CZECH UNIVERSITY OF LIFE SCIENCES

Faculty of Tropical AgriSciences

Department of Sustainable Technologies

Czech University of Life Sciences Prague

Faculty of Tropical AgriSciences

Review of the Implementation of China's Circular Economy Framework at the Tianjin Economic-technological Development Area

Bachelor Thesis

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Supervisor:
doc. Ing. Vladimír Krepl, Csc.

Author:
Vojtěch Vosecký

DECLARATION

I hereby declare that the present Bachelor Thesis: „***Review of the implementation of China's circular economy framework at the Tianjin Economic-technological Development Area*"** is my own work and effort. Together with my thesis supervisor guidance I have only used correctly and properly cited scientific and statistical references, as stated at the end of this thesis. As an author, I also declare that I have not violated copyrights of any third parties while working on this thesis.

In Prague, 16.4.2015 ___________________________

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ABSTRACT

In order to address the pollution and resource scarcity associated with rapid development, China has officially accepted and proposed Circular economy (CE) sustainable development strategy in 2002. Since then, CE framework has been implemented in a number of pilot projects across China. This paper provides the literature review on the CE by examining the concept, current practices and CE assessment at the Tianjin Economic-technological Development area (TEDA). To support the review and quantify the results, TEDA´s environmental performance indicators focused on waste, water and energy management are presented. Based on the examination and comparison of the indicators, it was concluded that TEDA has managed to improve its environmental performance in all the examined sections between years 2008 and 2011. Underlying challenges and problems of the China´s CE are also discussed.

Keywords: China, Circular Economy, Environmental Impact, Eco-Industrial Park, Environmental Management, Tianjin Economic-Technological Development Area

ABSTRAKT

Za účelem vypořádat se s materiálním nedostatkem a aktuálním stupněm znečištění, Čína v roce 2002 přijala koncept Cirkulární ekonomiky (CE) jako součást své strategie pro udržitelný rozvoj. Od té doby byl koncept CE realizován v několika pilotních projektech po celé Číně. Tato literární rešerše zkoumá jak definici konceptu CE, tak současné postupy a výsledky s ním spojené na Ekonomicko-technologické rozvojové oblasti Tianjin (TEDA). Pro lepší přehled a porovnání jsou v práci prezentovány jednotlivé ukazatele stavu životního prostředí se zaměřením na vodní, odpadové a energetické hospodaření v TEDA. Na základě porovnání a přezkoumání výsledků dochází autor k závěrům, že se v TEDA podařilo mezi lety 2008 a 2011 zlepšit všechny zkoumané ukazatele životního prostředí. V práci jsou zároveň diskutovány potenciální problémy a překážky spojené s konceptem CE.

Klíčová slova: Čína, cirkulární ekonomika, dopad na životní prostředí, environmentální management, ekonomicko-technologická rozvojová oblast Tianjin

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LIST OF ABBREVIATIONS

CE	Circular Economy
COD	Chemical Oxygen Demand
EIP	Eco-industrial Park
EPB	Environmental Protection Bureau
FYP	Five-year Plan
GDP	Gross Domestic Product
GHG	Greenhouse Gasses
IP	Industrial Park
IS	Industrial Symbiosis
IVA	Industrial Added Value
RES	Renewable Energy Sources
SEPA	State Environmental Protection Agency
TEDA	Tianjin-Economical-technical Development Area

1 INTRODUCTION

Over the last couple of decades it has become apparent that the current way of environmental management is not heading in the sustainable direction. China, currently the most heavily populated country in the world, accounting for 22% of the world population has been undergoing major socio-economic shift, making it the second biggest economy in the world (Dong et al., 2013). However this unprecedented economic success is being achieved at the expense of Chinese natural resources and environment. In order to respond to this unsustainable situation, Chinese government has adopted series of regulative and environmental protective laws in the last decade including the “Circular Economy (CE) Development Strategy” (Chang, 2014).

CE is a sustainable development strategy based on the creation of functional relationships between the human society and nature (Van Koppen, 2014). It is a framework that understands our current system of production and consumption as linear, where raw materials are shaped into products and services, sold and at the end of their life-cycle eventually disposed of at landfills or incinerators. CE strives to eliminate the concept of waste by proposing a system, where materials are extracted sustainably and products and by-products at the end of their life injected back into the manufacturer circuit. That way the goods are reused, refurbished, dismantled or recycled in a perpetual circle and can create further value (European Commission 2014).

CE framework implementation has saved substantial amount of money and resources in multiple examples throughout the world (Mathews et al., 2011). China has been continuously expressing further commitments towards further implementation of CE principles on many levels of society, and the number of the participating pilot projects has been growing. The purpose of this study is to evaluate and describe the results of the implementation of CE framework on one of the pilot projects, the Tianjin Economic-Technological Development Area (TEDA).

2 OBJECTIVES

Objective of this thesis is to analyse the problematics and outcomes of the innovative environmental management in Chinese industrial areas, with special focus on TEDA. Besides describing the emergence of environmental management systems within TEDA, aim of this thesis is to evaluate the environmental impacts connected with it. To support the arguments and case study research, author also focuses on Chinese environmental impact and environmental statutory targets development in the period of last 15 years.

The research question is:

"What are the environmental impacts of the implementation of China's Circular economy framework at the Tianjin Economic-technological Development Area?"

3 METHODOLOGY

This study is based on the principles of literature review. It was conducted by collecting and analysing the secondary data sources regarding the issue of the CE framework application on TEDA, China. Data were obtained from peer-reviewed scientific articles and studies, thematic books, governmental and official statistics and TEDA´s mandatory annual reports.

Study elaborated on the principals of qualitative research methods, although quantification of some results is presented as well. Large part of the data comes from scientific databases Web of Science, Scopus, Elsevier and ScienceDirect, particularly from the studies and articles falling under the Journals of Cleaner Production, Industrial Ecology, Energy Policy and Resources, Conservation and Recycling branches. The key words used were Circular Economy, Tianjin Economical-Technological Area, Eco-industrial Park, China, and Environmental Impact. All sources are in English.

4 LITERATURE REVIEW

4.1 CHINESE ENVIRONMENTAL IMPACT AND MANAGEMENT

4.1.1 Chinese Development

China has been going through an impressive economic change for more than 3 decades. The switch from highly controlled economy into market driven one brought about a lot of changes, creating country-wise unprecedented example of rocket-boom development. Thanks to the rapid industrialization of the economy, Chinese GDP average annual growth rate reached 9.9% between 1978 and 2012, making China the second largest economy in the world (Wu et al., 2014). During that period, Chinese population has grown by over 40%, reaching approximately 1 378 380 000 citizens nowadays. Almost 53% percent of Chinese now live in or near cities which is up from 26% in 1990 (Worldbank, 2015).

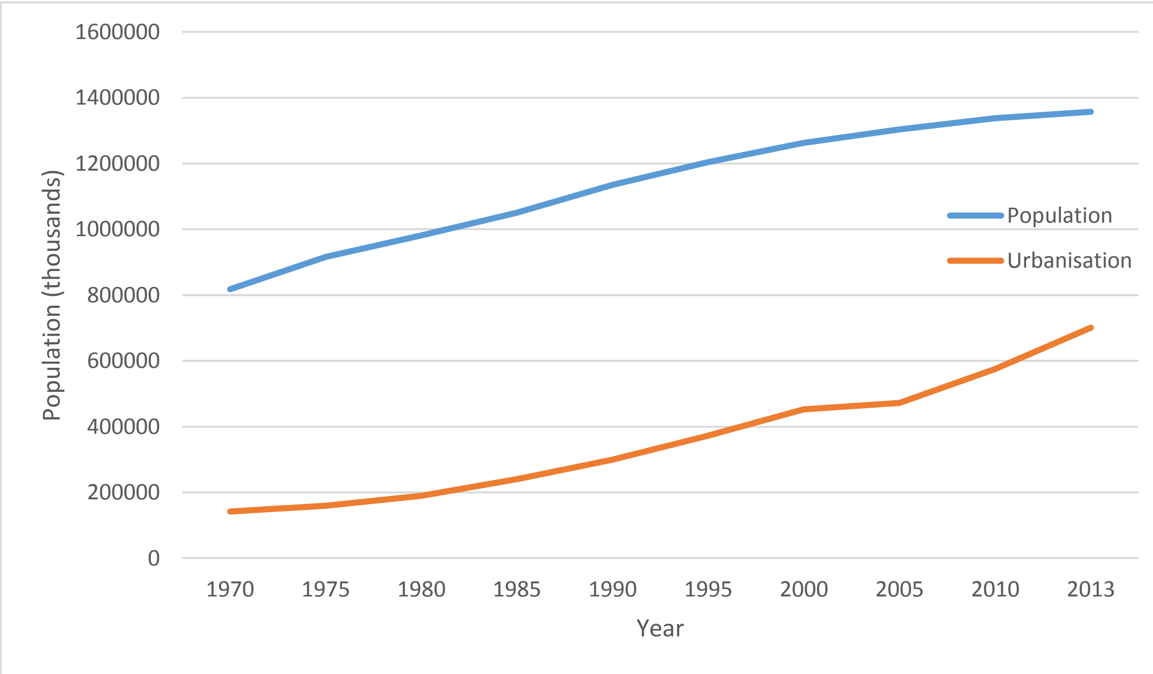

Figure 1: Chinese Population and Urbanisation growth (Worldbank, 2015)

