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Master Thesis in International Business

"Industrial clusters and industrial ecology as growth paths for China"

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Abstract

Industrial clusters have been recognized by past and contemporary authors as important leading forces in driving growth paths. However, their contribution is not confined to companies' evolution and development alone; it is also of great significance for national competitive advantage. In a particular type of cluster, named eco-industrial cluster, phenomena of industrial symbiosis may occur. There appear eco-linkages among firms that minimize environmental harm and benefit all actors involved in the cycle –for example by turning one company's waste products into another's raw materials. Therefore, latecomers such as China would draw advantages by grounding their economic development on these two themes, thus translating a late arrival into a profitable way to discover and study the latecomer pattern.

Key words

Industrial cluster, external economy, industrial ecology, eco-industrial park, industrial symbiosis, combined heat and power, renewable energy, latecomer advantage, Hsinchu Science Park, Xingwang cluster, Guigang group, Suzhou Industrial Park, Tianjin Economic-technological Development Area.

1. Introduction

Industrial clusters are geographic concentrations of firms that clearly show significant external economies. They demonstrate that what happens within firms is relevant, but what happens outside co-located firms is even more relevant. Proximity of several companies gives birth to externalities, resulting in "the whole greater than the sum of the parts".[1] External economies exist when social benefits are higher than private benefits, since clustering of business activities produces advantages such as labour market pooling, supplier specialization, and technological spillovers that are inimitable by firms alone.

Industrial ecology has created a new perspective on industrial development and aims at designing industrial agglomerates to resemble natural ecosystems and reduce environmental burden. Indeed, it focuses on optimally utilizing energy and resources, while obtaining good economic results. A branch of industrial ecology is occupied by industrial symbiosis, which concentrates on by-products exchanges among co-located firms. The main goal is to pass from the traditional linear economy (where raw materials enter from one side and wastes exit from

[1] Porter, M. E., "Clusters and the New Economics of Competition", *Harvard Business Review*, 1998, p. 81.

the other) to the circular economy (where wastes of certain activities become input for others).

A great example of circular economy is given by cogeneration (or Combined Heat and Power), which exists in industrial systems able to generate electricity and meanwhile capture the produced heat for heating purposes. Since traditional power plants release huge quantities of heat into the environment, CHP offers an environmentally desirable and cost-effective solution. The practical application of circular economy generally occurs within Eco-Industrial Parks, which are purpose-built entities composed of several industries together that foster economic development and environmental protection.

Within Eco-Industrial Parks, also may exist the use of renewable energies, which come from natural resources such as sunlight, wind, biomass, and tides. As opposed to fossil energies, renewables are naturally replaceable. Fossil fuels, instead, are non-renewable resources because they take millions of years to form and their reserves are depleted much faster than new ones are made. In addition, the production and use of non-renewable resources raise environmental concerns due to greenhouse gases' emission. Consequently, renewables seem the right alternative to minimize environmental harm and meet increased energy needs.

China is a latecomer country searching for strategies to catch up with developed nations. However, economic predictions forecast China as one of the future leading countries of the world; this notion can be easily realized by China exploiting its latecomer advantage through clusters, industrial symbiosis, and renewables. The term latecomer refers to a country that has started its industrial upgrading many decades after developed countries. Although, the late arrival does not have only negative aspects, it also has positive advantages. Developing countries face the opportunity to draw from western organizational and technological models, ideas, and management systems by linking with global actors, leveraging their national resources and learning from these repeated activities. More importantly, they do not have to encounter the long pattern and spend the same energy, time and economic resources employed by western inventors. And at the same time, these countries enjoy low cost advantages. Therefore, if we apply these concepts to the specific case of industrial symbiosis and low-carbon initiatives, we see how China has learned from its developed competitors and moved beyond. For instance, the German and Japanese environmental regulations and the Kalundborg case have offered China models to study, absorb, apply, and improve. The advanced Chinese environmental laws, and the number of eco-industrial initiatives carried out throughout the country, are proofs of this path. Indeed, since studies have shown how clusters benefit the economy and how by-products exchanges and renewables are useful to minimize environmental harm, China is basing its industrial growth on this specific pattern. Since the 70s, Chinese government has supported industrial agglomeration and proximity through SEZs; moreover, while it has recently approved the first national law proclaiming the circular economy as a model to follow, it is working hard on developing low-carbon technologies and increasing its reliance on renewable energy resources.

This thesis analyzes all of the above-mentioned topics through the lenses of important authors, including Marshall, Porter, Schmitz, Becattini, Mathews, Ehrenfeld, Fang, Desrochers, Yeung, Geng, Chertow, Sovacool, Zhu, and others. It first studies clusters and explains why they are so relevant to successfully compete in the world economy. Thereafter, the work focuses on industrial ecology, presenting all the three levels of application: intra-firm level; inter-firm level; and city-level. It even enriches the topic providing the example of Kalundborg, co-located firms linked by industrial symbiosis. Finally, it concentrates on China and presents a possible solution for this particular country to further develop. The theory that clusters and industrial symbiosis are satisfying routes to take is strengthened by five examples: Hsinchu Science Park; Xingwang cluster; Suzhou Industrial Park; Guigang group; and Tianjin Economic-Technological Development Area. HSP and Xingwang explain in practice how external economies work and why they foster cluster's upgrading and development. Suzhou, Guigang, and Tianjin cases, instead, present three succeeding examples of industrial growth coexisting with eco-linkages and environmental protection.

The three Eco-Industrial Parks located in the cities of Guigang, Suzhou, and Tianjin show implementation of the circular economy law, since they are characterized by by-products exchanges and renewables exploitation. Moreover, they confirm Desrochers theory, which counters the well-known "Porter Hypothesis". Porter makes the argument that properly designed environmental regulations can trigger innovative and environmentally friendly responses of firms. On the contrary, Desrochers believes that market incentives are sufficient for fostering green reactions and loop closing initiatives. The three cases here studied demonstrate that only profit-maximizing decisions, taken either by private or public entities, have led to these great examples of industrial symbiosis.

2. Industrial clusters

Thanks to external economies, social networks and relations, joint actions, and local institutions, clusters represent a completely different and successful way of organizing economic activities. Michael E. Porter is one of the main contemporary authors who have written about industrial clusters. His analysis points out clearly why clusters are economically relevant. Indeed, Porter claims they affect competition within countries and across national borders, requiring new agendas for all business executives (not only for those who compete locally), and for governments and institutions such as universities.[2] Porter defines clusters as: "geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions (for example, universities, standards agencies, and trade associations) in particular fields that compete but also cooperate".[3] On one hand, Porter highlights clusters' features already studied by the neo-classical economist Alfred Marshall; on the other hand, he goes beyond Marshall's work considering other important aspects.

The Marshallian Trinity

Marshall, observing Sheffield's cutlery works and other localized industries, realized that there were two efficient manufacturing systems: one, the production method based on large and vertically integrated units; two, the industrial district, characterized by co-location of many small factories specializing in different phases of the value chain. The manufacturing district showed what he later called external economies, generated by localization and, at the same time, reasons for co-locating. Three types of external economies were recognized by the neo-classical economist; these are generally known as "Marshallian Trinity" and, probably, are still the most significant ones. First of all, firms' clustering brings to labour market pooling: pool of specialized skills benefiting both firms and workers. Indeed, the origins of several specialized industries have to be traced back to the presence of a court, where the "rich folk" assembled by the court required goods of specially high quality. This phenomena attracted skilled workmen from everywhere and made pressure on specialization's development. Since then, employers have always been likely to base their economic activities wherever they could find good choices of workers with the necessary special skills; and employees have always been likely to move wherever there were employers requiring their skills.

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[2] *Ibidem*.

[3] Porter, M. E., "Clusters and competition: New Agendas for Companies, Governments and Institutions", from *On Competition*, *Harvard Business School Press*, 1998, p. 3.

Secondly, where enterprises concentrate they can support more specialized suppliers of inputs and services. In the district subsidiary industries devoted themselves to one small part of the production process; these actors worked for many of their neighbouring firms, being then able to utilize highly specialized machineries.

Thirdly, clusters facilitate technological spillovers because there is a rapid diffusion of know-how and ideas among neighbouring firms. "If one man starts –as Marshall states- a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of further new ideas".[4]

Arguably, Michael E. Porter underlines the importance of these Marshallian external economies. Indeed, clusters affect competition in three broad ways: first, by increasing the productivity of companies; second, by driving innovation's pace, which leads to future productivity growth; and third, by stimulating new business formation, strengthening the cluster itself. Considering productivity enhancement, Porter identifies a series of elements, which allows companies to operate more efficiently and effectively. As Marshall explained one hundred years before, companies in clusters can find specialized and experienced employees, lowering their search and transaction costs. Clusters also attract skilled workers due to reduced risk of relocation. Moreover, well-developed clusters offer a specialized supplier base, thereby reducing company's transaction costs, minimizing inventories (adopting for instance just-in-time inventory systems), and eliminating import costs and delays. At the same time, proximity fosters local reputation, avoiding the possibility that suppliers will cheat on prices or renege on commitments. Co-location also allows firms to obtain easily and quickly market, technical, and specialized information, which help them to increase productivity.[5]

Porter goes beyond

Porter indicates other external economies promoting productivity: complementarities; motivation and measurement; and access to institutions and public goods. Clusters show evidence that the numerous linkages among members result "in a whole greater than the sum of the parts".[6] Companies are mutually dependent and good or bad performances of one can influence the success of the others. Complementarities can exist for instance when products

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[4] Marshall, A., "Principles of Economics", New York, *Macmillan*, 1920.
[5] Porter, M. E., "Clusters and the New Economics of Competition", *Harvard Business Review*, 1998.
[6] *Ibidem*, p. 81.

complement one another in meeting customers' needs. Or they can arise in marketing when cluster's reputation affects individual firms' sales. Moreover, if companies cooperate, specializing in different stages of the value chain and avoiding to vertically integrating, they even compete resulting in a high incentive to increase performance quality. Competitive pressures exist above all horizontally, but they are even present between noncompeting or indirectly competing firms. Executives are pushed toward ever increasing results by pride and reputation, while they can easily compare and measure outcomes due to the significant presence of other firms performing the same activities. Finally, enterprises clustering together have access to investments made by governments and other public institutions (e.g. infrastructure, universities and educational programs), and to those made collectively by companies. These often recognize the benefits of private investments, such as construction and maintenance of testing laboratories and quality centres.

Clusters, however, do not have a relevant role just for current productivity, but even for future productivity and innovation. Future growth is fostered by the presence of sophisticated buyers within clusters, providing a clear window on market trends. Significant overviews of new technologies, machineries, and marketing concepts are even offered by multiple relationships between companies and other entities, such as universities or research centres. Also, firms have the possibility to implement technologies and other type of innovation as soon as they discover them, since specialized suppliers and service providers, located within the same cluster, can support them. Therefore, competitive pressure, peer pressure, constant comparison and the wish for a good reputation generate continuous performance improvements in all firms, thereby generating innovation.

It is not surprising then that firms proliferate within clusters, and new business formation is enhanced. Suppliers, on the one hand, tend to move into clusters since they know there are active buyers. Companies, on the other hand, cluster together since they find the required suppliers, assets, inputs, and skills. Besides, barriers to entry are generally lower than elsewhere. Moreover, local financial institutions often ask for low risk premiums on capital due to their familiarity with the cluster.[7]

Other relevant contributions

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[7] *Ibidem*.

There is a point in Porter's analysis –firms' collectively made investments- that other scholars emphasise more. In particular, Hubert Schmitz and John Mathews underline the importance of collective actions between neighbouring companies. In Schmitz's opinion, external economies (which are unintentional and seen as a passive concept) are not sufficient to explain the strengths of clustering, because consciously pursued joint actions (an active concept) play relevant roles as well. "Joint actions can be of two types: individual enterprises cooperating (for example, sharing equipment or developing a new product), and groups of firms joining forces in business associations, producer consortia and the like".[8] Schmitz believes that external economies together with joint actions give birth to what he calls "collective efficiency", which is simply the cluster's competitive advantage based on productivity growth.[9] Moreover, Mathews writes: "Firms that come together to form a cluster need to do more than collect external returns from each other (and from outside the cluster); what they need to do is to establish an identity, as a self-identified cluster, in some form of joint action".[10] Examples can be an export market's creation, a joint services organization (to train employees or for promotional activities), a development of an R&D institution and so on. Furthermore, the concept of economic learning is relevant. Economic learning is "the system through which an economy adapts to new circumstances through measures that are more than merely random, price-guided reactions. Learning involves the notion of adapting intelligently to new circumstances, through developing a repertoire of routines that are stored in memory and which can be drawn on as circumstances change".[11] The group of firms localized in the cluster that has learned to act jointly, and for the benefit of all members, give birth to this general economic phenomenon.

Now, it is possible to understand that clusters affect not only the competitive advantage of single companies, but also that one of entire nations. Governments' policies towards clusters play in this sense a crucial role. Above all for countries such as China whose advantage rests on cost competition (which by definition tends to be eroded), government should invest in clusters to form the basis of their future competitive advantage. As Porter writes, governments should promote the development and upgrading of all clusters without choosing

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[8] Schmitz, H., "Collective Efficiency and Increasing Returns", *Cambridge Journal of Economics*, 1999, p. 469.

[9] *Ibidem*.

[10] Mathews, J. A., "The Hsinchu Model: Collective efficiency, increasing returns and higher-order capabilities in the Hsinchu Science-based Industry Park, Taiwan", Keynote Address, Chinese Society for Management of Technology (CSMOT), 20th anniversary conference, Tsinghua University, Hsinchu Taiwan, 2010, p. 7.

[11] Mathews, J. A., "From National Innovation Systems to National Systems of Economic Learning: The Case of Technology Diffusion Management in East Asia", Paper submitted to DRUID Summer conference, National Innovation Systems, Industrial Dynamics and Innovation Policy, 1999, p. 26.

among them. They can help clusters in creating and developing those external economies that are so important in distinguishing a cluster from a sum of individual firms. Indeed, governments may finance institutions and entities that give birth to intense spillovers (for instance universities or research centres), and improve infrastructure and public transportations, which are main problems of countries such as India.

Another aspect of the cluster theory, and that Porter supports as well, is the “socioeconomy” of clusters. Economic activities are embedded in ongoing social relationships and clusters’ advantages have at least a relationship component. Proximity and ongoing transactions enhance trust and a sense of mutual dependence and of belonging to a specific community, while all these elements affect positively productivity, innovation, and new business formation.[12] To this regard, industrial clusters as models of socioeconomic organization find confirmation in the works of Giacomo Becattini. Becattini focused on the textile industrial district of Prato in Italy. He defines the industrial district as: “a socio-territorial entity which is characterized by the active presence of both a community of people and a population of firms in one naturally and historically bounded area”.[13] The industrial district presents some peculiar features: people, living in a naturally and historically bounded area, tend to have a common culture and frequent direct face-to-face relations; norms of reciprocity and social sanctions, such as expressions of disapproval, characterize the district's social culture; individual initiative is approved by the other actors due to the practice of self-help, providing that it is obtained within the rules of reciprocity. Taking into account these characteristics, it is quite clear that they are able to influence economic relations. The principal consequence of these attributes is a cooperative behaviour between industrial district members. Cooperation then generates trust and reduces greatly the need for monitoring, thus reducing costs as well. Furthermore, Becattini explains that local institutions, such as local government, entrepreneurial associations and trade unions, complement social sanctions, which sometimes are not sufficient in the complex environment featuring the industrial district. These institutions, indeed, ensure conformity to the custom of mutual cooperation and trust, which in turn helps in saving those costs that are typical of vertical integration.[14]

3. Industrial ecology

[12] Porter, M. E., “Clusters and competition: New Agendas for Companies, Governments and Institutions”, from *On Competition*, *Harvard Business School Press*, 1998.

[13] Becattini, G. *et al.*, “From industrial districts to local development: an itinerary of research”, *Edward Elgar Publishing*, 2003, p. 109.

[14] *Ibidem*.

Environmental thinking is increasingly interested in the intimate and critical relationship between human activities and natural environment. Due to the fact that the world economy still operates as an open system, industries draw raw materials from nature and return pollution and waste. The unsustainable aspects of today's industry are closely related to massive levels of resource consumption and ever-increasing amount of wastes in both developed and developing economies, while experts have long called for drastic reductions. Thus, until executives, and the economic world in general, will concentrate on products and processes viewed in isolation from the surrounding environment, environmental systemic problems, such as the accumulation of toxic materials or the greenhouse effect, will not be solved or, at least, minimized. The 1996 report of the President's Council for Sustainable Development (PCSD) in the United States explains: "In the end, we found agreement around the idea that to achieve our vision of sustainability some things must grow – jobs, productivity, wages, profits, capital and savings, information, knowledge, education – and others – pollution, waste, poverty, energy and material use per unit of output – must not".[15]

An ecological metaphor

Addressing simultaneously economic and environmental issues clearly requires new structures of socioeconomic systems. Thus, a possible solution could be referring to an ecological metaphor as first suggested by the famous article of Robert Frosch and Nicholas Gallopoulos published in 1989. According to these authors, "the traditional model of industrial activity – in which individual manufacturing processes take in raw materials and generate products to be sold, plus waste to be disposed of – should be transformed into a more integrated model: an industrial ecosystem. In such a system the consumption of energy and materials is optimized, waste generation is minimized and the effluents of one process – whether they are spent catalysts from petroleum refining, fly and bottom ash from electric-power generation or discarded plastic containers from consumer products – serve as the raw material for another process. The industrial ecosystem would function as an analogue of biological ecosystems (Plants synthesize nutrients that feed herbivores, which in turn feed a chain of carnivores whose wastes and bodies eventually feed further generations of plants)."[16]

Indeed, industrial ecology aims to create exactly what the two authors defined as "industrial ecosystem" in order to move from the linear economy (where raw materials enter at one end

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[15] President's Council for Sustainable Development, "Sustainable Development: A new consensus", Washington DC, 1996.

[16] Frosch, R. A. and N. E. Gallopoulos, "Strategies for Manufacturing", *Scientific American*, 1989, p. 144.

and wastes exit from the other) to the circular economy (where wastes coming from some industrial activities become inputs for others), thus generating the "loop closing". In Jingchao Lu's opinion, "circular economy is put forward as an important strategy aiming to improve the resource efficiency and the quality of the environment. It emphasizes to substitute traditional open-looped linear development model with cycle closed, feed-back model of economy. [...] Actually, CE implicates a basic transformation of economic development model, which requires many changes in ideology, mode of thinking, policies, institutions, *etc*."[17]

Applying the industrial ecology principle to products and processes reduces the environmental burden, while leading to more efficient use of materials and energy. In turn, greater efficiency allows individual firms as well as whole industrial areas to grow. As Lifset and Graedel explain, industrial ecology is industrial because it deals with product design and manufacturing processes; here firms are the key actors that have to successfully execute environmentally informed design of products and processes. Industrial ecology is even ecological since it takes natural ecosystems as models of industrial activity. It views human technology and industrial activity in concert with the larger ecosystem that supports them and, thereby, does not tend to isolate them from the surrounding natural environment.[18]

As suggested by Ehrenfeld, "industrial ecology makes a twofold contribution to environmental sustainability. First, it improves understanding of material flows and how they impact the environmental system. Second, it offers ways to redesign products, services, and production methods. It can reduce stress at every industrial stage: resource extraction, production, use, and disposal."[19] As Mathews and Tan argue, it operates at three levels. At the first level, main actors are the individual firms (or few firms) aiming at enhancing energy and resource efficiency. This first level is generally identified with the term "cleaner production". Then, there is the second level, the cluster level, which is normally defined as "industrial symbiosis". Here, firms are wishing to upgrade the efficiency of their shared energy and resources. Finally, the third level is the city level (or whole municipal area), where eco-linkages among business activities are fostered through economic and administrative incentives.[20]

Intra-firm level

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[17] Lu, J., "Circular Economy: from an Institutional Perspective", *Ecological Economy*, 2007, p. 114.

