Strategies for Sustainable Development of Industrial Park

-EIP Pilot Project of Ulsan, Korea

Outlines of Presentation

- Introduction of Ulsan City
- Sustainable Development and EIP
- Policies supporting EIP in Korea
- Pilot project for the development of EIP in Ulsan
- Conclusions
1. Ulsan Metropolitan City
   - From Past to Present

- Ulsan was designated as a special industrial zone in 1962
  1962 (pop. 85,000) -> 2003 (pop. 1,070,000)
- Most Polluted city in '70 – '80
  Onsan disease -> residents relocation
  Special air pollution control regions (1986)
- Ulsan Metropolitan city (1997)
- Declaration of “Eco-polis Ulsan” (2004)
  based on “The Mater Plan for Eco-polis Ulsan”
  include renovation of industrial parks to EIP
  sustainable industrial capital of Korea

Village View of Ulsan Petrochemical Plant Site (1962)
Industrial Park

Industrial estate may be defined simply as “a tract of land, subdivided and developed for the use of several firms simultaneously, distinguished by its shareable infrastructure and the close proximity of firms.

Though the industries located in industrial estate are afforded a number of benefits, including external economies of scale, reduced production costs, they also have disadvantages such as the increase of environmental issues.
Industrial Environmental issues

- Ozone-depleting and greenhouse gases
- Air pollution
- Landscape disturbance
- Habitat degradation
- Exposure to toxic chemicals
- Waste dumping
- Spills
- Nuisances: noise, lighting/transport
- Marine pollution
- Water pollution
- Soil contamination
- Groundwater contamination

Emergencies

Uljan Industrial Park (polluted 1990s)
2. Sustainable Development

- Sustainable Industrial Development

Sustainable Industrial Development

- Sustainable Industrial Development
  - Sustainable Industrial Development
  - Sustainable Industrial Development
Eco-Industrial Park Concept

- Member businesses seek enhanced environmental, economic, and social performance through collaboration in managing environmental and resource issues including information, energy, water, materials, infrastructure, and natural habitat.

- By working together, the community of businesses seeks a collective benefit that is greater than the sum of individual benefits each company would realize by only optimizing its individual performance.

Definition of an EIP [Lowe, 2001]

An eco-industrial park or estate is a community of manufacturing and service businesses located together on a common property. Member businesses seek enhanced environmental, economic, and social performance through collaboration in managing environmental and resource issues including information, energy, water, materials, infrastructure, and natural habitat.

By working together, the community of businesses seeks a collective benefit that is greater than the sum of individual benefits each company would realize by only optimizing its individual performance.
3. National policies driving IP to EIP

- National policies promoting innovation and entrepreneurship
- Supporting research and development in sustainable technologies
- Implementation of environmental standards and regulations
- Encouraging circular economy practices
- Policies fostering collaboration between industry and academia

Source: Allenby
Conceptual Diagram of KNCPC EIP

EIP Establishment Plan in Korea

<table>
<thead>
<tr>
<th>Phase</th>
<th>Objectives</th>
<th>Scope</th>
<th>Term</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 1</td>
<td>EIP infrastructure Construction of existing IP</td>
<td>Eco-networking between plans for 5 national industrial parks</td>
<td>2005–2009 (5y)</td>
<td>Implementation by KNCPC &amp; HICOX</td>
</tr>
<tr>
<td>Phase 2</td>
<td>Spreading EIPs, Success story</td>
<td>Transfer and disseminate to other industrial Parks(20 sites)</td>
<td>2010–2014 (5y)</td>
<td>Individual projects - Consortium</td>
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<tr>
<td>Phase 3</td>
<td>EIP Design (Zero emission IP)</td>
<td>EIP design on the basis of industrial ecology</td>
<td>2014–2018 (5y)</td>
<td>Voluntary participation</td>
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</table>
Stepwise EIP Establishment

4. EIP Pilot Project for Eco-Polis Ulsan

- Sustainable Industrial Development
- Business-oriented CP
- Industrial Park CP
- Water and CP
- Eco-Polis Ulsan Map

- Industry and CP
- Business-oriented CP
- Industrial Park CP
- Water and CP
- Eco-Polis Ulsan Map
### Economic Status of ULSAN Metropolitan City

