo city
Shimokawa town
Niseko town
Semboku city
Suzu city
Toyama city
Iide town
Nagano pref.
Matsushima city
Hakusan city
Tsukuba city
Maniwa city
Sakai city
Kanagawa pref.
Okayama city
Yokohama city
Ube city
Kamakura city
Kitakyushu city
Toyota city
Shizuoka city
Iki city
Hiroshima pref.
Totsugawa vil.
Hamamatsu city
Oguni town
Kamikatsu town
Shima city
30



Proposal for Local SDGs and New Life Design toward Post-COVID Society

National Cabinet Administration Office WG, 2020

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