[18] Lifset, R. and T. E. Graedel, "Industrial ecology: goals and definitions", in *A handbook of industrial ecology* edited by R. Ayres and L. Ayres, *Edward Elgar Publishing*, 2002.

[19] Ehrenfeld, J. R., "Industrial ecology: Environmental and Economic Boon", *Communities & Banking*, 2006, p. 4.

[20] Mathews, J. A. and H. Tan, "Progress towards a Circular Economy in China: The drivers (and inhibitors) of eco-industrial initiative", *Journal of Industrial Ecology*, 2011.

Cleaner production technologies, according to Frondel *et al.*, "reduce resource use and/or pollution at the source by using cleaner products and production methods".[21] Together with end-of-pipe technologies, cleaner production technologies mitigate the hazardous impact of industrial production, but these are generally more advantageous than end-of-pipe technologies for environmental and economic reasons. End-of-pipe technologies "curb pollution emissions by implementing add-on measures".[22] Examples are incineration plants (waste disposal), sound absorbers (noise abatement), and exhaust-gas cleaning equipment (air quality control). Instead, clean production deals with direct reduction of harmful impacts during the production process itself. Examples are environmentally friendly materials' use and modification of combustion chamber design. Therefore, end-of-pipe technologies operate *ex post*, diminishing toxic materials that are by-products of production, whereas cleaner production technologies operate both *ex post* and *ex ante*, because they reduce by-products but even facilitate energy and resource efficiency throughout the value chain.

Moreover, firms generally look for environmentally friendly strategies that can also bring positive economic results. Indeed, they have the chance to reduce costs, increase competitiveness, and enter markets destined to environmentally desirable products. Nevertheless, this chance is much more enlarged when firms rely on cleaner production technology rather than end-of-pipe technologies, since, by definition, the latter intervenes just at the end of the production process, which is still approached in the "traditional" way.[23]

In Lifset's and Graedel's opinion, at the cleaner production level, key words are eco-efficiency and eco-design. The World Business Council for Sustainable Development (WBCSD) describes eco-efficiency as "being achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the Earth's estimated carrying capacity".[24] Therefore, eco-efficiency is expressed in the form of a ratio: economic output divided by environmental resources or, however, some measure of economic value added to some measure of environmental impact. Particularly relevant in this sense are the concepts of dematerialization and decarbonization, where the first is measured

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[21] Frondel, M., J. Horbach and K. Rennings, "End-of-Pipe or Cleaner Production? An Empirical Comparison of Environmental Innovation Decisions across OECD Countries", *Business Strategy and the Environment*, 2007, p. 2.

[22] *Ibidem* p. 2.

[23] *Ibidem*.

[24] Ehrenfeld, J. R., "Eco-efficiency, Philosophy, Theory, and Tools", *Journal of Industrial Ecology*, 2005, p. 6.

in terms of masses of material per unit of economic activity and the second is concerned with the carbon content of fuels.[25] In addition, if the eco-efficiency ratio is inverted what comes out is known as "eco-intensity".

Nevertheless, Ehrenfeld states that quantification, defined as the process of choosing and enumerating the numerator and denominator of the eco-efficiency ratio, is difficult. The environmental impact is not easy to measure because of the uncertainty regarding which impacts to include, which boundaries are appropriate, and which metrics to use (mass, effects measures, values). The numerator also faces measurement problems due to the fact that sustainable development touches both human welfare and justice spheres. If the neoclassical approach to social welfare (which neglects wider social issues) is adopted, there is the doubt that it would not be as consistent as is required by these topics. Moreover, even if this doubt could disappear, it still remains difficult to compute firms' contribution. And Ehrenfeld also points out that the "Earth's carrying capacity" (cited from WBCSD's definition of eco-efficiency) is not something quantitatively well defined. Standard economic theory assumes that resources are limitless since scarcity will always lead towards innovation and alternative solutions.

Anyway, this is not to say that the eco-efficiency concept should not be used: first, eco-efficient choices are better than poorer choices; second, this concept could be a useful indicator for companies and policy makers if coupled with other tools and indicators.[26] In fact, an interesting manufacturing philosophy that can be implemented together with eco-efficiency is eco-design. Lifset and Graedel highlight that eco-design (or design for the environment) has a micro- and macro-perspective. Considering the micro, it allows the designing of products and processes in order to minimize the environmental impact. The micro-perspective focuses on the reduction in the use of damaging substances, lowers energy consumption, and fosters end-of-life management through recycling. The macro-perspective, which goes beyond the firm level here analyzed, evaluates whether technological innovations benefit the environment or which innovations need to be implemented to obtain a certain environmental quality. Indeed, the IPAT equation (Impact = Population x Affluence x

[25] Lifset, R. and T. E. Graedel, "Industrial ecology: goals and definitions", in *A handbook of industrial ecology* edited by R. Ayres and L. Ayres, Edward Elgar Publishing, 2002.

[26] Ehrenfeld, J. R., "Eco-efficiency, Philosophy, Theory, and Tools", *Journal of Industrial Ecology*, 2005.

Technology) is often adopted to examine the relative contributions of population, economic growth and consumption, and technology on environmental quality.[27]

Inter-firm level

Passing from the intra-firm level to the inter-firm level, industrial symbiosis plays the major role. Symbiosis is a biological term referring to "any of several living arrangements between members of two different species".[28] In economic systems symbiosis operates within clusters, denominated in this context "eco-industrial clusters", and "is principally concerned with the recovery and reuse of wastes (materials, water, or energy) from one industry as alternative input in a neighbouring facility".[29] Industrial symbiosis therefore "engages traditionally separate industries in a collective approach to business and environmental management involving the physical exchanges of materials, energy, water, and by-products".[30] Thus, the main focus of industrial symbiosis is the cyclical flow of resources through networks of businesses in order to foster ecologically sustainable industrial activities on a collective base, and not on an individual firm base. Indeed, some of the firms, viewed independently, may seem inefficient compared to others (even considering the same cluster), but the environmental and economic performance may be surprisingly good in the overall cluster due to inter-firm linkages (intending both 'eco-linkages' and linkages occurring in every cluster).[31]

According to Chertow, to be considered a basic type of industrial symbiosis at least three different entities must be involved in exchanging a minimum of two different resources. An example could be a wastewater treatment plant providing cooling water for a power station, which, in turn, supplies steam to an industrial user.[32] In fact, the resources exchanged among the various firms can be energy, material, and water. As will be explained later, the most important example of energy exchange is the Combined Heat and Power, whereas water exchanges are usually realized thanks to wastewater treatment plants. Material exchanges, instead, aim at taking full advantage of co-products and by-products, while minimizing residual products. Co-products and by-products are both unintentionally produced by

[27] Lifset, R. and T. E. Graedel, "Industrial ecology: goals and definitions", in *A handbook of industrial ecology* edited by R. Ayres and L. Ayres, Edward Elgar Publishing, 2002.

[28] Britannica Online Encyclopedia: www.britannica.com/EBchecked/topic/577677/symbiosis.

[29] Van Berkel, R., "Comparability of Industrial Symbioses", *Journal of Industrial Ecology*, 2009, p. 483.

[30] Chertow, M. R. and D. R. Lombardi, "Quantifying Economic and Environmental Benefits of Co-Located Firms", *Environmental Science and Technology*, 2005, p. 6535.

[31] *Ibidem*.

[32] Chertow, M. R., "Uncovering Industrial Symbiosis", *Journal of Industrial Ecology*, 2007.

industrial processes, and their difference rests on their respective value. Indeed, if co-products generally represent substantial value, the same cannot be said for by-products, which show modest positive value, frequently less than that of the original raw material. Finally, residual products are the process wastes (as emissions to the atmosphere, soil and water) that have negative values, since firms usually have to pay for their disposal.[33]

The environmental benefits of resource sharing are evaluated by calculating variations in consumption of natural resources and in emissions to the natural environment. The economic benefits are analyzed by measuring revenues and costs coming from by-products cycling. Above all, resource sharing increases stability of operations because it allows the access to critical or scarce resources such as water, energy, and raw materials. Moreover, by-products allow firms to obtain inputs at a lower price, decrease transaction costs, and avoid transport costs.[34]

To better clarify the functioning of industrial symbiosis and of eco-industrial clusters, an example of one of the most famous cases, Kalundborg in Denmark, is analyzed in detail. Kalundborg is a coastal industrial town located on the island of Seeland and is characterized by spontaneous industrial symbiosis and linkages among its industries. In fact, the industrial symbiosis of Kalundborg has gradually developed and was not intentionally designed. The main impulse was given by the firms willingness to use by-products and minimize the costs of compliance with environmental regulations. Also, firms here have had the chance to generate important savings due to the fact that differences in cost of by-products relative to virgin alternatives are less than the costs of waste management.

Kalundborg town was built around four principal industries: Asnaes Power Station, which is a coal-fired power plant; Statoil, which operates a large oil refinery; Novo Nordisk, which is a maker of pharmaceuticals and enzymes; and Gyproc, which is a plasterboard manufacturer. These main companies, together with other actors within the municipal area, have traded waste streams and energy resources, recycling by-products as raw materials. The Asnaes power plant, since 1981, has distributed heat to the city through a network of underground pipes and, thereby, has decreased the discarded energy by 80%. The homeowners, at the same time, have received cheap and reliable heat. Asnaes has also guaranteed process steam

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[33] Zhu, Q and R. P. Cote, "Integrating green supply chain management into an embryonic eco-industrial development: a case study of the Guitang Group", *Journal of Cleaner Production*, 2004.

[34] Chertow, M. R. and D. R. Lombardi, "Quantifying Economic and Environmental Benefits of Co-Located Firms", *Environmental Science and Technology*, 2005.

to Novo Nordisk, which has covered in this way all of its needs, to Statoil, which has received 40% of its steam requirements, and has supplied gypsum-containing feedstock to Gyproc, which has obtained two-thirds of its gypsum needs. Regarding the latter, Asnaes indeed has had a sulphur dioxide scrubber producing industrial gypsum as a by-product. Then, the remains of coal-burning power generation, fly ash and clinker, have been sold by Asnaes to road-building and cement-producing companies.

Statoil refinery, producing petroleum products, has piped the necessary gas to Gyproc, which has covered all its requirements, and has eliminated the practice of flaring waste gases. Moreover, Statoil has owned a sour-gas desulfurization plant producing liquid sulphur that has been then converted into sulphuric acid and, finally, burned by Asnaes. Statoil has even piped cooling water, used as boiler feed-water, and treated water previously wasted, used for cleaning purposes, for the neighbour Asnaes reducing water demand by 25%.

Novo Nordisk has obtained a nutrient sludge as a by-product of its activities and has distributed it to nearby farms where it has been used as fertilizer. The process sludge has gone into the countryside through pipelines and tanker trucks. Relying on this cheap method of getting rid of it, the company has respected the rule of not discharging the sludge into the sea.[35]

The Asnaes power plant offers an example of Combined Heat and Power (also known as Cogeneration). "Combined Heat and Power integrates the production of usable heat and power (electricity), in one single, highly efficient process".[36] Conventional ways of generating electricity waste vast amounts of heat since all power plants, during electricity generation, must produce a certain quantity of heat that is then released into the natural environment. CHP is instead able to capture some, or all, of the by-product heat for heating purposes, as happens in Kalundborg. In today's coal- and gas-fired power stations, up to two-thirds of energy utilized is wasted in this way. Therefore, CHP can be an environmentally friendly and cost-effective alternative. It can be applied to both renewable and fossil fuels, and can make a more efficient and effective use of energy resources. CHP reduces fuel consumption offering at the same time quality and reliability of energy supply to users. These also face lower expenses for their energy requirements. Indeed, cost savings are between 15% and 40% over electricity sourced from the grid and heat generated by on-site boilers. Energy savings and CO_2 savings

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[35] Ehrenfeld, J. and N. Gertler, "Industrial Ecology in Practice: The Evolution of Interdependence at Kalundborg", *Journal of Industrial Ecology*, 1997.

[36] Combined Heat & Power Association: www.chpa.co.uk/what-is-chp_15.html.

are minimum 10%. The overall efficiency is high – up to 80% or more at the point of use. Thereby, industries and businesses can be more competitive due to cost savings and enhanced security, quality and increased flexibility of energy supply.[37]

In 2004 Kalundborg estimated resource savings were: 2.1 millions m^3/y groundwater; 1.2 million m^3/y surface water; 20,000 tons/y oil; and 200,000 tpy natural gypsum.[38] Each of Kalundborg linkages creates an economic advantage for firms, while minimizing hazardous impacts of industrial activities and resources consumption. Moreover, as Gertler writes, the general public benefits from environmental protection and, meanwhile, does not have to worry about industrial symbiosis management, since it is a task pursued by firms themselves under the economic incentive of improving performance.[39]

As this point, two notable opinions should be discussed. Indeed, in order to foster the presence and growth of industrial symbiosis two approaches can be followed: a top-down and a bottom-up approach. Michael E. Porter and Claas van der Linde support a top-down approach, while Pierre Desrochers demonstrates the effectiveness and efficiency of the bottom-up approach.[40]

The so-called "Porter Hypothesis" is based on the concept that innovation can be triggered by properly designed environmental standards leading to increased competitiveness, as this in fact rests on the capacity to innovate and grow. Innovation then can offset the costs of complying with strict regulations and lead to advantages over firms not obliged to respect those rules. It may be unclear the reason why regulations are needed, since these lead to innovation and competitive positions. Nevertheless, firms do not always take profit-maximizing decisions, because they do not operate in a perfect competition regime where information is fully accessible to each economic actor. In reality, firms have to face incomplete information, changing technology, organizational inertia, and control problems. Also, companies are still inexperienced with environmental issues due to the fact that both corporate and technological attentions have not been addressed towards the environment.

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[37] Combined Heat & Power Association: www.chpa.co.uk/what-is-chp_15.html; www.chpa.co.uk/advantages--benefits-of-chp_183.html.

[38] Chertow, M. R. and D. R. Lombardi, "Quantifying Economic and Environmental Benefits of Co-Located Firms", *Environmental Science and Technology*, 2005.

[39] Gertler, N., "Industrial ecosystems: Developing sustainable industrial structures", Master thesis, MIT, Boston, 1995.

[40] Mathews, J. A. and H. Tan, "Progress towards a Circular Economy in China: The drivers (and inhibitors) of eco-industrial initiative", *Journal of Industrial Ecology*, 2011.

Thus, environmental regulations can pursue several purposes. First of all, they promote innovation and progress. Secondly, they can raise corporate awareness about current environmental situations. Thirdly, standards can reduce uncertainties and encourage investments that deal with environmental issues. Fourthly, they signal resource inefficiencies and potential technological improvements. Fifthly, they ensure the avoidance of opportunistic behaviours, since all firms have to respect them. Finally, they are needed when innovation cannot completely, but only partially, offset the costs of regulations compliance. For instance, this can happen when learning and innovation are not well developed yet; anyway, in the long-run costs are supposed to be totally overcome by benefits.

Developing the first point, innovation as a consequence of environmental regulations can occur in two forms: companies understand how to deal with pollution and waste management; or they can converge towards more environmentally desirable products and processes. The first case corresponds to what today is called “end-of-pipe technology”, where firms learn to process and treat hazardous materials and to minimize toxic emissions. This form of innovation just leads to reduction of costs of compliance with regulations, but does not bring any “innovation offset”. Instead, the second case coincides to what today is named “cleaner production” and shows innovation offsets, which are conducive to competitive advantage. These offsets can be of two types: product offsets and process offsets. Product offsets exist when, together with lower environmental impacts, higher-quality products or safer products are supplied to customers or lower product costs are encountered by firms. Process offsets occur when reduced pollution accompanies higher resource productivity, such as better utilization of by-products, lower energy consumption, material savings, and higher process yields.[41]

On the contrary, Desrochers explains that market incentives supported by enhanced private property rights can mitigate hazardous impacts of business activities. If flexibility and freedom are guaranteed, profit-maximization and competition will conduce to an effective and efficient resources utilization through closed-loop initiatives. Indeed, the development of “win-win” products and processes is merely the result of profit-pursuing decisions. By-products linkages are not only useful to deal with environmental issues, but even encourage firms’ clustering since they can turn a loss into a profit. Recycled products impose lower costs on companies than virgin products do, cheapening the cost of finished offerings and securing

[41] Porter, M. E. and C. van der Linde, “Toward a New Conception of the Environment-Competitiveness Relationship”, *The Journal of Economic Perspective*, 1995.

advantage over rivals. Furthermore, proximity of firms guarantees the presence of a vast supplier base, allowing entrepreneurs to choose the more valuable by-product to put again into the production process.[42]

Coming back to Kalundborg example, Gertler develops the argument, even confirmed by Desrochers, that Danish flexible environmental regulations were one of the drivers of Kalundborg industrial symbiosis. In particular, Gertler believes that environmental regulations imposing lower harmful impacts on nature were necessary, but not sufficient, to develop this industrial metabolism. These law requirements, in fact, gave the initial impulse. But then cooperation among companies developed in order to better exploit by-products and respect environmental laws. This cooperation was possible for two reasons: linkages were economically profitable; and regulations imposed performance standards and not technology standards. Indeed, performance standards allowed firms to find the best solution with both economic and environmental sense. Therefore, Gertler is in accordance with Porter regarding the usefulness of environmental rules in developing eco-linkages, but what Porter fails to capture is the importance of regulations flexibility. Thanks to performance standards, firms did not try to elude laws, but, on the contrary, to kill two birds with one stone. Gertler then accords with Desrochers: profit-maximizing decisions, requiring a certain degree of freedom, are successfully able to manage environmental issues.[43]

City level

The third level at which closed-loop initiatives are taken is the city level. Since half of world population lives in urban centres, economic activities are increasingly concentrated in cities, which are therefore the main generators of environmental harm. For this reason, industrial ecology is strengthening its attention on them and on metropolitan areas in general. Bai explains that, as with industrial systems, cities can be compared to ecosystems where each actor requires and releases materials and resources. But more importantly, spatial and functional linkages among cities and industries tend to develop, generating a big unique urban ecosystem. Above all in Asian countries, urbanization and industrialization grow and expand together, each of the two necessitating the other. Cities need industries for jobs and

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[42] Desrochers, P., "Did the invisible hand need a regulatory glove to develop a green thumb? Some historical perspective on market incentives, win-win innovations and the Porter Hypothesis", 25th Celebration Conference on Entrepreneurship and Innovation – Organizations, Institutions, Systems and Regions, Copenhagen, 2008.

[43] Gertler, N., "Industrial ecosystems: Developing sustainable industrial structures", Master thesis, MIT, Boston, 1995.

revenues and industries need cities for employees and customers. At the same time, pollution and wastes can reach worrying levels. This phenomenon is evident in China, which is experiencing rapid economic growth and urbanization, causing huge material and energy consumption. Thereby, recycling and by-products utilization are essential in closing the loop of urban metabolism and preserving the environment.[44] Since the city-industry interaction is stronger at the industrial park level, and since China is looking for sustainable development, eco-industrial parks represent a good solution.