#### Imports and exports

<table>
<thead>
<tr>
<th>Year</th>
<th>Export (unit: million $)</th>
<th>Import (unit: million $)</th>
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<tbody>
<tr>
<td></td>
<td>National</td>
<td>Ulsan</td>
</tr>
<tr>
<td>1992</td>
<td>76,537</td>
<td>9,157</td>
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<tr>
<td>1993</td>
<td>80,220</td>
<td>9,987</td>
</tr>
<tr>
<td>1994</td>
<td>90,015</td>
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<td>1995</td>
<td>125,058</td>
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<td>2001</td>
<td>109,430</td>
<td>14,151</td>
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<td>2003</td>
<td>135,867</td>
<td>27,485</td>
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Classification of industrial structures in Ulsan/Wipo and Onsan
National Industrial Estate

<table>
<thead>
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<th>Category</th>
<th>Ulsan</th>
<th>Onsan</th>
<th>Total</th>
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<tr>
<td>Food Products</td>
<td>9</td>
<td>–</td>
<td>9</td>
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<td>Textile Products</td>
<td>5</td>
<td>1</td>
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<td>Wood Papers</td>
<td>13</td>
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<td>Petrochemical</td>
<td>195</td>
<td>59</td>
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<td>Nonmetallic</td>
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<td>Steel</td>
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<td>Machinery</td>
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<td>Electric, Electronic</td>
<td>45</td>
<td>4</td>
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<td>Transport Equipment</td>
<td>97</td>
<td>28</td>
<td>125</td>
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<td>Others</td>
<td>13</td>
<td>2</td>
<td>15</td>
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<tr>
<td>Services</td>
<td>54</td>
<td>23</td>
<td>77</td>
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<tr>
<td>Total</td>
<td>592</td>
<td>178</td>
<td>770</td>
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(data: 2004)

Environmental Pollutants Generation from Ulsan Industrial Complexes

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<thead>
<tr>
<th></th>
<th>Air(^1)</th>
<th>Waste Water</th>
<th>Solid Waste</th>
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<tr>
<td></td>
<td>SO(_x)</td>
<td>NO(_x)</td>
<td>TSP</td>
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<tr>
<td>Ulsan (ratio)</td>
<td>87,971 (15.9)</td>
<td>63,569 (6.1)</td>
<td>72,849 (24.6)</td>
</tr>
<tr>
<td>Korea</td>
<td>526,599</td>
<td>1,045,331</td>
<td>692,720</td>
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</table>

Data: MOE(2003)

Note: 1) Data for air and general solid waste are from 2001

2) Neglecting generation ratio of Kwangyang complexes, accounting for over 50% of total and discharge ratio, 1.4% generation and discharge of waste water from Ulsan industrial complexes are accounting for 27.5% and 24.2%, respectively.
<table>
<thead>
<tr>
<th><strong>Title</strong></th>
<th>Pilot Project for the development of Ulsan/Mipo, Ulsan Eco-industrial parks</th>
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<tbody>
<tr>
<td><strong>Periods</strong></td>
<td>2004.7 - 2005.6 (planning), 1st phase (2005 - 2009)</td>
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<tr>
<td><strong>Host</strong></td>
<td>Ulsan Regional Environmental Technology Development Center</td>
</tr>
<tr>
<td><strong>Supervisor</strong></td>
<td>Prof. Hong-Sack Park (Univ. of Ulsan)</td>
</tr>
<tr>
<td><strong>Participants</strong></td>
<td>Hyundai motor corp., SK Corp., SK Chemical Corp., LG Nikko Corp., KONITECH Ltd, Sunkyangwatech Ltd., Energy Ltd.</td>
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<tr>
<td><strong>R&amp;D</strong></td>
<td>University of Ulsan, Ulsan Science college, Kyeongsung Univ.</td>
</tr>
<tr>
<td><strong>Cooperation</strong></td>
<td>Ulsan metropolitan city, Ulsan Regional Innovation Agency, KICOX Eastern chapter Ulsan office</td>
</tr>
</tbody>
</table>

**Case study of Industrial symbiosis**
Case of Industrial Symbiosis(1)

KOENTEC-SK Corp. Industrial Symbiosis

Industrial Wastes

KOENTEC Corp.
Waste Heat => Steam

Pure water supply

Steam supply
30 ton/hr

Surplus steam by SK corp.
+ Waste Heat by KOENTEC Corp.
Case of Industrial Symbiosis(2)

LG-NIKKO Corp. - KOREA ZINC Residues Recycling

LG-NIKKO Corp.