Urbanization, population and economic growth have launched the uprising of Chinese middle-class. Ordinary Chinese citizens started revaluating their needs, embracing the life-style of modern and developed countries.

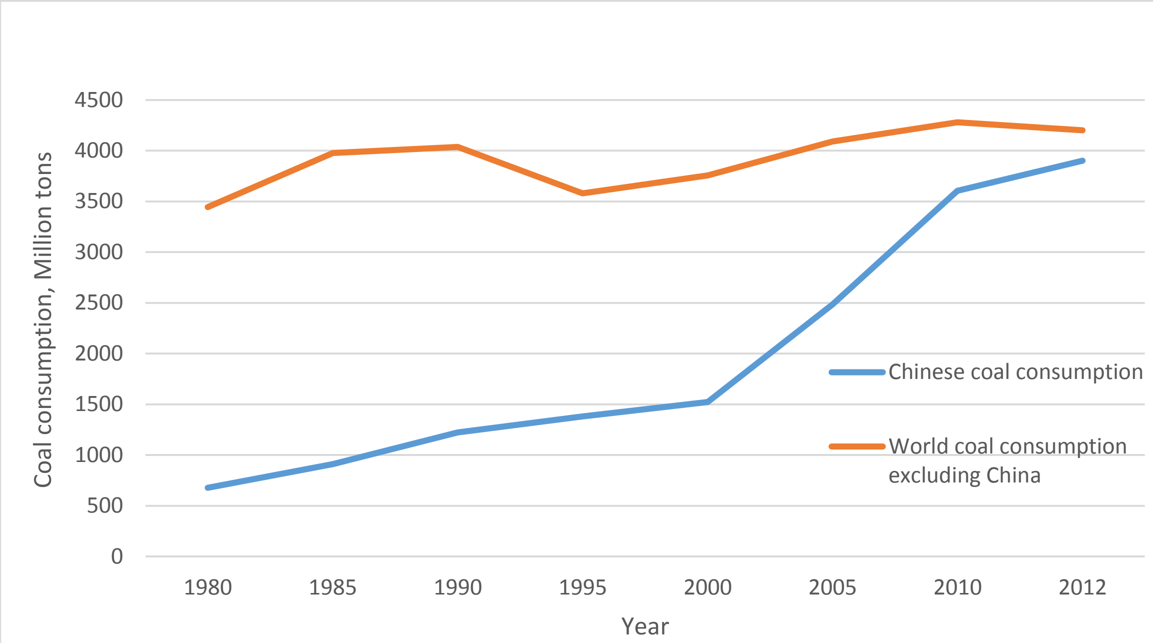

Figure 2: Chinese and global Coal Consumption (EIA 2013)

As China had to manage an urban transformation of nearly 400 million citizens in 25 years, new cities have appeared in the Chinese landscape literally overnight. Chinese citizens started to get richer and demanding. Cars, clothes, consumer electronics, and other equipment has become affordable, and common part of household equipment. But rapid growth has also logically induced extensive increase of Chinese energy demand and resource consumption.

As Figure 2 shows, in 2012 Chinese national energy consumption was 3 900 million tons of standard coal equivalents[1], with primary energy consumption growth rate 7.6% (Zhang, 2013). China has not only become the largest energy consumer in the world, accounting for 22.4% of global energy consumption but in fact annually consumes almost the same amount of coal, steel, aluminium, nickel and zinc as the rest of the world combined (IMF, 2012; EIA, 2013). The fact, that the majority of Chinese energy comes from coal which is usually burned in old and mostly inefficient

[1] Standard coal equivalent represents the unit of energy generated by burning one metric ton of coal.

boilers with outdated cleaning technologies only adds to the gravity of the whole situation.

4.1.2 Chinese Environmental Impact

Combination of massive growth of industrial sector, urbanization and energy structure dominated by coal together with lax environmental protection has driven China into environmentally daunting situation. According to Worldbank (2007) study, the Chinese economic burden of water and air pollution was equivalent up to 5.6 % of GDP. China has also become the largest emitter of $C0_2$ in the world in 2006, increasing the emission discharge volume ever since. According to OECD (2015), Chinese $C0_2$ emissions have been drastically growing by 7.5% annually for the last 15 years, reaching 8205.86 million tons emitted in 2012. Chinese GHG emissions have risen from 10% of the world´s total in 1990 to nearly 30% today. As developed countries are cutting down their emissions, China is going in the opposite direction, increasing the emission discharge by over 500 million tonnes annually, as shown in Figure 3.

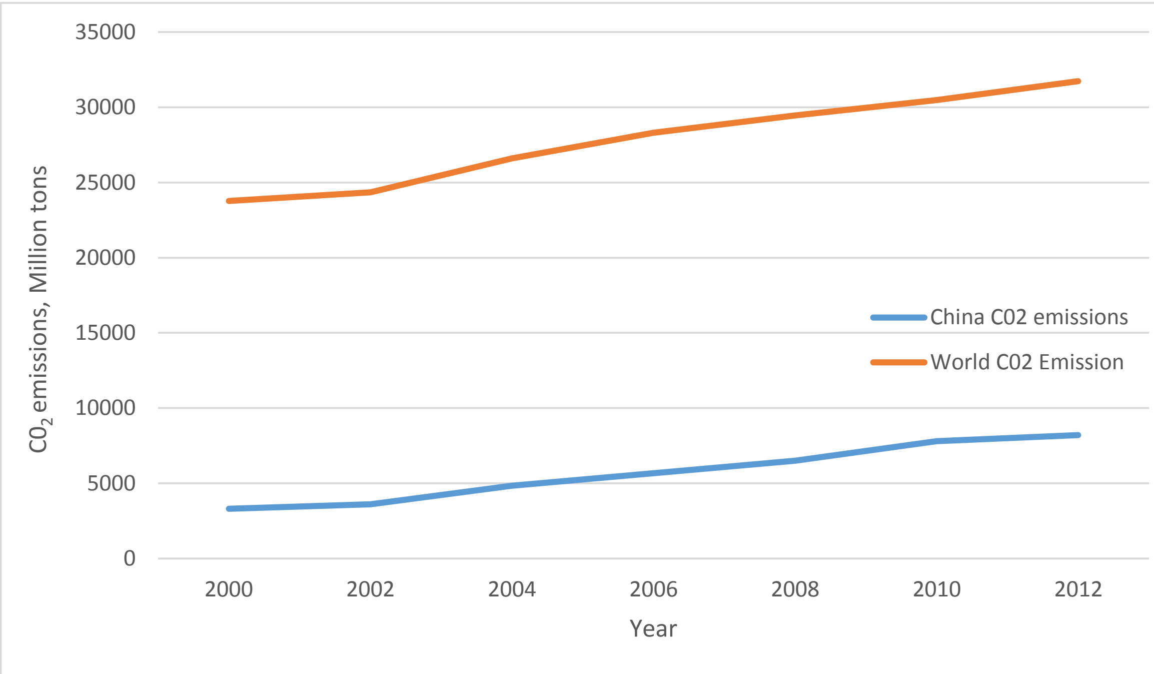

Figure 3: $C0_2$ Emissions World and China 2000-2012 (OECD, 2015)

The consequences of this situation are visible even from space, as space satellites in orbit cannot see Beijing on some days due to smog that the city produces (Tempest, 1994). In Hong Kong, pollution is so bad that the government often advises youngsters and elders not to come out. However, Hong Kong´s pollution levels are lower than in most parts of China (Asian Development Bank, 2012).