An industrial park is "a planned industrial or technologically-based district of a city; usually intended for light manufacturing, industrial usage, research, or for warehousing; often located in open land near the city or in a renovated urban area".[45] Substantially it coincides with a cluster in all features and the two terms are often used as synonymises. However, the term industrial park always refers to a purpose-built entity, whereas the term cluster can refer either to intentionally planned or unintentionally grown entities.

An eco-industrial park is simply an industrial park characterized by the phenomenon of industrial symbiosis. According to Côté and Cohen-Rosenthal, an eco-industrial park would: reduce environmental impact through substitution of toxic materials, absorption of carbon dioxide, material exchanges and integrated treatment of wastes; maximize energy efficiency through facility design and construction, cogeneration and cascading; recovery and recycle materials through facility design and construction; use economic instruments discouraging waste and pollution; employ an information management system facilitating the flow of energy and materials within a closed loop; create tools and programs to train and educate managers and workers about strategies and technologies linked to closed-loop activities.[46]

The present work will focus on three examples of eco-industrial parks in China.

4. China leapfrogging other countries: industrial cluster and industrial ecology

Generally defined as "the factory of the world", China is considered, together with India, one of the world's next major powers. Its political system has always determined a top-down approach in building the economic growth through legal and regulatory tools and now the

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[44] Bai, X., "Industrial Ecology and the Global Impacts of Cities", *Journal of Industrial Ecology*, 2007.
[45] Definition given by McGraw-Hill Dictionary of Architecture & Construction.
[46] Côté, R. P. and E. Cohen-Rosenthal, "Designing eco-industrial parks: a synthesis of some experiences", *Journal of Cleaner Production*, 1998.

country is in its fourth decade of free market reforms.[47] Indeed, after 1978, Mao's successor Deng Xiaoping focused on market-oriented economic development, adopting a more pragmatic perspective of socioeconomic problems and reducing the role of communist ideology in economic policy. The results have been the largest reduction of poverty and one of the fastest increases in income levels ever seen. Since the 1990's China has increased its global weight and participation in international affairs and, by 2000, the country's output has quadrupled in comparison to the 1980's. Nowadays, it is the third largest economy in the world (after US and Japan), with a GDP real growth rate of 9.10% (2009 est.), and an industrial production growth rate of 9.50% (2009 est.).[48]

According to Wilson and Purushothaman, over the next 40 years the largest developing countries (Brazil, Russia, India and China -the BRICs-) could be the strongest economic force in the world. In less than 30 years, the BRICs could outpace the G6 and by 2025 they could account for over half the size of the G6. China's economy could overcome the US's by 2041, becoming the first power in the world. By 2030, China's per capita income could be roughly that of Korea's today and, by 2050, similar to where the developed countries are now.[49]

But how can China achieve this pattern?

A latecomer advantage

China is a latecomer country, meaning that it started its industrial growth many decades after developed nations. However, the late arrival does not bring just negative aspects, but can also be exploited to translate what it is intended as a disadvantage into an advantage. As noted by Hu and Mathews, latecomers have the possibility to tap into advanced sources of management, organization and technology due to the multiple linkages with developed countries, while enjoying lower costs than their advanced competitors.[50] In fact, Wilson and Purushothaman underline how developing economies have less capital per worker than developed economies, thus showing higher returns on capital.[51] In other words, latecomers can learn, imitate, and even improve western models at lower costs and without having to face the long path toward their discoveries.

[47] Huang, Y. and T. Khanna, "Can India overtake China?", *Foreign Policy*, 2003.

[48] http://globaledge.msu.edu/countries/china.

[49] Wilson, D. and R. Purushothaman, "Dreaming With BRICs: The Path to 2050", Goldman Sachs, Global Economics Paper n° 99.

[50] Hu, M. C. and J. A. Mathews, "National innovative capacity in East Asia", *Research Policy*, 2005.

[51] Wilson, D. and R. Purushothaman, "Dreaming With BRICs: The Path to 2050", Goldman Sachs, Global Economics Paper n° 99.

Mathews explains how latecomer countries can implement catch-up strategies through private and public efforts. On the private side, according to the LLL (Linkage Leverage Learning) framework, firms, or groups of firms, can "link" to advanced companies, "leverage" their resources, and "learn" from these repeated activities. Indeed, in a globalized world an emergent firm constantly faces the opportunity to be part of global value chains and to connect with what Yeung calls "lead firms" (firms able to coordinate and manage global value chains, large transnational corporations influencing the global economy), which are always looking for cutting costs and enhancing flexibility of operations through outsourcing. Moreover, through the linkage with advanced players the emergent firm can secure more than merely revenue: it can acquire knowledge, technology, and market access. Thereby, a firm's capacity to obtain more than it puts in, allows to "leverage" resources and capabilities and provides the opportunity to become a global player as well. The continuous and repeated practice brings then to industrial "learning": an emergent firm understands how to move in the worldwide scene and is ready to become a global competitor.[52] But more importantly, Mathews states that the entire phenomenon is augmented if the latecomer firm is located within a cluster, because the multiple linkages of each member of the cluster create automatically opportunities for the others. Moreover, firms can cooperate to jointly adopt strategies of catching up.[53]

On the public side, the state and governmental agencies can invest in what Mathews calls Technology Leverage Institution (TLI), an institution able "to bridge the gap between the technological resources of the developed world and the aspirations to catch-up on the part of the developing world".[54] An example of TLI is provided by the Taiwanese ITRI (Industrial Technology Research Institute), which allows firms located in HSP to technologically upgrade even if they are not able to face huge costs. The task of TLI is to identify technologies of interest, adopt strategies for acquiring them, utilize them and diffuse them in the overall country. It has to provide shared R&D services for existing and emerging industries, acting as an R&D Department of a large company. Therefore, it would improve technologies in use, analyze technologies employed by rivals, construct the best available technologies and allow

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[52] Mathews, J. A., "Competitive Advantages of the Latecomer Firm: A Resource-Based Account of Industrial Catch-Up Strategies", *Asia Pacific Journal of Management*, 2002.

[53] Mathews, J. A., "The Hsinchu Model: Collective efficiency, increasing returns and higher-order capabilities in the Hsinchu Science-based Industry Park, Taiwan", Keynote Address, Chinese Society for Management of Technology (CSMOT), 20th anniversary conference, Tsinghua University, Hsinchu Taiwan, 2010.

[54] Mathews, J. A., "Latecomer strategies for catching-up: the cases of renewable energies and the LED programme", *International Journal of Technological Learning, Innovation and Development*, 2007, p. 36.

all national firms to have access to knowledge and modern tools.[55] Moreover, if the primary role of the government is to promote R&D centres, it is easier and less expensive to concentrate them where as many firms as possible can have access to them; thus, a solution is offered by industrial clusters. In fact, as in the case of HSP (described later), clusters show the presence of several consortia, public research centres, universities, and scientific platforms, which guarantee the technological upgrading of co-located firms.

Furthermore, Henry Wai-Chung Yeung is another author claiming that latecomer development is inevitably linked to global value chains, cooperation among firms, and public investments. He makes an explicit connection between regional development of East Asian countries and global production networks (GPNs). In his argument, the concept of "strategic coupling" is relevant, defined as "a mutually dependent and constitutive process involving shared interests and cooperation between two or more groups of actors who otherwise might not act in tandem for a common strategic objective. In the context of regional development, strategic coupling refers to the dynamic processes through which actors in regions coordinate, mediate, and arbitrage strategic interests between local actors and their counterparts in the global economy. These trans-regional processes involve both material flows in transactional terms and non-material flows (for example, information, intelligence, and practices)".[56] For regional development he intends what here is called industrial district, or cluster, and the actors of the described phenomenon are lead firms, strategic partners, and institutions. Lead firms are those firms able to coordinate and manage GPNs, large transnational corporations influencing the global economy. They usually invest in upper stages of the value chain such as R&D, leaving lower value added activities to partner companies (e.g. subcontractors). Thus, Yeung confirms Mathews' theory, since these suppliers are very often what we have defined as latecomer firms, searching roots for catching-up. Generally, they have to guarantee their support to the lead firm's businesses throughout the world.

Strategic coupling is strategic since the process requires active participation of all above mentioned actors. It is time-space contingent because it is destined to face important changes and it goes beyond geographical boundaries as it collects actors from everywhere. Three processes in East Asia facilitate what Yeung calls strategic coupling: emergence of

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55 *Ibidem*.

56 Yeung, H. W. C., "Regional Development and the Competitive Dynamics of Global Production Networks: An East Asian Perspective", *Regional Studies*, 2009, p. 332.

transnational communities; changes in industrial organization; and institutions' initiatives. Lots of notable entrepreneurs and technologists have appeared in the recent decades in these countries and, even due to their constant movements around the world, have contributed to skills and knowledge diffusion, local industrial upgrading and communication between different firms and institutions.

Regarding organizational changes, Yeung refers to the participation of multiple companies in current global value chains; each one of these companies specializes in different production stages, enhancing the connectedness between actors, even those headquartered geographically far. Moreover, public institutions of these countries, since the 1980's, have promoted industrial policies and fiscal incentives helping the take-off of several corporations and sectors.[57] To this regard, the below-described reforms implemented by Deng Xiaoping have to be seen as institutional initiatives helping strategic coupling and industrial clusters.

Clusters, industrial parks and China

In China there are already several industrial clusters and the Li & Fung Research Centre, considering top 100 Chinese clusters, confirms they are really contributing to the economic growth.[58] Anyhow, above all in peripheral countries, clusters do not always arise spontaneously, but, on the contrary, they develop within industrial parks. According to Geng *et al*., there are three types of industrial parks: sector-integrated group; venous group; and sector-specific group. The first corresponds to those parks housing multiple industrial sectors and substantially coincides with Special Economic Zones, the main form of Chinese industrial park. The second refers to those resource recovery parks where companies adopt environmental technology and produce green products. The last type indicates those parks primarily focusing on one main sector or anchor tenant.[59]

Functioning within an institutional entity such as an industrial park can be really advantageous for firms wishing to run their business activities in developing countries. Indeed, enterprises can find better infrastructure and physical utilities than elsewhere in the country and, sometimes, even laws are more closely observed within parks. Moreover, these geographic regions are characterized by more free-market-oriented laws and economic procedures than industrial areas located outside.

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57 *Ibidem*.

58 Li & Fung Research Centre, "Industrial Cluster Series", Issue 6, 2010.

59 Geng, Y., P. Zhang, R. P. Côté and T. Fujita, "Assessment of the National Eco-Industrial Park Standard for Promoting Industrial Symbiosis in China", *Journal of industrial ecology*, 2008.

Special Economic Zones are industrial enclaves that aim at fostering economic development, offering special preferential policies to firms. Over time SEZs have evolved in terms of objectives, preferential policies, governance, ownership, and location. The oldest forms of SEZs were free ports, which developed in the 16th and 17th centuries and were located in most ports of entry throughout the world. They gradually became free trade zones, small, fenced-in, duty-free areas with storage and distribution facilities for trade and export operations. At the beginning of the last century, Export Processing Zones (EPZ) started to emerge, offering incentives and facilities for export-oriented manufacturing activities. The EPZs were reserved exclusively for enterprises carrying out export operations and licensed under a SEZ regime. Finally, at the end of the 1970's, China designed its own model of Special Economic Zones, huge industrial towns occupying several square km. They accommodate all types of activities, including tourism and retail sales, allowing people to live within the area, guaranteeing better infrastructure than in the rest of the country and many more incentives and benefits than the other forms of industrial enclaves.[60] They gained a new lease of life from 1984 onwards, due to the "gradually opening door strategy" of Deng Xiaoping, and were designated by the central government as pilot areas to attract foreign direct investment, to test the applicability of market economy, and to develop export-oriented manufacturing activities in a socialist central-planning economy. After 1992, Deng Xiaoping decided to undertake further reforms, generating a rapid proliferation of development zones approved by the Chinese government at various levels.[61] In 2006 China employed 40 million people in SEZs, registering an increase of 10 million people since 2002. Moreover, nowadays SEZs are widely diffused in several developing countries (for example even in India and Brazil).[62]

John Mathews makes the argument that the success of China as an industrial giant cannot be understood without thinking to industrial clusters, housed within institutional entities such as SEZs and industrial parks. Externally, firms are connected to worldwide players facing the opportunity to leverage their resources and capabilities and learn from repeated operations. Indeed, incalculable linkages exist among cluster's members and each member, and above all what Yeung names "lead firm", has its own complex relationship pattern developing greatly beyond cluster's burdens. Thereby, companies become easily part of networks, mainly global

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60 Aggarwal, A., "Economic impacts of SEZs: Theoretical approaches and analysis of newly notified SEZs in India", Munich Personal RePEc Archive, 2010.

61 Yeung, H. W. C., W. Liu and P. Dicken, "Transational Corporations and Network Effects of a Local Manufacturing Cluster in Mobile Telecommunications Equipment in China", *World Development*, 2005.

62 Aggarwal, A., "Economic impacts of SEZs: Theoretical approaches and analysis of newly notified SEZs in India", Munich Personal RePEc Archive, 2010.

value chains and production networks. Consequently, firms have access to multiple resources and customers, even improving their specialization and implementing intermediation.

Within the park, externalities combined with public initiatives generate enhanced production capabilities, variety, innovation and economic learning. Indeed, industrial enclaves show the development of the following: labour market pooling, knowledge spillovers, supplier specialization, public platforms and institutions, cooperation and trust, incentives and privileges, and vertical and horizontal relationships (developed through explicit or tacit means). Thus, all the attributes identified by Marshall, Porter, Schmitz, Mathews, and Becattini, constitute the engine of Chinese wealth generation and give birth to increasing returns, something often discarded by economists but effectively present in the real world. In few words, focusing on localization clearly brings to global economic success.[63]

The Xingwang Industrial Park

Yeung, Liu, and Dicken analyzed a Chinese industrial park and demonstrated how the argument here presented (clusters' importance in growth trends) is valid. They focused on the Xingwang Industrial Park, located within the Beijing Economic and Technological Development Area (BDA). This development zone was approved in 1994 by the State Council, the highest governing body in the Chinese central government, and it is one of those SEZs generated by 90's Xiaoping's reforms. It has shown a rapid economic development with an annual GDP growth rate of over 60% (six times China GDP growth rate) and, by 2005, had hosted 1691 enterprises, which in terms of investments corresponded to $9.6 billion. More or less one quarter of these companies was foreign owned or members of joint ventures. At the end of 2004, the BDA's GDP was $1.5 billion (and the country GDP was 1,707,233 million[64]).

Telecommunications and IT constitutes the most important BDA's industry and the Nokia cluster is the BDA's primary economic engine. This cluster, named Xingwang Industrial Park, is a mobile-phone manufacturing cluster created by Nokia China Investment Co., Ltd. (NCIC) and the BDA. This purpose-built entity aimed at bringing together Beijing Capitel Nokia Mobile Telecommunications Ltd. (Nokia-Capitel) and its major suppliers. Nokia-Capitel is a 50-50 joint venture company established in 1995 between NCIC and the China Putian Beijing

[63] Mathews, J. A., "The Hsinchu Model: Collective efficiency, increasing returns and higher-order capabilities in the Hsinchu Science-based Industry Park, Taiwan", Keynote Address, Chinese Society for Management of Technology (CSMOT), 20th anniversary conference, Tsinghua University, Hsinchu Taiwan, 2010.

[64] http://unctadstat.unctad.org/TableViewer/tableView.aspx

Capitel Co., Ltd. (Capitel). In 2004, the sales of Nokia-Capitel and its suppliers were $3.15 billion, around 38% of BDA's total sales.

NCIC decided to expand its production capacity through Xingwang's establishment because in 1998 the Chinese market started to boom and was destined to become the largest mobile-phone market in the world. It then had the idea to apply the business model of assembler and suppliers cluster, already affirmed in the automobile sector and, particularly, in the automobile assembly plant of Volkswagen in Barcelona. The model adopts Just-In-Time inventory systems (JIT), which are able to reduce inventories, cut down production costs, and increase flexibility of production. Nokia wanted its major suppliers in the park in order to better control its supply chain without engaging in in-house production. Moreover, it could increase time efficiency and production customization.

The success of the park is due to several reasons. First of all, the BDA provides great administrative and economic support; for example, investments in the BDA are protected under laws and the BDA authority enjoys investment approval right as high as a provincial government (up to $30 million). Also, the BDA is able to guarantee that law and legality are respected within the area much more than elsewhere in the country, enabling long-term planning of investments and important decisions.

Secondly, Marshallian external economies do their job. A significant labour market pooling, both for skilled and unskilled workers, is present. Indeed, the number of scientists and engineers in Beijing accounts for 1/10 of the national total and about 400,000-500,000 university students are enrolled each year in the region. Moreover, unskilled labour does not suffer from the phenomenon of the "floating population", which leads to considerable workers' mobility, occurring in other parts of China.

In addition, relevant technological spillovers characterize the cluster and all the area in general, since huge investments in R&D are made by the BDA and other institutions. Furthermore, co-location determines information flow between all the companies present in the park. For instance, the BDA has created a Ph.D. workstation to favour research activities among scientists and engineers that increase quality and efficiency of economic activities. Also, a constant sharing of knowledge on markets and technology (for example through formal and informal meetings) exists between Nokia-Capitel and its suppliers.

Finally, supplier specialization avoids Nokia to vertically integrate and lose flexibility in response to market changes. It can easily invest in upper parts of the value chain, leaving backward activities to its partners. At the same time, 30 suppliers are clearly able to share the risks linked to Nokia business activity and, also, Nokia itself requires that all its suppliers sell up to 60% of their net sales to external customers, leveraging their production capabilities. Furthermore, proximity between Nokia and partners ensures trust and cooperation among them, which decrease monitoring costs and are conducive to joint actions whenever it is necessary.[65]

HSP as a right model for a latecomer

It would not be surprising then that politicians and institutions try to encourage clusters' creation and development. In doing so, they follow some models, but certain examples are more suitable than others. Indeed, the Silicon Valley model is not appropriate, since it is an unintentionally grown cluster, whose success derived from particular and difficult-to-imitate conditions. As O'Mara argues, Silicon Valley is the result of over 60 years of massive investments from public and private entities. The US government was the principal investor, because with the Cold War, and above all after 1957 launch of the Sputnik satellite, it was principally interested in having the required technology to face the Soviet Power. Thereby, it heavily financed research activities and innovation. Lots of money flew to research universities, such as Stanford and Berkeley, creating involuntarily another source of Silicon Valley's success: an inestimable and qualitative labour force. Stanford has indeed graduated more future tech-company CEOs than elsewhere in the world. Moreover, there were many risk-tolerant investors willing to fund untested entrepreneurs, providing incredible opportunities for business growth. To this, it has to be added the post 1965 immigration policy, which liberalized immigration and allowed foreign top students to study in the country. Indeed, more than half the companies located today in the Valley were founded by foreigners. Finally, Silicon Valley is the right place for those who have the education, money, and social advantages that permit them to live wherever they desire. It has good weather, is near to a metropolis, San Francisco, and it has several spaces for building houses and offices. Last but not least, there is abundance of capital and absence of social problems.[66]

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65 Yeung, H. W. C., W. Liu and P. Dicken, "Transational Corporations and Network Effects of a Local Manufacturing Cluster in Mobile Telecommunications Equipment in China", *World Development*, 2005.

