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A Framework for Integrating Ecosystem Services into China's Circular Economy: The Case of Eco-Industrial Parks

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Abstract: Identified as critical for sustainable development, ecosystem services are increasingly being put on the policy agendas of governments and corporations. China is now facing serious environmental challenges caused by losses of ecosystem services and recently has recognized that the country is reaching its environmental capacity. The circular economy (CE) has been positioned as a key strategy for national economic and social development by the national government as a way to resolve problems of resource depletion and environmental pollution. It will be increasingly critical to link ecosystem services to the CE. This means that the CE needs to be expanded to include restoration and regeneration of ecosystem services. This paper proposes a framework comprised of components including policies, governance, techniques and technologies, business development, key actors and support organizations for incorporating ecosystem services into the CE and focuses on industrial ecosystems, specifically eco-industrial parks (EIPs), as microcosms of a CE. Taking China as an example, this paper explores whether this framework can be applied to EIPs. The paper concludes that there are many opportunities to apply the framework to China's EIPs.

Keywords: ecosystem services; circular economy; industrial ecology; eco-industrial park; sustainable development; China

1. Introduction

Ecosystem services have been identified as critical for sustainable development by internationally important groups such as the United Nations Millennium Ecosystem Assessment (See http://www.unep.org/maweb/en/Index.aspx) and the World Business Council for Sustainable Development (WBCSD) (See http://www.wbcsd.org/home.aspx). Sustainable development for humans can only be realized by ensuring that the biosphere's capacity to provide a continuous flow of ecosystem services is maintained and enhanced [1–3]. However, ecosystem services, which cannot be easily replaced by technologies [4], are "undergoing rapid degradation and depletion" [5] (p. 395). The Millennium Ecosystem Assessment [6,7] has determined that 15 of the 24 ecosystem services examined are being seriously affected or unsustainably used. Currently, the global economy is being increasingly affected because of the degradation of ecosystem services [8].

Given this reality, it is imperative to reshape policies and decision-making with the concept of ecosystem services in mind. Ecosystem services are being increasingly put on policy agendas due to the contribution of the Millennium Ecosystem Assessment [9] and related projects such as The Economics of Ecosystems and Biodiversity (See http://www.teebweb.org/) (TEEB). Ecosystems are being recognized as natural assets with tremendous value by more governmental officials and corporate leaders [10,11]. Waage and Kester [11] reported that the integration of ecosystem services

into policies is being explored by several governments such as Australia, Canada, Denmark, France, Germany, and the U.K. Corporations such as Shell, Suncor, PUMA and UPM are also investigating the integration of ecosystem services into their decision making [12]. The Sustainable Development Goals put forward by the United Nations (UN) require integrating ecosystem values into national and local planning [13]. "One Planet Perspective", the WWF (World Wide Fund For Nature) Living Planet Report [14] outlines solutions for achieving sustainable development, including to "restore damaged ecosystems and ecosystem services" [14] (p. 108).

Since 2000, China's rate of growth has ranged between 6.9% and 11.4% [15]. However, during this process, substantial resources have been consumed and a large quantity of waste has been produced [16], causing losses of ecosystem services. Perhaps the most noteworthy is the critically serious air pollution problem in Beijing, Shanghai and some other big cities [17]. The central government of China embraced the concept of the circular economy (CE) in 2002 as a way to resolve the problem of serious natural resource depletion and environmental pollution [18,19]. In China, the CE absorbs concepts of industrial ecology (IE) and applies it at a jurisdictional and geographic level.

IE has spawned a number of concepts such as the industrial ecosystem, industrial metabolism and industrial symbiosis. However, linking the concept of ecosystem services with IE has only recently gained prominence by researchers and practitioners of the IE field. For example, some have made the case that the design and operation of eco-industrial parks (EIPs) should reflect this reality [20]. Some EIPs, such as the Devens eco-industrial park in America [21] and the Tianjin Economic-Technological Development Area (TEDA) in China [22], have taken some initiatives related with restoring ecosystem services.

This paper proposes a framework for incorporating ecosystem services into a CE and explores whether this framework can be applied to EIPs, which are microcosms of a CE. The paper is structured as follows: Section 2 discusses ecosystem services and CE theory, and introduces an approach to link with CE. In Section 3, we provide an overview of the general situation of China's ecosystem services, CE practice, and EIPs, and explore whether the framework can be applied to China's EIPs. Section 4 provides discussions including some challenges related to the implementation of the framework. Finally, in Section 5, we draw some conclusions.

2. Linking Ecosystem Services with CE

2.1. Ecosystem Services

Ecosystem services play a critical role in the functions of the Earth's life-support system [3]. Examples include climate moderation, pollination, and soil formation.

The Millennium Ecosystem Assessment [7] categorized ecosystem services into four types, i.e., provisioning, regulating, cultural and supporting services, which are highly interlinked.

While ecologists have been studying these services and functions for more than a 100 years for their own value, it can be seen in Table 1 that natural ecosystems are evidently valuable and provide extensive services for the development of human society. However, over the past 50 years, ecosystems have been changed more rapidly and extensively than in any other period of time in human history and these changes have serious consequences [7]. People and institutions urgently need to appreciate natural ecosystems as vital assets and incorporate their services into economic and industrial development decision making [23].

Table 1. Types of ecosystem services and the corresponding description and examples.