Even though China has been leading the Asian renewable energy sources (RES) development, recent study shown that 7 out of 10 most polluted cities in the world were in China (Koba, 2013). Another study claims, that only 1% of the Chinese largest cities managed to meet the WHO air quality standards (Asian Development Bank, 2012). According to Lanclet (2014), urban air pollution in China contributed to 1.2 million premature deaths in 2010, which is almost 40% of the global total.

Another report from 2013 by the China´s State Oceanic Administration (2014) claimed that 81% of the Chinese coastal waters were heavily polluted, 20% of rivers were toxic and 40% were identified as severely polluted, mainly due to the environmental pollution caused by humans and the resource over-extraction. Anorganic nitrogen and phosphates of domestic, industrial and agricultural waste origin were the two main pollutants discovered. There are similar studies and articles related to the China´s soil and forest degradation.

4.1.3 History of Chinese Environmental Awareness

Historically, China´s primary concern was economic growth and welfare. Iconic examples are the Mao Ce-tung´s campaigns underlining the population and industrial growth that have projected in enormous constructions showing the human triumph over the nature. Vast amounts of land was changed beyond recognition. However, it is important to mention that environmental awareness and protection was nor in the global agenda, nor included in the domestic politics of most of developed countries in the post-World War II period.

It was not until the 1990s when China had first started to be partially concerned about domestic environmental issues. That period of time is connected with formation of several governmental and non-governmental organizations and also Chinese participation in world environmental forums. Formation of institutions such as NEPA in 1988 (National Environmental Protection Agency) and first non-governmental organizations in 1993, opened the political decision making process to the public as well as increased China´s internal efforts. Thanks to the participation in the global forums and openness to the international cooperation, first FYP[2] (Five year plan) with focus on environmental protection was developed in 1996.

Matus (2005) states that major switch in Chinese environmental policy came in 1998 when China promoted NEPA to a parliamentary level SEPA (State Environmental Protection Agency), having the equivalent of Ministry of Environment. Suddenly the implementation of plans and proposals become faster and more effective. Before that moment, any important law proposal focused on emission reduction was not accepted, because many Chinese politicians believed that the energy and industrial restructuring would only slow down the Chinese economic growth.

At the same time, China had been dealing with growing number of citizens, who became unsatisfied and worried about the environment that they live in. The uprising of awareness has sparked series of protests. Chinese government had also been facing pressure from the international surroundings, as China´s environmental impact is barely a local problem. As a result, China had for example ratified the Kyoto protocols in 2002, a significant international treaty, setting boundaries to GHG emissions.

4.1.4 Chinese Environmental Management Development

Since 2000, China has also started to implement regulatory laws and policies in order to fight the increasing environmental degradation in its FYP. In the 10th FYP issued by Chinese government for 2001-2005, development and growth were still the main priorities, but the plan did include already some environmental targets, such as forest coverage increase on 18% or for example urban and rural pollutants reduction by 10% (Chinadialogue, 2011).

Nevertheless, as ambitious the environmental protection targets may have sounded, they were dwarfed by the economy growth and wealth generation, and the

[2] Chinese FYPs are an important series of major socio-economic development plans, shaping the country´s direction

implementation was in many cases vague. Chinese State Council in 2008 admitted, that effectiveness of environmental policy was far behind success:

"*There is no breakthrough in some in-depth environmental issues that should have been addressed during the '10th FYP' period. There is no fundamental change in the inappropriate industrial structure and extensive economic growth mode. There are also such problems as environmental protection lagging behind economic growth, poor or inflexible mechanism, insufficient input and capacity. The phenomena of no strict observation of laws, little punishment to lawbreakers, poor law enforcement and supervision are still very common."* (MEP, 2008)

It had become clear, that even some optimistic resolutions could not keep up with the Chinese growth and its impacts. China claimed to be aware of this fact, and it tried to address the burning environmental issues more consciously in the 11^{th} FYP from 2006-2010. Environmental quotas "were given the same emphasis" as the economic growth. The environmental degradation was highlighted and underlined by setting wider variety of protective measures, such as:

1. Reduction of energy consumption per unit of GDP by 20% in five years
2. Reduction of water consumption per unit of industrial value (IAV[3]) added by 30% in five years
3. Reduction of emission of major pollutants by 10 % in five years
4. Forest cover increase on 20% in five years
5. Rate of comprehensive use of solid industrial waste to 60% in five years (Fan & Cindy, 2006)

Yet again the implementation was lagging behind the intention, as not all of the goals were achieved by the end of 2010. For example water and air quality was not

3"The industrial added value also referred to as GDP by-industry, is the contribution of a private industry or government sector to overall GDP. The components of value added consist of compensation of employees, taxes on production and imports less subsidies, and gross operating surplus. Value added equals the difference between an industry's gross output (consisting of sales or receipts and other operating income, commodity taxes, and inventory change) and the cost of its intermediate inputs (including energy, raw materials, semi-finished goods, and services that are purchased from all sources)." (BEA, 2006) improved as planned. In other cases implementation and quota fulfilment was reached with counter-productive measures, resulting in electricity cut offs or temporal and expensive end-of-pipe solutions. Chinese efforts to slow down the environmental deterioration and to steer the country´s development towards the sustainable future started to have serious ambitions. But setting goals and achieving them are two different things and 10th and 11th FYPs continuously lacked effective enforcement (Fan & Cindy, 2006).

12th FYP set another hopeful ambitions to push China on a more sustainable way. Water usage per IAV was set to be cut by 30% in 2015, non-fossil energy sources of primary consumption in total should rise to 11.4%, energy intensity[4] was proposed to be decreased over 16%, whereas the forest coverage was aimed to increase by 600 million m^3 on 22% (Biwey et al., 2013).

The total investment into the environmental protection was estimated to exceed over 483 billion USD in the 12th FYP. The finances were divided into different categories of sustainable projects in order to help achieving targets, such as: pollutant reduction plan (focused on sewage, sludge, sulfurization, and denitrification treatments), water, air and soil living environment improvements, ecological preservation, environmental monitoring and risk prevention, etc. (OPCO 2010).

Only in 2013, China has invested 52 billion USD into the RES, more than the whole Europe combined. In the same year, China has also become the biggest investor

[4] Energy intensity is defined as energy use per GDP. It is used as a measure for the energy efficiency. It indicates that low energy intensity usually comes with lower cost of converting the energy into GDP. In reality it means that using less energy to produce a product reduces the intensity.

into the RES worldwide, spending more money on RES than on its new fossil fuel and nuclear capacity generation for the first time ever (REN21, 2014).

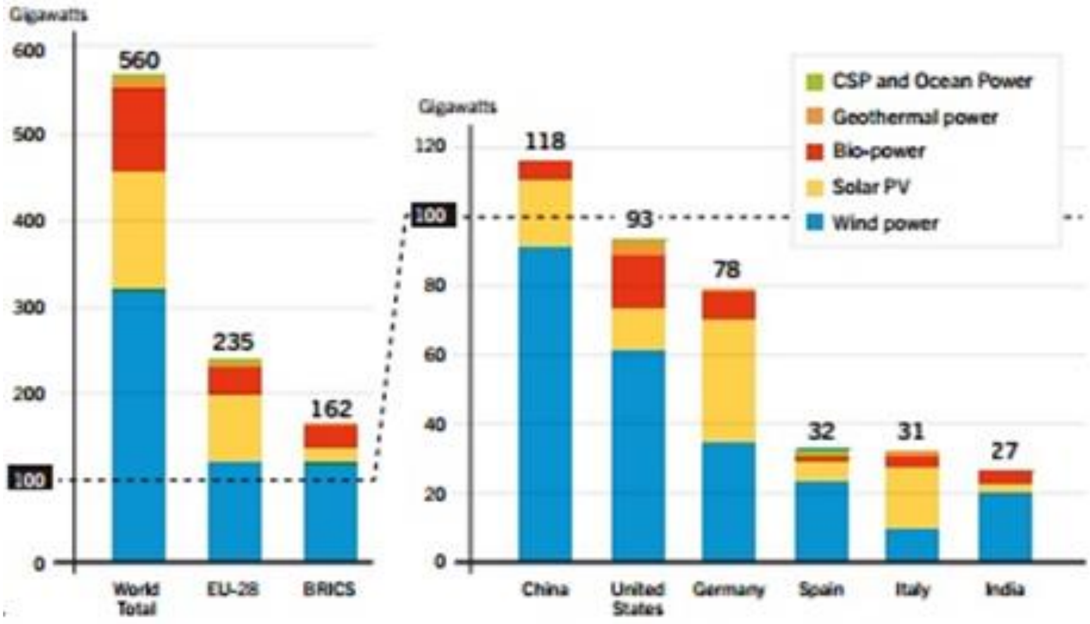

Figure 4: Global RES Capacity Development in 2013, not including the hydropower. Source: (REN21, 2014)