Zinc residues 5,300t/yr

Precious metal residues 2,100t/yr

KOREA ZINC

Case of Industrial Symbiosis(3)

SAMSUNG FINE CHEMICALS – ONSAN WWT Wastewater disposal System

ONSAN Industrial Complex

SAMSUNG FINE CHEMICALS Mecellose Line

Industrial waster water

WWT

Organic mates Treatment

Discharge after Treatment

Existing Line Symbiosis
#### Case of Industrial Symbiosis(4)

**Table 5 Material Exchanges in Ulsan Industrial Complexes**

<table>
<thead>
<tr>
<th>Material Exchanges</th>
<th>Material Exchanges</th>
<th>Material Exchanges</th>
<th>Material Exchanges</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Environmental Quality Improvement(1)

![Environmental Quality Improvement Graph](image)
Environmental Quality Improvement (2)

Environmental Quality Improvement (3)
Strategies for the construction of EIP in Ulsan

How to develop?
- optimizes the use of available resources, materials, infrastructure, and human resource to reduce costs, increase profits, improve the environment.

- Industrial symbiosis: creates material links, connects industries
- Community connections - involvement in Regional Planning
- Joint promotions (e.g., trade shows)
- Integrated logistics
- Common subcontractors
- Multi-media planning
- Wellness programs
- Accident prevention
- Joint Benefits packages
- Flexible employee assignments

Conceptual industrial symbiosis at Ulsan Industrial Complexes

- SSANGYONG CEMENT Corp.
- ULSAN PACIFIC CORP.
- SK CHEMICAL
- TAEYOUNG INDUSTRY Corp.
- TS Corp.
- KOENTEC Corp.
- LG-NIKKO Corp.
- HYUNDAI MOTORS ENERGY Corp.
- KOREAZINC Corp.
- SK CHEMICAL
- ULSAN NAMGU FOOD WT
- K WWT
- ENERGY Corp.
- KOREAZINC Corp.
- HANKUK PAPER Corp.
- SUNKYONG WATECH Corp.
- TAEYOUNG WATECH Corp.
- DWC
- D WWT
- SUNKYONG WATECH Corp.
- PVC Process
- K Corp.
- (Incineration WW)
- OW
- PW
- OS
- WT
- AR
- MS
- AL
- SW
- SL
- OI
- SH
- BA
- PB
- MB
- SG
- RM
- SS
- WS
- IW
- OW
- PW
- OW
- SK Corp.
Procedure of Project

What are areas for further improvement:

- Primary Component: Industrial – Metabolism
  - Resource Optimization
  - Product and Process Optimization
  - Information System

- Supportive Component
  - How to carry out project? – Multi-stakeholder
  - Clean Policy in place among inter-agencies,
    Park level Management, Programmatic actions on
    product and services, social needs.
Goal of Air quality Standard of Ulsan

<table>
<thead>
<tr>
<th></th>
<th>unit</th>
<th>Criteria</th>
<th>2001</th>
<th>2006</th>
<th>2011</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>ppm/year</td>
<td>0.02</td>
<td>0.012</td>
<td>0.008</td>
<td>0.006</td>
<td>0.005</td>
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<tr>
<td>CO</td>
<td>ppm/lhr</td>
<td>9</td>
<td>0.8</td>
<td>0.5</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
<td>NO₂</td>
<td>ppm/year</td>
<td>0.06</td>
<td>0.023</td>
<td>0.02</td>
<td>0.015</td>
<td>0.01</td>
</tr>
<tr>
<td>O₃</td>
<td>ppm/lhr</td>
<td>0.06</td>
<td>0.02</td>
<td>0.018</td>
<td>0.015</td>
<td>0.01</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>/year</td>
<td>70</td>
<td>55</td>
<td>50</td>
<td>45</td>
<td>40</td>
</tr>
</tbody>
</table>
Goal of Water Quality Standard of Ulsan

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2008</th>
<th>2011</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>River</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TAEWHA River</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>HOEYA River</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>DONO Stream</td>
<td>.</td>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>Coast</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ULSAN</td>
<td>.</td>
<td>.</td>
<td>.</td>
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<tr>
<td>OLNSAN</td>
<td>.</td>
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</tr>
</tbody>
</table>
5. Conclusions

- Existing industrial symbiosis in Ulsan industrial park are skewed to low-cost and no-cost approaches, or commonly termed as “low hanging fruit” approach in UNEP.