Types of Ecosystem Services	Description	Examples
Provisioning services	" . . . the products obtained from ecosystems." [7] (p. 40).	Food Fiber Fuel Genetic resources Biochemicals, natural medicines, and pharmaceuticals Ornamental resources Fresh water
Regulating services	" . . . the benefits obtained from the regulation of ecosystem processes." [7] (p. 40).	Air quality regulation Climate regulation Water regulation Erosion regulation Water purification and waste treatment Disease regulation Pest regulation Pollination Natural hazard regulation
Cultural services	" . . . the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences." [7] (p. 40).	Cultural diversity Spiritual and religious values Knowledge systems Educational values Inspiration Aesthetic values Social relations Sense of place Cultural heritage values Recreation and ecotourism
Supporting services	" . . . are those that are necessary for the production of all other ecosystem services." [7] (p. 40).	Soil formation Photosynthesis Primary production Nutrient cycling Water cycling

2.2. The CE

The CE concept emerged from the idea of substituting manpower for energy [24], first described in the 1970s in a report to the European Commission [25]. In 1990, Pearce and Turner [26] also reflected on the CE concept. They argued that the environment has three important economic functions, i.e., supplying resources, assimilating wastes, and providing recreational and aesthetic enjoyment. Based on these, they suggested that the linear economic system needs to be transformed into a circular economic system. CE was recently defined by the Ellen MacArthur Foundation (See https://www.ellenmacarthurfoundation.org/), which is playing an active role in popularizing the concept of CE, as "one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles" [8] (p. 2). The World Economic Forum has also shown some interest in the concept [27]. The European Commission is aiming to turn Europe into a CE [28]. Countries such as the UK, Germany, Netherlands, Finland and Japan have been attempting to implement the CE with an emphasis on reduce, reuse and recycle [29].

In China, the definition of CE still has not reached a broad consensus [18]. From a legal perspective, the Circular Economy Promotion Law of China provides a simple definition of CE: " . . . a generic term for the reducing, reusing and recycling activities conducted in the process of production, circulation and consumption." [30] (see Article 2). By analyzing and summarizing definitions of CE in various Chinese documents, it shows that: (1) CE is an economic concept and its essence is the ecological economy; (2) the basic philosophy of CE involves full utilization of resources, prevention and treatment of pollution, and realization of a harmonious development between economy and environment; (3) the

word "circular" refers to the material cycle in the economic system and (4) the goal of the CE is to achieve sustainable development.

It should be understood that "natural capital is the bedrock that underpins industrial, manufactured, social and financial capital" [31]. Through the lens of the CE, maintaining the functioning of ecosystem services should be emphasized because of their value in supporting the development of economy. Closing loops and fostering symbioses are important, but restoring environmental capacity for the benefit of economic and social development is arguably more important. To be restorative and regenerative, the CE should take the source of the resources we wish to reduce, reuse and recycle into account.

This requires decision-makers to attach importance to protecting and restoring natural ecosystems, for example, encouraging the development of scavenger and decomposer companies in the economic system [32–34]. In natural systems, scavenger and decomposer species are critical to the cycling of nutrients, both biological and technical.

In this paper, we expand the definition of CE to include restoration and regeneration of ecosystem services, in essence adding two more 'REs', namely restoration and regeneration of ecosystem services to the list of reduce, reuse, repair, remanufacture and recycle. We therefore suggest that CE should be defined as prevention and control of pollution, full utilization of resources and realization of the harmony between human and nature during the overall material flow process including restoration and regeneration of ecosystem services, which aims to achieve an ecologically and economically sustainable development. Figure 1 shows the CE expanded to include restoration and regeneration of ecosystem services.

According to the United States President's Council on Sustainable Development (PCSD) [35], an eco-industrial park (EIP) is "a community of businesses that cooperate with each other and with the local community to efficiently share resources (information, materials, water, energy, infrastructure and natural habitat), leading to economic and environmental quality gains, and equitable enhancement of human resources for the business and local community". Positioning EIPs as the meso-level for implementing the CE strategy [36], China actively promoted the development of EIPs and was the first country to adopt standards for these parks. In this paper, we have selected EIPs as ideal microcosms of a CE.

Prior to presenting and discussing our framework, the next section will provide an overview of the state of some ecosystem services in China.

