Industrial parks and Eco-industrial parks in China

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Outline

- Industrial parks in China
- Eco-industrial parks (EIPs)
  - EIP in theory and in practice
  - Status quo of Chinese eco-industrial parks
  - Case studies in Tianjin and Dalian
Timeline of China’s industrial parks

- **1980s**: National Economic-technological Development Areas
- **2001**: National Demonstration Eco-Industrial Parks
- **Present**: New district/Eco-city
Industrial parks in 1980s: National Economic-Technological Development Areas (NETDA)

• **Background:**
  • “Reform and Open door” policy in 1978
  • Reform of the economic system in 1984
  • Exploration of institutional innovation, market mechanisms, technology and economic growth

• **Goals of the NETDA program:**
  • Attract foreign investment through industrial projects and improve export;
  • Promote manufacturing industry, hi-tech and high added value.
Geographical distribution of the 54 NETDAs

http://www.cadz.org.cn/kfq/
Example: Tianjin Economic-technological Development Area (TEDA)

- Established in 1984
- 3 sub-zones established in 1996:
  - Micro-Electronics Industry Park (Xiqing) (MIP)
  - Yat-Sen Scientific Industry Park (YSP)
  - TEDA Industrial Park
- Tianjin Export Processing Zone (TEPZ) established in 2000 in TEDA
- TEDA West: the expansion area of TEDA in 2003
- Micro-Electronics Industry Park (Jinman) established in 2003

http://www.teda.gov.cn
Example: Tianjin Economic-technological Development Area (TEDA)

- Established time: 1984
- Developed area: 98 km²
- Population: 536 thousand.
- GDP (2011): RMB 190.85 billion, contributed 17% of the GDP to Tianjin City.
- Number of companies: >20000.

The proportion of the industries in TEDA by 2011.

- Electronics & telecommunications: 25.14%
- Automobile: 22.66%
- Equipment manufacturing: 20.27%
- Petro-chemistry: 13.07%
- Food & beverage: 7.64%
- Biomedicine: 5.19%
- New energy & new materials: 3.70%
- Other: 2.28%
Strengths and weaknesses of China’s national industrial parks in 1980s-1990s

- **Preferential policies** (e.g., tax reduction)
  1st and 2nd year: income tax waive; 3rd year: 50% income tax deduction.
- **Efficient government service** (e.g., one-stop service center)
- **Mostly manufacture industries** (e.g., processing the supplied materials)
- **Criteria for recruiting**
  - Overemphasize on the amount of foreign investment
  - Neglect the industrial networks and cluster effect
  - Low environmental standard
- **What are the consequences?**
Question: What do you want from an industrial park in China in 2000s?

- If you are a company
  - Tenant in an industrial park
  - A company looking for an industrial park
- If you are a resident
- If you are a government (administrative committee, in charge of park management)
A new strategy of Chinese industrial parks: eco-industrial park in 2000s

• Definition:

A holistic community of businesses that cooperate with each other and with the local community to efficiently share resources (information, materials, energy, infrastructure and natural habitat), leading to economic gains, improvements in environmental quality and equitable enhancement of human resources for business and the local community.

(Eco-efficiency Task Force Report by the US President’s Council, 1997).
**Industrial symbiosis**

- **Definition**

  Industrial symbiosis is to engage traditionally separate entities in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products (Chertow, 2000).

- **Principles**

  - Sharing public utility;
  - Someone’s waste is another’s raw materials;
  - Economically and environmentally profitable.

  (Kalundborg, 2006)
Industrial symbiosis engages diverse organizations in a network to foster eco-innovation and long-term culture change. Creating and sharing knowledge through the network yields mutually profitable transactions for novel sourcing of required inputs, value-added destinations for non-product outputs, and improved business and technical processes.

(Lombardi and Laybourn, 2012).
Theory study: Research themes of industrial symbiosis

Network of the core literatures about industrial symbiosis
Status quo of Chinese EIP development

Program of National Demonstration Eco-industrial Parks, since 2001.

By the end of 2012, 65 industrial parks—ratified to construct toward national EIPs.

18 industrial parks—passed the evaluation and entitled as national EIPs.


Geographical distribution of Chinese National Demonstration Eco-industrial Park by the year of 2012
Status quo of Chinese EIPs

Supporting policies at national level

• Administrative and financial instruments since 2007
  • Energy saving and emission reduction → officials’ working performance.
  • 3.2 billion yuan of the special funds for pollution treatment was established by central finance.

• Circular Economy Promotion Law of China. 2008
  • 3R principles: Reduce, Reuse and Recycle
  • 3 levels: intra-firm (cleaner production); inter-firms (EIP); city/province (eco-city)
  • Encouraging enterprises in various industrial parks and zones to exchange wastes with purposes of utilization, cascade utilization of energy, intensive utilization of land, classified and recycled utilization of water, and jointly sharing infrastructure and other relevant facilities.
The scale level of eco-industrial development in China. (Use Liaoning province as an example)

Status quo of Chinese EIPs: Examples

- In 1956, a sugar refinery and an alcohol plant.
- Over years, three paper mills.

Industrial symbioses in the Guitang Group, Guigang City.

