

## CAPSULE PROFESSIONNELLE 9

# Dynamics of circular economy in China: illustration on the industrial port area of Ningbo

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## Biographies

**Lei Shi** is associate professor of the School of Environment, Tsinghua University, vice director of the State Environmental Protection Key Laboratory of Eco-industry. He obtained his PhD degree on Process Systems Engineering from Dalian University of Technology. His research interests include industrial ecosystem complexity, industrial metabolism and eco-innovation. Dr. Shi has lead more than 20 projects on eco-industrial parks and circular economy planning.

He also leads more than 10 projects from NSFC, MEP and other Ministries. He is the Treasurer of the International Society for Industrial Ecology (2015-2017), co-chaired the 4th International Conference on

*Industrial Ecology (Toronto, 2007) and the 3rd ISIE Asia-Pacific Meeting (Beijing, 2012). He was the expert of formulating China Circular Economy Promotion Law, and develop the Industrial Ecology Social Network <http://www.ieminer.org>.*

**Dong Ying** currently is an associate professor at School of Economics and Management of Zhejiang University of Science and Technology. She got a PhD degree in Management in Zhejiang University in 2011. As visiting scholar, she visited Tsinghua University (2005-2006) and the University of Michigan (2014-2015). Her research interests include eco-innovation and industrial sustainable development, and lead some projects on eco-innovation and circular economy. She has published two books, the mechanism of corporate eco-innovation (2013) and Ningbo Beilun industrial Linkage and eco-industrial development (2014).

**Wu Zhongfang** is vice Director of Ningbo Beilun Development and Reform Committee, is responsible for circular economy and energy saving. In his charge, Beilun circular economy achieved good results and received a lot of honours, including the title of the Best Practices of circular economy by Zhejiang Province, the national pilot eco-industrial park by the Ministry of Environmental Protection, the national pilot circular economy park by the National Development and Reform Committee.

# Introduction

Circular economy, according to the China Circular Economy Promotion Law, refers to the general term for the activities of reducing, reusing and recycling in production, circulation and consumption processes (Sun & Zhang, 2008). China trialed circular economy pilots firstly at urban or provincial levels, such as in Shanghai, Guiyang and Liaoning province on the turn of the 21st century, then upgraded to the national level in 2005. In the past ten years, China has approved more than 300 circular economy pilots including industrial parks, urban mines, cities and provinces, more than two-thirds of which are located in coastal areas, such as the Yangtze river delta, Pearl river delta and Bohai-around area.

Ningbo, a port city located in south of Shanghai, was listed as one of the circular economy piloted cities in 2010. Ningbo Port has 305 working wharfs including a 250,000 deadweight tonnage (DWT) level crude oil wharf, a 200,000 tons level ore transfer berth and 8 international container berths. At present, the sea routes are open to all large ports in China and 600 ports in over 100 countries in the world. In 2014, its cargo throughput was 500 million tons and the container freight volume was over 18.7 million TEUs, the third among Chinese ports.

The industrial port areas of Ningbo mainly include Zhenhai District and Beilun District. The former is dominated by petrochemical industries with crude oil processing capacity of 23 million tons per year (t/y) and ethylene capacity of 1 million t/y. The latter is an integrated heavy industrial base including iron & steel industry, chemical industry, pulp and paper industry, power plants and automotive industries and so on. Both districts were approved as National Pilot Industrial Parks by the central government. By taking Beilun port area as a case study, this chapter illustrates the dynamics of circular economy in China. It starts with a brief review of economic development and circular economy development in Beilun. The subsequent section illustrates the dynamics and mechanism of circular economy.

## *Circular economy development and material flow profiles at Beilun*

The Beilun District is located in the east of the Ningbo City, with the East China Sea to the east and the Hangzhou Bay to the north (Figure 1). Beilun covers a land area of 585 km<sup>2</sup> and has a resident population of 700,000. At present, Beilun hosts total five state-level development zones: Ningbo Economic and Technological Development Area (ETDA), approved in 1984 as one of the first batch 14 ETDAs, Ningbo Free Trade Zone (1992), Daxie Development Zone

(1993), Ningbo Export Processing Area (2002) and Ningbo Meishan Bonded Port Area (2008), which makes Beilun to be one of the most highly-opened areas in Zhejiang Province.