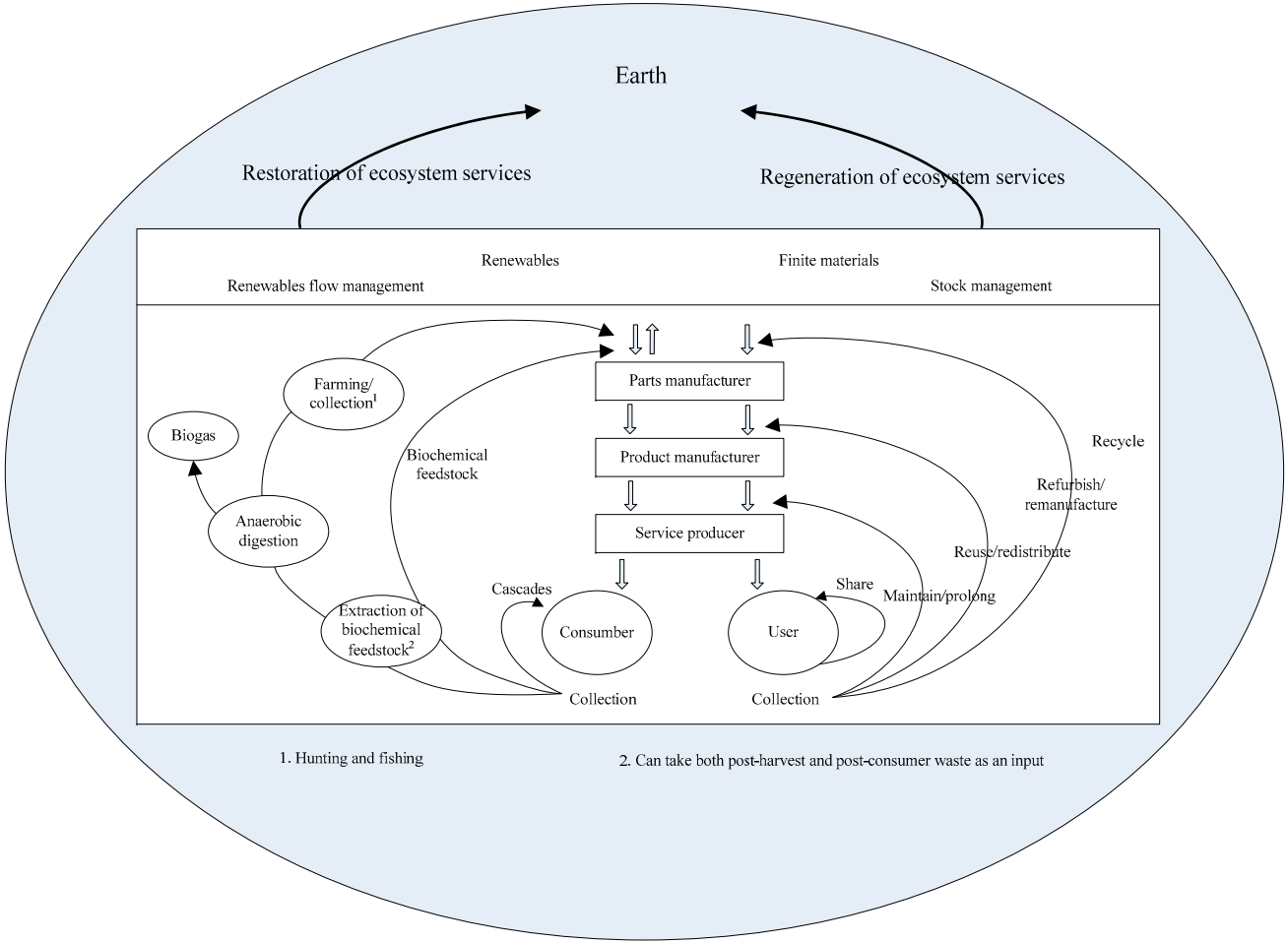

Figure 1. Circular economy expanded to include restoration and regeneration of ecosystem services. Source: Adapted from [8].

3. Incorporating Ecosystem Services into China's CE Practice

3.1. The Current State of Ecosystem Services in China

China's ecosystems are suffering degradation, erosion and contamination, resulting in major losses of valuable services. The ecological deterioration continues and the functions of many ecosystem services are weakening [37]. For example, soil erosion now affects 2,949,000 km^2, representing 31.1% of the surveyed land area of China [38]. Approximately 16% of soil and 20% of farmland in China exceeds the Quality Criteria for Soil Environment issued in 1996 [37]. Water resources have also been seriously polluted. The percentages of water resources, such as reservoirs, lakes, and groundwater, which exceed standards, are respectively 11%, 70% and 60% [39]. Rivers and lakes that are seriously polluted now exceed 40% of the total [40]. Perhaps the most noteworthy is the extremely serious air pollution problems [17]. In 2015, 265 of the 338 prefecture-level cites of the country exceeded air quality standards [38]. From Spring Festival Eve to the Spring Festival of 2017, the air in 124 of the 338 prefecture-level cites was considered heavily air polluted [41]. In addition, because of the excessive use of chemicals, the natural pollinators in China have been largely obliterated [31]. This loss of ecosystem services is becoming a major bottleneck which will seriously restrict China's sustainable development of society and economy [42], if it has not done so already. This was recognized at the highest level when President Xi Jinping of China noted that the environmental carrying capacity in China has been reached or exceeded [43].

The contradiction between the demand for a sustainable ecological environment by Chinese people and the continuous ecological deterioration is increasingly evident [37].

3.2. CE Policy and Practice in China

CE is a relatively new development paradigm for China [18,44–46], potentially allowing China to "leapfrog" into a more sustainable economic development model [46]. Positioned as a sustainability strategy [18], CE is being promoted by governments at all levels in China.

Some initiatives of China's CE practice have been investigated by researchers [18,19,44,46,47]. These initiatives encompass the implementation of CE at the individual firm level, industrial park level and city, province or state level. These initiatives have been supported by demonstration projects, formulation and promulgation of laws, and establishment of relevant organizations.

The Circular Economy Promotion Law of China was issued by the Chinese government and went into effect in January 2009. The government also launched a large number of demonstration projects nationwide. Interestingly some symbiosis projects had already been in place and successfully demonstrating CE concepts, such as the Guitang Group [48] and the Hai Hua Group [49].

In January 2013, the State Council [50] issued "the Development Strategy and Recent Action Plan for the Circular Economy". This is the first national CE development strategy and plan. Issuing this plan suggests that the Chinese government is keen to promote the expansion of CE development to more sectors and a larger geographic area.

The government also strongly supports the establishment of organizations related to CE. In 2013, the China Association of Circular Economy (CACE) (See http://www.chinacace.org/) was established [51]. As a non-profit organization, it is positioned as a platform for implementing CE across country. Its purpose is to provide services for companies, government and industries in the development of CE.