Status quo of Chinese EIPs: Examples

Selected industrial symbioses in Lubei Industrial Park. The variation in the thickness of the lines is an indication of the magnitude of the flows; the squiggly lines indicate the raw materials taken from nature outside the eco-industrial parks. SO2=sulfur dioxide; kt=kilotonne; kwh=kilowatt hour; NaOH=sodium hydroxide

Status quo of Chinese EIPs: Examples

CHP (Combined Heat and Power) plant EIP

1. Coal mine-CHP plant
2. Petro chemistry-CHP plant
3. Aluminum (steel)-CHP plant-building material
4. Forest-CHP plant-paper mill

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Supporting policies at national level

• National EIP Standards (2006, revised 2009 and 2012)
  • Sector-integrated EIP (i.e., mixed sectors)
  • Sector-specific EIP (i.e., single industry, center in anchor tenant)
  • Venous EIP (i.e., recycling industries)

• Four groups of indicators:
  • Economic development
    • E.g., industrial added value per capita
  • Material reduction and recycling
    • E.g., energy consumption, fresh water consumption, waste discharge.
  • Pollution control
    • E.g., COD, SO2.
  • Administration and management
    • E.g., Institutional capacity of environmental management
Status quo of Chinese EIPs

• Planned EIP model:

Procedure for eco-industrial park planning, implementation and nomination in China. LG: Leading Group. MEP: Ministry of Environmental Protection. MOC: Ministry of Commerce. MOST: Ministry of Science and Technology.

Status quo of Chinese EIPs

• Planned EIP model: Top-down planning
  • Retrofit or build environmental infrastructures e.g., wastewater reclaimed plant, co-generation plant.
  • Recruit projects to connect industrial networks agglomeration $\rightarrow$ cluster effects
  • Quantitative targets for EIP performance
  • Mandatory environmental management or energy audit for intensive energy consumers or polluters.

• What are the pros and cons of this planned EIP model?
• What else are needed to promote EIP’s development?
Status quo of Chinese EIPs

EIP performance: Energy

Percentile of decrease of energy consumption intensity for the individual EIP during the period of $Y_{\text{check}}$ to $Y_{\text{plan}}$

Tian et al. (2013). http://dx.doi.org/10.1016/j.jclepro.2013.08.005
Status quo of Chinese EIPs

EIP performance: Water

Percentile of decrease of freshwater consumption intensity and wastewater generation intensity for the individual EIP during the period of $Y_{\text{check}}$ to $Y_{\text{plan}}$

Tian et al. (2013). http://dx.doi.org/10.1016/j.jclepro.2013.08.005
Status quo of Chinese EIPs

EIP performance: Solid waste

Tian et al. (2013). http://dx.doi.org/10.1016/j.jclepro.2013.08.005

Percentile of decrease of solid waste generation intensity for the individual EIP during the period of $Y_{\text{check}}$ to $Y_{\text{plan}}$
Status quo of Chinese EIPs

EIP performance: Pollution control

Percentile of decrease of COD intensity and SO$_2$ emission intensity for the individual EIP during the period of $Y_{\text{check}}$ to $Y_{\text{plan}}$

Tian et al. (2013). http://dx.doi.org/10.1016/j.jclepro.2013.08.005
Question:
What is EIP in reality?

• Eco-industrial park = factories in the garden?
• Eco-industrial park = pollution treatment plants + waste recycling?
• Government’s job or companies’ job?
Case studies in Tianjin and Dalian

Case study 1: Tianjin Economic-technological Development Area (TEDA)

Case study 2: Dalian Development Area (DDA)
Research goal and research questions

- **Research goal:** how to steer the eco-transformation of an industrial cluster.
- **Research questions:**
  - What factors can influence the development of EIPs?
  - How can we trace and illustrate the changes in EIPs unfolding over time?
  - What mechanisms can be extracted to explain these changes?
Theory study: Conceptual model of an EIP
Example: System analysis of STYRIA

[Diagram showing various components and interactions related to environmental systems and policies in Styria, Austria, including Municipalities/Governments, Eco World Administration Committee, Member Companies, Research Institutes/Experts, NGOs, and other clusters.]
Theory study: Key activities—variables and indicators

Literature review about the determining factors for influencing EIPs/IS projects.

<table>
<thead>
<tr>
<th>Key activities</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutional activity</td>
<td>• Policies, regulations, planning, voluntary agreement and evaluation for EIP/IS (+1)</td>
</tr>
<tr>
<td>Technical facilitation</td>
<td>• Projects of infrastructures and utilities for enabling IS (+1)</td>
</tr>
<tr>
<td>Economic and financial enablers</td>
<td>• Financial incentives (subsidies, investments, preferential tax/pricing policies) (+1)</td>
</tr>
<tr>
<td>Informational activity</td>
<td>• Training and educational programs (+1)</td>
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<td></td>
<td>• Feasibility/assessment research projects (+1)</td>
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<td></td>
<td>• Workshops, conferences, seminars and forums for networking (+1)</td>
</tr>
<tr>
<td>Company activity</td>
<td>• IS projects started (+1)</td>
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<tr>
<td></td>
<td>• Join the information exchange activities for seeking synergy partners (+1)</td>
</tr>
<tr>
<td></td>
<td>• Environmental information disclosure (+1)</td>
</tr>
</tbody>
</table>
Theory study: Evaluate the EIP performance