Table 4-1: 10th, 11th and 12th FYP Environmental Targets

Sector/Targets	10th FYP 2001-2005	11th FYP 2006-2010	12th FYP 2011-2015
Forest coverage increase to	18%	20%	22%
Energy intensity reduction by		20%	16%
Water consumption per IAV reduction by		30%	30%
Reduction of emission of major pollutants by	10%	10%	17%
Industrial waste treatment increase to		60%	85%

Source: (Fan & Cindy, 2006; OPCO 2010; Chinadialogue, 2011)

As the Table 4-1 shows, China has been continuously making progress towards improving its environmental targets in the last 15 years. However, the question whether the goals can keep up with its vast economic and industrial expansion remains unresolved. Previous chapters have showed, that China has been polluting its environment increasingly, but at the same time undertaking important steps and expenditures on improvement. Next chapter describes the tool of CE framework used in China which aspires to make the goals and targets reality.

4.2 CIRCULAR ECONOMY FRAMEWORK DEFINITION

So what exactly has been done in order to meet the governmental targets? To support the FYPs, series of regulatory and supportive laws are usually passed. In terms of environmental protection in China, Mathews (2011), Geng et al. (2012), Biewi al. (2013) and Wu et al. (2014) agree on that one of the major and perhaps the most important of such series falls under the CE development strategy, formally accepted by the Chinese government in 2003.

Following pages are focused on describing the meaning of the CE concept globally, and in China, as well as evaluating its effectiveness and results on a pilot project of TEDA.

4.2.1 Definition of Circular Economy Framework

CE concept was first introduced in the report for the European Commission for Environment in 1974 by a group of scientists from environmental think tank. It has developed due to the need and desire to change the current unsustainable production system. Although there is no widely accepted definition yet, CE is often described as an approach underlining the 3R´s principles – Reduce, Reuse and Recycle of materials and energy (Yuan, 2006; Ying, 2012). In other words, it promotes sustainable development via closing the material and energy cycles, while minimising the virgin material use. EU Commission for Environment (2014) defined CE as:

"Circular economy systems keep the added value in products for as long as possible and eliminate waste. They keep resources within the economy when a product has

reached the end of its life, so that they can be productively used again and again and hence create further value"

In the ideal case, nothing is lost and everything is transformed. That exactly as in natural ecosystems, waste of any kind is still regarded as valuable resource used to create something else than just troubles. CE concept opposes our current industrial system that is designed on a linear, one-way take-make-consume and dispose model, described by Braungart & McDonough (2009) as a system where:

"*Resources are extracted, shaped into product, sold and eventually disposed of in a "grave" of some kind, usually a landfill or incinerator."*

In both systems, valuable materials are used for construction, food, and the production of goods and services. But normally, when the materials show signs of wear, or are no more necessary, they are discarded and labelled as waste. However, the current population growth and rising wealth makes the demand for materials high as never before, which logically leads to environmental degradation. Metals, minerals, fossil fuels, food, fresh water and fertile soil are at the same time getting more scarce and expensive, yet we still treat them as if the supplies were infinite.

Girling (2005) came with alarming numbers regarding the raw material use during manufacture and end-user behaviour. Girling claims, that the situation in 2005 was that up to 90% of the raw materials used for manufacture became waste before the products even left the factory and 80% of the products manufactured were thrown away 6 months after leaving the factory.

On the other hand, in the 2014 European Union Commission for Environment report, CE framework has been identified to have the potential to save the EU businesses up to 340-620 USD billion (European Commission, 2014). Energy and resource efficiency together with waste prevention measures were also said to have the possibility to generate up to 2 million job opportunities and decrease the GHG emissions significantly (European Commission, 2014).

China could benefit from the CE practices, as it currently generates around 360 million tonnes of domestic waste annually, with the quantity growth rate of 8%/year.

Approximately 50% of that amount is disposed of at landfills of dubious quality, another 12% is being burned, 10% is turned into fertilizers and the rest is simply dumped illegally (Ying, 2012; Chinadialogue, 2012)

Resource scarcity and tighter environmental standards are here to stay, as pursue of wealth prevails over the common benefits and sustainable vision of our future. Chinese government appears to be aware of this situation and according to its own words, it continues to emphasize on measures towards environmental security more than ever before. As a result, for example the expenses on industrial waste disposal in China have doubled over the last four years and increased by 90% in last 15 years, reaching the total spending on waste management to 41 billion of USD (Chang 2014).

Nevertheless, most of the investment was spent on the construction of new incineration plants all over China. But incinerating the valuable materials and organic nutrients does not solve the scarcity issue, it does quite the opposite. CE concept sets a different paradigm in the waste management field, because it promotes the waste conservation and reusability. Unnecessary disposal of valuable and scarce resources is a loss, because what is burned can never be obtained back. Moreover, Morris et al. (1996) proves that:

„Recycling conserves energy that would otherwise be expended extracting virgin raw materials from the natural environment and transforming them to produce goods that can also be manufactured from recycled waste materials. Furthermore, energy conserved by recycling exceeds electricity generated by energy-from-waste incineration by much more than the additional energy necessary to collect recycled materials separately from mixed solid waste, process recycled materials into manufacturing feed-stocks, and ship them to manufacturers, some of whom are located thousands of miles away.“

4.2.2 Circular Economy Worldwide

Since 1990, CE concept has been accepted and proposed by many groups on a corporate, national and even international level. German government was the first one to do so, and the CE implementation started in 1996 under a law "*Closed Substance*

Cycle and Waste Management Act". As the name suggests, the law was focused on environmentally responsible closed waste management cycles. In 2010, Germany had almost 0% of landfilling, as waste recycling rate rose up to 62% and incineration to 37% (Mühle et al., 2010). Similar strategies have been accepted in countries across all five continents, but mainly in Europe and Asia (UNEP, 2006; Andersen & Mikael, 2007; Yong et al., 2012).

CE has recently brought a lot of attention on the international level as well. European Union Commission for Environment has expressed its commitment to the CE by adopting the Communication "*Towards a Circular Economy: Zero Waste Programme for Europe*" in 2014 with ambitious plans regarding material use and waste management targets by 2020, respectively 2030 (European Commission 2014).

CE topic has for the first time appeared at the prestigious World Economic Forum in Davos in 2014, where awards were given to the businesses and individuals involved in embracing the CE framework. Companies such as IKEA, Coca Cola, DHL, Apple, Phillips and many others were present and are beginning to embrace innovative approaches towards CE in their sustainability departments (Braungart & McDonough, 2009; Ellen MacArthur Foundation, 2014; Dumaine, 2015).

But the way CE has been understood and implemented in China is close to unprecedented.

4.2.3 Circular Economy Development in China

Whereas in the majority of the countries, CE has been seen as an environmental strategy which strives to deal with the unsustainable waste management, Chinese perception of CE is different. By creating the CE a country-wise development strategy, Chinese government has changed the traditional meaning of the CE from purely environmental strategy, to a national and economic development plan (Mathews et al., 2011).

CE concept has been introduced to China in 1998. Already in 2002, it was officially accepted by the Chinese government as a supportive strategy for a new development plan and has been seen as:

“*Key part of the solution for China’s battle to address its environmental problems while maintaining its economic growth*“(Mathews et al., 2011).

This decision was followed by the implementation of regulative laws focused on environmental management, such as Cleaner Production Promotion law (2003), Environmental Impact Assessment Law (2003), Prevention and Control of Pollution by Solid Wastes Law (2004), and CE Promotion Law (2008) (Chang, 2014). All of the laws mentioned above foster companies, counties, areas and cities to entail fundamental principles of CE, such as energy, water and material saving and waste recycling and resource recovery strategies.

