The Case Studies of Regional Energy

and Resources Integration

區域能資源整合成功案例宣導手冊



Industrial Symbiosis • Naturally Inspired Progress

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Collaboration is the new competition. It's about working with each other, not against. Together we all win!

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Preface

The Circular Economy Promotion Plan, passed by Taiwan's Executive Yuan, lays out a framework to promote the concept of industrial symbiosis where factories share waste to improve competitiveness and reduce environmental impacts. Its main purpose is to highlight successful energy and resource exchanges between businesses, and to spread this concept across Taiwan.

Since the concept of sustainable development was first proposed in 1984, it has steadily become a mainstream concept in industry development. Yet these ideas are necessary for national security as well. Taiwan is an island country, lacking natural resources and energy. Through energy efficiency and reusing resources companies here can not only reduce waste, but also reduce the cost of raw material and energy. Natural limits create an incentive for economic profit and sustainable development together.

Circular parks developed with the concept of industrial symbiosis have become one of the major policies for governments across the world to promote circular economy, increase resource utilization and reduce greenhouse gas emissions. The idea behind integrating regional energy and resources is to make a mutually beneficial situation for sustainability and industry development by using geographic advantages within the parks and complementary resources between industries to create higher profits with the least energy and resources.

After years of collaboration between government and industry, regional energy and resource integration has made clear progress. Based on the data from Ministry of Economic Affairs in Taiwan, energy and resources integration plans exist for 23 industrial parks. This report focuses on introduce successful cases and related policies in Taiwan.

Circular Economy Promotion Plan

- Make Industry Circular
- Make Circularity into Industries



Circular Economy (CE)

Circular economy can roughly be divided into micro, meso and macro levels. The micro level focuses on a firm or a product. Meso level focuses on a group of firms such as an industry cluster, an industrial park or an industry network. The macro level focuses on a city, a nation or a region. This manual focuses on the meso level of circular economy, that is, through more circular management manufacturers can reduce cost and increase productivity.

Industrial Symbiosis (IS)

Industrial symbiosis learns from ecosystems. The natural world produces no wastes, everything gets utilized by some organism or process. When two species have a close relationship through a long term cooperation, they gradually develop a frequent positive and negative feedback loop which forms a new ecological structure.

Ecology Industrial Park (EIP)

Most countries view industrial symbiosis as a long-term goal, ecological industrial parks (EIPs) are the basic industrial cluster to achieve relevant environmental targets. The U.S. Business Council for Sustainable Development defines EIPs as an industrial park which shares resources with local suppliers, brings economic profit and environment benefits, including suppliers relating to one another, service suppliers and related research institutions.

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Global Eco-Innovation Parks

According to the report International Survey on Eco-Innovation Parks (2014), there are 168 ecology industrial parks in 27 countries around the world. The criteria includes: energy efficiency, renewable energy, waste management, water management, logistics, biodiversity, transportation, land use, air pollution prevention, noise prevention, environment management system, culture, society, health and safety.

According to the report, out of 168 parks, 116 of them are in Europe, 37 in Asia, 11 in America and 4 in Oceania. Some of the featured EIPs include: Kalundborg in Denamark: Kalundborg in Denmark, Green Park in United Kingdom, Rotterdam Harbor in Netherlands, Eco-Town Kitakyushu in Japan, Ulsan in Korea, Juron Island in Singapore, Tianjin Economic Development Area in China, Brownsville in U.S. Texas, Civano in U.S. Arizona, Kwinana and Styria in Australia, etc. Unfortunately, industrial parks from Taiwan were not included in this report.



Kalundborg park in Denmark is one of the most famous EIPs in the world and has had numerous peer reviewed articles written about its success. In the 1970s, a refinery in the region started providing extra gas to a nearby plaster factory; in order to in order to meet water demands, factories connected pipelines with one another to share; power plant adopted cogeneration and provided the fly ash collected to cement plant. The key factors of Kalundborg's success are the close proximity of factories and long term mutual trust between partners.