66 O'Mara, M., "Don't Try This at Home", *Foreign Policy*, 2010.

Thus, several circumstances led to Silicon Valley's economic boom and these are impossible to recreate. What Chinese institutions and companies have to look for is a model nearer their capacities, culture, and history. The Hsinchu Science-based Park (HSP) in Taiwan offers this chance. As Mathews claims, "the Hsinchu park works as a cluster, with firms capturing systemic gains, and thereby provides a model for the rest of the world".[67] But it is not the right model only for its success; on the contrary, it provides a philosophy of development that perfectly fits countries wishing to emerge into the international context. As it is explained above, the government, having captured the relevance of parks for economic growth, had the clear intention to launch HSP businesses and guaranteed several incentives and aids. Corporations, on their side, appropriately responded to these inputs and had the willingness to demonstrate how latecomer firms could translate an apparent disadvantage into a real advantage. Bartlett and Ghoshal say: "Contrary to popular wisdom, companies from the fringes of the world economy can become global players. What they need is organizational confidence, a clear strategy, a passion for learning, and the leadership to bring these factors together".[68]

The government of Taiwan (China) gave birth to HSP in 1980 in order to move up in the value chain and reach the high-tech industry. The park has offered generous fiscal incentives to its enterprises, such as a five-year tax holiday on business income tax, the exemption of tariffs on imported machineries and materials, and a subsidized rent for land. However, the park was initially anything but a success. Indeed, in the first ten years PCs and related companies were located in HSP, but, instead of being new start-ups, they were companies already established in Taiwan (Acer and Mitac) aiming at exploiting HSP fiscal incentives. Even if they had access to external economies such as labour market pooling and common utilities and infrastructure, they mainly worked as subcontractors and did not invest in R&D, causing a lack of innovation and technological spillovers. By 1990, HSP was nothing more than an agglomeration of subcontractors that had no influence on the world's high-tech industry.

The situation changed when semiconductor manufacturing entered the park. Already in 1993, IC production and design outpaced computers and HSP revenue doubled if compared to that of 1990. By 2001, firms generated revenues of $32 billion and in 2003 revenue reached an amount correspondent to seven times that of 1993. In 1982 United Microelectronics

[67] Mathews, J. A., "The Hsinchu Model: Collective efficiency, increasing returns and higher-order capabilities in the Hsinchu Science-based Industry Park, Taiwan", Keynote Address, Chinese Society for Management of Technology (CSMOT), 20th anniversary conference, Tsinghua University, Hsinchu Taiwan, 2010, p. 17.

[68] Bartlett, C. A. and S. Ghoshal, "Going Global: Lessons from Late Movers", *Harvard Business Review*, 2000, p.133.

Corporation (UMC), financed by the government and state-owned banks, built its first plant at HSP. Later, Mosel and Vitelic, two IC design houses, came into the park and continued to source foundry services from Japan. The government, subsequently, recognized the opportunity to provide foundry services within the park and initiated a project, called Very-Large-Scale IC, which ended with the creation in 1987 of Taiwan Semiconductor Manufacturing Corporation (TSMC). The company, which guaranteed foundry services, led to the establishment of another 37 IC design houses, since relying on a close foundry service provider meant the possibility to be highly competitive. Thereafter, UMC copied TSMC to become a foundry service provider as well, initiating a long and profitable rivalry. Their competition, based on high advanced technologies, gave to Taiwan the leadership in the sector until today.

The government played an important role, since it deeply nurtured the semiconductor industry through firm building, market building, infrastructure, technology inputs, and fiscal incentives. However, the success was mainly due to innovation and technological spillovers generated by HSP high-tech business activities. Externalities created ever-increasing opportunities for other companies and attracted both private and public capital. Moreover, the business model pioneered by TSMC, and then followed by UMC, was without any doubt a success, because it was able to change the rules of the world's semiconductor industry. Previously, the sector was dominated by vertically integrated companies, barriers to entry, and several technological and capital requirements. TSMC and UMC offered foundry services without engaging in design activities and relying on the best technology available. Therefore, design houses did not need to invest in modern machineries (saving billions of dollars) and meanwhile gave TSMC the chance to leverage its technology by learning from them.

As underlined by Chen, a cluster to be successful has to be characterized by highly performing competition and by firms of relevant size. The latter is particularly important to sustain necessary investments and firms in related industries. Indeed, TSMC and UMC have undertaken mergers, acquisition, and other investments in order to increase their size year after year. In addition, their rivalry has prompted many innovations and high qualitative products.

Coordination and problem solving, required above all by innovative activities involving complex knowledge and instruments, were facilitated by proximity. Furthermore, TSMC and UMC have provided testing services relevant to the new functions' implementation and even guaranteed to their clients their own intellectual property. In return, the two foundry service providers have had the chance to operate always at the border of the known technology.

Favourable labour force was another HSP attribute providing winning results. Lots of engineers graduated in Taiwan were available in the park, giving huge impulse to R&D. In fact, today 21.4% of HSP employees are master or Ph.D graduates. Loyalty and encouragement toward extra efforts are even fostered thanks to company shares given at the end of each year.[69]

As noted by Mathews, nowadays the park houses several clusters working in ICs, computers and peripherals, telecommunications, flat panels *etc*. All of these have developed horizontal and vertical linkages both within the park and with the global economy. Several labs and research facilities are also available in HSP and firms in 2001 spent 5.4% of sales revenues in R&D. Moreover, an average of 3000 patents each year is issued.

Therefore, interdependencies and passion for innovation have allowed HSP to avoid the "lock-in", meaning the intense specialization only in particular sectors and activities relying on deeply specialized labour force. The ability to go beyond and create new lines of development is the key strategy for a park, and above all for a high-tech park. Succeeding stories including HSP and Silicon Valley have their roots in the desire to always explore new fields of research. This is only possible when firms are deeply connected to each other, sharing ideas, knowledge, capital, and workers and then base their growth on these constant exchanges and on heavily investing in R&D.

In addition, several R&D consortia emerged in Taiwan during the 80's and acquired efficiency and effectiveness during the 90s. These have as their objective the technological learning of firms, which, relying on a cooperative approach, have to leverage their technological skills so to compete successfully in high-tech industries. It has also to be stated that Taiwan shows clearly the merger of private and public efforts in technology-upgrading strategies, since collaborative actions of firms through R&D ventures are in constant exchanges with labs and research institutes. Indeed, the basic model of Taiwanese consortium is an alliance between firms and ITRI (Industrial Technology Research Institute) where R&D costs are shared and risks reduced. The goals are rapid adoption and diffusion of new technology, products, and processes, to as many firms as possible. In this way, even those firms that are too small to

[69] Chen, T.J., "The Emergence of Hsinchu Science Park as an IT Cluster", from *Growing Industrial Clusters in Asia* edited by S. Yusuf, K. Nabeshima and S. Yamashita, The World Bank, 2008.

invest in R&D can have access to benefits of innovation and contribute to the region's economic development.

HSP in now enjoying increasing returns as a consequence of positive externalities, including firms' embeddedness within several networks and Marshallian trinity, and of technological learning, which is mainly an example of what Mathews calls "economic learning". As a result, firms show value-added of 50% (when Taiwanese firms outside HSP show figures of 30%), being 66% more productive than counterparts established outside the park.[70]

China's environmental problems

Both the Xingwang case and the HSP case give evidence of clusters' importance, confirming authors' theories previously described. External economies, linkages, and networks are impressive consequences of firms' proximity and, meanwhile, reasons for co-location. Nevertheless, if economic development has arrived at the expense of natural environment, probably there is the need for some public interventions. The Li & Fung Research Centre has studied the top 100 industrial clusters in China and sustains clusters' contribution to economic development. In particular, it states that Chinese industrial clusters are featured by enhanced efficiency and productivity thanks to high degrees of specialization and division of labour, but, meanwhile, several pollution problems are generated. In fact, clusters' success is obtained at the expense of over-exploitation of natural resources and the environment. Recognizing the importance of sustainable development, the central government as well as local governments is developing systems and tools to deal with this issue.[71]

As noted by Chiu and Yong, the Kuznets curve explains that the economic growth of a country first increases the environmental burden and then, after a certain level of economic development is achieved, the burden starts to diminish. China indeed, as a consequence of its rapid economic growth, has experienced increasing environmental harm, while the practice of "pollute now, clean up later" has created difficulties for further development. Sandstorms, acid rain, water pollution, forest depletion, intensive soil erosion, floods, siltation, solid waste pollution, dumpsite accidents, and so on, generate health issues as well as obstacles to

[70] Mathews, J. A., "The Hsinchu Model: Collective efficiency, increasing returns and higher-order capabilities in the Hsinchu Science-based Industry Park, Taiwan", Keynote Address, Chinese Society for Management of Technology (CSMOT), 20th anniversary conference, Tsinghua University, Hsinchu Taiwan, 2010.

[71] Li & Fung Research Centre, "Industrial Cluster Series", Issue 6, 2010.

economically upgrade.[72] The New York Times wrote: “No country in history has emerged as a major industrial power without creating a legacy of environmental damage that can take decades and big dollops of public wealth to undo”.[73] It is estimated that Zhejiang province and Suzhou, if they keep exploiting land at the current trend, will finish their land resources in ten years. Shenzhen, instead, has also exploited all of the land in the past years.[74] Furthermore, water crisis can generate troubles for the country. As the United Nations Human Development Report affirms, rapid growth has strained water resources since it has increased demand for water and has polluted a great part of the remaining water supply. Since 1980, annual water withdrawal rates in the Huai, Hai and Huang river basins have increased by 42 billion cubic metres and the share of industry in water use has doubled since 1980. Chinese companies use 4-10 times more water than companies in industrialized countries, partly because of the absence of policies addressing the problem. Projections suggest that demand will rise by 20% within 2030. Moreover, over 80% of the Hai and Huai basins are highly polluted and more than 70% of the water in the Huai, Hai and Huang basins is too degraded for human use.[75]

In addition, air pollution causes hundreds of thousands of deaths each year and only 1% of the population breath air considered safe. The major culprit of air pollution is coal, which is utilized for two thirds of China’s energy needs. The country burns more coal than the United States, Europe and Japan all together, and coal-fired power plants generate huge quantities of sulphur dioxide and nitrogen oxides that fall as acid rains on cities.[76] Finally, according to the United Nations Environment Programme (UNEP) Year Book, in 2004 China surpassed America as the largest producer of rubbish and, by 2030, predictions suggest that it will be churning out 500 million tonnes of wastes a year.[77]

Toward a circular economy

Nowadays, China is showing new developments in governance philosophy. Even if it has achieved the most remarkable GDP growth at all costs, sacrificing environmental resources and social equity, the country is now clearly taking more sustainable strategies to further develop. In 2003 the government has inaugurated a people-oriented development philosophy

[72] Chiu, A. S. F. and G. Yong, “On the industrial ecology potential in Asian Developing Countries”, *Journal of Cleaner Production*, 2004.
[73] Kahn, J. and J. Yardley, “As China Roars, Pollution Reaches Deadly Extremes”, *The New York Times*, 2007.
[74] Li & Fung Research Centre, “Industrial Cluster Series”, Issue 6, 2010.
[75] UN Human Development Report, Published for the United Nations Development Programme (UNDP), 2006.
[76] Kahn, J. and J. Yardley, “As China Roars, Pollution Reaches Deadly Extremes”, *The New York Times*, 2007.
[77] UNEP Year Book, “New Science and Developments in our Changing Environment”, 2009.

based on scientific concepts and promoting a sustainable approach to economic, social, and environmental issues. Furthermore, in 2006 Chinese policy-makers set up a key ambitious goal: building a harmonious society. Therefore, under the scientific development strategy and harmonious society goal, China is moving toward a resource-saving and environmentally friendly society, following five criteria: technological orientation, resource efficiency, low pollution, high economic results, and a full use of human resources. In other words, the new governance philosophy is laying a favourable ground for supporting a circular economy in the country.[78]

The current Premier, Mr. Wen Jiabao, and all the Chinese government, are greatly committing to respond to climate change and protect the environment. For this reason, they are working to develop low-carbon technologies, rely on renewable energy resources, expand China's forests, implement closed-loop initiatives, and internationally cooperate to address climate change and environmental issues. In order to carry out a circular economy and focus on industrial ecology, China is aiming at using mineral resources, recycling industrial waste, generating electricity through by-product heat and pressure, and transforming household solid waste into resources.[79]

Arguably, as underlined by Chiu and Yong, industrial ecology is not only a concept for developed countries; in fact, for its legal framework and for the number of eco-industrial initiatives already carried out, China is proving to be greatly ahead of several countries, even developed ones. Thanks to its diversity of industrial actors (opening up paths to innovation and learning), abundance of human resources, presence of several academia and research institutions (e.g. Beijing University, Fudan University, Tianjin Financial University) already working on industrial ecology's concept, governmental key role in running EIP projects, and shared awareness of the importance of sustainable development in the Chinese business world, the country is enjoying the chance to take the lead in this theme. And more importantly, China can learn from past experience and mistakes of developed countries, starting to avoid all those environmental issues linked to economic expansion, while imitating and improving western technologies by for example international cooperation.[80]

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78 Yong, R., "The circular economy in China", *Journal of Material Cycles and Waste Management*, 2007.

79 Xinhua, "China to build industrial system of low-carbon emissions", *China Daily*, 2010. Available at: www.chinadaily.com.cn/bizchina/2010-03/05/content_9542319.htm.

80 Chiu, A. S. F. and G. Yong, "On the industrial ecology potential in Asian Developing Countries", *Journal of Cleaner Production*, 2004.

Furthermore, this point is even confirmed by authors as Mathews and Tan, who highlight that latecomers can draw on the discoveries accumulated around the world, and they can also have the chance to shape their favourable industrial pathways without having to replace legacy systems. Moreover, developing countries can exploit their low cost advantage, while enjoying state agencies' supports pushing toward EIP's development.[81]

As noted by Yong, the circular economy's concept was first introduced in China at the end of the 90's. Indeed, in 1994 Germany enacted the "Closed Substance Cycle and Waste Management Act" that promoted closed substance cycle waste management in order to conserve natural resources and to ensure environmentally compatible disposal of waste. Consequently, basing their analysis on German experience, Chinese scholars begun to introduce concepts as recycling economy or circular economy at the end of the decade. Thereafter, other impulses arrived from Japan, which in 2000 issued the "Basic Law for Establishing a Recycling-Based Society" articulating fundamental matters for making policies for establishing recycling-based society and clarifying the responsibilities of the State, local governments, businesses, and the public. The aim of the law was to restrain the consumption of natural resources and reduce the environmental load as far as possible. As a result, in China circular economy became a fashionable topic and captured the attention of SEPA (State Environmental Protection Administration of China), which advocated the philosophy of closed-loop initiatives at the beginning of the century. SEPA, the first central government agency to foster the concept of circular economy, then started to support studies on this theme, submitted it to important stakeholders as the State Council, and in 1999 begun to launch pilot projects. Already in 2002, former President Jiang Zemin stated the necessity of promoting circular economy in China at the members of the Second Global Environment Facility, moving the first crucial step toward the law adopted in 2008.[82] Moreover, in 2004 the State Council appointed the National Development and Reform Commission (NDRC), a unit of the State Council studying Chinese economic situation and formulating and implementing economic and social development strategies, to take over the duty of pursuing a circular economy in the overall country. Indeed, when it was clear that this approach was an efficient response to environmental issues, the central government wanted to position the circular economy as a comprehensive state policy rather than simply as an environmental strategy.

[81] Mathews, J. A. and H. Tan, "Progress towards a Circular Economy in China: The drivers (and inhibitors) of eco-industrial initiative", *Journal of Industrial Ecology*, 2011.
[82] Yong, R., "The circular economy in China", *Journal of Material Cycles and Waste Management*, 2007.

Thus, even if SEPA continued to play an important role in supporting closed-loop projects, NDRC took the lead in guiding these plans.[83]

Analyzing the legal framework, three fundamental laws were approved by the country. The Law of Environmental Protection, passed in 1989, underlines the possibility for each local administrative unit to enact laws and regulations addressing environmental issues in accordance with local economic development and characteristics of environmental problems. Moreover, the Cleaner Production Promotion Law, approved in 2002 and effective from 2003, encourages cleaner production, resources utilization's efficiency, and sustainable development, while discourages pollutant agents. Cleaner production is supported not only at the firm level, but even at the inter-firm level and regional level, substantially providing the ground for eco-industrial development.[84] Furthermore, circular economy became the subject of one legal provision adopted in 2008, when China, under the NDRC pressure, enacted the "Law for the Promotion of the Circular Economy" that came into force on January 1, 2009. The aim of the law is to boost sustainable development by passing from the linear economy, where the environment provides raw materials and receives industrial and household waste, to the circular economy, where wastes of certain industrial activities are converted into inputs for others generating both ecological and economic efficiency. An example of circular economy is the Combined Heat and Power, already defined in this work, which is being considered in China as a principle of industrial design. This provision represents the first national law throughout the world proclaiming a different model of economy. Indeed, countries as Germany and Japan have already embraced similar regulations addressing environmental issues, but the Chinese law is the first one considering circular economy a pattern of socio-economic development.[85]

The government, under the law, monitors high-consumption and high-emission industries. Moreover, enterprises are required to introduce water-saving technologies and, for crude oil refining, power generation, steel, and iron production plants, to use clean energy (e.g. natural gas) instead of oil-guzzling fuel generators and boilers. They also have to utilize renewable

[83] Yuan, Z., J. Bi and Y. Moriguichi, "The Circular Economy: A New Development Strategy in China", *Journal of Industrial Ecology*, 2006.

[84] Fang, Y., R. P. Côté and R. Qin, "Industrial sustainability in China: Practice and prospects for eco-industrial development", *Journal of Environmental Management*, 2006, p. 325.

[85] Mathews, J. A. and H. Tan, "Progress towards a Circular Economy in China: The drivers (and inhibitors) of eco-industrial initiative", *Journal of Industrial Ecology*, 2011.

energies in new buildings, such as solar and geothermal energies, and recycle coalmine waste and coal ash. Those companies not respecting the provision could face fines of 50,000 to 200,000 yuan. The central government is even committed to fund enterprises to encourage innovation in recycling technologies and firms can get tax breaks for relying on environmentally desirable products and processes.[86]

This governmental effort has to be included within the 12th Five-Year-Plan (2011-2015), which has a particular focus on eco-efficiency.[87] Indeed, since the state exerts great control over much of the economy, every five years China approves economic development initiatives, named Five-Year-Plans, which are key indicators of the current Chinese development philosophy. In particular, in 2010 the 11th Five-Year-Plan (2006-2010) expired, which was described as revolutionary and signalled Chinese rethinking of economic strategies. During the considered period, China became a more powerful nation, where people's livelihood had improved and the country's status in the world had notably ameliorated. The plan, among multiple goals, promoted sustainable development and environmental protection as main principles on which base economic growth. Arguably, the focus on environmental harm was principally due to severe environmental degradation and previous inability of Chinese leadership to address the problem. The country then decided to link economic maturation to the carrying capacity of the natural environment, which is even the concept expressed in the definition of eco-efficiency given by the World Business Council for Sustainable Development. The plan set several targets that had to be achieved at the end of the five years, including energy consumption reduction of 20% per GDP unit, water consumption reduction of 30% per unit of industrial value added, reduction of emission of major pollutants by 10%, and increase of forest cover by 1.8%. All these objectives were indicated with the term "restricted", meaning that the government at the central level, as well as at local levels, was seriously obliged to meet them.[88] Indeed, it mobilized a national campaign to promote the "Top 1,000 Program", an initiative to bring energy efficiency among the top 1000 largest and least efficient energy consuming companies. Indeed, since these companies were causing the consumption of about one-third of the country's total energy, the targeted 20% reduction

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[86] The law is available at: www.fdi.gov.cn/pub/FDI_EN/Laws/GeneralLawsandRegulations/BasicLaws/P020080919377641716849.pdf (English Version).