Practically it now works like that for every construction project, report on the environmental impact must be written and handed down to a local environmental protection agency, which than decides about its approval. Moreover, innovative and supportive measures that increase the environmental performance by improving the energy, waste and resource management must be incorporated. Laws are strengthened by a series of strict rewards and penalties.

In China, CE concept is deployed at three main levels, as shown in Figure 5. The first, Small circulation level, includes single enterprises, e.g. particular companies which are encouraged to take actions towards putting the 3R´s principles into practice (Mathews et al., 2011; Chang, 2014). They are required to do so by accepting measures focused on more ecological design of their production process and final products and

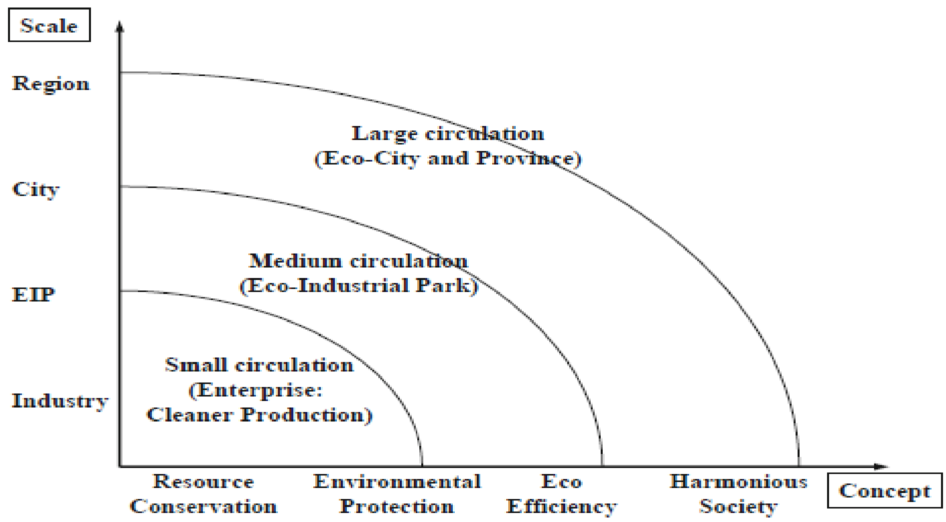

Figure 5: Levels of implementation of CE in China. Source:(Chang, 2014)

by addressing the generation of pollution and efficient use of resources. Under the second, or Medium circulation level, falls a clustering of industrial enterprises engaging in CE framework. This clustering is also called Eco-industrial park (EIP), and following pages elaborate on this concept. The third, Large circulation level, promotes the application of CE concepts in the whole cities and provinces, where complex cooperation relationships between primary, secondary and tertiary sectors are established. The principles of CE are to be achieved by redesigning the city´s infrastructure, waste and water management, or for example by eliminating the heavily polluting industries (Biwei al., 2013).

4.2.4 Eco-Industrial Parks

4.2.4.1 Industrial Parks

It is widely believed that vast industrialization is alpha and omega of Chinese economic success (Geng et al., 2009; Yu et al., 2015). Industrialization has projected in growing number of largely concentrated areas specifically designed to fulfil the needs of society. Concentrating different businesses and companies into small areas projects in minimizing the space demands. Infrastructure and machine costs can also be reduced. Those areas are called industrial parks (IP), and often defined as:

> „*A portion of a city that is zoned for industrial use"* or "*A clustering of industries designed to meet compatible demands of different organizations within one location*"(Geng et al., 2009)

Through IPs, companies profit from economies of scale in terms of construction, common fabrics, facilities and land and resource management (Côté et at., 1998). IPs have played crucial role in developments of many countries, due to such advantages. Since Chinese opening to the foreign investors in the late 1970s, there has been large establishment of IPs throughout the whole country. According to Geng et al. (2009), there were 6866 IPs in China, as of 2009. Chinese IPs are also very active for foreign investment. Although the Chinese IPs cover the 0.004% of land, they account for 10% of the total foreign investment (Geng et al., 2009). In 2012, the IPs GDP growth rate was 30.3% on average, number distinctly higher that the national average of 9.2% (Yu et al., 2015).

But the intense industrial development does not generate only fortune and prosperity. Chinese industry has been extremely energy and resource demanding and to some extent even jeopardizes the ecological security of its local communities by poisoning the surrounding water, air and land. It is in fact the Chinese industrial sector that has accounted for 71.6% of the national energy consumption and 82.6% of total $C0_2$ emissions in 2007 (Dong et al., 2013).

Chinese government has been continuously putting more pressure on environmental standards. Pollution prevention together with energy intensity improvements were said to be the main goals in the 12^{th} FYP. As both of the topics are deeply related to the industry, improving its performance is of high priority.

4.2.4.2 Eco Industrial Parks Description

To address the environmental degradation caused by its industrial sector, China has started adopting the idea of EIPs since the late 1990s (Geng et al., 2012, Dong et al., 2013). At the medium circulation level, EIP is the main strategy of the CE implementation in China. The definition of EIPs is often described as part of the Industrial Symbiosis (IS) framework which:

"Engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water and by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity."(Chertow, 2010).

In EIP, one does not look at the IP from a product chain or single company perspective, but:

"*Envisages industrial production as an ecosystem of organisms, exchanging information, energy and materials with each other and with their environment.* "(Koppen, 2014)

The main principles of EIP according to Koppen (2014) are to:

1. Connect the individual firms into industrial ecosystems by:
    a) Closing the loops through recycling and reusing
    b) Maximising the efficiency of materials and energy use
    c) Minimizing the waste generation
    d) Defining all wastes as potential products

2. Balance inputs and outputs to natural ecosystem capacities by:
    a) Reducing the environmental degradation created by the energy and material releases into the natural environment
    b) Designing the EIP with respect to the natural environment
    c) Avoiding or minimizing the creation and transportation of toxic and hazardous waste

3. Re-engineer industrial use of energy and materials by:
    a) Redesigning processes in order to reduce energy usage
    b) Substituting technologies and product design in order to reduce the use of materials disposed beyond the possibility of recapture

Perhaps the most famous and studied example of IS is the EIP Kalundborg in Denmark (Chertow, 2010; Koppen, 2014). Kalundborg EIP consists of several industrial facilities, such as power plant, oil refinery, wallboard factory, recycling company, wastewater treatment plant, or pharmaceutical fermentation plants. At Kalundborg, waste and by-products such as steam, sludge, fly ash, heat, gypsum, or for example water have been traded between both private and public sector companies for almost over 30 years. This spontaneous profit driven project had evolved into a network of 32 bi or tri-lateral agreements and contracts between 8 founding companies, as shown in Figure 6 (Jacobsen & Noel, 2006; Ellen MacArthur Foundation, 2014).

Kalundborg EIP example is by far not self-sufficient and perfectly closed looped, as numerous raw materials has to still come in from outside. However, these exchanges has led and contributed to important energy and material savings. Koppen (2014) has showed that circular approach in Kalundborg annually saves up to 3 million m^3 of water through reuse and recycling, which is almost 20% of the total use, reduces S02 emission by 16%, or saves up to 170 000 tons of gypsum. The payback period of the investments was 5 years, and total accumulated savings were estimated to 310 USD millions, as of 2011 (Mathews et al., 2011).