3.3. EIPs in China

As recognized by the United Nations Environment Programme (UNEP), industrial parks are a growing feature in the global landscape [52]. They have played an increasingly important role in China's economic development. Of the estimated 3,000 industrial parks in China [53], about 300 are considered to be national industrial parks as of 2013 [54]. In 1997, China began paying more attention to environmental management of industrial parks and adopted the EIP concept from an

UNEP report [52] and began to support EIP demonstration projects in 2000 [55]. According to the Ministry of Environmental Protection (MEP) [56], which is responsible for EIP demonstration projects, of the 300 national industrial parks, 93 have been designated as national eco-industrial demonstration parks in China. The EIP is viewed as the meso-level (the industrial park level) for implementing CE strategy in China [36]. In the list of national eco-industrial demonstration parks established by MEP, there are 17 industrial parks which are also designated by the National Development and Reform Commission (NDRC) to be the national CE pilot units.

As an enabler, the Chinese government plays an important role in promoting the EIP development at a national level [54]. EIPs have been regarded as a platform of innovation in environmental management [57]. For example, many EIPs were also selected as pilot units of low carbon and circular transformation. This will facilitate the transition from end of pipe to a system-oriented approach [54].

However, the development of EIPs in China is still in the early stages because many parks still face challenges in design and planning, technologies, management, and regulations [58].

While some of the pillars are in place, to enable China to move forward in incorporating ecosystem services into the development and operation of EIPs, a framework is required. This framework must be integrated within itself and with other relevant policies of the government.

3.4. Framework for Incorporating Ecosystem Services into China's EIPs

The framework put forward in this paper is composed of two general components with several elements in each component. One component requires additional emphasis to modifying and strengthening government policies on ecosystem services, governance emphasis on ecological values, business development of companies and research and development into relevant technologies and techniques. The second component of the framework involves greater awareness and effort by key actors, specifically government agencies, industrial park managers, business leaders and researchers at government institutes and universities, and establishing support organizations. Integration of the components and elements is expected to result in greater protection and restoration of ecosystem services creating enhanced conditions for CE, EIPs and sustainable development. Figure 2 shows the elements and structure of the framework.

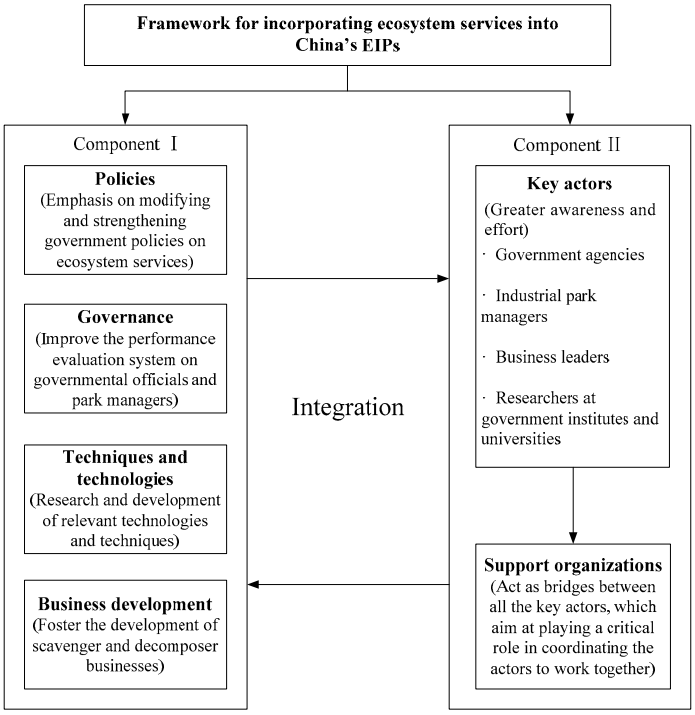

Figure 2. Framework for incorporating ecosystem services into China's eco-industrial parks (EIPs).

3.4.1. Policies

China has adopted a number of policies which could encourage greater consideration of ecosystem services in the planning, construction and operation of industrial parks. One of the most innovative policies related to ecosystem services is eco-compensation [59]. China's eco-compensation (Eco-compensation was first officially defined by the CCICE in 2007 as "a type of institutional arrangement to protect and sustainable use ecosystem services, and to adjust the distribution of costs and benefits between different actors and stakeholders, mainly through economic measures" [60].) policies are mainly implemented through pilot projects. The MEP [61] issued "Guiding Opinions on the Development of Eco-compensation Pilot Work" in which it identified four key zones for implementation: (1) nature reserves; (2) key ecological function areas; (3) mineral development areas; and (4) watersheds. In order to further integrate ecosystem services into decision making, the government has put forward more policies in recent years (see Table 2). Firstly, these policies address more aspects such as biodiversity and habitat protection, carrying capacity, and natural capital. Secondly, policies such as Ecological Functional Zoning, Ecological Protection Red Line and Main Functional Zone Planning can ensure that ecological space is preserved during the development of economy and society. Thirdly, as the ministry in charge of environmental protection, the MEP has issued many directives related to ecosystem services, such as promoting the integration of biodiversity protection into relevant planning.

Table 2. Policies related to ecosystem services issued by the Chinese government in recent years.