- A question of Multi-Criteria Decision Analysis.
- Mathematical model: TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution)

<table>
<thead>
<tr>
<th>Alternative A</th>
<th>...</th>
<th>Alternative N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicator 1</td>
<td></td>
<td></td>
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<tr>
<td>...</td>
<td></td>
<td></td>
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<tr>
<td>Indicator M</td>
<td></td>
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</tbody>
</table>

Matrix \((x_{ij})_{m \times n}\)

\(i\) represents indicator (for example, energy consumption per IAV) and \(j\) represents alternative (for example, TEDA 2008)
Case studies in Tianjin and Dalian
Case study 1: Tianjin Economic-technological Development Area (TEDA)
Case study 2: Dalian Development Area (DDA)

- TEDA
  - Same economic and environmental policy background of China
  - The largest mixed industrial parks (total companies >20000, respectively) (Developed area > 90 km², respectively)

- DDA
  - Established in 1984 and started eco-transformation in 2000
  - Pilot EIP participants and initiated by local authorities
Case study 1: Tianjin Economic-technological Development Area (TEDA)

Comparison of major economic indicators between TEDA and Tianjin in 2011.

http://en.investteda.org/FactsFigures/BI/t20120709_69874.htm
Case study 1: Tianjin Economic-technological Development Area (TEDA)

2000
- Cleaner production
- Regional ISO 14000
- Environmental infrastructures

National Demonstration Zone for ISO 14001 (2000)

2005
- Circular economy
- Closed-loop chains

National Pilot Industrial Area for Circular Economy (2005)

2008
- Industrial symbiosis
- Low carbon economy

National Demonstration Eco-industrial Park (2008)

Roadmap of TEDA’s Eco-transformation
Environmental infrastructure facilitation in TEDA

The centralized water and energy system in TEDA.

Recovered fly ash for building material
- Electricity: $2.59 \times 10^8$ kWh/year
- Steam: 140-160 tons/hour
- District heating area: $2.4 \times 10^6$ m$^2$

Binhai Energy Cogeneration Power Plant
(No.5 thermal plant) (2003, 1$^{st}$ stage. Desulphurization. Coal: ~47000 tons/year; 2007, 2$^{nd}$ stage)

High quality reclaimed water for TEDA area

Reclaimed water production

Water for cooling and production

Ecological restoration of landscape river (2001)
(Area: 0.22 km$^2$; Water storage: $2.25 \times 10^6$ m$^3$)

Green lands irrigation

Ocean

Stabilized sludge

Waste recycler company

TEDA Wastewater Treatment Plant (1998; retrofitted in 2011. COD: 440.13 tons/year) (10000 tons/day)

Wastewater Treatment Plant in west zone (2006) (12500 tons/day)

Electroplating Wastewater Treatment Plant (2001) (1000 tons/day)

New Water Source No.1 Plant (2002; retrofitted in 2006) (30000 tons/day)

New Water Source No.2 Plant (2005; retrofitted in 2009) (10000 tons/day)
Funding for environmental protection projects by TEDA Administrative Committee. Unit: RMB $10^4$ (approx. Euro 1200)

In 2009, the total funding increased by 86% compared to that in 2007.

Number of energy-saving projects funded by TEDA Administrative Committee. Unit: RMB $10^4$

The total number of funded projects on energy-saving increased from 6 to 95 and the amount of the funds grew by 83.6%. 

**Milestone events-Economic and financial enablers**

- **Economic and financial enablers**
  - Funding for environmental protection projects by TEDA Administrative Committee. Unit: RMB $10^4$ (approx. Euro 1200)
  - In 2009, the total funding increased by 86% compared to that in 2007.

**Graphs**

- **Graph 1**: Amount of the funds for environmental protection projects
  - Comparison from 2007 to 2009
  - Data points: 2007 (464.08), 2008 (845.59), 2009 (1364.44)

- **Graph 2**: Number of energy-saving projects funded
  - Comparison from 2008 to 2009
  - Data points: 2008 (435.37), 2009 (2659.67)

- **Graph 3**: Total amount
  - 2007: 38
  - 2008: 2659.67
  - 2009: 435.37

**Chart**

- **Chart 1**: Management Project vs Engineering Project vs Desulfuration Equipment Operation
  - Comparison of total funding from 2007 to 2009
  - Data points: 2007 (464.08), 2008 (845.59), 2009 (1364.44)
Milestone events - Informational activity

TEDA Waste Minimization Club (NGO)

- A platform for training and knowledge dissemination
- Experts investigate the efficiency of energy and water consumption.

TEDA Environment Protection Bureau

- Solid Waste Management Information System (SWIMS)
- Workshops to encourage and train companies to use the online questionnaire system.

TEDA Eco-center

- Engage stakeholders to join eco-oriented business projects and assist companies to identify the synergy possibilities.


Twice online surveys by SWIMS in 2004 and 2005, involving 62 solid waste producers (accounting for 85% of this type of companies in TEDA) and 57 resource recycling companies.

By the end of 2011:
- 6 match-making workshops.
- 8 IS conferences.
- 205 investigations (questionnaires and on site)

Let companies know  Let companies learn  Let companies meet
Barriers in the informational activity

- Companies don’t participate.
- Companies agree to join training, but don’t show up.
- Companies have cognitive differences about “waste minimization”, “industrial symbiosis”, “circular economy”.
- The solutions from experts are not applied.
- Competition and confidential information.