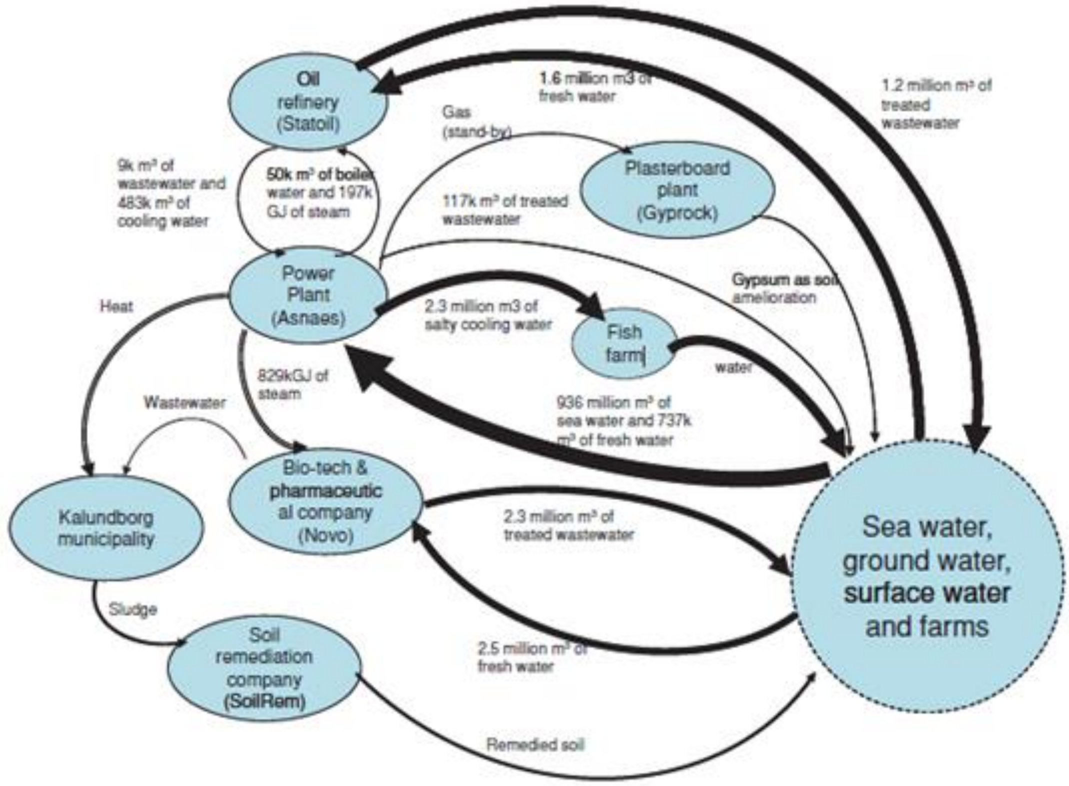

Figure 6: Selected industrial symbioses in Kalundborg. Thickness of lines indicates the magnitude of flows. Source: Mathews et al., 2011

China found inspiration in similar projects. As a part of the CE development strategy, SEPA has launched 22 National Demonstration EIPs from 2000 until 2013. Another 62 pilot projects were approved but have not acquired the EIP label yet (Chang, 2014). Next chapter focuses on describing the basic characteristics of TEDA EIP and the actions that it undertook towards National CE Development framework, and the results showed on a group of selected environmental indicators.

4.3 CIRCULAR ECONOMY ASSESMENT AND DEVELOPMENT AT TIANJIN ECONOMIC-TECHNOLOGICAL DEVELOPMENT AREA

4.3.1 General Introduction of Tianjin Economic-technological Development Area

TEDA was founded in 1984 on a salt pan, during the first batch of construction of 14 Chinese National Development areas. Back in 1984, the only business activity in TEDA was the salt-making. Since then, TEDA has evolved into a 98 km^2 developed industrial area.

Figure 7: Geographical location of TEDA. Source: Shi et al., 2010

There were over 28 000 companies doing business in TEDA in 2010, of which 4900 international and the rest domestic. TEDA´s GDP in 2010 was estimated to 25 billion USD and the annual GDP growth to 25% (TEDA, 2010). TEDA belongs to one of the richest biggest and prosperous IPs in China, and has been ranked as the most attractive region for foreign investment by the Chinese Ministry of Finance in the last 10 consecutive years (Shi et al., 2010).

As most of the IPs in China of this size, TEDA's space is not only occupied by factories and industrial buildings. It also serves as workspace for nearly 536 000 people (TEDA, 2010). Therefore the decent environmental conditions are of crucial importance. It also does not consist of only one major type of industry, but from a mix of several different industrial sectors, as described in Figure 9. That gives the emergence of IS bigger opportunities, because the waste and by-product exchanges can find more end users and customers.

Figure 8: TEDA´s appearance. Source: (TEDA, 2010)

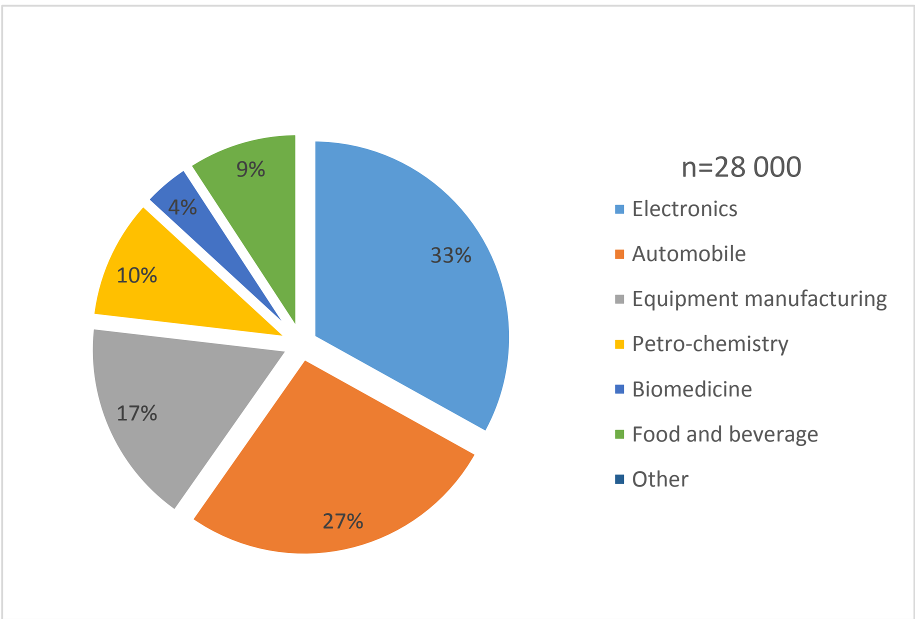

Figure 9: Proportion of TEDAs industries in 2010. Source: Chang 2014

4.3.2 Emergence of Environmental Management in TEDA

Soon after its establishment, TEDA and many other IPs across China have started to struggle with several issues. As TEDA continued to grow rapidly due to China´s opening to the foreign markets, the environmental consequences followed. Massive industrialisation and the lack of environmental governance in the 1990s allowed companies to extract the water sources excessively, which has caused the deficit of total available water supplies, resulting in acute shortages of the local reservoir and decrease of the groundwater levels. Moreover, the uncontrolled wastewater discharge caused sever coastal and inland pollution, affecting local biotope and communities (Geng et al., 2009).

TEDA´s development and construction projects also led to a serious local farmland degradation, due to the high demand for soil and resources derivation. As enormous amounts of fertile land had to be moved inside TEDA to make sufficient background for factories and housing projects, surrounding farmers did not have much left to work with (Shi et al., 2010)

On the other hand, as the export and GDP of China´s IPs continued to rise, the manufacturing processes within China needed to improve in order to legally enter the international markets. Tighter environmental standards together with serious scarcity of fundamental resources started to constrain the production and further development of TEDA. Due to these circumstances, TEDAs leadership has decided to take a step ahead of its competition and applied and adopted basic principles of ISO 14001[5]as well as the SEPA´s call for the implementation of EIP strategy in 2000 (TEDA, 2010; Chang 2014). Since 2000, TEDA has achieved several milestones on the field of environmental management systems (See table 4-2).

[5] ISO 14001 is defined as: "That part of the overall management system which includes organisational structure, planning activities, responsibilities, practices, procedures, processes, and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy"(Van Koppen, 2014)

Table 4-2: Institutional activities stimulating EIP development in TEDA

Year	**Event**
1986	TEDA establishment
1990	TEDA establishes Environmental Protection Bureau (EPB)
1996	Environmental Protection Association established among companies
2000	ISO 14001 certified
2001	TEDA´s companies Environmental reports made public and annual
2002	National Pilot EIP certified by SEPA
2005	Water and industrial waste management system incorporated
2006	CE National Pilot park certification obtained
2007	Implementation of information disclosure systems.
2007	Provisional Regulation System for Promoting Energy-saving projects (17 million USD/year)

Source: Geng et al., 2009; Shi et al., 2010; Chang, 2014

4.3.3 Examples of Environmental Management in TEDA

Previous chapter has showed that TEDA has been increasingly putting more effort into its environmental performance by developing advanced environmental management systems and measures, and by participating in several Chinese development plans. But what is the real meaning of those commitments? This chapter is focused on describing what and how has been achieved in terms of water, energy and waste management in TEDA in the last 15 years.