Name	Government and Time	Main Keypoints Related to Ecosystem Services
China Biodiversity Conservation Strategy and Action Plan (2011–2030)	MEP, 2010 [62]	Promote to integrate biodiversity protection into relevant planning. Strengthen habitat protection.
National Ecological Functional Zoning (Revision)	MEP, 2015 [63]	Classify ecological function into three types, i.e., ecological regulation, product offering, and human habitat guarantee. Ecological regulation involves water conservation, biodiversity protection, soil conservation, wind-break and sand-fixation, and flood control. Special plans such as economic and social development plan, land use plan, urban and rural construction plan, ecological protection and construction plan, which are drawn up by governments at all levels are required to be based on Ecological Functional Zoning.
Technical Guide for Delimiting Ecological Protection Red Line	MEP, 2015 [64]	Ecological protection red line refers to the strict control of the border delimited for the key ecological function areas and ecological sensitive and fragile areas. It is the bottom line for ecological security of nation and region. The region surrounded by the ecological protection red line is the ecological protection red line region. It is of great importance for maintaining ecological security, protecting ecosystem function, and supporting economic and social sustainable development. The ecological protection red line is an insurmountable protection line of the space, which requires implementing the most strict environmental standard and management measures.

Table 2. *Cont.*

Name	Government and Time	Main Keypoints Related to Ecosystem Services
Notification on Issuing National Main Functional Zone Planning	The State Council, 2010 [65]	Determine the main function for different regions based on resources and environmental carrying capability, developing intensity and development potential.
Report for the 18th Communist Party of China (CPC) National Congress	The CPC Central Committee, 2012 [66]	Leave more space for nature to achieve self-renewal. Accelerate the implementation of the main functional zoning strategy and require all regions to pursue development in strict accordance with this strategy. Launch major projects for restoring the ecosystem. Increase the capacity for producing ecological products. Expand the area of forests, lakes and wetlands. Protect biodiversity. Establish the eco-compensation system.
The Decision on Some Major Issues Concerning Comprehensively Deepening the Reform	The CPC Central Committee, 2013 [67]	Draw a "red line" for ecological protection. Implement the main functional zone system. Establish monitoring and warning mechanisms for the carrying capacity of natural resources and the environment. Take restrictive measures for overload areas of water and soil resources, marine resource, and environmental capacity. Implement the eco-compensation system.
Integrated Reform Plan for Promoting Ecological Progress	The CPC Central Committee and the State Council, 2015 [68]	Cultivate respect for the value of nature and natural capital. Prior to the formulation of a plan, a resource and environmental carrying capacity assessment must be carried out, and the results of the assessment should serve as the fundamental basis of planning. All wetlands will be contained in the scope of protection. Determine the services of various wetlands. Establish a mechanism for the ecological restoration of wetlands.

In addition, some important national policies, such as the "Integrated Reform Plan for Promoting Ecological Progress", which was issued by the CPC Central Committee and the State Council in 2015 [68], also included many elements relevant to ecosystem services. Furthermore, because establishing an ecological civilization has become the governing philosophy for Chinese government [66], ecosystem services are expected to receive more attention by the government and policies relevant to ecosystem services will be strengthened in the future.

Industrial parks can be a good platform for pilot projects to assess the implementation of these policies, especially those parks identified as EIP demonstration projects. In China, although CE and EIPs still mainly stress recycling and symbiosis, some policies, which cover contents that can be connected with ecosystem services, have been issued by the government focusing on industrial parks (See Table 3). From Table 3, it can be seen that low carbon, which is relevant to ecosystem services, has been regarded as a key aspect for the development of industrial parks and special policies have been issued by the government. For example, the MEP required low carbon should be incorporated into the development of EIPs [69]. The NDRC put forward that transforming industrial parks to circular ones aims to make industrial parks realize an ecological benign cycle and environmental carrying capacity needs to be considered [70].

Table 3. Policies focusing on industrial parks which can be connected with ecosystem services issued by the Chinese government.

Name	Government and Time	Main Keypoints
Notification on Strengthening the Development of Low Carbon Economy for National Eco-industrial Demonstration Park	MEP, 2009 [69]	Integrate the development of low carbon economy as a key aspect into the construction and operation of EIPs. Enhance energy utilization efficiency and improve energy structure. Stress on the utilization of clean energy. Strengthen the utilization of clean energy infrastructure. Promote energy-saving reconstruction for existing buildings and energy-saving design for new buildings.
Work Program for National Pilot Low Carbon Industrial Park	MIIT and NDRC, 2013 [71]	Increase the use of renewable energy. Strengthen the construction of low carbon infrastructure. Encourage the installation of renewable energy infrastructure for buildings and transportation facilities.
Guidelines for Implementation Plan of Circular Transformation for Industrial Parks	NDRC, 2015 [70]	Promote green, circular, and low-carbon development of industrial parks. Realize an ecological benign cycle. Consider the environmental carrying capacity of industrial parks. Increase the utilization rate of renewable energy.

Guided by these policies, more contents relevant to ecosystem services could be incorporated into CE and EIPs. For example, in China, the current indicator system for EIPs stresses eco-efficiency [72]. These indicators have been revised recently and could be expanded to incorporate maintenance and restoration of ecosystem services into the design and operation of EIPs.