In order to copy the successful experience of Kalundborg, the Danish government established the Symbiosis Center Denmark to promote and manage industrial symbiosis in Denmark. For the past 10 years, the institute has counselled more than 500 enterprises on energy and resources, created over 170 supply and demand matches, produced 10,000 job opportunities and mitigated 280,000 tons of greenhouse gas (GHG) emissions. This center created a strong foundation for better industrial symbiosis.

Policies of Taiwan

Industrial parks in Taiwan used to be designed around clusters based on vertical integration in a product's supply chain. The management department in the park provided water, electricity and sewage treatment, but factories in the park had to produce their own heat energy or resources. Take energy for example, if the factories want to ensure adequate heat for a process, usually they built their own boilers, and due to economics chain-grate boilers were often chosen. However, these boilers are inefficient, causing air pollution and increased greenhouse gasses emissions. For raw resources, factories needed to find waste disposal separately. Since there is no effective mechanism for communication, any potential for resource sharing between industries went unrealized.

Starting in 2005, Taiwan's government began to facilitate communication within industrial parks between manufacturers to promote energy and resources recycling. The work began by taking inventories of waste, step by step, it clarified the fact that most of the waste were coming from electronic, dyeing, pulp and paper, steam supply, petrochemical and steel industry. For example, Linhai Industrial Park in Kaohsiung initiated their energy and resources integration with China Steel Corporation. China Steel Corporation would sell steam, oxygen, nitrogen, argon and other resources to nearby factories, as part of regional energy integration.

There are many successful integration cases, for example: (1) a cogeneration power plant provides extra steam to nearby factories to replace their own inefficient and polluting boilers; (2) pulp and paper factories recycle production waste and convert it into steam; (3) petrochemical fiber and textile factories reprocess PET bottle and make functional clothing; (4) livestock farms processes animal excrement with anaerobic treatment and produces biogas to generate electricity for factories and grid use.

Targets of Energy and Resources Integration

- Increase resource recovery by 5%
- Increase energy linkage in specific regions by 5%
- Reduction of GHG emissions annually by 400,000 tons



Principles of selecting an industrial park

- Scale of energy consumption: parks with larger scale of energy consumption net larger benefits
- Industry cluster: focus on industries in the park with integration potential and prioritize industries with complementary supply chains within the park or at nearby industry parks
- Resources linkage: parks with more factories and lower recycling rates have larger resources linkage potential
- Energy linkage: parks with more factories with higher energy demands, that also contain large energy intensive production have better chances of energy linkage

Integration strategies

- Regional supply of electricity, steam and pure water
- Reduction and recycling of waste and by-products that need immediate processing
- Introduce industries with ecology linkage potential into industrial parks
- Send waste to nearby processing institutions
- Recover materials from waste that are landfilled or incinerated
- Find more advanced technology for reduction and recycling

Linhai Industrial Park



Linhai Industrial Park is the largest industrial area in Taiwan. It consists of 493 companies and across more than 20 industries. Top industries include petrochemicals and steel manufacturing. Well known national companies have major operations in Linhai, such as Taiwan Sugar, Tang Eng Iron, CPC Dalin factory, China Steel, China Steel Machinery, CSBC Taiwan, and China Petrochemical Development. Linhai is an important cluster for Taiwan's economic development.

Linhai Industrial Park covers a relatively wide area, has a high number of manufacturers, high energy consumption, and produces large amounts of waste. China Steel has the most operations in the park with the highest energy demand, and operates closely with more than 20 companies located in or outside the zone. Factories in the zone share steam, industrial gases, and excess energy with each other. The resource sharing network is also constructed to efficiently integrate resources, such as ground granulated blast-furnace slag, air-cooled blast furnace slag, desulfurized slag, basic-oxygen-furnace (BOF) slag, sludge, coal tar oil, waste acids, and waste refractories. Resource and energy sharing of these hard to manage compounds increases energy efficiency, decreases energy consumption, decreases overall pollution, and decreases GHG emissions.