• If you are a coordinator, how to solve these problems?
Industrial symbiosis coordinating program: TEDA and NISP

Really simple principle: *making matches*...

- **What do you **HAVE**?**
  - Unwanted resources

- **What do you **WANT**?**
  - Resources you can use / process

= **MATCHES** are made

http://www.youtube.com/watch?v=cGsU73UwHfE
Industrial symbiosis coordinating program: TEDA and NISP

1.3.2 Programme Profile and Areas of Responsibility

The following programme team profile is assumed around an area equivalent to 1000km² with a population of about 5 million people that comprises industry, agriculture and/or mixed economies within it.

Figure 2.0 Example of a team profile for an industrial symbiosis programme

- Strategic
  - Target Setting
  - Monitoring & Analysis
  - Team Management & Motivation

- Practical Implementation
  - Business Engagement
  - Identification of Synergies
  - Problem Solving

- Administrative & Clerical Support
  - Coordination & Implementation of office procedures
  - Management of programme events & workshop logistics

- Programme Manager
  - Industrial Symbiosis Practitioner
  - Industrial Symbiosis Practitioner
  - Industrial Symbiosis Practitioner

Typical NISP Workshop

TU Delft
Industrial symbiosis coordinating program: TEDA and NISP

**IS Activities Flowchart**

1. **Binhai IS Forum**
   - Targeted at CEOs of enterprises; Raise public awareness

2. **IS Info Survey**
   - Distribute surveys regarding their waste, byproducts, and spared resources, etc., to enterprises

3. **Quick Win Workshop**
   - Targeted at EHS and production personnel; Communication opportunity to identify potential synergies between enterprises

4. **Data Analysis**
   - Collect and analyze data collected from Activity 2 and 3; Identify important synergy opportunities

5. **Site Visit**
   - Visit synergy related companies and Confirm resources information on site;

6. **Synergy Follow-up**
   - Facilitate communication between companies - meetings, discussion and negotiation etc; Complete synergy
Industrial symbiosis coordinating program: TEDA and NISP

3. Quick Win Workshop

Objectives:

- Face to face communication opportunity for representatives from different companies to exchange information about their supply and demand for various types of waste/byproducts/resources.

- Identify potential synergies
- Networking opportunity for representatives from different sectors to learn more about other sectors
Industrial symbiosis coordinating program: example-recycle waste yeast

- Project participants: Kingway Beer and Tuopo Bio

Kingway Beer and Tuopo Bio met at the workshop, then

Kingway Beer and Tuopo Bio
## Milestone events-Company activity

<table>
<thead>
<tr>
<th>Number of recruited companies</th>
<th>Number of synergies</th>
<th>CO₂ reduction (10,000 tons)</th>
<th>Landfill diversion (10,000 tons)</th>
<th>Raw materials reduction (10,000 tons)</th>
<th>Revenue increase (10,000 RMB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>536</td>
<td>27</td>
<td>1.1</td>
<td>0.3</td>
<td>0.3</td>
<td>552</td>
</tr>
</tbody>
</table>

The environmental and economic results of the synergy projects within IS program by 2011. Synergy projects involve packaging waste, scrap, iron, waste water treatment and waste oil.
Trends of the 5 key activities in TEDA from 2000 to 2011

(a) Numbers of the new events of institutional activity per year
(b) Numbers of the new events of technical facilitation per year
(c) Numbers of the new events of economic and financial enabler per year
(d) Numbers of the new events of informational activity per year
(e) Numbers of the new events of company participation per year
## Trends of the 5 key activities from 2000 to 2011

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Not significant</td>
<td>Increased markedly and physical synergies gradually emerged; rapid surge occurred in 2010</td>
</tr>
<tr>
<td>Intra-firm cleaner production; Building water treatment and co-generation plants</td>
<td>Trigger companies’ spontaneous behavior to share information and join the IS network.</td>
</tr>
<tr>
<td>Few events</td>
<td>Economic incentives have been strengthened consistently</td>
</tr>
<tr>
<td>Stable and low level</td>
<td>Increased remarkably</td>
</tr>
<tr>
<td>No main coordination body</td>
<td>Coordination body, TEDA’s Eco-center, functioned as a broker and institutionalization mechanism for building and identifying IS relationships.</td>
</tr>
</tbody>
</table>

- IS-related company activities
- Emphasis of the planning and policy
- Economic and financial incentives for encouraging IS
- Informational activities
- Coordination body to solve the incomplete information and disseminate new IS-related ideas
System analysis about the process of TEDA’s eco-transformation

TEDA’s system structure in the initial era (2000-2005)
System analysis about the process of TEDA’s eco-transformation