[87] Mathews, J. A. and H. Tan, "Progress towards a Circular Economy in China: The drivers (and inhibitors) of eco-industrial iniziative", *Journal of Industrial Ecology*, 2011.

[88] Fan, C. C., "China's Eleventh Five-Year-Plan (2006-2010): From Getting Rich First to Common Prosperity", *Eurasian Geography and Economics*, 2006.

could be reasonably achieved.[89] In 2009, exactly a year before the schedule, the country already met three major environmental goals and, during 2010, other indicators improved showing the great country's commitment.[90] As an example, the energy intensity reduction fell into the range of 19.1 percent, just slightly under the planned 20 percent.[91]

The 12th Five-Year-Plan aims at moving one step forward, because it does not consider that it is sufficient to reduce industrial emissions and energy consumption; it looks instead for a way of completely renewing industrial processes in a more environmentally friendly direction. As is proved by the law for the circular economy, the entering plan provides a framework for progress and is going to build a cleaner and greener China, even because its politicians have clearly understood the importance of nature's safeguarding for humans' life and well-being. As China Daily affirms, the country is introducing harder environmental targets and the green and low-carbon sectors have been identified as the core of industrial strategies and as main pillars for growth.[92] In particular, the proportion of non-fossil energy consumption in primary energy consumption should reach 11.4%, carbon dioxide emission per unit GDP should be cut by 17%, and annual energy consumption per unit GDP should decrease by 16%.[93] Furthermore, the plan includes targets to improve the rate of forest coverage by just over 21%.

The 16% reduction of energy intensity, even if it is less than the 20% planned during the 11th Five-Year-Plan, seems to be a great challenge, since it should be realized by all those smaller and probably more energy efficient firms that were not included within the "Top 1,000 Program". In fact, the 11th Five-Year-Plan targeted large and inefficient plants, whereas the current Plan focuses on firms of different magnitude, including medium and small ones, launching the "Top 10,000 Program".

Considering carbon intensity, the established 17% reduction is an interim target that China set in order to meet the agreement it reached during 2009 Copenhagen climate negotiations. At that time, the country pledged by 2020 a 45% reduction of carbon exploitation from 2005 registered levels. In addition, the 12th Five-Year-Plan aims at establishing an improved system

89 Lewis, J., "Energy and Climate Goals of China's 12th Five-Year-Plan", *Pew Center on Global Climate Change*, 2011.

90 Yiqing, W., "Save energy for better future", *China Daily*, 2011.

91 Lewis, J., "Energy and Climate Goals of China's 12th Five-Year-Plan", *Pew Center on Global Climate Change*, 2011.

92 Chunyan, Z., "Low-carbon programs foster links with EU", *China Daily*, 2011.

93 Yiqing, W., "Save energy for better future", *China Daily*, 2011.

for measuring greenhouse gas emissions to evaluate the compliance with the carbon intensity target and to prepare greenhouse gas (GHG) reports. These last ones have to be submitted to the UNFCCC (United Nations Framework Convention on Climate Change), an international treaty joined by China and several other countries with the objective of reducing global warming.

Moreover, the 12th Five-Year-Plan considers many industrial policies to sustain clean energy industries and related technologies and to replace what are generally considered China's pillar industries: coal and telecom. It fosters indeed the development of solar, wind, biomass energy technology, and nuclear industries, as well as it supports hybrid and electric vehicles and all those technologies guaranteeing energy savings and environmental protection.[94]

Eco-Industrial Parks

In order to comply with the law promoting circular economy and with the incoming plan, best tools are eco-industrial clusters or parks. Because EIPs increase industrial growth as well as decrease pollution and waste, the economic and environmental win-win potential of eco-industrial strategies has captured the attention of Chinese policy-makers. Indeed, eco-industrial clusters or parks show all the benefits of traditional clusters, including Marshallian Trinity, access to public institutions and R&D centres, trust and cooperation among firms, linkages with global value chains, enhanced production capabilities… *etc*, but meanwhile are able to guarantee high environmental results due to by-products exchanges and resource efficiency.

As a result, the government is explicitly interested in these initiatives and controls EIPs development, planning and instructing their building and evolution. Fang *et al*. claim: "The Central Government of China plays key roles in promoting eco-industrial development through such aspects as decision-making, creating policies, issuing laws and regulations, organizing pilot activities, providing financial incentives, encouraging innovations in technology and systems, fostering mew markets and promoting both education and academic research partnerships".[95] As a result, eco-industrial parks are already widely dispersed throughout the country. The SEPA (State Environmental Protection Administration), the national Chinese agency of environmental protection, initiated the pilot construction of eco-

[94] Lewis, J., "Energy and Climate Goals of China's 12th Five-Year-Plan", *Pew Center on Global Climate Change*, 2011.

[95] Geng, Y., M. Haight and Q. Zhu, "Empirical Analysis of Eco-Industrial Development in China", *Sustainable Development*, 2007.

industrial demonstration parks in 1999 and established standards for building and management in 2006.[96] It published a comprehensive guide describing the concept of EIP and highlighting criteria and indicators for succeeding in EIP projects. The guideline represents the first national guide aiming at EIPs evolution and implementation. It defines industrial park as "land reserved by a municipal authority for industrial development; it includes an administrative authority for making provisions for management and enforcing restrictions on tenants and detailed planning with respect to lot sizes, access, and facilities".[97] The Eco-Industrial Park includes all the features of an industrial park, but "emphasizes the establishment of an industrial symbiosis network composed of varied industries".[98] To become an EIP, a park has to improve the overall eco-efficiency of the industrial area by relying on cleaner production, industrial symbiosis, and the circular economy. In particular, it has to respect certain strict criteria. First of all, the park has to comply with all the national and regional environmental regulations and, during the previous three years, no accidents related to environmental issues may happen. Then, the local concept of environmental quality must meet national targets. Finally, the SEPA and the local government have to approve the eco-industrial project. The SEPA has even identified appropriate indicators for EIPs that are grouped into four categories: economic development; materials reduction and recycling; pollution control; park management. These indicators can provide a detail picture of how the park is performing and are similar for all the three types of industrial parks –sector-integrated, venous, and sector-specific- with the only exception of the second category, materials reduction and recycling. For sector-integrated and sector-specific parks, key indicators of this category consider energy and fresh water consumption per added industrial value, industrial wastewater, and solid waste generation per added industrial value, the industrial water reuse ratio, and the solid waste integrated use ratio. For venous parks, key indicators refer to resource recycling and reuse, and include recycling and reuse ratios of discarded home electronic appliances, discarded abandoned vehicles, waste tires, and waste plastics. For the economic development category, added industrial value per capita and growth rate of added industrial value are the considered measures. For pollution control, principal indexes are SO_2 emissions per added industrial value, disposal rate of dangerous solid waste, waste collection systems, and environmental management systems. The last

[96] Fang, Y., "Eco-industrial parks in China", in *The Encyclopedia of Earth*, 2008. Available at: www.eoearth.org/article/Eco-industrial_parks_in_China

[97] Geng, Y., P. Zhang, R. P. Côté and T. Fujita, "Assessment of the National Eco-Industrial Park Standard for Promoting Industrial Symbiosis in China", *Journal of Industrial Ecology*, 2008, p. 16.

[98] *Ibidem*, p. 16.

category, park's administration and management, includes environmental report release and extent of public satisfaction with local environmental quality.[99]

The first EIPs were created in 2001, such as Guigang and Nanhai. Thereafter, other four parks, including Lubei, were approved in 2003, seven parks, including Suzhou and Tianjin, in 2004 and other three in 2005.[100] In 2008, the Ministry of Environment Protection together with other two ministries had already designated 30 Eco-Industrial Parks (EIPs). The most famous cases are: Guigang group; Pingdingshan coal mining group; Lubei chemical group; Suzhou Industrial Park; and Tianjin Economic Technological Park.[101]

As recognized by Fang, there are basically two types of eco-industrial parks: reconstructed parks and greenfield parks. The first type refers to those areas converted from previously existing industrial parks. The second type, instead, are new and purpose-built parks. Since greenfield parks require huge investments, there are few examples of them in China, whereas reconstructed parks are the predominant rule.[102]

The present work analyzes in detail the Guigang, Suzhou and Tianjin cases, which are all reconstructed parks. However, the Guigang case offers an example of a sector-specific park, whereas Suzhou and Tianjin are clearly sector-integrated development zones.

The Guigang group

The Guigang group (GG) is a sugar company in southwestern China, which controls one of the largest Chinese sugar refineries covering more than 2km^2. The GG offers an interesting example of industrial symbiosis, evolving over the past five decades from a stand-alone refinery to a site that is featured by symbiotic inter-linkages. It is today composed of several firms located in Guigang and employs over 3000 workers. The city of Guigang lies in a rural area of southeastern Guangxi Zhuang Autonomous Region, where sugarcane is a traditional crop due to the local natural conditions. In fact, this activity positively affects the Guigang economy, since sugarcane refinery and related industries employ 30% of the population

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99 *Ibidem*.

100 Fang, Y., "Eco-industrial parks in China", in *The Encyclopedia of Earth*, 2008. Available at: www.eoearth.org/article/Eco-industrial_parks_in_China

101 Mathews, J. A. and H. Tan, "Progress towards a Circular Economy in China: The drivers (and inhibitors) of eco-industrial initiative", *Journal of Industrial Ecology*, 2011.

102 Fang, Y., "Eco-industrial parks in China", in *The Encyclopedia of Earth*, 2008. Available at: www.eoearth.org/article/Eco-industrial_parks_in_China

situated in Guigang administrative area and account for about one-third of the area's GDP.[103] The local industries linked to the sugar industry include sugarcane planting, the paper industry, the alcohol industry, and the cement industry.[104]

The GG was founded in 1954 as a state-owned entity producing cane sugar, but then in 1994 the group was turned into a stock company and in 2001 had an ownership change in favour of a private company. Indeed, its facilities were sold to Shenzhen Huaqiang Holdings Limited, an enterprise committed to foster sustainable development. During these years, it developed both internally, by establishing new processes able to reutilize by-products, and externally, by building close relationships with suppliers (mainly sugarcane farmers) and the local government.[105] The group has always looked for a close relationship with its main suppliers in order to obtain adequate raw materials with high quality. Furthermore, it has aimed at producing high quality products, which are vital to gain market share and optimal economic benefits, while it has taken full advantage of the sugarcane, thus developing all industries able to use by-products and residual products. As a result, the Guigang Group produces the best quality sugar in China according to colour, sulphur, and impurity content, sharing a large market and establishing an average sugar price higher than that of other Chinese sugar refineries.[106]

Initially, the complex had an alcohol plant that used the molasses from the sugar operation run by the refinery. Over time, three paper mills were constructed and started to use bagasse (fibre residues from the crushing and grinding of raw sugarcane) as raw materials. Thus, the resulting high integration of material and energy by-product exchanges, together with relevant product quality, led to good profit and limited environmental burden. As a result, since 2000 the achievement of both ecological and economic efficiency by the GG has driven the attention of the State Environmental Protection Administration of China (SEPA) in Beijing. Therefore, SEPA gave its approval and offered its guidance to transform the group in an Eco-

103 Zhu, Q., E. A. Lowe, Y. Wei and D. Barnes, "Industrial Symbiosis in China, A Case Study of the Guitang Group", *Journal of Industrial Ecology*, 2007.

104 Zhu, Q. and R. P. Cote, "Integrating green supply chain management into an embryonic eco-industrial development: a case study of the Guitang Group", *Journal of Cleaner Production*, 2004.

105 Zhu, Q., E. A. Lowe, Y. Wei and D. Barnes, "Industrial Symbiosis in China, A Case Study of the Guitang Group", *Journal of Industrial Ecology*, 2007.

106 Zhu, Q. and R. P. Cote, "Integrating green supply chain management into an embryonic eco-industrial development: a case study of the Guitang Group", *Journal of Cleaner Production*, 2004.

Industrial Park. In July 2001, the Guigang Group formally became an EIP, the first national park designated by the central government.[107]

Altogether the group produces annually 120 kt of sugar, 85 kt of paper, 10 kt of alcohol, 330 kt of cement, 8 kt of alkali, and 30 kt of fertilizer, while it has two main value chains.[108] As Figure 1 describes[109], the sugarcane goes into the sugar mill and is processed either along the sugar chain or along the paper chain. The sugar chain produces sugar, alcohol, cement, and compound fertilizer. The sugar refinery uses the sugarcane juice released from the sugar mill to obtain a high quality refined sugar through a carbonation process. However, filter mud from the carbonation process can be hazardous for the soil if directly applied to the land. Thus, it is used as an input to the cement production facility, which is owned by the State but managed by GG. The GG pays for the transportation costs of filter mud, but generates savings from not having to pay disposal costs. Finally, the alcohol plant utilizes molasses produced by the sugar refinery to obtain alcohol, while alcohol residues, instead of being released into the environment, become inputs to the production of compound fertilizer that in turn goes back to the sugarcane fields.

Figure 1 is about here

The paper chain utilizes bagasses (residual products of the sugar mill) as raw materials, since 60% of the bagasse has fibres appropriate for papermaking. The short fibres, which are not useful for paper processing, become biofuel in a cogeneration power plant, guaranteeing heat and power to all other industrial processes of the group. The pulp is then processed by the paper mill, generating white liquor as a major waste that is then treated to obtain fibre and water, recycled to the paper mill. Moreover, the pulping operation needs significant additions of alkali, which subsequently forms the residual part of the operation. Therefore, an alkali recovery plant, built by the GG, collects these wastes in order to obtain recycled alkali and white sludge. The alkali goes again into the papermaking process, whereas the white sludge is used as an input to the cement mill.

Within the industrial complex, there is even an energy recovery chain that burns pith in the GG boiler house to power the plant, lowering emissions and eliminating pith's disposal costs.

[107] Zhu, Q., E. A. Lowe, Y. Wei and D. Barnes, "Industrial Symbiosis in China, A Case Study of the Guitang Group", *Journal of Industrial Ecology*, 2007.

[108] Mathews, J. A. and H. Tan, "Progress towards a Circular Economy in China: The drivers (and inhibitors) of eco-industrial initiative", *Journal of Industrial Ecology*, 2011.

[109] Figure 1 is at page 69.

The boiler house has air pollution control equipment consisting of a Venturi "dry" scrubber for large particulates, a wet scrubber for sulphur dioxide, and an electrostatic precipitator for small particulates. In 2003, sulphur dioxide emissions decreased from 11,200 tonnes per annum to 7,840 tonnes per annum. In addition, gypsum from the wet scrubber is given to farmers to reduce soil acidity. Finally, the recovered ash is given to cement making and road construction activities.

The GG was able to become part of a complex relationship network including the government, customers, suppliers, and competitors. Due to the great contribution of sugarcane industry to the local economy, all factors influencing the sector can indirectly affect the region. For this reason and for others reconnecting to the communist doctrine, the local government plays an important role in shaping markets and businesses and the GG had to establish a close relationship with it. The Guigang city government acts as an intermediary between the GG and farmers, setting prices and quantities. In fact, in 2004-2005 it set the sugarcane price that the GG had to pay farmers 50% higher than the average, reducing the group's competitiveness. The government aimed at ameliorating farmers' income and at encouraging sugarcane's plantation in order to meet regional requirements. Moreover, it also fosters symbiotic linkages, since generally the government asks the small sugar producers to send their by-products to the GG and, in turn, the GG has to meet certain by-product utilization targets set by the government itself. As a result of this governmental *modus operandi*, a collective tension between farmers, the group, and the government occurs, but this acts as a stimulus to improve efficiency and effectiveness of all parties and to better coordinate actions among them.

Furthermore, due to carbonation-refined sugar GG products show higher quality than its competitors, which still rely on sulfitation-refined sugar. The use of carbonic acid technology allows the GG to meet foreign and domestic requirements and, thus, it was able to gain several contracts with major soft drink companies, such as Coca-Cola, Pepsi-Cola, and Wahaha. Nevertheless, this technique makes the cost of production higher and increases waste's quantity. The GG solves the problem by using by-products in the cement plant, eliminating disposal costs and generating higher profits which offset carbonation costs. Zhu *et al.* recognize that the quality of sugar products ensures a price premium of 10%, while resulting symbiosis reduces pollution.[110] Moreover, as noted by Fang *et al.*, the Guigang group's

[110] Zhu, Q., E. A. Lowe, Y. Wei and D. Barnes, "Industrial Symbiosis in China, A Case Study of the Guitang Group", *Journal of Industrial Ecology*, 2007.

economic gains “lie in the reduction of raw material and energy costs, waste management costs, and costs resulting from environmental legislation, as well as the improvement of its environmental image to increase its green market potential”.[111]

In addition, since 2001 the group has established a great leadership in the paper manufacturing, which has become its major profit centre. Again, the quality of its products has played the biggest role. For example, the GG Technology Centre has developed new-patented technologies to produce high-quality toilet paper and the GG has reached better economic results, indeed it ranks third in domestic output.

Regarding competitors, the GG actually benefits from their presence, since it sources two-thirds of its bagasse’s requirements from local competitors, even including small actors operating in the area. In this way, the GG can improve its production scale for alcohol and paper, while it provides competitors with revenue for something that before they had to pay to discard, and at the same time minimizing environmental burden.

Considering the Marshallian trinity, the GG has certainly contributed to the development of two external economies identified by Marshall. First, it has created a long and profitable relationship with its suppliers, which have to ensure high-quality sugarcane. The company has signed long-tern contracts with farmers and even has provided them with technological support, seeds and organic fertilizer at a nonprofit price. For instance, in 2000 the GG gave farmers the necessary impulse to move toward organic production as a way for increasing competitiveness and margins. It has indeed guaranteed two organic fertilizers made from alcohol residue; the observable results were augmented sugarcane yields and increased sugar content of the cane. The size of the group is therefore able to foster supplier specialization and ameliorate suppliers techniques, benefiting both parties.

Secondly, the company has positively affected labour market pooling, since the modern technology adopted within the park requires top graduate and talented students. The GG has attracted several young educated people for research and production activities. A significant number of graduates from the Guangxi universities and technical schools has decided to move into the park instead of migrating toward more developed areas. Moreover, the GG itself has highly invested in training by supporting institutes, including the Sugar Refinery Institute,

[111] Fang, Y., R. P. Côté and R. Qin, “Industrial sustainability in China: Practice and prospects for eco-industrial development”, *Journal of Environmental Management*, 2006, p. 318.

Paper Institute, Environmental Protection Institute, Biotechnical Institute, and Automation Institute.[112]

The missing externality, technological spillovers, is absent because the park is not composed by different firms and, instead, all the plants are parts of the same group. Thus, the advanced technology adopted in production processes is commonly shared between all members with no need for spillovers between one company to another. The same argument can be made for complementarities and motivation pressure between corporations; the presence of one single enterprise makes impossible these attributes to occur.