3.4.2. Governance

The performance evaluation of government leaders and industrial park managers will influence how ecosystem services are incorporated into CE practice. In China, the performance evaluation of government leaders has focused primarily on economic performance [73]. For this reason, local government leaders always pay more attention to economic growth of the local region [46]. This will easily lead the local government to pursue short-term economic growth at the expense of the environment and ecosystem services. Thus, the effective integration of ecosystem services into CE will require a change in the performance evaluation system on governmental officials. Currently, this performance evaluation system is being modified. In 2015, the State Council [42] required that the evaluation of government performance should include other factors, namely resource consumption, environmental damage, eco-efficiency and technological innovation. Some specific requirements related to productivity of ecosystems were also introduced. These include drawing a "red line" for ecological protection, building mechanisms for monitoring the carrying capacity of natural resources and the environment, executing a fee system for resources and eco-compensation, and reforming the prices of natural resources and products in order to fully reflect market supply and demand, resource scarcity, environmental damage cost and ecological restoration. The new factors introduced should contribute to improving the assessment of performance and provide a stronger rationale for incorporating ecosystem services into decision-making by ministries, provinces, cities and enterprises.

With the increasing concern about climate change, carbon emission intensity is also being incorporated into the assessment system of local governments [74]. Reduction of CO_2 emission per unit GDP is viewed as an important aspect for evaluating governmental leaders. The MEP, which is in charge of the national eco-industrial demonstration parks, required that the established national eco-industrial demonstration parks incorporate the development of low carbon economy into key performance evaluation [69].

Based on this analysis, it may be possible to integrate ecosystem services into CE and EIPs under the new performance evaluation system in China.

3.4.3. Techniques and Technologies

When developing a new or expanding an existing industrial park, the ecosystem services that are likely to be negatively affected need to be understood. This could be done with an environmental impact assessment [75]. For an existing park, management needs to understand the ecosystem services which have been degraded. In this case, an environmental restoration plan could be developed [76].

There are many opportunities for incorporating ecosystem services into industrial parks, some of which have an additional benefit of reducing carbon emissions. These can occur at the design stage for new or expanding parks, at the construction stage as well as at the operational stage. At the design stage, ecosystem services can be considered when the infrastructure is built. For example, where natural wetlands are threatened, constructed wetlands can be used to treat runoff or gray water [77]. This will reduce the need for expensive storm water piping. Also, some wetland plants can be used to remove nutrients while others can detoxify pollutants [31]. Pervious pavement can be used on parking areas to allow infiltration of rainwater and snowmelt. Upstream of the industrial parks, forested areas should be maintained or planted to filter rainwater and reduce the need for expensive technologies to treat drinking water [78]. Within a new park, there are also many opportunities to maintain or replant forest plantations as carbon sinks [79]. At the construction stage, buildings should be built with cisterns to hold water for various purposes [80]. The roofs of buildings should be designed to hold solar thermal, solar voltaic panels, green roofs and small wind turbines to provide renewable energy and reduce carbon emissions [81]. Buildings can also be built with heat recovery systems. Biodegradable carbon-neutral materials can be selected for some uses in buildings [82].

Industrial symbiosis is considered as "an innovative way to improve resource and a recognized part of achieving a low-carbon economy" [83] (p. 5). At the operational stage, the symbiotic relationships between firms in the parks need to be continuously explored. For example, Bühner [84] claimed that the greenhouse gas (GHG) emissions of industrial parks can be reduced by 35% through inter-firm collaboration. Opportunities can be found to heal soils in order to recover their ecosystem functions such as absorbing and storing water and carbon [31]. Using fresh and composted urban wastes, which contain a high organic fraction, soil can be restored because this organic matter can enhance biogeochemical nutrient cycles of the soil [85]. There are many techniques for repairing and restoring ecosystem services [77,78,86], which could be helpful for incorporating ecosystem services into industrial parks. They are listed in Table 4 and related to the four types of ecosystem services raised by Millennium Ecosystem Assessment.

In addition, as industrial parks are often built on the edge of cities near agricultural areas, landscaping of properties should include wild flower gardens to encourage birds, bees and butterflies which are critical to the pollination of most of our food supplies. It is also possible that not all ecosystem services can be mitigated. Sometimes it may be necessary to compensate for them beyond the boundaries of the park.

There have been some successful initiatives to incorporate ecosystem services into EIPs. In China, the Tianjin Economic-Technological Development Area (TEDA), which is one of the national demonstration EIPs in China, has implemented a number of successful initiatives to repair and restore ecosystem services. One of the companies within the park, the TEDA Eco-landscaping Development Co. Ltd. produced new soil with an innovative technology [55], TEDA also explored other approaches to green the park, such as roof gardens and bridge greening [22], which are helpful in reducing CO_2 emissions and regulating climate of the park area. However, the nature and scale of the lost ecosystem services due to the construction of TEDA, such as salt marshes, is unknown.

There is an opportunity for researchers and government research institutes and universities to develop and adopt these techniques and technologies.

Table 4. Examples of techniques for incorporating ecosystem services into industrial parks (related to the four types of ecosystem services raised by the Millennium Ecosystem Assessment).