TEDA’s system structure in the emerging era (2006-2011)
Main barriers of TEDA

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A mixed industrial park</td>
<td>• Large number of companies from diverse industrial sectors with different types of waste. The scale of each type is small.</td>
</tr>
<tr>
<td>Closed-loop chains</td>
<td>• Closed-loop chains have had a short-term effect, but in reality the links did not evolve in a natural way, resulting in incompatible and unstable couplings.</td>
</tr>
<tr>
<td>No landfill tax and Extended Producer Responsibility</td>
<td>• Lack of pressure and motivation for companies to reduce, reuse and recycle.</td>
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<tr>
<td>Existing regulations on industrial waste classification and reclamation</td>
<td>• Not systematic. Lack of practical and standardized instructions.</td>
</tr>
<tr>
<td></td>
<td>• The immature market of waste recycling is taken by unqualified recyclers.</td>
</tr>
<tr>
<td>Strong government involvement</td>
<td>• Some companies participated only passively in the IS projects.</td>
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## Performance of EIP development in TEDA

<table>
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<tbody>
<tr>
<td>Economic development</td>
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<tr>
<td>I_1  IVA per capita (≥15)</td>
<td>10,000 RMB/per person</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>74.72%</td>
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<tr>
<td>I_2  Growth rate of IVA (≥15)</td>
<td>%</td>
<td></td>
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<td>-20.6%</td>
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<td>Material reduction and recycling</td>
<td></td>
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<tr>
<td>I_3  IVA of industrial land use (≥9)</td>
<td>100 million RMB/km²</td>
<td></td>
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<td></td>
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<td></td>
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<td>107.17%</td>
</tr>
<tr>
<td>I_4  Energy consumption of IVA (≤0.5)</td>
<td>ton of coal equivalent/10,000 RMB</td>
<td></td>
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<td></td>
<td></td>
<td>-47.31%</td>
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<tr>
<td>I_5  Freshwater consumption of IVA (≤9)</td>
<td>m³/10,000 RMB</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>-56.80%</td>
</tr>
<tr>
<td>I_6  Wastewater discharge of IVA (≤8)</td>
<td>ton/10,000 RMB</td>
<td></td>
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<td>-57.01%</td>
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<tr>
<td>I_7  Reuse rate of industrial water (≥75)</td>
<td>%</td>
<td></td>
<td></td>
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<td></td>
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<td>3.96%</td>
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<td>I_8  Solid waste discharge of IVA (≤0.1)</td>
<td>ton/10,000 RMB</td>
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<td></td>
<td></td>
<td>-55.93%</td>
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<tr>
<td>I_9  Comprehensive use rate of industrial solid wastes (≥85)</td>
<td>%</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>9.10%</td>
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<tr>
<td>Pollution control</td>
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<td>I_10  COD discharge of IVA (≤1)</td>
<td>kg/10,000 RMB</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>-34.78%</td>
</tr>
<tr>
<td>I_11  SO₂ discharge of IVA (≤1)</td>
<td>kg/10,000 RMB</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>-71.01%</td>
</tr>
<tr>
<td>I_12  Disposal rate of hazardous waste (100)</td>
<td>%</td>
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</tr>
<tr>
<td>I_13  Disposal rate of domestic waste (100)</td>
<td>%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>---</td>
</tr>
</tbody>
</table>
Procedures of TOPSIS:

Step 1: Normalize the decision matrix and the normalized value \( n_{ij} \) is as:

\[
n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}; \quad i = 1, \ldots, m; \quad j = 1, \ldots, n
\]  

(1)

Step 2: Calculate the weighted normalized matrix. The information entropy method is used to obtain the objective weight of the indicators (Jingwen 2008; Wu et al. 2008). The entropy value of each indicator \( e_j \) is as:

\[
e_j = -\frac{1}{\ln m} \sum_{i=1}^{m} n_{ij} \ln n_{ij}; \quad i = 1, \ldots, m; \quad j = 1, \ldots, n
\]  

(2)

The weight of each indicator \( w_j \) is calculated as:

\[
w_j = \frac{1-e_j}{n-\sum_{j=1}^{n} e_j}; \quad j = 1, \ldots, n
\]  

(3)

Therefore the weighted normalized matrix \( v_{ij} \) is as:

\[
v_{ij} = w_j n_{ij}; \quad i = 1, \ldots, m; \quad j = 1, \ldots, n
\]  

(4)

Step 3: Select positive ideal solution \( A^+ \) and negative ideal solution \( A^- \)

\[
A^+ = \{v_1^+,...,v_n^+\} = \{(\max_i v_{ij} | j \in J_1), (\min_i v_{ij} | j \in J_2) | i = 1,...,m\}
\]  

(5)

\[
A^- = \{v_1^-,...,v_n^-\} = \{(\max_i v_{ij} | j \in J_2), (\min_i v_{ij} | j \in J_1) | i = 1,...,m\}
\]  

(6)

where \( J_1 \) is associated with the positive indicator (the larger, the better) and \( J_2 \) is associated with the negative indicator (the smaller, the better).

Step 4: Calculate the separation measures by using Euclidean distance. The separation between each alternative and the positive ideal solution is as:

\[
d_i^+ = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_{ij}^+)^2}; \quad i = 1, \ldots, m
\]  

(7)

And the separation between each alternative and the negative ideal solution is as:

\[
d_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_{ij}^-)^2}; \quad i = 1, \ldots, m
\]  

(8)

Step 5: Calculate the relative closeness to the ideal solution

\[
c_i = \frac{d_i^-}{d_i^++d_i^-}; \quad i = 1, \ldots, m
\]  

(9)

Step 6: Rank the alternatives based on the descending order of \( c_i \). The better alternative is the one having smaller distance to the positive solution and greater distance to the negative solution.
Performance of EIP development in TEDA

Multi-Criteria Decision Analysis.
Mathematical model: TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution)
Goal: select the best EIP performance in TEDA from 2004 to 2011, based on 13 indicators.