4.3.3.1 Water Management

TEDA has tried to deal with the unsustainable water management situation by targeting both supply and demand approaches. It encourages companies to reduce their water consumption and at the same time to look for new water supply sources (TEDA, 2010). In the built up areas, TEDAs EPB promoted rainwater collection from rooftops and streets. Collected rainwater is now in some cases “cascaded” down and used for industrial purposes or for irrigating surrounding lands.

TEDA is located in the coastal area and often struggles with the freshwater supply. Fresh water is transported from the water reservoir located 50 km outside of the Tianjin area and it used to be overdrew by the local industries frequently, causing massive shortages. As a response, Tianjin municipality together with EPB encouraged heavy industries located within TEDA to use seawater directly for the cooling purposes and put a higher tax on the usage of freshwater since 2000 as well as built a desalinization facility. Quotas for specific amounts of water extracted were given and 20 times higher prices set when the limits were overreached (Geng et al., 2007; Chang 2014).

As a part of the TEDAs EIP certification process, the local authorities initiated two major projects in order to intensify the inter-companies´ collaboration and symbiosis. Projects were focused on water recycling and sharing. The “Sewage disposal fee” exempted company from the disposal fee, if its wastewater met certain quality standards or was reused. On the top of that, EPB has put and sponsored a 20% discount on the reclaimed water. As a result, over 25% of discharged water in TEDA was recycled in 2009 (Chang, 2014).

Moreover, projects focused on stimulating companies to build their own wastewater plants were realized, increasing the sales of recycled water by 83% from 2003 to 2004 (Geng et al., 2007). TEDA also invested in its own centralized wastewater treatment plants that now connect the whole park with pipes and provide many companies (especially the coal power plants with car industry facilities) with recycled water and hot steam, which would have been discharged otherwise. The New Water Source plant now supplies roughly 1000 tons of reclaimed water daily to the cogeneration power plants for cooling purposes (Shi et al., 2010). In 2011, 3 million tons of reclaimed water were sold locally, saving 700 000 USD/Year (Chang, 2014). From 2008 – 2011, TEDA managed to lower its total freshwater consumption by 30%, and wastewater discharge by 40% and at the same time increase its municipal water treatment by 31% (Biwei et al., 2013; Chang, 2014)

Table 4-3: Water management performance in TEDA

	Indicators (Rate of Change from 2008-2011)	Unit	Growth Rate	Material Savings
Water Management	Municipal water treatment	%	31	1.26 million m^3 of reclaimed water sold
	Wastewater discharge per IAV	%	-40	1.35 million m^3 of water treated and reuse.
	Freshwater consumption per IAV	%	-30	

Source: Biwei et al., 2013; Chang, 2014

4.3.3.2 Energy Management

Energy consumption and efficiency is another crucial challenge for TEDAs leadership. According to Geng et al. (2009), approximately 22% of total operating costs of TEDA's industries accounted for energy bills in 2006. That means that better use of the energy can save significant amounts of money to the local businesses as well as decrease the environmental impact at the same time. Following the CE National Development plan for EIP, TEDA has launched series of programs for optimizing the energy structure.

As a part of the "Provisional Regulation for Promoting Energy-saving" plan in 2007, TEDAs leadership has created an investment fund, which gives 17 million USD annually as a support to companies engaging in energy-saving projects. Thanks to this fund, companies can get as much as 30% of total investment amount for free. In two years, already 140 projects were financed (Chang, 2014).

At the same year, compulsory energy auditing system was put in practice. It obliges companies to find, store, and release information about its energy and pollution performances. If the company refuses or fails to meet the standards, it does not receive the certification to sell its products on the market and is financially persecuted (Geng et al., 2009).

TEDAs EPB also formed and advisory Eco-centre group in 2004, strictly focused on providing knowledge to the companies about IS possibilities in their surroundings. It seeks, identifies and helps to create new relationships on the IS basis between companies. As of 2012, Eco-centre managed to help over 600 companies and created 40 IS material and energy exchanges projects thanks to educational seminars, workshops and information sharing (Chang, 2014).

One of the most successful and important projects was focused on steam condensation water exchanges. Soon after the initiation of TEDAs Eco-centre, it was discovered that 65% of steam generated as by-product by 4 coal-fired power plants, can be reused for heating purposes, rather than being discharged (Shi et al., 2010). Because of the lack of information and cooperation within companies, nobody did not know about this fact before. In 2005, all 4 Tianjin Energy Cogeneration Plants together produced over 2 million tons of steam as by-product (Shi et al., 2010). Steam is now piped to other companies, mainly in the car industry (Toyota), pharmaceutics (Novozymes Biotechnology, Zhongxin), textile (Hartwell) and food and beverage industries (Coca Cola, Tingyi Food, Fuji Protein) and used as an input for their production processes.

Another activity of EIP framework in TEDA is the application of energy-saving practices , such as improvement of motor systems and equipment, supplementing with LED lights, use of RES (solar roofs, wind turbines), or shut downs of energy inefficient factories. Overall, the energy consumption per unit of IAV has decreased by over 11% between 2008 and 2011, as shown in Table 4-4 (Chang, 2014).

Table 4-4: Energy management performance in TEDA

	Indicators (Rate Change from 2008-2011)	Unit	Growth Rate	Material and Energy Annual Savings in 2006
Energy Management	Energy Consumption per IAV	%	-11	120 GWh from incineration plant 2 million tons of steam transferred for heating purposes

Source: Shi et al., 2010; Chang, 2014

4.3.3.3 Waste Management

Solid waste problematics is another very important topic in China, not only because of the environmental consequences, but also because of the resource scarcity and prices. Due to the increasing prices of major materials and resources, companies themselves have started to seek innovative options in terms of waste management. Since its establishment, TEDA has developed several strategies in order to reduce the resource consumption and increase the waste reclamation and recycling rates according to the CE principles.

One of the initial examples of IS in TEDA dates to 1997, when TEDA's Eco-Landscaping Development firm invented a way, how to create new soil for construction purposes from 3 types of waste. It used the sediments from the Bohai Sea, fly ash from the TEDA's coal-fired power plants, and caustic soda sludge out of metal industry factories. As a result, significant reduction in extraction of topsoil from TEDA's surroundings farms was recognized (Shi et al., 2010).

Another example of IS is related to the biological nutrients exchanges within multiple companies. First activity started in 1998 when the producer of instant noodles started to sell the scraps from the floor to the nearby pig farms as food. Soon, other companies working in the food and beverage business, such as Nestle, Kraft, Coca Cola or Tingyuan Food, joined this concept as well (Shi et al., 2010). 3 years later, Danish company Novozymes Biotechnology, as the matter of fact also participating in the IS in Kalundborg EIP, started to give away for free its nutritionally rich production waste. Material, earlier regarded as waste for which disposal the company had to pay, suddenly gained importance because of its high nitrogen and phosphorous content and has been transformed into the organic fertilizer and donated to local farms and land cultivating companies.

By constructing the Municipal Waste Energy-Recovery Incinerator in 2004, TEDAs municipality has ensured that 400, 000 tons/year of solid waste is burned and transformed into 120GWh. Biwei et al., (2013) calculated, that the facility saves up to 480, 000 tons of coal annually. On top of that, the incineration plan now creates floor tiles out of the fly ash generated during combustion.

Numerous examples of waste exchanges based on IS are available and currently underway. To foster the inter-firm IS concepts, TEDA started to emphasize on companies and their duty to keep tracks of their waste production and information sharing. Moreover, companies within TEDA have available the Eco-centre´s knowledge regarding waste-product exchange and reuse possibilities. It works so that the companies are provided with information about who their neighbours are, what is their industrial specialization and therefore potential by-products demand or supply.

Between 2010 and 2011, another 500 companies were recruited into IS project organized by the EU, creating 27 examples of material exchanges. The project was estimated to save approximately 11 000 tons of $C0_2$ emissions and avoided the usage of 3000 tons of raw materials. Because the TEDA has decided to subsidize the technological improvements focused on desulphurization, S02 emissions per IAV were decreased by almost 50% since 2000. During the period between 2008 and 2011, TEDAs use of solid wastes materials rose up to 95% with improvement rate 4.6%, generation of solid waste per IAV decreased by 35% and chemical oxygen demand[6] (COD) emission rate per IAV was decreased by 12% (Biwei et al., 2013; Chang, 2014).