Examples	Benefits	Main Ecosystem Services Provided
Green roofs	Reduce storm water run-off, Reduce GHG emissions, Reduce noise pollution, Regulate air-quality, Filter air pollutants, including PM and gaseous pollutants such as NO_X, SO_2, CO, and ground-level O_3	Regulating services. Supporting services
Constructed wetlands	Store water with rainwater harvesting, Manage storm water runoff, Water purification and wastewater treatment, Provide habitat for fish and birds, Byproduct optimization (fresh water, biomass), Educational opportunities for local schools, Provide recreational benefits	Regulating services. Provisioning services. Cultural services. Supporting services
Planting and maintaining trees	Air quality regulation and climate regulation, Reduce carbon emissions, Absorb and reduce various pollutants, such as particulate matter (PM), nitrogen oxides (NO_X), sulfur dioxide (SO_2), carbon monoxide (CO), and ground-level ozone (O_3), Regulate heat island effects through shading and evaporation, Increase groundwater recharge, Filter storm-water runoff in order to prevent flooding and improve water quality, Provide wind-breaks to protect buildings from wind damage, Preserve urban watersheds in order that drinking water supply and quality is protected, Provide wildlife habitat, Provide recreational benefits	Regulating services. Supporting services
Planting flower gardens	Assists with pollination, Provide recreational benefits.	Regulating services, Cultural services
Permeable pavement	Reduce storm-runoff, Replenish groundwater supplies	Regulating services, Supporting services

3.4.4. Business Development

The WBCSD has recognized that "business impacts and depends on natural capital" [87]. The Business Ecosystems Training (BET) program has been developed by the WBCSD to assist businesses to understand the links between themselves and ecosystem services [88]. This is an opportunity to support ecosystem functions while creating businesses and employment. Scavengers and decomposers are critical to the effective functioning of ecosystems because they assist in cycling materials and nutrients and reduce the quantity of materials discharged into air, water and soil [33]. In industrial systems, scavenger and decomposer functions also have an important role to play in reusing, repairing, remanufacturing, recovering and recycling materials [34]. Unfortunately, the development of such companies is not always encouraged and wasted materials are incinerated or buried. The CE concept is one that embraces their development. When incorporating ecosystem services into CE, it is essential to establish an industrial structure that includes these functions as key services.

In China, the Energy Conservation and Environmental Protection Industry (ECEPI), which refers to the industry sector that provides technologies and technical support for conserving energy and resources and protecting the environment, has been identified as a key sector for supporting CE and is being vigorously promoted by the government [89]. The sector has been confirmed as one of seven strategic emerging industries cultivated by the national government.

The State Council [89] has identified some key areas related to CE such as comprehensive utilization of solid wastes, remanufacturing, utilization of kitchen and food wastes, utilization of

wastes from agriculture and forestry and conservation and utilization of water resources. All of these topics will be supported by scavenger and decomposer businesses which will also create employment while reducing environmental impacts.

Because of the concentration of industries in industrial parks, management can readily foster businesses involved in reusing, repairing, remanufacturing, restoring and recycling materials while reducing the overall environmental impact of the park. In one study in Burnside Industrial Park in Canada, 12% of the businesses in the park performed these functions in whole or in part, assisting in the cycling of equipment and materials within the park and the adjacent community [33]. In addition, industrial parks can be developed with these functions in mind. In China's national EIP demonstration program, a category of parks known as venous industry parks was identified. For example, the Qingdao New World Venous Industry Park collects and disassembles discarded appliances and abandoned vehicles, reusing some parts and recycling others [49].

3.4.5. Greater Awareness and Effort by Key Actors

The role of key actors is essential for incorporating ecosystem services into CE and EIPs. These key actors mainly involve government agencies, industrial park managers, business leaders, and researchers at government institutes and universities. These key actors have been identified from the experiences of CE and EIPs practice and it has shown that they played a critical role in promoting the development of CE and EIPs [8,90–93]. For example, through education and training on cleaner production, IE and CE, an industrial symbiosis at the industrial park level was discovered and improved with the role played by key actors composed of government agencies, companies, and universities [93]. Although incorporating ecosystem services into CE and EIPs makes sense, it is a new thinking for most of these key actors and needs to be further practiced. This requires a greater awareness and effort by them. In China, the communication and cooperation between these key actors has been established during the process of CE practice. This will facilitate the key actors to make great effort to work together on incorporating ecosystem services into the development of CE and EIPs when they understand the necessity of linking ecosystem services with CE, especially for China. Currently, ecological civilization, eco-compensation and low carbon economy has become hot topics in China and the environmental carrying capacity in China has been reached or exceeded [43]. This could drive all the key actors to further realize the significance of integrating ecosystem services into China's CE and test it at the EIPs level.

3.4.6. Support Organizations

Establishing special organizations assists in supporting the implementation of integrating ecosystem services into CE and EIPs. These supporting organizations encompass key actors from governments, industrial parks, companies and research institutions and universities and act as bridges between all the key actors, which aim at playing a critical role in coordinating the actors to work together on integrating ecosystem services into CE and EIPs. For example, they can provide training opportunities for actors on incorporating ecosystem services into CE and EIPs, popularizing relevant technologies and techniques, promote the implementation of policies, and provide feedback and suggestions to government.

In China, there are some organizations which can be connected with ecosystem services. The CACE is playing a critical role in promoting CE and EIPs. Its members are from government, universities, research institution and companies [51]. The China Council for International Co-operation on Environment and Development (CCICED) (See http://www.cciced.net/) is an international senior advisory organization with a goal of facilitating the sustainable development and ecological civilization construction for China. It pays more attention to the challenges of global environmental problems that China faces, including climate change and ecosystem protection, and provides forward-looking, strategic and practical policy recommendations for Chinese government. In addition, other

organizations such as China Ecological Environment Protection Association and China Association of Environmental Protection Industry are also relevant to CE and ecosystem services.

Currently, the CACE is the most influential organization for promoting the development of CE in China. Its members cover a broad range of key actors. It has played a vital role in encouraging and coordinating its members to practice CE under the guidance of related policies. For this reason, the CACE has great potential to be positioned as such a support organization under the cooperation with other relevant organizations when it embraces the concept of integrating ecosystem services into CE and EIPs.