Arguably, the Guigang Group is a case supporting Desrochers theory. Indeed, the development of industrial symbiosis has occurred as a consequence of profit-maximizing business decisions. First of all, the loop closing reduces the quantity of raw materials to buy, since a great part of inputs is obtained by threatening by-products of other industrial processes. Secondly, thanks to by-products utilization, disposal costs are greatly neutralized. Finally, as suggested by Fang *et. al.*, appropriately addressing environmental issues provides the company with a better image and it can then enlarge its market share. Therefore, the entire system has been created by people pursuing economic interests, which meanwhile had the chance to operate in an environmentally desirable direction. The central government arrived later; only when it realized the symbiosis was functioning well and that it could offer an example of environmentally friendly industrial activity, it nominated the group an Eco-Industrial Park. Certainly, by-products utilization targets set by the local government make some pressure on the GG, but the public effort toward Guigang industrial metabolism, whether central or local, has occurred only because the private effort has shown how economy and ecology could develop together, each one fostering its own objectives.

Suzhou Industrial Park

The Suzhou Industrial Park is located near the city of Suzhou, about 100 km far from Shanghai. The place is particularly favourable, because Suzhou lies in the resource-full Yangtze Delta region, also called the "Golden Triangle". The region includes eight important conurbations (e.g. Shanghai and Nantong), covering 43,000 square kilometres for a total population of more than 40 million. It is a region of productive agriculture, considerable

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[112] Zhu, Q., E. A. Lowe, Y. Wei and D. Barnes, "Industrial Symbiosis in China, A Case Study of the Guitang Group", *Journal of Industrial Ecology*, 2007.

water supply, advanced tertiary and research institutes, abundant industries, good infrastructure and financial services.[113]

In 1994 the China-Singapore Suzhou Industrial Park was formalized by three agreements made by the Chinese and Singaporean governments. It was viewed as an important project in fostering economic cooperation between China and Singapore. Indeed, the main developer (China-Singapore Suzhou Industrial Park Development Co., Ltd) was a joint venture between a Singapore consortium (Singapore-Suzhou Township Development Co., Ltd) and a Chinese consortium (Suzhou Industrial Park Co., Ltd). Most of the members of the Singaporean consortium were affiliated with the Singapore government and the Chinese consortium was composed by Chinese state-owned enterprises. From January 2001, the Chinese consortium has owned 65% equity stake of the joint venture and the Singaporean consortium the remaining part.[114]

Economic performance is impressive: in 2002 it showed an average economic growth of 47% and its GDP achieved RMB 25.2 billion (21 times of that obtained in 1994);[115] in 2008 import and export totalled over US $65 billion (increasing by 14% and 11% compared to 2007);[116] in 2010 GDP reached 133.02 billion yuan with a year-on-year growth of 14%, import and export accounted for US $73.82 billion, and urban per capita disposable income grew by 12.6%.[117]

The park was formally approved as EIP in 2004[118] and in 2008 it has been recognized one of the first three approved EIPs in China. It has attracted both local and foreign firms, counting 2,400 foreign-funded enterprises. It shows the presence of several industries, such as chemical, pharmaceutical, health care, machinery, electronics, IT, and software. SIP currently produces 16% of IC Chinese products and is the largest Chinese export base of LCD panels. Furthermore, firms in the park are well integrated in complex value chains. For instance, the IT value chain consists of upstream electronic chemicals manufacturers, semiconductor and

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[113] Wong, T. C. and C. Goldblum, "The China-Singapore Suzhou Industrial Park: A Turnkey Product of Singapore?", *The Geographical Review*, 2000.

[114] Inkpen, A. C. and W. Pien, "An Examination of Collaboration and Knowledge Transfer: China-Singapore Suzhou Industrial Park", *Journal of Management Studies*, 2006.

[115] Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/2002y/200607/t20060720_16558.htm

[116] Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/2009y/200902/t20090211_37392.htm

[117] Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/categoryreport/AuthoritiesAndPolicies/201102/t20110218_83811.htm

[118] Fang, Y., "Eco-industrial parks in China", in *The Encyclopedia of Earth*, 2008. Available at: www.eoearth.org/article/Eco-industrial_parks_in_China

TFT-LCD producers and downstream producers of finished products, while it is able to implement e-waste recycling. Moreover, the largest Chinese gas-fired cogeneration plant is in Suzhou park, functioning as a power generator, a heating system for both industrial activities and residents, and converting treated waste water into cooling water.[119] Suzhou has been prioritizing power conservation and consumption reduction and, in 2009, the total funds given by the government to follow this pattern exceeded 70 million yuan (more than US $ 10 million). Since 2006, 280 enterprises in Suzhou have obtained the title of clean production firms and 24 have activated the Star of Energy Efficiency Plan.[120] These energy efficient pilot enterprises have realized an amount of energy saving of 702,000 tons, reducing carbon dioxide emissions by 1.755 million tons, and have generated economic benefits of 7 hundred million yuan.[121]

In accordance with the 12th Five-Year Plan, Suzhou Industrial Park adopts a growth path based on technological innovation, circular economy, resource conservation, and environmental protection. The results are clear: for 10,000 yuan GDP correspond 0.33 ton of standard coal (one-third of the national average); Chemical Oxygen Demand per 10,000 yuan is one-eighteenth of the national average; and sulphur dioxide emission is one-fortieth of the national average.[122] The park's territory is covered by 45% of green area and, since it was founded, SIP has implemented about 300 projects concerning environmental issues, corresponding to a total investment of US $2 billion.[123] In February 2011, SIP was elected by the provincial government as one of the ten industrial parks experimenting low-carbon economies. Indeed, recently it has attracted industries related to low-carbon economies, energy saving firms, and green enterprises, gathering, therefore, the attention of prestigious universities such as Tsinghua University, Shanghai Jiaotong University, and Renmin University to locate their service platforms within SIP.[124] In March 2011, the park initiated a cooperation program in low-carbon and green innovation with Nanjing University, Menglan

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119 Mathews, J. A. and H. Tan, "Progress towards a Circular Economy in China: The drivers (and inhibitors) of eco-industrial initiative", *Journal of Industrial Ecology*, 2011.

120 Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/categoryreport/IndustriesAndEnterprises/201008/t20100830_70956.htm

121 Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/categoryreport/InfrastructureAndEcology/201012/t20101227_80558.htm

122 Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/news/201102/t20110228_84390.htm

123 Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/zhuanti/jg60n/gjlnbtsj/

124 Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/news/201102/t20110228_84390.htm

Group, Sujing Group, and US Institute for Sustainable Communities to establish a series of institutes and research centres either located within the park or at Nanjing University.[125]

An example of the policy fostered by SIP is provided by the Sino-French Environmental Technology, which in its SIP facility produces a sludge that can be used as a fuel, offering a great example of circular economy. As shown by Figure 2[126], the sludge from sewage treatment is converted into fuel for a thermal power plant. In particular, the sewage from the entire park is treated in appropriate plants to obtain recycled water and sludge. Sludge is processed in two phases: in the first stage it is dried to achieve a dryness level of 45%; in the second, it is moulded into granules with choppers and further dried to the level of 70-90%. Part of the surplus energy from the first stage is recovered to heat the second stage, saving energy consumption by 30% in comparison with traditional techniques. Then, recycled water is heated to be turned into steam needed by the thermo-power plant and dried sludge is mixed with coal to fuel the plant. Released steam is captured by a central heating/cooling system and then sent back to the park in the form of water. A ton of wet sludge becomes 0.1 ton of cinder (generated by the thermo power plant), which is recycled as secondary construction material. The waste gas is collected and processed before being discharged into the air. As a result, the entire process does not create any secondary pollution and the loop is perfectly closed.[127]

Figure 2 is about here

Moreover, in March 2011 the sewage treatment plant built and operated by Qingyuan Hong Kong & China Water (affiliated to China-Singapore SIP Public Utilities Development Group) in Suzhou won the prestigious Jiangsu Province Yangtze Cup Quality Award, the highest provincial honour. It is the biggest in Jiangsu Province, providing great resource efficiency in the overall park.[128]

Furthermore, the Moon Bay Community located within SIP is equipped with the Province's First Regional Central AC Systems. The Moon Bay central is composed of a heating system and a cooling system. The first delivers steam heat produced by local thermal power plant to the

[125] Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/categoryreport/InfrastructureAndEcology/201103/t20110321_85743.htm

[126] Figure 2 is at page 70.

[127] Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/news/201102/t20110216_83622.htm

[128] Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/categoryreport/InfrastructureAndEcology/201103/t20110302_84519.htm

buildings through pipelines, while the second uses lithium bromide refrigerating units to produce low-temperature chilled water. Both systems use steam energy, reducing the emission of Freon (a greenhouse gas) by 8,000 tons each year[129], and energy consumption by 34% in comparison with traditional AC system. In particular, the central is furnished with an integrated piping trench, which contains two centralized cooling and heating pipelines and seven-layer stand. It integrates power and water supply, AC, and telecom pipeline networks.[130] Every year the overall complex saves 3,390 tons of standard coal, reduces 8,000 tons of carbon dioxide emissions, and decreases about 70 tons of sulphur dioxide emissions and nitrogen oxides emissions respectively.[131]

SIP even offers several examples of renewables utilization. One is furnished by the Suzhou Institute of Architectural Design, which has 96 solar lighting systems providing daytime lighting from solar energy and consuming zero electricity. The system transmits light alone but no heat and filters ultraviolet rays, while the utilization rate of natural light reaches 97%. It offers stable performance and, apart from the sunlight, is able to capture the moonlight, starlight and the light coming from the whole city.[132]

In addition, in April 2011 L'Oreal Suzhou placed thousands of solar panels on the lawn east of Auchan in Suzhou Industrial Park in order to use more green energy. The project is the biggest photovoltaic power generation construction in Jiangsu Province and has 6,400 panels that will provide 15% of the yearly needed power, generating 1.6 million kWh each year. L'Oreal, which invested 50 million yuan in the project, allocated a total area of 25,000 square metres for the entire construction, including 15,000 square metres of roof area and 10,000 square metres of lawn, and expects to cut carbon emission by 12% each year.[133]

Similarly, in May 2011 Bosch Suzhou has officially launched its "Solar Modules from Bosch Solar Energy" project, constructing 126 solar panels on a 300 square metres area. The company has invested 1.2 million RMB to obtain an average of 100 kWh each day, which can

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[129] Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/news/201004/t20100408_62029.htm
[130] Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/categoryreport/InfrastructureAndEcology/201102/t20110217_83684.htm
[131] Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/news/201101/t20110119_82272.htm
[132] Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/categoryreport/InfrastructureAndEcology/201103/t20110309_84905.htm
[133] Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/news/201105/t20110510_89121.htm.

charge up over 500 electric vehicles, reducing the emission of 30 tons of carbon dioxide each year.[134]

Marshallian trinity is really favourable within the park, since SIP invests greatly in training and education through research centres, schools, and universities. The presence of more than two thousand firms and multiple public and private entities enhances technological spillovers and supplier specialization. The park covers several industrial sectors and value chains are well integrated, resulting in an island of qualified and advanced corporations. There are multiple research centres, including BioBay and China-Singapore Ecological Science Hub, funded by both the government and enterprises whose principal aim is to upgrade the park in each sector it operates. In addition, SIP offers education at all levels, starting from primary schools to arrive to universities. In fact, the park has several primary schools and high schools as well as one university. The Xi'an Jiaotong-Liverpool University, born from a partnership between the universities of Liverpool and Xi'an Jiaotong, is located within SIP and certainly guarantees the park young and talented students. Moreover, the prestigious Soochow University and the University of Science and Technology of Suzhou lie exactly in the city of Suzhou, a few kilometres from the park. To this, it has to be added the multiplicity of agreements that SIP has taken with several universities, institutional entities, and companies to promote innovation, technology and industrial symbiosis.[135]

Thinking about the 12th Five-Year-Plan, the park is heavily focused on talent programs and on acquiring the best available personnel. It wants to double the total number of high-end employees with master degrees and senior professional titles in order to become one of the leaders among national economic technological development zones and hi-tech development areas.[136] SIP aims at optimizing its structure and promoting high-end sectors, centring on IT and precision machinery, finance and service outsourcing, nano-tech industries, optical energy, bio-med, and, last but not least, ecological protection.[137]

SIP as well as Guigang group confirms Desrochers theory. In this specific case, environmental laws did not give any impulse toward eco-industrial initiatives. For instance, the park was

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134 Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/news/201105/t20110511_89193.htm.

135 Suzhou Industrial Park Official Web Site: www.sipac.gov.cn/english.

136 Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/categoryreport/AuthoritiesAndPolicies/201103/t20110318_85657.htm

137 Suzhou Industrial Park Official Web Site: http://www.sipac.gov.cn/english/categoryreport/IndustriesAndEnterprises/201103/t20110303_84592.htm

recognized as an EIP after it was already operating environmentally friendly business activities. Certainly, once the local and central government acknowledged the relevance of its ecological effort, they have started to foster the development of the park by means of programs funding and establishment of research centres. However, the economic benefits resulting from industrial ecology implementation have been of great significance, and have continuously provided incentives and motivation for both private companies and public-owned entities towards this growth path.

The Tianjin Economic-Technological Development Area

Tianjin Economic-Technological Development Area (TEDA) was founded in 1984 as one of the first development zones promoted by Deng Xiaoping's reforms. It is located on the northeast cost within the Tianjin Binhai New Area (TBNA), in the municipality of Tianjin city. TBNA covers 2270 square kilometres, has a coastline of 153 kilometres, and a population of 2 million people. Moreover, Tianjin Economic-Technological Development Area is about 45 kilometres east of Tianjin downtown and 130 kilometres southeast of Beijing city. TEDA lies in a favourable geographic position, since it is near the Tianjin port (the second for importance in the overall country), the international Tianjin Binhai airport, and is well connected through highways and railroads to Tianjin, Beijing, and other important airports.

TEDA built up area covers 45 square kilometres, of which 34 are destined to industrial activities and 11 to the residential zone. The first economic activity carried out within the park was salt-making;[138] then, since 1984 until now, 76 multinationals have established 158 enterprises.[139] 4,864 foreign-funded companies have been approved[140] and 9527 domestic firms have grown in the area.[141] By the end of 2010, the total cumulative investment since the early stages accounted for 61.6 billion dollars, while the real foreign investment registered 25.73 billion dollars. In 2009, the GDP was 127.40 billion yuan, the gross industrial output value corresponded to 420 billion yuan, and the gross export value accounted for 13.34 billion dollars.[142] For ten years, from 1998 to 2007, TEDA has been described by the Chinese Ministry of Commerce as the most attractive development zone in China for foreign

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138 Shi, H., M. Chertow and Y. Song, "Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological Development Area in China", *Journal of Cleaner Production*, 2009.

139 TEDA Official Web Site: http://en.investteda.org/linvinginnorthernchina/TEDA2/Overviewteda.

140 TEDA Official Web Site: http://en.investteda.org/FactsFigures.

141 Shi, H., M. Chertow and Y. Song, "Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological Development Area in China", *Journal of Cleaner Production*, 2009.

142 TEDA Official Web Site: http://en.investteda.org/FactsFigures.

investment.[143] In 2005, Mr. Wen Jiabao, Premier of the State Council of China, praised Tianjin Binhai New Area as "China's third economic growth engine after the Pearl River Delta and the Yangtze River Delta".[144]

The most important industries are: electronics (accounting for more than 40% of total gross industrial output); automobile & machinery (about 30%); biotechnology & pharmaceutical (about 5%); and food & beverage (about 3%). Electronics is largely TEDA primary anchor, and important brands as Motorola, Samsung, Fujitsu Ten, and Panasonic have built their own plants within the zone. The automobile industry has developed thanks to the German SEW-Eurodrive and to Toyota Motors and FAW (an important Chinese automaker), which in 2000 have decided to jointly invest in auto-making facilities. The biotechnological and pharmaceutical cluster has grown since 1994, when Novo Nordisk, even present at Kalundborg cluster, created one of its production bases within the park. Thereafter, other companies such as GSK and Servier have entered into TEDA. Finally, Coca-Cola, Nestle, Kraft, Pepsi, and Tingyi dominate TEDA food and beverage sector. In particular, the Taiwanese Tingyi has become the Chinese market leader in instant noodles, ready-to-drink teas, and sandwich crackers.

TEDA's focus on eco-industrial development is merely due to economic reasons. Indeed, TEDA has been aiming at consolidating its leadership among national economic-technological development zones and, therefore, has decided to enhance its investment climate and public image by adopting environmentally friendly business strategies. TEDA was the first development zone in China to establish its own environmental regulatory body, the Environmental Protection Bureau (EPB), which was created in 1990. Since then, external technical expertise has always been actively sought to assist the development process of eco-industrial initiatives. Consequently, TEDA environmental and pollution management has continuously improved, introducing tools as environmental impact assessment of new investment projects, monitoring of water and air pollution sources, pollution discharge levies, and control of pollutant emissions. In addition, TEDA is provided with its own government authority, called TEDA Administrative Commission, which is in charge of daily operations and

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143 Shi, H., M. Chertow and Y. Song, "Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological Development Area in China", *Journal of Cleaner Production*, 2009.

144 TEDA Official Web Site: http://en.investteda.org/linvinginnorthernchina/TEDA2/Overviewteda.

has always been heavily focused on implementing environmentally sound projects.[145] This commission furnishes to the overall park policy guidance and information platform. In 2003, it publicized "The Construction Plan for TEDA State Eco-industrial Demonstration Park" to develop eco-industrial chains among TEDA major industries and recycle projects as water regeneration and desalination. In this sense, the Commission has subsidized all the "eco-projects" through e.g. direct incentives or financing R&D on critical technologies. TEDA government has also conducted trainings and exchanges to promote information dissemination and public awareness for environmental protection. Finally, it has supported the creation of TEDA Recycle Economy Promotion Centre, which aims at solving technological and administrative problems linked to the development of recycle economy, and at fostering the evolution of the Eco-industrial Park.[146]

Thanks to the efforts of TEDA Administrative Commission and of the Environmental Protection Bureau, the industrial estate obtained in 2000 the ISO 14001 certification, showing the compliance with certain environmental standards and an effective environmental management system. Moreover, in 2004 SEPA nominated TEDA as an Eco-Industrial Park and in 2005 the National Development and Reform Commission, the Chinese macroeconomic management agency with broad control over economic and social policies, choose TEDA as a national pilot zone for demonstrating the circular economy model. In 2008 the Ministries of Environmental Protection, Commerce, and Science and Technology designated TEDA, together with SIP, as one of the first three Eco-Industrial Parks.

Since the early 1990's, TEDA has conserved and made efficient use of critical natural resources as water and usable land. The earliest symbiotic relationships were formed spontaneously across industrial companies in order to obtain economic cost-savings, while the ecological benefits were recognized later due to the environmental degradation of near areas. Indeed, nearby rural zones have faced severe farmland degradation because of the transfer of great amount of topsoil to the industrial area. To this, it has to be added the acute shortage of water resources faced by the entire region, which reasonably creates several concerns. Thereby, TEDA has developed a well-integrated symbiotic system, where water, energy, and materials are greatly exchanged. TEDA shows a total of 81 exchanges, energy

[145] Shi, H., M. Chertow and Y. Song, "Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological Development Area in China", *Journal of Cleaner Production*, 2009.