- Ulsan EIP project can lead the Korean EIP project by the support of new Ulsan regional strategic industry, Environmental Industry.

- Ministry of Environment must involve more actively in Korean EIP Project in cooperation with MOCIE.
Exchanges of Asian EIP Experiences such as Japan, China and Thailand will be very helpful to the success of Korean EIP projects.

Thank you very much for your attention!
Strategies for sustainable development of industrial park

- planning for eco-industrial park in Ulsan, Korea

Hung-Suck Park, Soo-mi choi and Sang-Yoon Lee

1) Department of Civil and Environmental Engineering, University of Ulsan, Ulsan 680-749, Korea (*Corresponding Author, E-mail: parkhs@ulsan.ac.kr).

Abstract

An eco-industrial park or estate, alternatives of IE, is a community of manufacturing and service business located together on a common property, which seek enhanced environmental, economic, and social performance through collaboration in managing in environmental and resource. Korea National Cleaner Production Center(KNCPC) affiliated to Korea Institute of Industrial Technology(KITECH) has just started 15 year 3-phase Master EIP plan with the support of Ministry of Commerce, Industry, and Energy. 6 industrial parks, including industrial parks in Ulsan city, known as the industrial capital of Korea, are performing planning project to find the feasibility of shifting existing industrial parks to eco-industrial parks. This paper describes the Korean national policies to drive this global trends of innovation of industrial parks and existing inter-industry waste, energy, and material exchange developed in Ulsan industrial complexes. In addition, Ulsan EIP pilot project, which will be implemented for 15 years from 2005, is elaborated including regulatory issues and technologies to be applied.

1. Introduction

Ulsan was appointed as a special industrial zone in Korea in 1962 and, since then, industrial complexes have been built without considering of the environment. Though Ulsan city has grown up to be the industrial capital of Korea, as a stronghold of petrochemistry, nonferrous metals, ship building and auto mobile industries, Ulsan has been called "pollutants department store" and 'the worst polluted city' thereafter.

With the deteriorating environmental quality, Ulsan and Onsan industrial complexes were appointed as the special air pollution control regions in March '86. The special
emission standard 30 to 80% stricter than other areas was enforced and has been applied to newly-built factories since Oct. '91, thus these regulations were in operation 10 years earlier than in other areas. The 'stricter emission standard' 30 to 60% higher than other area has been applied in existing plants since Feb. '92, 5 years earlier than other areas. Enterprises have intensified investment on clean production, pollution prevention facilities and environmental management to meet the enhanced environmental standard. Without the efforts and investment of business enterprises, it may be almost impossible to improve the environmental quality of Ulsan, where heavy industrial and chemical plants are densely located.

Since the 1992 Earth Summit in Rio de Janeiro, local authorities are generally considered important actors in the transition towards sustainable development. In order to enhance the environmental quality drastically the Ulsan metropolitan city has commissioned "The Environmental Pollution Investigation and Comprehensive Environmental Master Plan" for '98 to 2002, where seven environmental fields were included such as water, air, odors, ecosystem, waste, soil and the Taewha River. The comprehensive action plan for improving environment for '98 to 2002 was made based on the environmental investigation. It was planned to invest a total of 1,200 billion won including a municipal budget of 700 billion won on a 94 projects for the planned period.

In the mean while, to improve the urban infrastructure, environmental quality, educational and cultural conditions, Ulsan citizen and NGO's made a civic movement of the establishment of Ulsan metropolitan city, which resulted in raising metropolitan status June 15, 1997.

Ulsan industrial complexes has been continuously evolving from conventional industrial complexes to eco-industrial parks, based on sustainable development concepts imposed in industries after Rio Earth Summit in 1992. To change the Ulsan more environmentally-friendly ecology city where human and nature coexist, “Ecopolis Ulsan” was declared in 2004 based on “The Master plan of Ulsan”, which include the eco-industrial park as an action plan.

This article introduces the concets of eco-industrial park and describes the existing industrial symbiosis in Ulsan industrial complexes and evaluates the economic and environmental effects. In addition, Ulsan EIP pilot project, which will be implemented for 15 years from 2005, is addressed including regulatory issues and technologies to be required.