**Figure 1 : Geographical location of Beilun**



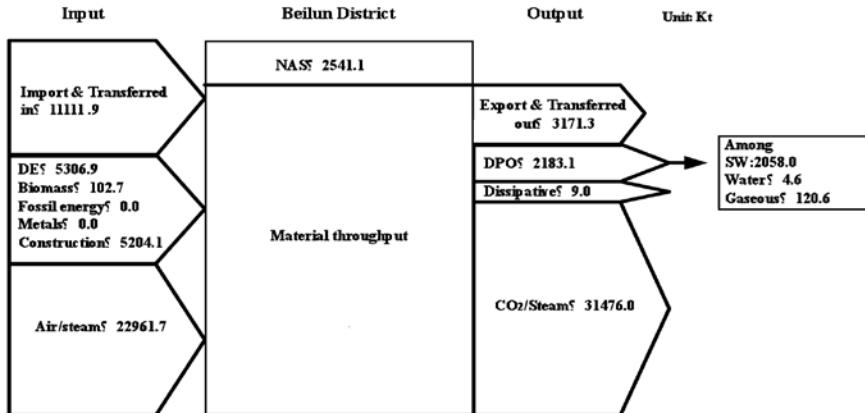
Since its establishment in 1985, Beilun industrial park has gradually formed into a comprehensive industrial base including petrochemicals, energy, steel, paper, automobile, ship and other six port industrial clusters. In 2014, Beilun realized a gross regional domestic product of 97.5 billion Yuan, annual increase by 15.2% comparing to 27.4 billion Yuan in 2005. Petrochemical industry is the leading sector with a total investment of 7.6 billion USD and large factories such as Taiwan Plastics, Mitsubishi, Yisheng Petrochemicals, Esso Petrochemicals, Yashuo Technology, Pacific Chemicals and Linde Gas as the backbone.

The heavy industries contribute to rapid economic growth, but also bring huge resource and environmental burdens to Beilun. Since 2005, Beilun explored a sustainable development model according to circular economy principles and achieved remarkable results. In 2008, Beilun was awarded the title of the Best Practices of circular economy in Zhejiang Province. The EDTA was listed as the national pilot by the Ministry of Environmental Protection in 2010. In 2013, Beilun also listed as the pilot circular economy for the industrial parks.

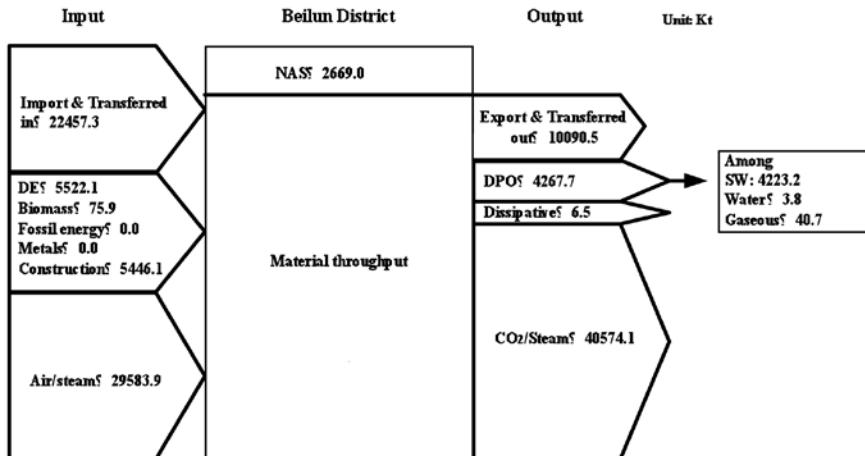
Following the material flow analysis (MFA) framework at urban level (Shi & Lou, 2008), the material flows profiles in Beilun are presented in Figure 2. In 2010, the direct material input (DMI) of Beilun is 27.98 Mt, including domestic extraction (DE) 5.52 Mt and import & transferred (IT) 22.46Mt. The dominating DE item is construction material, followed by biomass. As for import items, the dominant materials are iron ores and coals. The ratio of IT/DMI increased from 67.7% in 2005 to 80.3% in 2010, which shows Beilun economic development depends

more and more on imports and transferred from other regions. Resource productivity (GDP/DMI) of Beilun increased from 1665Yuan/ton in 2005 to 1752Yuan/ton in 2010, with an increasing ratio of 5.2%. The reason why the increase was not remarkable lies in that Ningbo Iron & Steel Company started operation after 2005.