[6] COD is often used as an indicator of water pollution in the environmental engineering. It indirectly measures the amount of organic compounds in the water. The test is carried out by chemical decomposition of organic and inorganic contaminants disolved in water. The result indicates the amount of oxygen consumed by the contaminants. The higher the demand for oxygen, the higher the water pollution.

Table 4-5: Waste management performance in TEDA

	Indicators (Rate Change from 2008-2011)	Unit	Growth Rate	Material and Energy Annual Savings in 2006
Waste Management	COD discharge per IAV	%	-12	400 000 tons of municipal solid waste incinerated
	S02 discharge per IAV	%	-48.7	91 000 tons of fly ash used in construction and landscaping
	Generation of solid waste per IAV	%	-35	24 000 tons of Novozymes bio-waste turned into fertilizers
	Use of industrial solid wastes material	%	4.6	30 000 tons of E-waste recycled 10 000 tons of lead waste turned to lead alloy 3700 tons of food waste turned into animal feed

Source: Biwei et al., 2013; Chang, 2014

5 RESULTS AND DISCUSSION

Within the total of 81 ongoing symbiotic inter-firm exchanges identified in Figure 10, majority accounted for material-based types (76%). Water and energy exchanges accounted for 15% and 9% respectively. Chang (2014) shows that similar number of exchanges was still under way in 2013. This fact confirms that working and complex IS within TEDA has developed since its establishment. It also indicates, that waste and by-product material exchanges play much bigger role in the EIP symbiosis than energy and water exchanges, as concluded by Tian et al., (2014).

Table 4-6 presents the overview of performance of selected environmental indicators, used in official evaluation systems for EIPs by Chinese authorities (Geng et al., 2012). TEDA has managed to make positive progress in all the evaluated areas. Wastewater discharge together with freshwater consumption was reduced by 40%, and 30% respectively, whereas the municipal water treatment was increased by 30%. It indicates that TEDA has improved water management and pushed the area towards more sustainable situation. It is a proof that the construction of wastewater treatment and desalinization plants together with supportive policies has had effects on the local water scarcity and pollution control, as suggested by Geng et al., (2009).

By applying the EIP principles, TEDA improved its use of industrial solid waste and at the same time decreased the amount of solid waste generated. By providing subsidy for the desulphurization projects, TEDA has cut its $S0_2$ emissions by almost 50% (Chang, 2014). Also at the field of waste management, the FYP quotas were met. Although the TEDA´s energy intensity reduction results were 70% above the IPs average, and showed 11% decrease, the results did not meet the FYP quotas (Shi et al., 2010).

As TEDA´s (2010) annual report indicates, TEDA´s GDP annual growth rate was 25% during the same period. This corresponds with Mathews et al., (2011) and shows that the CE framework provides a functioning tool to ease the environmental deterioration by solving the resource scarcity and emissions issue while maintaining economic growth. Moreover Chang (2014) & Van Koppen (2014) proves that many projects based on the EIP principles in China and abroad had five-year payback period.

On the other hand Shi et al. (2010) shows that bigger projects such as waste water treatment and desalinisation plants were heavily subsidized and dependent on the governmental support.

Côté et al. (1998) & Shi et al. (2010) & Biwei et al. (2013) & Van Koppen (2014) & Chang (2014) agree that the bottom line of a successful EIP realization is the information system which provide necessary information for companies about the IS possibilities. Authors also agree that effective law enforcement, government support and local authorities commitment are yet another crucial factors in EIP establishment. As Biwei et al. (2013) explains, information systems in Chinese IPs are quite rare. Therefore the importance of information exchange between the local companies is pointed out and recommended in particular in all the studies mentioned.

Even though the majority of CE projects eventually proved to bring both environmental and economic benefits, technology improvements are costly. Especially in China, CE practices require a lot of advanced technology and facility updates (Biwei et al., 2013). Therefore the lack of governmental economic support and expensive investments were one of the major reasons for companies to avoid participation in reducing their environmental impact (Geng et al., 2009).

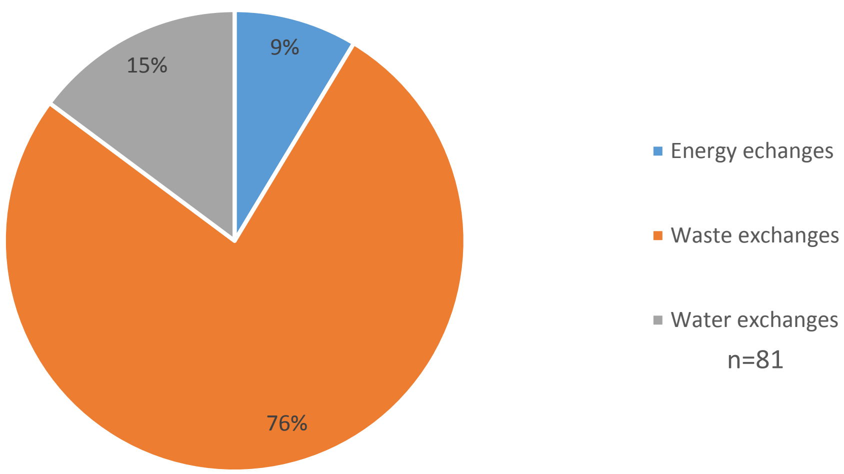

Figure 10: Industrial Symbiosis exchanges overview in TEDA 2007. Source: (Shi et al., 2010)

Table 4-6 Overview of the environmental management performance in TEDA

	Indicators (Rate Change from 2008-2011)	Unit	Growth Rate	Material and Energy Annual Savings in 2006	Environmental Management Projects
Water Management	Municipal water treatment	%	31	1.26 million m^3 of reclaimed water sold	“Sewage disposal fee”
	Wastewater discharge per IAV	%	-40	1.35 million m^3 of water treated and reused	Wastewater treatment plant
	Freshwater consumption per IAV	%	-30	182 000 m^3 of reclaimed water used for substituting the boiler supply	Desalinisation plant
Energy Management	Energy consumption per IAV	%	-11	120 GWh electricity generated from incineration plants	Energy saving plan
				2 million tons of steam transferred for heating purposes	Eco-centre
					Auditing systems
Waste Management	$S0_2$ discharge per IAV	%	-48.7	400 000 tons of municipal solid waste incinerated	Energy Recovery Incineration plant
	Solid waste generation per IAV	%	-35	91 000 tons of fly ash used in construction and landscaping	Eco-centre assistance
				24 000 tons of Novozymes bio-waste turned into fertilizers	Subsidy for desulfurization projects
	Use of industrial solid wastes material	%	4.6	30 000 tons of E-waste recycled	
				10 000 tons of lead waste turned to lead alloy	
	COD discharge per IAV	%	-12	3700 tons of food waste turned into animal feed	

Source: Shi et al., 2010; TEDA, 2010; Biwei et al., 2013; Chang, 2014

6 CONCLUSION

China´s extensive economic growth and lax legislature structure has brought the country into an environmentally daunting situation. China has been facing alarming results in terms of resource waste and environmental degradation. In order to deal with the unsustainable direction the country has been heading, China adopted the idea of CE as part of its National Development Plan.

Thesis provides assessment of the effects of the CE framework implementation in case of TEDA. Thesis also attempted to provide insight into statutory targets development in China over last 15 years. TEDA´s indicators analysis has focused on waste, water and energy management, and revealed several outcomes.

The environmental performance of selected indicators of the accredited EIP TEDA showed improvements in all the examined sections. In comparison with the Chinese national average, water and waste management showed the most significant improvements. By implementing variety of measures focused not only on the technological improvements but also on the development of economic, regulatory, and voluntary instruments, TEDA shows the signs of a successful EIP pilot project.

In accordance with the majority of published studies, it is concluded that the CE framework helped to improve the environmental performance of TEDA significantly. Its implementation eased the pressure on the area´s environment while maintaining the economic growth. However, it is important to mention that EIP development in China is a rather niche trend. Because of the insufficient legislative and financial support, Chinese industry continues to affect the country´s nature with ever increasing impacts. Even though the Chinese FYPs and law development indicates deepening environmental awareness and recognition, great majority of authors propose further establishment, specification and improvements of environmental protection laws and supportive strategies.

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