[146] Tan, R. and L. Bao, "Constructing Eco-industrial Park: the Road for Tianjin Economic-technological Development Area", *Journal of US-China Public Administration*, 2006.

exchanges accounting for 9%, water exchanges for 15%, and material-based exchanges for 76%. Water recycling started in 1995, when TEDA's first water treatment plant became operational. Thereafter, in 2000 the TEDA Wastewater Treatment Plant was put into operation, and in 2003 the TEDA Water Reclamation Plant was put into use. This last one was built by Tianjin TEDA Water Technologies Co., Ltd. and uses effluent of treatment plants as inputs, adopting micro-filtration (CMF) pre-treatment and a reverse osmosis (RO) process for deionization. In 2006, 1.43 million tons of RO-treated reclaimed water was supplied for industrial activities and 2.35 million tons of CMF-processed water for recharging an artificial wetland and for landscaping. In total, 1.26 million cubic metres of reclaimed water were purchased by industrial users in 2006. Generally, major users are Tianjin FAW-Toyota Motors Co., Tianjin Binhai Energy and Development Co., SEW-Eurodrive, and TEDA Eco-landscaping Development Co. In addition, in 2006 1.35 million cubic metres of tertiary treatment effluent were utilized for supplementing local water necessities.

Regarding energy exchanges, cogeneration systems are the rule rather than the exception in TEDA. The first cogeneration power station was put into operation in 1987 and nowadays TEDA has four thermal power plants supplying steam and hot water for industrial activities and residents. The low-pressure steam generated by thermal power stations can be used in desalination facilities, while the major part of water utilized by these stations comes from water treatment centres.[147]

Furthermore, TEDA is famous for its advanced wind turbines. Indeed, the wind energy industry is an emerging pillar of the development area and important companies as Vestas, Dongqi Wind Turbine, Sibre, MID American Supply Corp, and Zollern have already made up a complete wind energy industrial chain in the region.[148] The Danish company Vestas is the largest wind system supplier and boasts the latest R&D, manufacturing, sales, and maintenance expertise of wind turbines in the world. [149] Up to October 2009, its investment in TEDA mounted to 380 million dollars, accounting for over 70% of its total investment in China. Vestas entered TEDA in 2006 and, since then, has continuously expanded its production facilities. In 2009 Vestas built in TEDA its world's largest integrated wind energy equipment production base with products involving nacelles, blades, generators, control

[147] Shi, H., M. Chertow and Y. Song, "Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological Development Area in China", *Journal of Cleaner Production*, 2009.

[148] TEDA Official Web Site: http://en.investteda.org/aboutteda/keyindustriesbrief/wind/t20050126_64625.htm.

[149] TEDA Official Web Site: http://en.investteda.org/informationcenter/news/t20090319_65319.htm.

systems, and mechanical components. This production base is then enhancing the production capacity of Vestas in, China and guarantees advanced wind energy equipment manufacturing technology to China so as to provide hi-tech and hi-quality wind turbines.[150] Furthermore, an important Vestas supplier is MID American Supply Corp, which opened its plants in TEDA in 2009. The American company is the largest trader and producer of composite for wind turbine blades in China and is one of the top 200 tax contributors of Tianjin city. In particular, it is specialized in the R&D of high-performance epoxy resin and other reinforced fibrous materials. Its epoxy resin has obtained the ISO14001:2004 certification of environment management.[151]

Considering facilities' exchanges, Figure 3 shows an interesting example[152] characterized by energy and resource efficiency. In particular, the water coming from the nearby lagoon goes into TEDA Water Treatment Plant, which, after having purified it, sends the water to Guohua Cogeneration Plant, to industrial, commercial and residential users, and to Binhai Energy Cogeneration Plants. Guohua and Binhai Energy Cogeneration Plants provide fly ash to construction companies, which utilize it as a secondary construction material, bottom ash to TEDA Eco-landscaping Co., and steam to industrial, commercial, and residential users. Indeed, 98,591 tons of fly ash and bottom ash were used in 2006 for constructing and landscaping. TEDA Eco-landscaping Development Co., Ltd. is a company that generated an innovative technology able to produce new soil from solid wastes, such as sea sediments, caustic soda sludge, and ash from thermal power plants. In this way, neighbouring farmland topsoil is less exploited and nearby rural areas are more preserved. Binhai Plants even guarantee low-pressure steam to a desalination plant, and recycle condensate from large steam users, such as automobile manufacturers, to obtain other steam. The desalination plant treats seawater coming from Bohai Bay, guaranteeing pure water to residential and industrial actors. Furthermore, TEDA Shuanggang Municipal Waste Energy-Recovery Incinerator, which began operation in 2004, converts each year 400,000 tons of solid waste into energy, achieving about 120 GWh. It also recycles bottom ash to make floor tiles and uses fly ash to obtain haydite, a lightweight aggregate. Finally, the sewage generated by the entire park goes into the TEDA Wastewater Treatment Plant, which separates sewage's liquid and solid components, and sends treated effluent to TEDA New Water Source Co., Ltd. This company then supplies reclaimed and pure water to residential and industrial users, including

[150] TEDA Official Web Site: http://en.investteda.org/informationcenter/news/t20091027_66761.htm.
[151] TEDA Official Web Site: http://en.investteda.org/informationcenter/news/t20090928_66656.htm.
[152] Figure 3 is at page 71.

cogeneration plants. The sludge instead (which is sewage's solid component) can be employed as cement raw material and, in 2006, 1400 tons of sludge were recycled with this end.

Figure 3 is about here

Considering material exchanges, companies working in the electronics industry as Motorola, Tianjin Samsung Electronics, General Semiconductor, and Tianjin Fujitsu Ten Electronics recycle spent lead solder materials, CRT glass, waste oil, and silver extracted from electroplating residues. In 2006, 16 tons of spent lead-containing electronic solder were recycled for solder materials.[153] For instance, the tin soldering paste Motorola discards becomes input for Rising Co., Ltd., while the high qualitative soldering paste is transformed into paste end product with lower quality. Moreover, Motorola is heading for zero-discharge of wastewater in the process of mobile phone production and is at the centre of a closed recycle of packing paper. In fact, Motorola wasted packing paper is reclaimed by Tangshan No.1 Packing Factory, then re-pulped by Lingxian Environmental Protecting Packing Co., Ltd. and, finally, converted into mobile phones packing moulds for Motorola again.[154]

Within the food and beverage sector, enterprises as Tianjin Tingyi International Food, Tianjin Nestle, and Kraft Tianmei Food, sell their food scraps to neighbouring farms that use them to feed animals. In 2006, more than 3700 tons of food wastes were made into animal feed.[155] For instance, Tingyi produces waste flour crumbs, which can be used as feeds for the nearby aquatic farm, while the fish-cultivating water, since it is really nutritious, can be employed for irrigating neighbouring farmlands. Moreover, the wastewater produced by Tingyi can be regenerated and then used for green lands irrigation.[156] In addition, Tianjin Tingfung Starch Development Co., Ltd. offers its starch scrap to a local coal briquette factory to produce coal briquette, while Chia Tai Tianjin Industrial Co. supplies fatty acid and lecithin to food producers.

[153] Shi, H., M. Chertow and Y. Song, "Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological Development Area in China", *Journal of Cleaner Production*, 2009.

[154] Tan, R. and L. Bao, "Constructing Eco-industrial Park: the Road for Tianjin Economic-technological Development Area", *Journal of US-China Public Administration*, 2006.

[155] Shi, H., M. Chertow and Y. Song, "Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological Development Area in China", *Journal of Cleaner Production*, 2009.

[156] Tan, R. and L. Bao, "Constructing Eco-industrial Park: the Road for Tianjin Economic-technological Development Area", *Journal of ,US-China Public Administration*, 2006.

The biotechnological and pharmaceutical cluster shows an interesting example of industrial symbiosis thanks to the Danish bioengineering company Novozymes. Indeed, its bulk production waste, which are spent biomass with high levels of nitrogen, phosphorus, potassium, and other organic materials, has been transformed into a solid organic fertilizer named NovoGro®30. This fertilizer is useful for TEDA land reclamation and farmland fertilization, and is supplied free of charge. In 2006, 23,193 tons of NovoGro were used in nearby greenery, orchards, and farms.[157] In addition, Novozymes has a great volume of wastewater discharge and, for this reason, has built its own wastewater treatment factory with a capacity of 2000 tons per day. Thus, apart from utilizing the treated water for irrigating its lands, it furnishes water to TEDA Eco-landscaping Development Company, which needs it for irrigating greenery, and to TEDA Public Works Company, which utilizes it for road cleaning.[158]

Finally, in the automobile & machinery cluster closed loop initiatives characterize several companies. Toyota auto making facilities recycle scrap galvanized sheets as raw materials and auto moulds; in 2006, 12,000 tons of scrap-galvanized plates were used for auto-making. Furthermore, Tianjin Toyotsu Resource Management Co., Ltd. has annual scrap recycling capacity greater than 60,000 tons, whereas Tianjin Toyotsu Aluminium Smelting Technology Co., Ltd. produces molten aluminium for Tianjin FAW Toyota Engine Co., Ltd. from locally produced and imported aluminium scrap. Tianjin TOHO Lead Recycling Co., Ltd., the first environmentally sound recycler of used lead-acid batteries and other lead waste in the Tianjin and Beijing regions, recycles lead waste from enterprises as Motorola and used lead-acid batteries coming from all the Tianjin and Beijing regions.[159] Furthermore, as shown by Figure 4[160], Tongyee Industry Co., Ltd. provides an example of eco-industrial chain. The batteries discarded by end-consumers are reclaimed by a regeneration company and, then, the resulting regenerated lead is used by Tongyee for battery production. In addition, Tongyee lead-containing waste is treated by Tianjin Jinghai Fuqiang Metallurgical Co., Ltd.,

[157] Shi, H., M. Chertow and Y. Song, "Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological Development Area in China", *Journal of Cleaner Production*, 2009.

[158] Tan, R. and L. Bao, "Constructing Eco-industrial Park: the Road for Tianjin Economic-technological Development Area", *Journal of US-China Public Administration*, 2006.

[159] Shi, H., M. Chertow and Y. Song, "Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological Development Area in China", *Journal of Cleaner Production*, 2009.

[160] Figure 4 is at page 72.

transformed into regenerated lead, and used again by Tongyee during the production process.[161]

Figure 4 is about here

Looking closely at the park, it is possible to see the Marshallian trinity at work: supplier specialization is enhanced due to the presence of multiple enterprises and industries operating in large scale; spillovers, on one side, are fostered by the clustering of important brands that even work in high-tech sectors and, on the other, by several universities and institutions that encourage research and development; finally, labour market poling, managed by the TEDA Service Centre for Human Resources, is composed of an important basin of high-skilled employees coming from several universities and technical schools. Tianjin is rich in higher education resources, having 55 higher education institutions supplying about 60,000 graduates annually. The most important universities are: Tianjin University, Nankai University, Hebei University of Technology, Tianjin Normal University, Tianjin University of Finance & Economic, and Tianjin Foreign Studies Universities. In addition, 30 educational institutions, including Tianjin University of Science and Technology, TEDA College of Nankai University, TEDA Foreign-Related Vocational Secondary School, Tianjin Beida Jade Bird High Vocational School, Tianjin Maritime Vocational Institute, and Tianjin Institute of Biological Engineering, are located within TEDA. Furthermore, TEDA has 54 post-doctoral stations and 23 post-doctoral innovation bases. At the end of 2009, it had 375,000 employees, of whom 170,000 were managers and technical professionals, 205,000 high-quality skilled personnel, and 202 post-doctoral employees.[162]

In addition, TEDA is not only a place to work; instead, it is even a place to live. Indeed, the park strives to create a fashionable and elegant living atmosphere for its citizens, offering bars and restaurants, supermarkets, shopping malls, stadiums, libraries, sport centres, cinemas, theatres, post offices, banks, churches, hospitals, and so on. Thus, apart from being a successful industrial development zone, it constitutes a highly liveable community.[163]

Finally, Shi, Chertow and Song, supporting Desrochers theory, believe that the sustainability of TEDA industrial symbiosis relationships depends heavily on their economic feasibility. Certainly, public institutions have the chance to foster and help symbiotic exchanges through

[161] Tan, R. and L. Bao, "Constructing Eco-industrial Park: the Road for Tianjin Economic-technological Development Area", *Journal of US-China Public Administration*, 2006.
[162] TEDA Official Web Site: http://en.investteda.org/doingbusiness/employment.
[163] TEDA Official Web Site: http://en.investteda.org/linvinginnorthernchina/TEDA2/Overviewteda.

incentives, lower fees, educational and training programs, and regulations, but they would not be able to establish from the early stages successful industrial symbiosis examples. When symbiotic benefits do not include economic savings, no one will engage in eco-industrial initiatives.[164] Surely, in TEDA the concern toward the surrounding environmental degradation has played an important role in developing the Eco-industrial Park, since it has given the direction to follow, and has dictated which resources had the priority to be safeguarded. However, neither water scarcity or farmland problems, nor environmental regulations, which arrived after eco-industrial projects had already been carried out, have transformed TEDA in one of the first three Chinese Eco-industrial Parks; only profit-maximizing decisions can do that.

EIPs and renewables: an international comparison

If other important countries, as the US, are studied, it will appear how they are behind China in terms of efforts, results, way of thinking, and legislation addressing environmental issues. Gibbs and Deutz, basing their analysis on a study conducted on ten Eco-Industrial Parks in the US and six in Europe, affirm that these areas show absence of inter-firm exchanges and interactions and very few sites have plans to either monitor or develop targets for waste, emissions or energy use. Consequently, only few locations among those considered can be viewed as closed systems. Moreover, both in the USA, where eco-industrial strategies are encouraged by the Federal government, and in Europe the sites reveal high levels of public sector involvement, because they are seen as part of local economic development strategies fostering eco-efficiency and positive economic results of participant firms. However, they do not appear central planks of policy, but rather they seem isolated responses to the need of touching the environmental issue, while continuing on the road of the traditional linear economy. Furthermore, USA and UK companies argue that existing regulations act as a deterrent to the establishment of symbiotic relationships between firms. For instance, the definition of a substance as hazardous waste under the US Resource Conservation and Recovery Act prohibits recycling, whereas UK waste management regulations inhibit symbiotic relationships due to regulations on storage of wastes.[165] This argument is even confirmed by Mathews and Tan, Desrochers and Gertler. According to Mathews, countries, such as the US, Germany, and Japan, have environmental laws, for example laws on toxic

[164] Shi, H., M. Chertow and Y. Song, "Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological Development Area in China", *Journal of Cleaner Production*, 2009.

[165] Gibbs, D. and P. Deutz, "Reflections on implementing industrial ecology through eco-industrial park development", *Journal of Cleaner Production*, 2007.

wastes and their control, which may discourage inter-firm exchange of wastes. Furthermore, as it has already been explained, Desrochers and Gertler sustain that the take-off of Kalundborg eco-linkages was partially due to the flexibility of Danish environmental laws.[166]

In addition, even if we consider the particular case of renewable energies, we see how China is leading the global race towards clean fuels. As explained by Mathews, investing in renewable energies constitutes an important point of latecomers' catching up, since these fuels have demonstrated several advantages over oil-based conventional systems. These are many and include: being more competitive and cheaper than fossil fuels; being able to guarantee energy security as opposed to dependence on unstable oil prices and political decisions; the capacity to produce less amounts of greenhouse gases; the chance to foster rural development; the provided alternative of building new export industries; their excess supply in developing countries (as in the case of sugarcane crops providing biofuels); and the fact that they do not generally require high levels of expertise and scientific knowledge. Therefore, from promoting renewables, latecomers have everything to gain and nothing to lose: fossil fuels are clearly expensive and untrustworthy, while clean fuels are anything but certain.[167]

In China development of renewable energy has received an important boost with the passage of the "Renewable Energy Law" in 2005. The law aims at promoting the development of renewables, protecting the environment, preventing energy shortages, reducing dependence on imported energy, and realizing the sustainable development of the economy and society. It focuses on incrementing the use of renewable energy capacity up to 10% by 2020 by encouraging the construction of renewable energy power facilities, offering financial incentives to foster renewables development, and also discounting taxes for renewable energy projects.[168]

As a result, China has leapfrogged developed countries as Denmark, Germany, Spain, and the United States, to become the world's largest maker of wind turbine and the world's largest manufacturer of solar panels.[169] Moreover, China is the world's largest producer and consumer of solar water heaters, accounting for 50% of the world's total production and 65% of installations. It produces 300,000 tons of biodiesel annually from cottonseed oil, wood oil,

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[166] Mathews, J. A. and H. Tan, "Progress towards a Circular Economy in China: The drivers (and inhibitors) of eco-industrial initiative", *Journal of Industrial Ecology*, 2011.

[167] Mathews, J. A., "Latecomer strategies for catching-up: the cases of renewable energies and the LED programme", *International Journal of Technological Learning, Innovation and Development*, 2007.

[168] The law is available at: http://www.ccchina.gov.cn/en/NewsInfo.asp?NewsId=5371.

[169] Bradsher, K., "China Leading Global Race to Make Clean Energy", *The New York Times*, 2010.

tea oil, and used oil. Also, high-quality and self-cultivating energy plants such as Jatropha are greatly available. Finally, the country has even the chance to exploit 600 million tons of straw and forestry waste to produce cellulosic ethanol.[170]

Indeed, this work has already presented three examples of renewable energy production: the biofuel utilized in the Guigang Group to power a cogeneration plant, which is obtained from short fibres not useful for paper processing; the Suzhou Industrial Park solar panels constructed by the Suzhou Institute of Architectural Design, L'Oreal, and Bosch; TEDA famous wind turbines producing clean energy.

Chinese top leaders are intensely focused on energy policy and in 2010 a National Energy Commission, led by Prime Minister Wen Jiabao itself, was formed. Its main purpose is to draft new energy development strategy, coordinate international cooperation on climate change, carbon reduction and energy efficiency, and evaluate energy security. Policy makers have also set mandates for power generation companies to increment their reliance on renewables, have established loans to allow the renewable "take-off", have created incentives for household installations of solar panels and solar water heaters, and have charged a renewable energy fee to all electricity users, increasing residential electricity bills by 0.25% to 0.4% and average industrial electricity expenses by 0.8%.