2. Eco-industrial parks
Industrial estate may be defined simply as “a tract of land, subdivided and
developed for the use of several firms simultaneously, distinguished by its shareable
infrastructure and the close proximity of firms. Though the industries located in
industrial estate are afforded a number of benefits, including external economies of
scale, reduced production costs, they also have disadvantages such as the increase of
industrial pollution.

With the combined influence of increased awareness of environmental issues and
more stringent regulations, estates are being obliged to look for cost-effective ways of
improving their environmental performance.

An eco-industrial park or estate, emerging as an alternative of IE, is a community of
manufacturing and service business located together on a common property, which seek
enhanced environmental, economic, and social performance through collaboration in
managing in environmental and resource issues. The goal of an EIP is to improving the
economic performance of the participating companies while minimizing environmental
impacts. Components of the EIP approach include green design of park infrastructure
and plants(new or retrofitted); cleaner production; pollution prevention; energy
efficiency; and inter-company partnering. An EIP is also seek benefits for neighboring
communities to assure that the net impact of its development is positive.

There are three basic categories of eco-industrial project:
1. Eco-industrial park or estate(EIP) – an industrial park developed and amaged as a
real estate development enterprise and seeking high environmental, economic,
and social benefits as well as business excellence.
2. By-product exchange(BPX) – a set of companies seeking to utilize each other’s
by-products(energy, water, and materials) rather than disposing them as waste.
3. Eco-industrial network(EIN) – a set of companies collaborating to improve their
environmental, social, and economic performance in a region.

3. Policies supporting eco-industrial park in Korea

3.1 Sustainable development of industrial policy

The chapter 30 of Agenda 21, in which the role of business for the support of
Agenda 21 is defined, states the involvement and cooperation of business are vital
factors in achieving the objectives of Agenda 21, sustainable development.

Industrial environmental policy have drastically changed after the Ministry of
Commerce, Industry, and Energy(MOCIE) enacted ‘APEFIS, Act to Promote

Based on the APEFIS, MOCIE established institutional system for clean production (CP) and environmental management system (EMS) based on ISO 14001 as implementing tools, and “The first comprehensive master plan for environmental friendly industrial development” was made and operated based on APEFIS.

This plan included streamlining the supporting system, CP transfer and dissemination, promoting environmental industry, and stimulating environmental management.

1) Clean production program

Cleaner production is the continuous application of an integrated preventive environmental strategy to processes, products, and services to increase overall efficiency, and reduce risks to humans and the environment. Cleaner production can be applied to the processes used in any industry, to products themselves and to various services provided in society. This program supports the development of cleaner production technology that helps industry be eco-efficient.

O Cleaner production technology development

This program supports the development of cleaner production technology that helps industry be eco-efficient. It is classified into three categories; general project, shared project and consolidated project.

O CP Technology transfer and dissemination program

This program supports transfer of domestic and foreign technologies that increase productivity and reduce environmental load for the company. Supporting area are CP Assessment, technology transfer, international joints projects, information service, training and education, supply chain environmental management (SCEM), environmental management system (EMS), regional dissemination center, open laboratory, eco-industrial park (EIP)

2) EIP Project

Korea National Cleaner Production Center (KNCPC), Korea Institute of Industrial Technology (KITECH) started 15 year 3-phase project, 'Eco-industrial park (EIP) construction for infrastructure of cleaner production in Korea' with the support of Ministry of Commerce, Industry, and Energy.

In 2004, trial projects are performed for 6 industrial parks including Ulsan...
industrial complexes to find the feasibility of applying industrial ecology to existing industrial parks. For inter-networking businesses, cleaner production assessment will be done before making by-products exchange network, that will characterize so called 'Korean Eco-Industrial Park Model' with the introduction of environmental management system. KNCPC and Korea Industrial Complex Corp. will be the main actors in implementing phase 1. In phase 2, the success stories in phase 1 will be transferred and disseminated to other industrial parks. This requires the active participation of institutes, colleges, and consultants. In phase 3, industrial parks will be designed on the basis of industrial ecology at the first stage and EIP construction model will be also applied.