**Figure 2 : MFA profiles of Beilun in 2005 (a) and 2010 (b)**



(a)



(b)

Domestic processing output (DPO) increased from 2183Kt in 2005 to 4223Kt in 2010. The increase of DPO was mainly contributed by solid wastes, increased from 2058Kt in 2005 to 4268Kt in 2010. However, the water-borne wastes

(mainly COD, chemical oxygen demand) decreased from 4.6Kt in 2005 to 3.8Kt in 2010, the gaseous wastes (mainly SO<sub>2</sub> and NO<sub>x</sub>) decreased from 120.6Kt in 2005 to 40.7Kt in 2010. The reason of decrease was owe to the strict control on these pollutants in the 11th five-year plan period.

## *Evolution of key industrial sectors*

### **The evolution of petrochemical industrial ecosystem**

Ningbo is one of eight petrochemical industrial bases in China. Unlike Zhenhai District focusing on the refining stage, Beilun focuses on the petrochemical downstream industries, including polypropylene (PP), polyethylene (PE), polyvinylchloride (PVC), acrylonitrile butadiene styrene (ABS), polyamide (PA), etc. The leading companies are Yisheng Petrochemical Company and Formosa Plastics Group (FPG). Yisheng was established in 2003 and currently becomes the leading PTA producer in China. Taiwan FPG invested at Beilun in about 2001 and has established highly integrated chemical industrial complexes. To take unique geographical and industrial clusters advantages, some new companies emerge. For example, Ningbo Haiyue New Material Co., Ltd., founded in 2011, established a complex including 600K t/y propane dehydrogenation (PDH) unit, 600K t/y isooctane unit and 40K t/y methyl ethyl ketone (MEK) unit.

### **The evolution of pulp-paper-packages industrial ecosystem**

The leading company of this chain is Asia Pulp & Paper Group, (APP-China). It established two plants at Beilun, Ningbo Zhonghua and Ningbo Asia, both being among the largest industrial paper companies in China. Though APP implements a plantation-pulp-paper integration strategy in China, there is no plantation base at Beilun because of limited land resources. Ningbo Zhonghua Paper Company was established in 1992, with the annual production of white paper boards of about 500,000 tons. Zhonghua Paper uses old newspaper, office paper and magazines as its raw materials to produce pulp. Being the result of extension and development of Ningbo Zhonghua, Ningbo Asia was constructed in 2002 and started operations in 2005 with the annual production capability of 750,000 tons of high class packaging paperboards. The environmental utilities include wastewater treatment stations with daily treatment capability of 45000 tons, a closed white water recycling system, the de-dusting and desulfurizing processes for boilers and hazardous solid waste treatment facility. All these utilities link APP closely with other companies by waste exchanging and service sharing. Due to the severe pressure on carbon emission reduction at Beilun, however, the company currently encounters a big challenge to shut down its own boilers and import steam from regional networks.

## The evolution of iron-steel-metal products industrial ecosystem

There are two leading companies on iron & steel production. Ningbo Baoxin Stainless Steel Co., Ltd was established in 1995 with a current annual capacity of 600,000 tons cold-rolled stainless steel sheet. Ningbo Steel Co., Ltd. was established in 2003 with a current annual capacity of 4,000,000 tons steel. Ningbo Steel is an integrated iron & steel company from raw materials to coke, iron, steel, continuous casting, hot rolling and other processes. The products cover steel billets, hot rolled straight roll and automobile structural steels, which provide local market with hundreds of automobile part companies. Ningbo Steel has established a rather sound circular economy system with indicators as follows: water reuse rate 97.09%, gas recovery rate 100%, iron dust utilization rate 100%, slag utilization rate 100%, steel slag utilization rate 100% and the boiler fly ash (slag) utilization rate 100%.