1- Coke Oven Gas; 2- Steam; 3- Argon; 4- Hydrogen; 5- Nitrogen; 6- Aluminum slag; 7- EAF Dust; 8- EAF Oxidizing Slag; 9- EAF Reduction Slag; 10- EAF Slag; 11- Incineration Bottom Ash; 12- Liquid Alkali; 13- Non-hazardous Dust; 14- Non-hazardous Organic Waste Solven; 15- Sandblasting Waste; 16- Waste Insulation Material; 17- Waste Solvent; 18- Waste Woods

Figure 1. Energy and Resources Linkage in Linhai Industrial Park

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Linyuan Industrial Park



Linyuan Industrial Park is one of important petrochemical industrial areas in southern Taiwan. Large companies with operations there include: the Petrochemical Business Division of CPC Taiwan, Formosa Plastics, Taiwan Prosperity Chemical, Taiwan Styrene Monomer, and Oriental Union Chemical. Within the park there are upstream, midstream, and downstream manufacturers within the petrochemical industry. In addition, as it is nearby the Linhai Industrial Park energy and resources integration is promoted together with the manufactures in Linhai in order to achieve better economies of scale.

Linyuan Industrial Park mainly consists of factories in the petrochemical industry. CPC Taiwan, Formosa Plastics, and other 5 petrochemical companies, namely China Synthetic Rubber, Taiwan Styrene Monomer, LCY Chemical, Nan Ya Plastics, Tasco Chemical, are the main companies located in the zone. Factories in the zone share steam, industrial gases, and other kinds of excess energy with each other. The resource sharing network was also constructed to turn the by-products of oil refineries into the raw materials of nearby manufacturers and the water regeneration demonstration plant in Linyuan. Different kinds of energy and resources integration were completed in Linyuan, such as incineration bottom ash and waste insulation materials. Steam integration has completed between some manufacturers leading to a reduction in the number of small boilers and reductions of pollution.



Key network attributes

- Energy is supplied by the petrochemical companies and most of industrial wastes are recycled by companies outside the zone.
- Many manufacturers in the zone are listed companies and value corporate social responsibility.



1- Steam; 2- Coal Bottom Ash; 3- Coal Fly Ash; 4- Inorganic Sludge; 5- Non-hazardous Catalyzer; 6- Non-hazardous Waste Solvent; 7- Organic Sludge; 8- Waste Insulation Material; 9- Waste Oil Sludge; 10- Waste Refractories

Figure 2. Energy and Resources Linkage in Linyuan Industrial Park

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Tainan Technology Industrial Park



The Tainan Technology Industrial Park is close to Tainan City, Anping Port, and National Cheng Kung University. There are manufacturers of electronics and metal products, such as Catcher Technology, SOLAR, DARFON, and AU Optronics, located in the zone. The main industrial waste types include: flammable waste liquids, chromium-containing sludge, waste electronic components, electroplating sludge, and copper-containing sludge. There is great long term potential for reuse and recycling.

According to a survey by the IDB, the amount of potential integration in the Tainan Technology Industrial Park is around 3,000 tonnes of waste per year and it mainly includes waste solvent, waste liquid alkali, refractory waste, inorganic sludge, non-hazardous dust, paint waste, electroplating sludge, calcium fluoride sludge, sandblasting waste, and waste plastic mixture. Total benefits are estimated to be NTD 8 million. The ratio of waste recovery is expected to rise from 61.6% to 83.0% after these interventions. So far, energy and waste integrations that have already been completed include calcium fluoride sludge, waste insulation material, waste sulfuric acid, waste hydrofluoric acid, waste glass, and waste ceramics.