Comprehensive evaluation of TEDA’s EIP performance from 2004 to 2011.

Evaluation of the sub-group indicators on economic development, material reduction and recycling, pollution control in TEDA from 2004 to 2011.
What can we learn from TEDA case study?

**System analysis**
- Decompose the case and illustrate how changes unfolded during TEDA’s eco-transformation.

**Dynamic system thinking of EIP**
- It is a progressive process co-shaped by various actors and forces in terms of institutional activity, technical facilitation, economic and financial enablers, informational activity and company activity.

**The trajectory of TEDA**
- A transition from “a planned EIP” to “a planned + facilitated EIP”.
“By-product” of TEDA case: Knowledge management for industrial symbiosis

Using semantic wiki to manage knowledge and data

http://enipedia.tudelft.nl/wiki/Main_Page

Traditional ways to manage knowledge and data
Raw Data and Machine-readable Data

- Recognizes that people need data and data needs people
- Provides a platform for exploring energy and industry topics
- Uses hybrid of wiki and database technologies - structured + unstructured information
- Allows users to enter/migrate information to the form in which it is most useful

“Itaipu Powerplant is located in Brazil and it produces 63,300,000 Mwh annually.”

1. Itaipu Power Plant Described using Plain Text

Itaipu [[is a::Powerplant]] is located in [[located in::Brazil]] and produces [[produces::63,300,000 MWh]] annually.

2. Itaipu Power Plant Described using Semantic MediaWiki Syntax

3. Graph describing the Itaipu power plant

4. Enipedia.tudelft.nl page with information on the Itaipu

### Information of TEDA Industrial Symbiosis

<table>
<thead>
<tr>
<th>Synergy Title</th>
<th>Outcome Name</th>
<th>Supplier company (Date: yy-mm-dd)</th>
<th>Receiver company (Date: yy-mm-dd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>赫比-优利科: Herbie sends packaging waste to Unico. (carton, plastic and wooden packaging)</td>
<td>Additional Sales (unit:yuan)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>赫比-优利科: Herbie sends packaging waste to Unico. (carton, plastic and wooden packaging)</td>
<td>CO2 Reduction (unit:ton)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>赫比-优利科: Herbie sends packaging waste to Unico. (carton, plastic and wooden packaging)</td>
<td>Cost Savings (unit:yuan)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>赫比-优利科: Herbie sends packaging waste to Unico. (carton, plastic and wooden packaging)</td>
<td>Diversion From Landfill (unit:ton)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>赫比-优利科: Herbie sends packaging waste to Unico. (carton, plastic and wooden packaging)</td>
<td>Hazardous waste (unit:ton)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>赫比-优利科: Herbie sends packaging waste to Unico. (carton, plastic and wooden packaging)</td>
<td>Raw Material Reduction (unit:ton)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>维斯塔斯-Unico: Vestas sends packaging waste to Unico.(plastic,wooden packaging, carton and copper)</td>
<td>Additional Sales</td>
<td></td>
<td></td>
</tr>
<tr>
<td>维斯塔斯-Unico: Vestas sends packaging waste to Unico.(plastic,wooden packaging, carton and copper)</td>
<td>CO2 Reduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>维斯塔斯-Unico: Vestas sends packaging waste to Unico.(plastic,wooden packaging, carton and copper)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>维斯塔斯-Unico: Vestas sends packaging waste to Unico.(plastic,wooden packaging, carton and copper)</td>
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<td></td>
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<td>维斯塔斯-Unico: Vestas sends packaging waste to Unico.(plastic,wooden packaging, carton and copper)</td>
<td>Raw Material Reduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>斯莱克-优利科: 纸箱和塑料 Asymchem Life Science（天津）-Unico: Asymchem sends packaging waste to Unico. (carton and plastic)</td>
<td>Additional Sales</td>
<td></td>
<td></td>
</tr>
<tr>
<td>斯莱克-优利科: 纸箱和塑料 Asymchem Life Science（天津）-Unico: Asymchem sends packaging waste to Unico. (carton and plastic)</td>
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<td>Hazardous waste</td>
<td></td>
<td></td>
</tr>
<tr>
<td>登士柏-优利科: 纸箱和塑料 Dentsply (TianJin)-Unico:Dentsply sends packaging waste to Unico.(carton and plastic)</td>
<td>Additional Sales</td>
<td></td>
<td></td>
</tr>
<tr>
<td>登士柏-优利科: 纸箱和塑料 Dentsply (TianJin)-Unico:Dentsply sends packaging waste to Unico.(carton and plastic)</td>
<td>CO2 Reduction</td>
<td></td>
<td></td>
</tr>
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<td>登士柏-优利科: 纸箱和塑料 Dentsply (TianJin)-Unico:Dentsply sends packaging waste to Unico.(carton and plastic)</td>
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<td></td>
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<td>Hazardous waste</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Ontology design and application

"An ontology formally represents knowledge as a set of concepts within a domain, and the relationships between those concepts. It can be used to model a domain and support reasoning about concepts."