Table 1. Korean EIP Construction Plan

<table>
<thead>
<tr>
<th>Categories</th>
<th>1yr</th>
<th>2yr</th>
<th>3yr</th>
<th>4yr</th>
<th>5yr</th>
<th>Total</th>
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<td>By-product exchange</td>
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<td>348</td>
<td>348</td>
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<td>435</td>
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<td>Process analysis and optimization</td>
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<td>Alternative raw material</td>
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<td>Waterpinch expansion</td>
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<td>Process diagnosis analysis</td>
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</tr>
<tr>
<td>By-product and waste recycle DB</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td>87</td>
<td></td>
<td>348</td>
</tr>
<tr>
<td>EIP professional education</td>
<td>87</td>
<td>87</td>
<td>43</td>
<td>43</td>
<td></td>
<td>260</td>
</tr>
<tr>
<td>Integrated Recycling Pilot Plant</td>
<td>174</td>
<td>867</td>
<td>867</td>
<td>1,739</td>
<td></td>
<td>3,652</td>
</tr>
<tr>
<td>Integrated resource recycling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>system</td>
<td></td>
<td></td>
<td></td>
<td>130</td>
<td>870</td>
<td>1,739</td>
</tr>
<tr>
<td>Comprehensive Water reuse Network</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>870</td>
<td>1,304</td>
</tr>
<tr>
<td>Total</td>
<td>757</td>
<td>1,652</td>
<td>2,521</td>
<td>3,652</td>
<td>6,200</td>
<td>14,783</td>
</tr>
</tbody>
</table>

(unit : 10,000 $, $=1,150\)
3.2 Environmental policies stimulating sustainable development

The government has discarded the growth-driven policies of the past strengthening the environmental preservation and standards. It now strives to achieve sustainable development that pursues environmental preservation and economic development simultaneously. There are several environmental policies, which stimulate the sustainable development of industry such as environmental impact assessment (EIA), prior environmental review systems (PERS) and environment-friendly business management policies.

1) Environmental impact assessment system

The EIA has been focused on aims to promote or enforce environment-friendly development because it most deal with large-scale development project during the execution stage, after plans have been approved and confirmed. It also mainly reviews pollution reduction measures.

2) The prior environmental review system (PERS)

The PERS aims to balance development and preservation by identifying possible environmental impacts of development plans or projects in the early stages of planning. The system includes considerations of ways to carry out development plans while harmonizing the built and natural environments in an aesthetically pleasing manner.

3) Environment-friendly business management policy

Throughout the world, environment-friendly products and management structure of corporations are becoming overriding determinants of their competitiveness. Against this backdrop, first rate are endeavoring to raise their real corporate value through increased sales, cost reduction and investment efficiency via means of environmental management.

In parallel with this trend, Korea is implementing and environment-friendly business designation system to foster sound environmental management. The government designated businesses that practice prevention-oriented environmental management as “environment-friendly.”

The system promotes preventive solutions to environmental pollution that arises during production processes. The businesses handle pollutants in a responsible manner and make tangible contributions to environmental improvement.

Also, a corporate environmental information disclosure system and An eco-
4. The pilot project for eco-industrial parks in Ulsan, Korea

4.1 Status of industrial complexes.

There are two national industrial complexes, Ulsan/Mipo and Onsan industrial complexes, and 4 agricultural and industrial estates in Ulsan. Ulsan industrial complex, the core site for automobile, shipbuilding and petrochemical industries, and Onsan complex come together to form a horizontally integrated industrial system, leading Korea’s economic development. (Fig. 2, Table 2 and 3).

Fig. 2 Map of Ulsan Industrial Complexes
Table 2. Status of Ulsan, Mipo and Onsan National industrial Estates

<table>
<thead>
<tr>
<th>Item</th>
<th>Ulsan Mipo</th>
<th>Onsan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area(1000㎡)</td>
<td>40,340</td>
<td>15,237</td>
</tr>
<tr>
<td>Factory area(㎡)</td>
<td>34,567</td>
<td>13,422</td>
</tr>
<tr>
<td>Construction</td>
<td>1975. 6. 23</td>
<td>1974. 4. 1</td>
</tr>
<tr>
<td>No. of Companies</td>
<td>558</td>
<td>212</td>
</tr>
<tr>
<td>Moved in</td>
<td>485</td>
<td>158</td>
</tr>
<tr>
<td>In operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Supply capacity</td>
<td>641,000/day</td>
<td>340,000/day</td>
</tr>
<tr>
<td>Waste water</td>
<td>250,000/day</td>
<td>150,000/day</td>
</tr>
<tr>
<td>Production(100 million $)</td>
<td>443</td>
<td>99</td>
</tr>
<tr>
<td>employ(person)</td>
<td>87,494</td>
<td>9,716</td>
</tr>
</tbody>
</table>