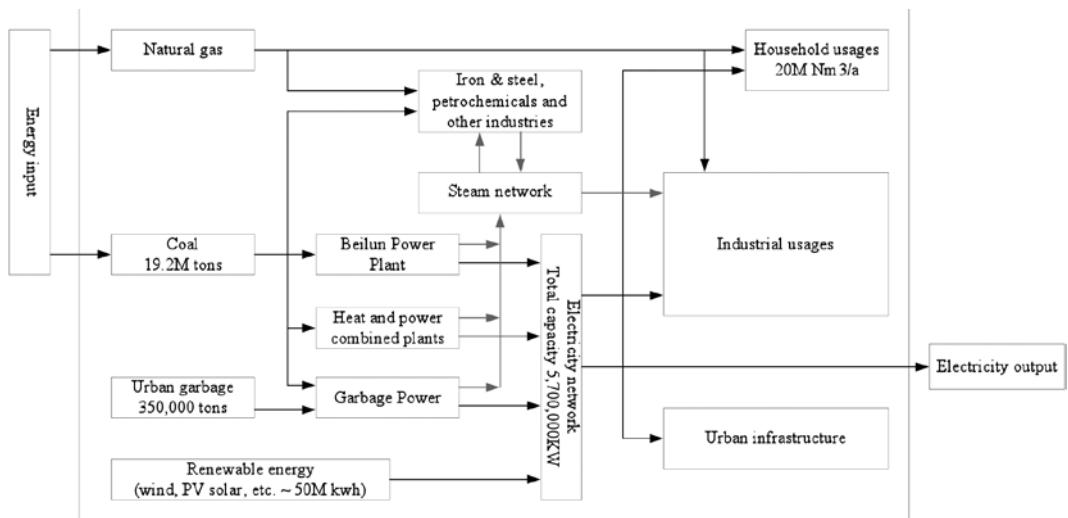
## The evolution of automotive and parts industries

The leading automotive company is Zhejiang Geely Holding Group which was listed in Fortune Global 500 as the only private automobile enterprise from China. In 2000, Geely established a complete vehicle manufacturing base at Beilun. About 40% suppliers locate within Zhejiang Province. In fact, Beilun hosts about 100 companies producing auto parts, including brake, shock absorption, cooling, transmission, combination instrument, lighting, molds and other accessories. Besides Geely, the customers of these companies include Volkswagen, Toyota, Ford and Honda. To further speed up the development of complete vehicle and auto parts industries, Beilun set up the Auto Parts Industrial Park. The outstanding advantages finally lead Geely to make a decision to build a new complete vehicle manufacturing base at Beilun.

## *Evolution of infrastructure*

### The evolution of energy infrastructure

Beilun energy production and consumption profiles are shown in Figure 3. Beilun imports coal from Qinhuangdao and other north portal cities in China and then consumes in power plants and other industries. Beilun is the landing station of natural gas from the East China Sea, and also imports LNG from Indonesia and other countries. Beilun also built a garbage power plant in 2008 and a wind mill farm in 2013. To improve energy infrastructure, Beilun has formulated a central heating plan by considering regional functional zoning, industrial layout, heat source distribution and other factors. Some new projects are planned, including natural gas power plant, Ningbo iron and steel waste heat recovery and steam networks optimization.

**Figure 3 : Beilun energy production and consumption profiles**

## The evolution of water infrastructure

Beilun has established a sound water cycle network by integrating all types of water resources, including piped water, industrial water, reclaimed water and other water resources. Currently, the reclaimed water has reached 5 million tons per day, and provides directly to power plants, iron and steel plants and other large industrial users.