--Wikipedia

“An ontology formally represents knowledge as a set of concepts within a domain, and the relationships between those concepts. It can be used to model a domain and support reasoning about concepts.”

--Wikipedia
Ontology design and application
Use Enipedia to analyze industrial symbiosis in TEDA

Create wiki pages for companies.
Use Enipeida to analyze industrial symbiosis in TEDA
Use Enipeida to analyze industrial symbiosis in TEDA

Edit SynergyLink: SynergyLinkNestleLifusi

Warning: You are not currently [[Special:UserLoginLogged in]]. If you save any edits, your IP address will be recorded publicly in this page's history. If you create an account, you can conceal your IP address & IP can be viewed on [[Special:Mytalk|your talk page]].

Name:

FromFacility: SynergyLinkNestleLifusi

toFacility: TianjinNestle

Start Date: 31 August 2011

End Date: 31 August 2012

Coordinator: TEDA-Eco-center

Additional Income: 20000 Yuan

Additional Private Investment: 0 Yuan

Create wiki pages for synergy links.
Use Enipeida to analyze industrial symbiosis in TEDA
Knowledge infrastructure: Industrial symbiosis in TEDA on Enipedia
Knowledge infrastructure: Industrial symbiosis in TEDA on Enipedia
Industrial symbiosis in TEDA on Enipedia
Industrial symbiosis in TEDA on Enipedia

http://enipedia.tudelft.nl/wiki/TEDA
Industrial symbiosis in Kalundborg on Enipedia

http://enipedia.tudelft.nl/wiki/Category:SynergyLink
Case study 2: Dalian Development Area (DDA)

- Established time: 1984
- Developed area: 90 km².
- Population: 650 thousand.
- GDP (2010): RMB 120 billion.
- Number of companies: 24727
- Industry:
  - Petro-chemistry
  - Electronic telecommunications
  - Equipment manufacturing
  - Automobile parts
  - Shipbuilding
# General features of TEDA and DDA

<table>
<thead>
<tr>
<th></th>
<th>TEDA</th>
<th>DDA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td>Tianjin City, China</td>
<td>Dalian City, China.</td>
</tr>
<tr>
<td></td>
<td>Connected with Tianjin Port, 38 km away from airport and 1 hour to Beijing by car.</td>
<td>Nearby Dalian Port, 27 km away from Dalian City center and 25 km away from airport.</td>
</tr>
<tr>
<td><strong>Established time</strong></td>
<td>1984</td>
<td>1984</td>
</tr>
<tr>
<td><strong>Developed area (km²)</strong></td>
<td>98</td>
<td>90</td>
</tr>
<tr>
<td><strong>Population (thousand)</strong></td>
<td>536</td>
<td>650</td>
</tr>
<tr>
<td><strong>Companies</strong></td>
<td>28464</td>
<td>24727</td>
</tr>
<tr>
<td><strong>Main industries</strong></td>
<td>Electronics and telecommunications, automobile manufacturing, equipment manufacturing, petro-chemistry, food and beverage, biomedicine, aerospace industry, new energy and new materials.</td>
<td>Petro-chemistry, electronic telecommunications, equipment manufacturing, automobile parts and shipbuilding.</td>
</tr>
<tr>
<td><strong>Start time of eco-transformation</strong></td>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td><strong>Status</strong></td>
<td>Brownfield industrial cluster with multi-industrial sectors</td>
<td>Brownfield industrial cluster with multi-industrial sectors</td>
</tr>
<tr>
<td><strong>Initiator of eco-transformation</strong></td>
<td>TEDA Administrative Committee</td>
<td>DDA Administrative Committee</td>
</tr>
<tr>
<td>Policy instruments to promote EIP in TEDA and DDA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Economic instruments</strong></th>
<th><strong>TEDA</strong></th>
<th><strong>DDA</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>Exemption from sewage disposal fee.</td>
<td>2000</td>
</tr>
<tr>
<td>2002</td>
<td>Encouraging reclaimed water.</td>
<td>2000</td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td>2002</td>
</tr>
<tr>
<td>2007</td>
<td>Subsidy for desulphurization facilities to reduce SO₂.</td>
<td>2006</td>
</tr>
<tr>
<td>2007</td>
<td>Funding for waste reduction and recycling, energy-saving and environmental information disclosure</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Regulatory instruments</strong></th>
<th><strong>TEDA</strong></th>
<th><strong>DDA</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>Mandatory environmental information disclosure for pollution intensive and energy intensive companies.</td>
<td>2001</td>
</tr>
<tr>
<td>2009</td>
<td>Integrity evaluation for companies' environmental performance.</td>
<td>2009</td>
</tr>
<tr>
<td>2010</td>
<td>Measures on energy management for the energy intensive companies (energy consumption ≥ 1 kiloton standard coal equivalent/year).</td>
<td>2011</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Voluntary instruments</strong></th>
<th><strong>TEDA</strong></th>
<th><strong>DDA</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>Waste minimization club.</td>
<td>2000</td>
</tr>
<tr>
<td>2007</td>
<td>Guidelines for voluntary environmental information disclosure.</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>Industrial symbiosis coordination program involving dissemination, training and match-making workshops.</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>Negotiated agreement on energy-saving between AC and energy intensive companies.</td>
<td></td>
</tr>
</tbody>
</table>
A database of worldwide environmental instruments (OECD/European Environmental Agency)