Table 3. Classification of industries in Ulsan/Mipo and Osan national industrial park

<table>
<thead>
<tr>
<th>Category</th>
<th>Ulsan</th>
<th>Onsan</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food Products</td>
<td>9</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>Textile Products</td>
<td>5</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Wood Papers</td>
<td>13</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Petrochemical</td>
<td>105</td>
<td>52</td>
<td>157</td>
</tr>
<tr>
<td>Nonmetallic</td>
<td>24</td>
<td>9</td>
<td>33</td>
</tr>
<tr>
<td>Steel</td>
<td>8</td>
<td>13</td>
<td>21</td>
</tr>
<tr>
<td>Machinery</td>
<td>149</td>
<td>43</td>
<td>192</td>
</tr>
<tr>
<td>Electric, Electronic</td>
<td>45</td>
<td>4</td>
<td>49</td>
</tr>
<tr>
<td>Transport Equipment</td>
<td>97</td>
<td>28</td>
<td>125</td>
</tr>
<tr>
<td>Others</td>
<td>13</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>Services</td>
<td>54</td>
<td>23</td>
<td>77</td>
</tr>
<tr>
<td>Total</td>
<td>522</td>
<td>178</td>
<td>700</td>
</tr>
</tbody>
</table>

(4.2 Pollutants generated from Ulsan industrial complexes)

Table 4 is summary of the pollutants generated from Ulsan industrial complexes, which are accounted for high percentage of total generation in Korea. Though
significant efforts have been made in many fields to improve the environmental quality, Ulsan is still suffering from environmental issues. Due to the strengthening environmental regulations imposed on the stack industries, movement and shutdown of company are becoming another social problems in Ulsan. Thus, innovation of industrial complexes to eco-industrial park is urgently required for sustainable development of industrial parks.

Table 4. Pollutants generated from Ulsan industrial complexes(2002)

<table>
<thead>
<tr>
<th></th>
<th>Air 1)</th>
<th>Waste Water</th>
<th>Solid Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SO2</td>
<td>NO2</td>
<td>TSP</td>
</tr>
<tr>
<td>Ulsan (ratio)</td>
<td>82,971</td>
<td>63,569</td>
<td>22,849</td>
</tr>
<tr>
<td>(ratio)</td>
<td>(15.8)</td>
<td>(6.1)</td>
<td>(24.6)</td>
</tr>
<tr>
<td>Korea</td>
<td>526,599</td>
<td>1,045,332</td>
<td>92,720</td>
</tr>
</tbody>
</table>

Data: MOE(2003)

note: 1) Data for air and general solid waste are from 2001

* Neglecting generation ratio of Kwangyang complexes, accounting for over 50% of total and discharge ratio 3.4%, generation and discharge of waste water from Ulsan industrial complexes are accounting for 27.0% and 24.2% of the total, respectively.

4.3 Industrial symbiosis at Ulsan industrial parks.

Ulsan industrial complexes were originally developed as conventional industrial estate, with a collective energy provider such as electricity, steam and water. The industrial collaborations in Ulsan complexes were spontaneously occurred by meeting the stringent environmental regulations and economic benefits.

As the concept of EIP has just introduced in Korea, the municipality and managers and citizen are gradually interested in by-product exchanges already operated in Ulsan complexes.

The Ulsan industrial collaboration now includes six partners:

Koentec Ltd. – Industrial waste treatment and disposal company with incinerator capacity of 300 ton/day and landfills

SK Corp. – Leading petrochemical industry in Korea, production capacity
of 4,500,000 tons of petrochemicals/yr (aromatics, olefins, PE, PP, solvent, etc.). Total annual sale of 220 million barrels in 2003, grasping 34% of the domestic market share

SK Chemicals Corp. - SK Chemicals was the leader to develop high-performance PETG resin (SKYGREEN ®), and is making rapid and steady progress in the polyurethane business.