As noted by Bradsher, important multinationals have already entered the Chinese renewable energy market, as in the case of the Danish Vestas, which in 2009 opened the world's largest wind turbine manufacturing complex in Tianjin Economic-Technological Development Area. As declared by the President of Vestas China, Jens Tommerup, "nobody has ever seen such fast development in a wind market".[171] However, it is important to stress that in countries as the United States, where the power equipment market is mature, power companies have to decide to buy renewable energy equipment or to continue with fossil-fuel-fired power plants, choosing frequently the second option because traditional plants are already installed and have already been paid for. Instead, in China, where the market is greatly less developed than western countries, the latecomer effect has produced positive results: power companies have to invest in new equipments anyway, often deciding for renewables due to their

[170] J.P. Morgan's Hands-on China Report, "China's Clean Revolution", 2009.
[171] Bradsher, K., "China Leading Global Race to Make Clean Energy", *The New York Times*, 2010.

competitiveness. To this, we have to add the Chinese low-cost advantage: as an example, Vestas pays its workers about $4,100 a year. [172]

Gregory Unruh believes that industrial economies have become locked-into fossil fuel-based energy through co-evolutionary processes among technological infrastructure, organizations, society, and governing institutions, giving birth to what he calls a techno-institutional complex. This articulated entity, involving the government, enterprises, and the public, has developed upon conventional energy sources and creates difficulties for western countries to adopt renewables.[173]

Moreover, Benjamin Sovacool, substantially confirming Unruh's theory, sustains that the carbon lock-in of the United States is due to "socio-technical" impediments, which encompass technological, social, political, regulatory, and cultural reasons. In his opinion, multiple factors have brought to the heavy reliance of the United States on fossil energies. From an economic point of view, consumers ignore clean energies because they do not have access to accurate electricity price signals, and the existing system prices electricity in a manner that favours conventional sources. Indeed, American regulators have always focused on making electricity abundant and cheap by subsidizing all forms of energy to protect consumers from true costs of extraction, generation, distribution, and use. To provide an example, in 2007 fossil fuelled and nuclear power generators exacted $420 billion in damages that were not reflected in electricity prices; in fact, the American electricity industry reported for the same year an amount of $277 billion revenues, $143 billion less than the declared damages. Furthermore, consumers expect excessively short payback times (correspondent to three years or even less) for investments in energy technologies, while the real payback period for renewables is longer. For instance, commercial solar power installations have a payback time between five and nine years. In addition, most small and large enterprises are not interested in investing in renewables because they believe that required technologies deviate from their own mission. Even though these businesses obviously use electricity, the aims they promote are not considered interoperable with becoming a micro- or quasi-utility. In other words, most businesses have goals and priorities that have nothing in common with electricity and, consequently, they do not want to engage with renewables promotion. Moreover, customers are used to big monopolistic entities managing the whole electricity production and distribution; thus, economically they do not feel confident to face such big competitors, and

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[172] *Ibidem*.
[173] Unruh, G. C., "Escaping carbon lock-in", *Energy Policy*, 2002.

culturally they are not use to it. Finally, conventional utilities often charge high rates to those using renewable energy systems intermittently. Indeed, when renewable energy generators are not working, its users have to rely on conventional electricity distributors, which may ask for higher prices than those normally charged to constant users.

From a political point of view, the government and public agencies have often manifested disinterestedness toward renewables and have, therefore, influenced utilities and interest groups. The political support for clean energies was frequently inconsistent, and if conventional generators have always achieved subsidies and incentives, the same cannot be said for renewable energy providers: policies addressing renewables have constantly changed and have thus caused a lack of confidence among the public. For instance, conventional sources have received almost 90 percent of all subsidies for the past six decades, causing an underfunding of R&D on renewable power technologies by both public and private capital.

From a behavioural point of view, Sovacool suggests that American public ignorance towards electricity is another obstacle to clean energies. Many Americans believe that they have access to abundant and cheap sources of electricity, but they do not know what they should do to continue to rely on electricity. In fact, while utilities and operators have exploited this ignorance to maintain their profitable control, for most of the past five decades citizens have placed faith in continuous material progress and high-technological development, convinced that energy supplies are never-ending and always accessible. They have never thought about replacing conventional systems, above all because they are unaware of environmental issues and are not really informed about renewables.[174]

In one speech held in 2010, President Obama recognized that the US was falling behind China on the energy theme and stated: "I do not accept a future where the jobs and industries of tomorrow take root beyond our borders".[175] Anyway, there is the chance that western countries will reduce their heavy dependence on fossil fuels coming from the Mideast, while incrementing their reliance on Chinese gear as solar panels and wind turbines.[176]

5. Conclusion

[174] Sovacool, B. K., "Rejecting renewables: The socio-technical impediments to renewable electricity in the United States", *Energy Policy*, 2009.
[175] Bradsher, K., "China Leading Global Race to Make Clean Energy", *The New York Times*, 2010.
[176] *Ibidem*.

Arguably, there is the chance that economic success does not mean natural resource exploitation. Multiple studies and examples have shown how protecting the environment and its resources can positively affect industrial performance. Even if China has created its impressive economic growth at the expense of nature, it is now the time to change things. The Chinese government has already perfectly understood the importance of the natural environment surrounding us and its provision of the necessary resources for business activities and human life. And, also, it has perfectly understood that safeguarding the environment can even accelerate industrial growth and profit accumulation. As explained by Guigang, Suzhou, and Tianjin cases, within eco-industrial parks the benefits characterizing traditional clusters tend to be added to the benefits of industrial symbiosis, ultimately generating a green and successful way to further develop. Indeed, Marshallian external economies offer advantages that firms cannot find elsewhere; and eco-linkages among co-located firms reduce wastes and lower input prices and transaction costs.

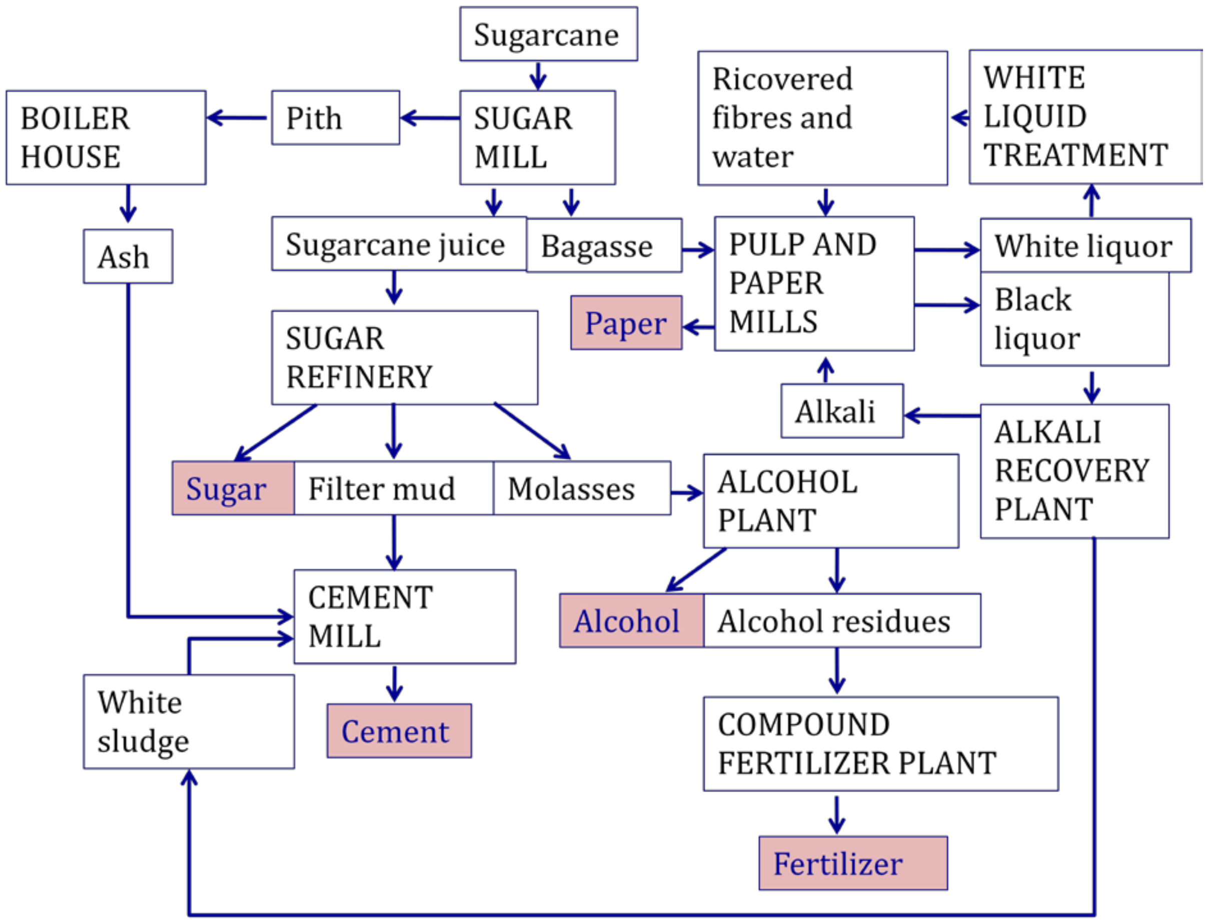
China is exploiting its latecomer advantage by grounding its growth path on industrial clusters and industrial ecology. By linking economic profit to environmental protection, China is laying down its successful pattern in a cleverer and more creative way than developed countries. Its late arrival has given the chance to learn and imitate, as in the case of German and Japanese environmental regulations or of Danish Kalundborg example. And now the country is proving to be even more determined than its advanced competitors to foster a sustainable development. Even if the industrial symbiosis concept comes from the western world, no country has demonstrated the same legal and institutional framework, and the same number of eco-industrial initiatives as China's. Linking to global actors, leveraging its national resources, and learning from its western competitors, the country has absorbed and improved their technologies, information, and ideas without having to make similar errors, thus sparing the amount of time, energy, and economic resources developed actors needed to discover them.

China is already heading several developed countries in EIP's implementation and renewables exploitation. For the number of successful Eco-Industrial Parks, for the advanced environmental legislation, and for its commitment on low-carbon alternatives, the dragon is showing the difference between being committed and appearing to be committed, the difference between taking the lead and merely following. As shown by Gibbs and Deutz, in western countries, apart from some exceptions, eco-industrial parks have not took-off yet. On the contrary, we have seen how Chinese EIPs show Marshallian externalities, advanced R&D

centres, several public institutions, and profitable eco-linkages among firms. In addition, Bradsher states that China has recently leapfrogged the US and other European nations in the wind turbine and solar panel themes. And Sovacool explains that this is merely the result of a socio-technical embeddedness that tightly links the whole industrialized society with non-renewable energies. In other words, while China is understanding and learning the new green streets towards an increasing economic growth, the western world is still thinking about how to forget its past, traditions, and behavioural patterns.

This emergent dragon has already taken its decisive step toward a new and sustainable era: the law promoting circular economy, the 12th Five-Year-Plan, and successful cases as those provided in this work prove to the world how this country is greatly determined to go beyond, better than before and further than before. Without any doubt, it is one of the future leaders of the world economy.

Figure 1



Source: Zhu, Q., E. A. Lowe, Y. Wei and D. Barnes, "Industrial Symbiosis in China, A Case Study of the Guitang Group", *Journal of Industrial Ecology*, 2007.

Figure 2

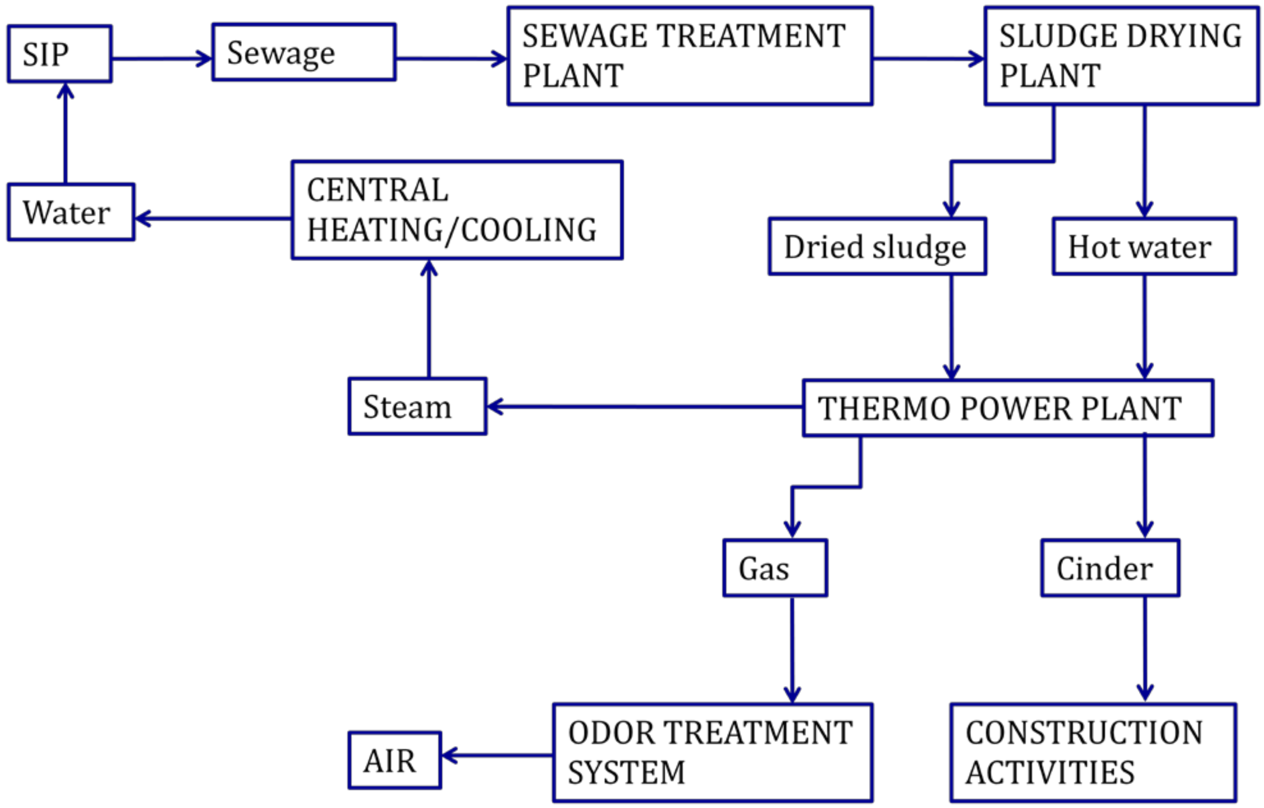


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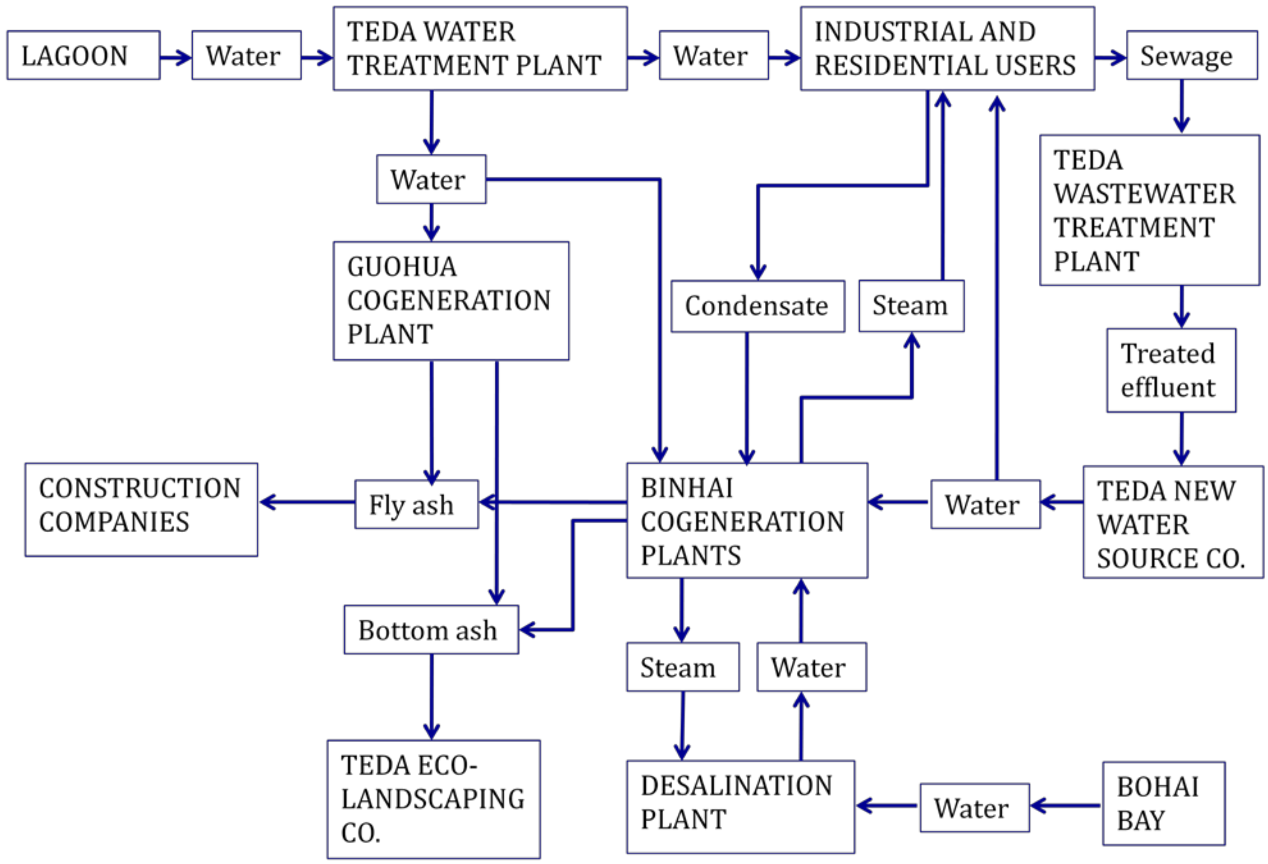
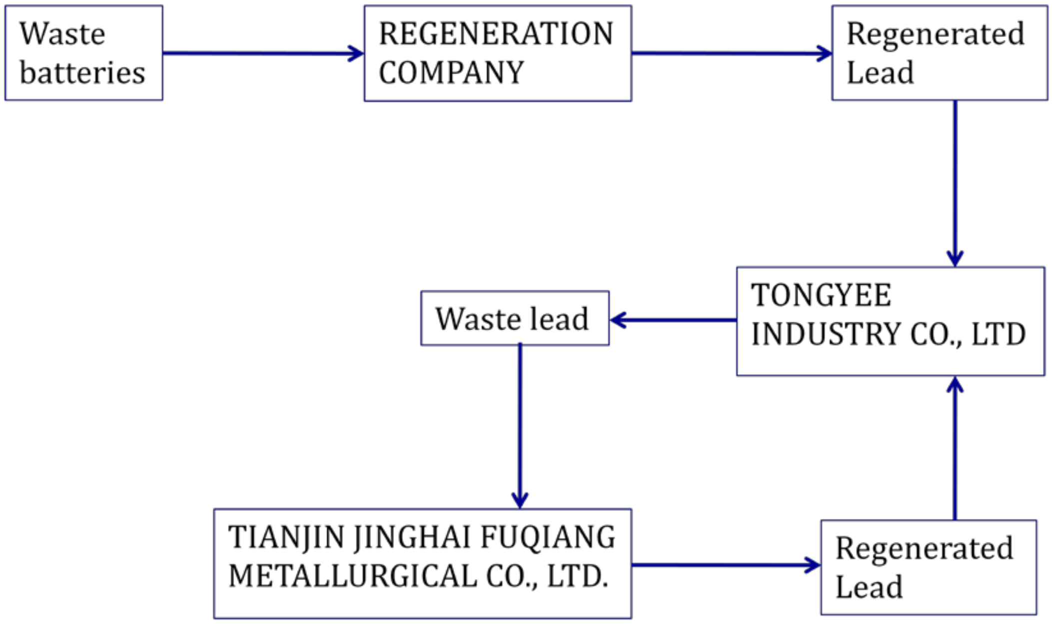
Figure 3



Source: Shi, H., M. Chertow and Y. Song, "Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological Development Area in China", *Journal of Cleaner Production*, 2009.

Figure 4



Source: Tan, R. and L. Bao, "Constructing Eco-industrial Park: the Road for Tianjin Economic-technological Development Area", *Journal of US-China Public Administration*, 2006.

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