1- Calcium Fluoride Sludge; 2- Copper-Containing Waste Liquid; 3- Inorganic Sewage Sludge; 4- Nickel-Containing Electroplating Sludge; 5- Non-hazardous Dust; 6- Organic Sewage Sludge; 7-Paint Waste; 8- Sandblasting Waste; 9- Waste Ceramics; 10- Waste Glass; 11- Waste Hydrofluoric Acid; 12- Waste Insulation Material; 13- Waste Liquid Alkali; 14- Waste Plastic Mixture; 15-Waste Solvent; 16- Waste Sulfuric Acid

Figure 3. Energy and Resources Linkage in Tainan Technology Industrial Park

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Hsinchu Industrial Park is located south of the capital in Taipei within Hsinchu county. There are more than 470 factories in the zone, such as Powertech Technology, Chang Chun Plastics, Unimicron, CMC, and Gemetk. Chang Chun Plastics has a steam plant and supplies excess steam to around 10 factories. The energy sharing network is constructed in the zone. Furthermore, industrial wastes in the zone include: phosphate coating sludge, organic waste solvent, dust, copper-containing sludge, and calcium fluoride sludge, have been reused and integrated with recovery companies outside the park.

According to a survey by the IDB, the amount of potential material integration in the Hsinchu Industrial Park is around 68,000 tonnes of waste per year. The total economic benefit is estimated to be NTD 94 million. Energy integrations would lead to a reduction of GHG emissions annually by an estimated 11,000 tonnes per year. The ratio of waste recovery is expected to rise from 41.8% to 59.3% and the ratio of steam integration is expected to rise from 8.9% to 35.3%. Different kinds of energy and resources integration have already been completed in Hsinchu Industrial Park such as reclaiming copper-containing sludge, refractory waste, waste oil mixture, and non-hazardous dust. Steam integration was completed between some manufacturers and it lead to a reduction in boilers.



Key network attributes

- Chang Chun Plastics is the primary steam provider. Water recovery and electronic waste recycling is strong.
- There are many types of industrial wastes in the zone, which is conducive to construction of resource sharing network.



1- Steam; 2- Calcium Fluoride Sludge; 3- Copper-Containing Sludge; 4- Incineration Bottom Ash; 5- Inorganic Sludge; 6- Metal Mixture; 7- Non-hazardous Dust; 8- Non-hazardous Organic Waste Solven; 9- Organic Sewage Sludge; 10- Paint Waste; 11- Phosphate Coating Sludge; 12- Waste Hydrofluoric Acid; 13- Waste Oil Mixture; 14-Waste Paper Mixture; 15- Waste PCBs; 16-Waste Plastic Mixture; 17- Waste Refractories; 18- Waste Resin; 19- Waste Solvent

Figure 4. Energy and Resources Linkage in Hsinchu Industrial Park

Guanyin Industrial Park



Guanyin Industrial Park is located in the coastal area of Taoyuan. The park includes 365 factories across multiple sectors including the manufacture of chemical materials, textiles, and metal products. Major companies include FENC, Taiwan Glass, Dupont Taiwan, Zig Sheng Industrial, Everlight Chemical Industrial, Hwa Ya Power, and Oriental Petrochemical (Taiwan). There are complementary industries with potential energy and resources integration inside the park. Oriental Petrochemical (Taiwan) and Hwa Ya Power are the steam centers that supply excess steam to factories in the zone. Industrial wastes in the zone reused and integrated with recovery companies outside of the park include hydrofluoric acid, copper-containing sludge, waste paper mixture, waste plastic mixture, dust, and organic waste solvent.

According to a survey by the IDB, the amount of potential integration in Guanyin Industrial Park is around 182,000 tonnes per year; the total economic benefit is estimated to be NTD 290 million; the reduction of GHG emissions annually is estimated at 32,000 tonnes; the ratio of waste recovery is expected to rise from 50.3% to 60.7%; and the ratio of steam integration is expected to rise from 12.6% to 16.7%. Some already completed energy and resource integrations in Guanyin Industrial Park include steam, copper-containing sludge, waste cutting fluid, and inorganic sludge.