General Information on all types of Instruments by Environmental Domain

- Water Pollution
- Air Pollution
- Climate Change
- Land Contamination
- Waste Management
- Natural Resource Management
- Noise
- Ozone Layer Protection
- Energy Efficiency
- Transport
- Land Management

Environmentally Related Taxes, Fees and Charges

- Main Characteristics
- Revenues Generated by Environmentally Related Taxes
- Tax Rates of Environmentally Related Taxes
- Exemptions in Environmentally Related Taxes
- Refund Mechanisms in Environmentally Related Taxes
- Tax Ceilings in Environmentally Related Taxes
- Earmarked Environmentally Related Taxes

 Tradable Permit Systems

- Main Characteristics
- Annual Information and permit allocation information
- Geographical and Sectoral Coverage
- Environmental Domain

Deposit-Refund Systems

- Main Characteristics
- Environmental Domain

Environmentally Motivated Subsidies

- Main Characteristics
- Types of Activities Supported
- Annual Cost
- Target Groups

Voluntary Approaches

- Main Characteristics
- Participants
- Geographical and Sectoral Coverage
- Environmental Domain

http://www2.oecd.org/ecoinst/queries/index.htm
Question: What kinds of policy instruments can you think of to reduce pollution in an industrial park? (e.g., water pollution)

- Fee, tax, subsidy, reward, technology...
Environmental infrastructure facilitation

The centralized water and energy system in DDA.
System structure of DDA’s eco-transformation
## Performance of EIP development in TEDA and DDA

<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic development</td>
<td>I₁</td>
<td>Annual growth rate of IVA (≥15) %</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material reduction and recycling</td>
<td>I₂</td>
<td>Energy consumption of IVA (≤0.5) ton of coal equivalent/10,000 RMB</td>
<td>✓</td>
<td></td>
<td></td>
<td>×</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I₃</td>
<td>Freshwater consumption of IVA (≤9) m³/10,000 RMB</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I₄</td>
<td>Wastewater discharge of IVA (≤8) ton/10,000 RMB</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I₅</td>
<td>Reuse rate of industrial water (≥75) of TEDA; Reuse rate of recycled water of DDA (≥40) %</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>×</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I₆</td>
<td>Solid waste discharge of IVA (≤0.1) ton/10,000 RMB</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I₇</td>
<td>Comprehensive use rate of industrial solid wastes (≥85) %</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pollution control</td>
<td>I₇</td>
<td>COD discharge of IVA (≤1) kg/10,000 RMB</td>
<td>✓</td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I₈</td>
<td>SO₂ discharge of IVA (≤1) kg/10,000 RMB</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>×</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table. Performance of economic growth, energy efficiency, material reduction and recycling in TEDA and DDA.
### Performance of EIP development in TEDA and DDA

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Results of the comprehensive evaluation of the entire 8 indicators</td>
<td>0.630557</td>
<td>0.709215</td>
<td>0.664549</td>
<td>0.782742</td>
<td>0.275347</td>
<td>0.558256</td>
<td>0.440217</td>
<td>0.398107</td>
</tr>
<tr>
<td>Rank</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Results of the evaluation of the sub-groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rank of economic development</td>
<td>5</td>
<td>7</td>
<td>8</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Rank of material reduction and recycling</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>8</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Rank of pollution control</td>
<td>5</td>
<td>1</td>
<td>7</td>
<td>4</td>
<td>8</td>
<td>6</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

**Table.** TOPSIS results of the relative closeness (Ci) of the comprehensive evaluation and the sub-groups.
Discussion: Similar starting conditions → Different enforcements, patterns and performance.

<table>
<thead>
<tr>
<th>Policy Instrument</th>
<th>TEDA</th>
<th>DDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price mechanisms for water consumption and reclaimed water usage</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Funding for ISO14001, cleaner production audit, energy audit, and environmental technologies</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Wastewater treatment plant</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Reclaimed water plant</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Co-generation plant equipped with SO$_2$ scrubber</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Mandatory energy audit and cleaner production audit</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Mandatory environmental information disclosure</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Training and dissemination for eco-solutions</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Networking activities to engage company participation</td>
<td>+++</td>
<td>+</td>
</tr>
</tbody>
</table>

Table. The effectiveness of the policy instruments found in TEDA and DDA. The scale is from partly, largely to mostly.
Conclusions from the comparative study

• 1) The tailored policy instruments along with the ongoing EIP development are vital to favor the eco-transformation of Chinese EIPs;

• 2) The planned EIP model is useful in the beginning of eco-transformation and the facilitated model should be combined to achieve long-term goals for eco-transformation.
Next step of Chinese EIPs: wide company participation

Figure. Importance of various barriers (left) and incentives (right) for engaging companies in environmental management initiatives in Suzhou Industrial park.
Next step of Chinese EIPs: eco-city?

Annual GDP of three industrial sectors and the registered permanent population in Suzhou Industrial Park. Unit of GDP: billion RMB. Unit of population: 10000 people.
Next step of Chinese EIPs: eco-city?

Figure. GHG emissions in Suzhou Industrial Park from different sectors, 2005–2010.