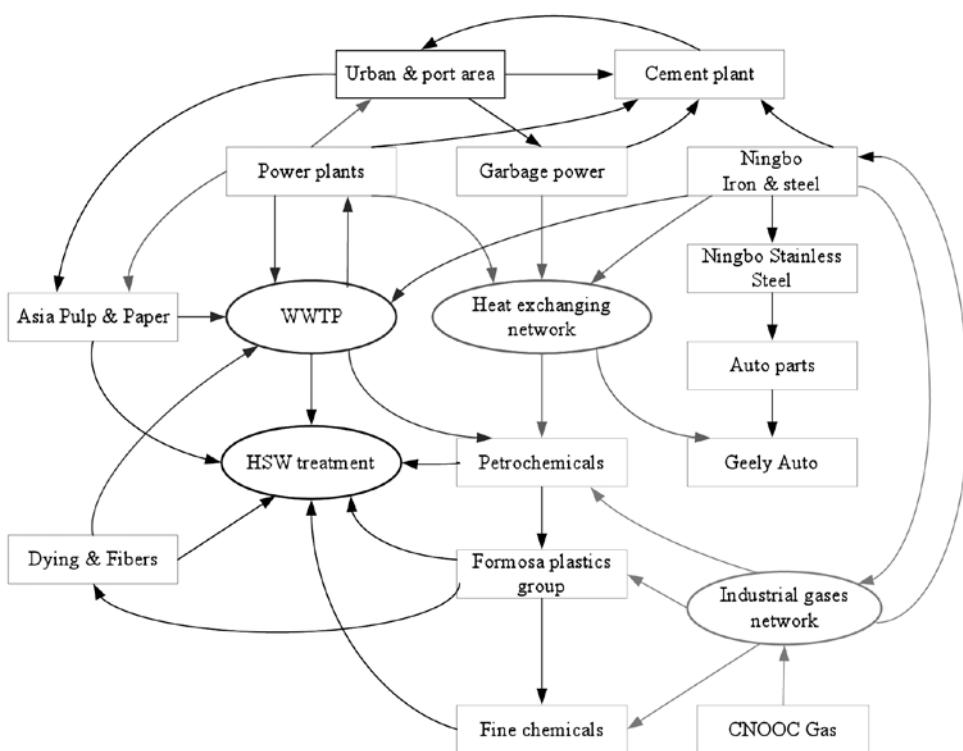
## The evolution of industrial gases infrastructure

Beilun industrial gas pipeline network is mainly built and operated by Linde Gas (Ningbo) Co., Ltd. The company was founded in 2004, with main products of oxygen, nitrogen, argon and their liquid products and hydrogen and other industrial gas products. Up to now, Linde has built a length of 120 kilometers of industrial gas transmission network, the total capacity of 8000 tons per day. Each hour, the network can provide 10 million cubic meters of gas to more than 34 big port enterprises. Currently, Zhejiang LNG and other companies have also built gases stations at Beilun. With the development of gases infrastructure, Beilun begins to send gases to Zhenhai and Daxie Island.

## *The regional circular economy system*

With the rush of leading companies, Beilun established the skeleton of industrial symbiosis for the future regional circular economy system around 2004. To support industrial development, four types of infrastructure (energy, water, gases and wastes recycling) were upgraded step by step, from the beginning point to point state, to pipeline state and then finally evolved into network states (Dong & Shi, 2014). The co-evolution of industries and infrastructures enhanced the competitiveness advantages, and finally led Beilun to the top level of portal industrial bases. The regional circular economy system of Beilun is shown in Figure 4.

**Figure 4 : Beilun circular economy system**



# Conclusion

Along with the deepening of pilots, circular economy does not just stay at the conceptual level, but has been embodied into eco-industrial development and regional sustainable transition. By taking Beilun as a case study, this chapter briefly uncovered the evolution of key industrial sectors and ecological infrastructures, and presented the overview of regional circular economy system. As for circular economy dynamics mechanism and driving forces behind, we can observe the roles of technological improvement, market evolution and environmental governance. Due to the port geographical advantage and industrial features, Beilun circular economy system is expected to be evolved continuously in future. In fact, we do have a lot of interests to continue to keep an eye on its development, and hope to explore more details about its sustainable transition mechanism.

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