1- Steam; 2- Aluminum Containing Alkaline Waste; 3- Copper-Containing Sludge; 4- Dust ; 5- Incineration Bottom Ash; 6- Inorganic Aluminum-Containing Sludge; 7- Inorganic Sewage Sludge; 8- Sandblasting Waste; 9- Waste Cutting Fluid; 10- Waste Hydrofluoric Acid; 11- Waste Optoelectronic Parts and Components; 12- Waste Paper Mixture; 13- Waste PCBs; 14-Waste Plastic Mixture; 15- Waste Wire/Cable

Figure 5. Energy and Resources Linkage in Guanyin Industrial Park

Dayuan Industrial Park



Dayuan Industrial Park, near Taiwan Taoyuan International Airport contains 177 factories. Major companies include TATUNG, COMPEQ Manufacturing, Taiwan Uyemura, Jentech Precision Industrial, Ta-Yuan Cogeneration, and Cheng Loong. Sectors in the park include chemicals, textiles, and the pulp and paper industry. Factories in the park have high energy demands because they need thermal energy during manufacturing. Ta-Yuan Cogeneration is the steam center for 64 factories in the zone. Industrial waste which has been reused and integrated with recovery companies outside of the park include waste solvent and heavy metal sludge.

For Dayuan Industrial Park, the planning of energy and resources integration includes: (1) extending steam supply lines within the zone; (2) steam integration between the CHP plant and manufacturers; (3) waste recovery and recycling (e.g., organic sludge, copper-containing sludge, and organic waste liquids). According to a survey by the IDB, the amount of potential integration is around 229,000 tonnes per year; the total economic benefit is estimated at NTD 340 million; the reduction of GHG emissions annually is estimated at 46,000 tonnes; the ratio of waste recovery is expected to rise from 27.6% to 30.6%; and the ratio of steam integration is expected to rise from 23.9% to 31.2%. So far, energy and resources integration already completed in Dayuan include steam, copper-containing sludge, copper waste wire, non-hazardous waste solvent, and waste solvent.



Key network attributes

- Ta-Yuan Cogeneration is the steam center for factories in the zone.
 The park contains sectors including: chemicals textiles and pulp ar
- The park contains sectors including: chemicals, textiles, and pulp and paper, which all have a large and stable demand for steam.



1- Steam; 2- Copper Waste Wire; 3- Copper-Containing Sludge; 4- Non-hazardous Organic Waste Solvent; 5- Organic Sewage Sludge; 6- Waste Refractories; 7- Waste Solvent; 8- Waste Woods

Figure 6. Energy and Resources Linkage in Dayuan Industrial Park

Benefit and Prospect

Promoting eco-industrial parks has become one of the main policies for the government to create a circular economy. Regional energy and resources integration can reduce the raw material transportation cost and centralize waste management and processing. One of the keys to success is energy exchange, such as sharing a cogenerate factory for cost reduction and selling the excess energy to other industries; another key is not regarding waste as harmful nor useless, but as a chance for different industries to cooperate and discover new recycling potential.

For the past ten years, thanks to the mutual efforts made by local government and industry, Taiwan has laid a solid foundation for regional energy and resources integration. In the future, by promoting regional energy supply and developing fuel systems using biomass and organic waste, we can further elevate our reuse rate to march toward a brighter future with better economics, a safer environment, and cleaner energy.



Economic benefits

From 2005 to 2018, energy and resource integration promotion has been conducted in 23 industrial parks. The linkage network saves 3.62 million tons of steam per year, with steam sales generating NTD 3.13 billion per year.

0.8 million tonnes/year

GHG emissions reduction

Environmental benefits

From 2005 to 2018, a reduction of 154 boilers lead to cutting GHG emissions by about 803,000 tons because of steam integration. It contributes saving energy and virgin materials consumption. Waste reduction leads to extending lifespans of landfills and incineration plants.

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You take a long-term view on it when you invest in something like this - you think beyond today, you think the next 20, 30, 40, up to maybe a hundred years.

Fernanda Chavez

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