4. Discussion

4.1. Implementation of the Integrated Framework

The framework put forward in this paper provides a comprehensive approach for integrating ecosystem services into CE and EIPs. For example, policies related to ecosystem services, such as eco-compensation and shadow pricing, can encourage and guide industrial parks to develop in a manner that will move them to incorporate ecosystem services into design and operation. Through governance, maintenance and restoration of ecosystem services can become one of the performance goals of government officials and park managers. Techniques and technologies can provide concrete methods for an industrial park to maintain and restore ecosystem services. Business development assists in providing an opportunity to support ecosystem functions while creating businesses and employment.

All the elements composing the framework are highly interlinked and need to be systematically implemented. For example, because the ecological civilization is becoming the governing philosophy for Chinese government and being incorporated into the performance evaluation of government leaders [66], this will assist in modifying and strengthening government policies on ecosystem services. However, there also exist problems associated with the implementation of the current policies in China. As one example, a mechanism for eco-compensation has not been established [94]. Some statements, as noted in Table 2, issued recently such as "requiring that all wetlands will be contained in the scope of protection" and "planning to establish the eco-compensation mechanism" suggest that the policy will be expanded. While progress has been made, the full range of ecosystem services is not yet covered by the policies. This requires a greater awareness of integrating ecosystem services into CE and EIPs by all the key actors for implementing the framework.

4.2. The Role of Government in Implementing the Framework

In the implementation of the framework, the role of government in China is critical. Government plays an essential role in governance, policy-making and providing support systems for the development of business. Incorporating ecosystem services into CE and the design and operation of industrial parks in China involves the direction and commitment of governments at all levels. Chinese government has been playing an active role in promoting the development of CE and EIPs. A few governments such as Australia, Canada, Denmark, France, Germany and the UK are exploring the integration of ecosystem services into policies [11]. The government plays many roles in implementing the framework, such as issuing policies, regulating performance evaluation system, fostering the development of scavenger and decomposer businesses and promoting the establishment of support organizations. The Chinese government has positioned ecological civilization as a governing philosophy [66]. The implementation of the philosophy has proven challenging. Initiatives taken by other governments might be helpful in providing guidance for implementing the framework.

In addition, more coordination is needed among government agencies. At the national level in China, the key ministries and departments relevant to controlling ecosystem services are the State Forestry Administration (SFA), the MEP and the NDRC [95]. Due to the complexity of ecosystems themselves and resources therein, management and resolution of problems involves many different

administrative departments. Taking wetlands ecosystems as an example, the SFA is in charge of protecting wetlands ecosystems. The utilization and restoration of wetlands ecosystem is relevant to decisions about land use, which is regulated by Ministry of Land and Resources (MLR). Water is the lifeline of a wetland ecosystem. The Ministry of Water Resources (MWR) is in charge of water resource management. However, environmental issues associated with water is the responsibility of the MEP. Because of the overlap of management functions, different management departments often protect their interests, which can lead to inefficiency [95]. As a department in charge of CE, the NDRC has played a role in coordinating different departments to cooperate with each other during the process of promoting CE development. For this reason, NRDC could be given new responsibilities to play a more comprehensive and active role in coordinating relevant administrative departments to collaborate, which ensure that ecosystem services are properly considered in the implementation of CE and in the design of EIPs.

There are now many examples of techniques and technologies that can mimic, replace or restore ecosystem services. These services need to be incorporated into CE and EIPs and they can be driven by market mechanisms, supported by government regulations.

4.3. EIPs as Platforms for Testing the Framework

EIPs have great potential to reduce their influence on natural ecosystems and their functions. The design and operation of an EIP can reduce the damage of infrastructure and industrial operations on its surrounding environment while restore some damaged or lost functions. For example, Chertow and Lombardi [96] found that industrial symbiosis, a key characteristic of EIPs, can contribute to the realization of environmental benefits such as reducing waste emissions and conserving natural resources. There have been a number of articles which have demonstrated that establishing symbiotic relationships can reduce CO_2 emissions at the industrial park level [81,84,97–101]. Some EIPs have emphasized climate control, ecological design, landscaping, and green infrastructure [21,92].

China has embraced the concept of EIPs and identified many national eco-industrial demonstration parks. Moreover, EIPs have been regarded as an important platform of testing new concepts such as low carbon economy. Some of these parks have already implemented some initiatives to repair and restore ecosystem services. The EIPs in China are often managed by an administrative committee [93], which acts as a regional government. This assists in implementing policies at the industrial park level. However much more remains to be done in implementing the philosophy of ecological civilizations and the policies of the CE.

5. Conclusions

Recognized as natural assets with tremendous value and significant for sustainable development, ecosystem services are being increasingly put on the policy agendas of government and corporations. Because of the value of ecosystem services to the economy, they should be incorporated into the development of a CE, and we have proposed that the CE concept should be expanded to include two additional 'REs', namely restoration and regeneration of ecosystem services. China is facing major threats in terms of losses of ecosystem services and identified CE as a way to resolve the problem of serious natural resource depletion and environmental pollution. We have identified key components of a framework such as policy coordination, governance, technologies and techniques and EIPs that will facilitate the incorporation of ecosystem services into the CE. Choosing EIPs as microcosms of a CE, we show that there has many opportunities to apply the framework put forward for incorporating ecosystem services into CE and China's EIPs. It is a comprehensive approach and needs the leadership and commitment of government. Although the framework is based on the situation of China, it might be helpful for providing guidance on how to factor ecosystem services into policies and decision making for other countries.

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