LG-Nikko Corp. - Leading Cu smelting industry with production capacity of Cu 200,000 ton/yr, Sulfuric acid 1,170,000 ton/yr, Au 100 ton/yr, Ag 230 ton/yr, Pt 60 kg/yr, Pd 500 kg/yr, Se 230 ton/yr

Koreazinc Corp. - Korea Zinc founded in 1974 and is the world No. 1 manufacturer of non-ferrous metals. Korea Zinc and its overseas subsidiaries are together producing 10% of the global zinc production.

The Ulsan metropolitan city – Operate the Ulsan Municipal Wastewater Treatment Plants (350,000 m³/day)

Table 5. Industrial symbiosis in Ulsan industrial complexes in 2004

<table>
<thead>
<tr>
<th>Material</th>
<th>From</th>
<th>To</th>
<th>Sold/Free</th>
<th>Investment (10000$)</th>
<th>Revenue (10000$/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure Water</td>
<td>SK Corp.</td>
<td>COENTECH</td>
<td>Sold</td>
<td>209</td>
<td>411</td>
</tr>
<tr>
<td>Steam</td>
<td>KOENTEC H</td>
<td>SK Corp.</td>
<td>Sold</td>
<td>1,739</td>
<td></td>
</tr>
<tr>
<td>Stream</td>
<td>SK Corp.</td>
<td>ULSAN PACIFIC</td>
<td>Sold</td>
<td>696</td>
<td>261~348</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TAEYOUNG IND. TS Corp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovery Zn</td>
<td>LG-NIKKO</td>
<td>KOREAZINC</td>
<td>Sold</td>
<td>461</td>
<td></td>
</tr>
<tr>
<td>Recovery Cu</td>
<td>KOREAZINC</td>
<td>LG-NIKKO</td>
<td>Sold</td>
<td>1,739</td>
<td></td>
</tr>
<tr>
<td>Steam</td>
<td>LG-NIKKO</td>
<td>HANKUK PAPER</td>
<td>Sold</td>
<td>96</td>
<td>261~348</td>
</tr>
<tr>
<td>Biogas</td>
<td>Y WWT</td>
<td>SK CHEMICAL</td>
<td>Sold</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Waste MeOH</td>
<td>SAMSUNG</td>
<td>O WWT</td>
<td>Free</td>
<td>130</td>
<td></td>
</tr>
</tbody>
</table>
Over very short periods of time, these partners spontaneously developed a series of bilateral exchanges, which also include a number of other companies. It simply evolved as a collection of one-to-one deals that made environmental and economic benefits for pairs of participants in each.

4.4 Feasible industrial symbiosis to be implemented in pilot study

The pilot project is to investigate the feasible industrial symbiosis by intra-plant innovations and approaches, and inter-plant collaboration in improving environmental and economic performance, both of individual companies and collective industrial system.

Fig. 2 is the proposed EIP based on industrial symbiosis at Ulsan Industrial Complexes including existing industrial symbiosis. SK Corp, Y municipal wastewater treatment plant and LG-Nikko Corp are anchor businesses.

Some technologies of interest to the Ulsan EIP pilot project are
1) plastic separation
2) solvent recycling and recovery
3) recovery of by products
4) RDF production and utilization
5) Wastewater treatment and reuse

5. Conclusions
An eco-industrial park or estate, emerging as an alternative of IE, is a community of manufacturing and service business located together on a common property, which seek enhanced environmental, economic, and social performance through collaboration in managing in environmental and resource issues.

Though Ulsan industrial complexes were originally developed as conventional industrial estates, with a collective energy provider such as electricity, steam and water, the concept of industrial ecology have been already applied due to the stringent environmental regulations and economic benefits.

In 2004, “Eco-polis Ulsan” was declared first in Korea based on “The Master plan of Ulsan”, in which Ulsan EIP Pilot project is included as an action plan. So, success of Ulsan EIP pilot project is key factor to be sustainable Eco-polis Ulsan.

Ulsan eco-industrial development can be achieved by expanding existing by-product exchange(BPX) and eco-industrial network(EIN). However, system analysis including industrial metabolism, input-output analysis, environmental evaluation, flexibility analysis must be conducted in detail. In addition, Ulsan EIP project must be associated with the regional strategic environmental technologies and businesses to upgrade environmental technologies. To get the public support, education, publicity and leadership for Ulsan EIP are also highly required.

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