Resources, Conservation & Recycling 140 (2019) 137–144

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

journal homepage: www.elsevier.com/locate/resconrec

Full length article

Review of the development of China's Eco-industrial Park standard system

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ARTICLE INFO

Keywords:
Eco-industrial Park
Industrial symbiosis
Standard system
China

ABSTRACT

Eco-industrial Parks (EIP) have become a central element in China's industrial strategy to combine industrial development while minimizing environmental impacts and improving resource efficiency. National standard system has been developed as a main tool for assessing EIPs. This paper provides a review of the development of China's EIP standard system. The focus of the analysis is the new national demonstration EIP standard (HJ/T274-2015), including a review of calculation methods for some key indicators. The analysis also provides a comparison with previous standards to identify the main changes and improvements in the assessment of EIPs. Comparison findings illustrate that the new standard provides a more consistent indicator system by providing a consolidated standard system, and offering more comprehensive and quantitative indicators. Moreover, the new standard aims to better manage environmental issues by supplementing more comprehensive environmental indicators. The standard also strengthens the emphasis of the industrial symbiosis dimension in the evaluation of EIPs. By offering optional indicators and giving distinct targets based on contextual conditions for a number of indicators, the flexibility and rationality of the EIP assessments are also enhanced. Although many positive changes have been identified, there are still some shortcomings exist in the new EIP standard. The paper proposes a number of recommendations based on analyzing shortcomings, for instance further improving of the industrial symbiosis indicators, offering social benefit evaluation indicators, and strengthening the reduction action evaluation. China's experience of setting EIP standards and indicators may provide lessons for other countries' attempts to develop industrial estate indicators. In order to observe and effectively promote industrial estates at the global range, several remaining research questions that need further exploration are put forward in this study.

1. Introduction

With the aim of responding to environmental pollution and global warming, many countries are seeking innovative ways to relieve these problems. Establishing Eco-industrial Parks (EIPs) is considered as one effective way for coordinating environmental pollution and economic development (Lai, 2013; UNEP, 1997; Zhang et al., 2010; Song and Shen, 2015). Though being a policy-concept which is infused with different meanings depending on political, socio-economic and cultural context (Boons et al., 2017), EIP is usually proposed as a community of manufacturing and service businesses seeking enhanced environmental, economic, and social performance through collaboration in managing environmental and resource issues (Lowe, 1997; Valenzuela-Venegas et al., 2016).

Practically, a precursor to EIP is the regional industrial symbiosis[1] at Kalundborg in Denmark, uncovered in 1990 (Ehrenfeld and Gertler, 1997; Chertow, 2000). Other eco-innovation park cases were also initiated and investigated, such as in the US (Chertow, 2000), Canada

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[1] Industrial symbiosis is a subset of industrial ecology, which is usually happened in EIPs. Industrial symbiosis engages traditional separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water and by-products. The key to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity (Chertow, 2000).

https://doi.org/10.1016/j.resconrec.2018.09.013
Received 25 January 2018; Received in revised form 9 June 2018; Accepted 12 September 2018
0921-3449/

(Cote and Cohen-Rosenthal, 1998; Fleig, 2000), Korea (Kim and Powell, 2008; Park et al., 2008, 2016), Japan (Van Berkel et al., 2009; Geng et al., 2010), European countries (Massard et al., 2014) and Australia (Roberts, 2004; Van Berkel, 2007; Van Beers et al., 2007). China began to facilitate the EIP strategy in early 2000s and actively promoted it with the enactment of both cleaner production promotion law and circular economy promotion law (Geng and Cote, 2003; Geng et al., 2009, 2013, 2016; Chiu, 2001; Fang et al., 2007; Shi et al., 2012a, 2012b; McDowall et al., 2017). The first reported EIP case in China is the Guitang sugar-making complex approved by the State Environmental Protection Administration (SEPA)[2] (Zhu and Cote, 2004; Zhu et al., 2007). China developed large amount of EIP networks since then.

Although EIP can be developed and promoted in different forms, setting of standards and guidelines is found helpful for promoting EIP development in China (Shi et al., 2012a, 2012b). Several regions also designed their own EIP criteria, including Port of Cape Charles in the US, Virginia in the US, Thailand, and the Eco-star criteria in Devens, Massachusetts (Cote and Liu, 2016). Yet only China designed a national EIP standard that is applied in large number of parks, and there is no internationally accepted standard for EIP. Several studies discussed about the EIP evaluation standard system in China. Geng et al. (2008) argued that some of the criteria in EIP standard released by SEPA in 2006 are vague and difficult to evaluate. Meanwhile, the standard is criticized having not considered the principles of eco-industrial development and local realities (Geng et al., 2009). Yu et al. (2014) and Liu et al. (2007) reviewed the EIP performance according to the Chinese EIP standards, and found indicators such as reuse rate of reclaimed water, recycling rate of solid waste are usually challenging for industrial parks to execute.

As mentioned, China has become a major player in EIP experimentation in the last decade, and use EIP standardas a main management tool to promote the EIP development. Reflection on the experience indicates that the development of practical quantitative assessment indicators for EIPs has been a crucial factor for the ongoing success of China's national demonstration EIP program (Shi et al., 2012a, 2012b). The performance of environmental pollutant emission and energy consumption intensity in certified EIPs is discovered much better than the average level of ordinary industrial parks (Tian et al., 2014). In this sense, a review of the EIP standard system is crucial in understanding how it has evolved over time adapting to both criticism from academia and needs from business. EIP standards in China have already experienced several rounds of revision since the first standards were established in 2006. In 2015, MEP (Ministry of Environmental Protection) released the new standard for national demonstration EIP (HJ/T274-2015) to replace the previous standards. Our literature review reveals that although several articles discussed the Chinese EIP standard system released in 2006 and 2009, no research has yet been undertaken to investigate the 2015 standard and assess progress. In order to fill this research gap, this paper will carry out an analysis of the newly released EIP standard. We will try to identify the primary changes and key improvements of the new version of EIP standard system. Furthermore, we will try to explore what are the shortcomings still existing in the new standard.

2. Research framework and methodology

2.1. Research framework

This study will first give a review of Chinese EIP standards development. The newest 2015 version of standard is illustrated in the manuscript, while the 2006 and 2009 versions are presented in our supplement material. Meanwhile, the enforcement and management mechanisms of EIPs in China are described. As the next step, the main changes among the series of EIP standards will be identified, and reasons of the modifications are discussed. Furthermore, shortcomings of the existing standard and outlook of EIP standard development in China are analyzed.

2.2. Methodology

Several approaches are conducted to collect materials and information in this study, including literature and report review, stakeholder interview and informal meetings. (1) The review of the EIP standard development was based on the released EIP standard documents. (2) Reasons of the several rounds' modifications were collected by interview and informal meetings with EIP standard designers from China Environmental Science Research Institute. (3) Critical analysis including the shortcomings of the current EIP standard and outlook of the EIP standard development is conduced based on interviews and informal meetings with EIP standard designers, EIP administrative office members and researchers within the EIP field.

3. China's EIP development

3.1. EIP and standards development

There are many types of industrial parks in China. In fact, it needs to be recognized that a significant share of China's manufacturing is being managed through those parks, much larger than e.g. in OECD countries (Mathews and Tan, 2016). In order to better manage these industrial parks, SEPA categorized these industrial parks into three groups, namely the sector-integrated group, the venous[3] group and the sector-specific group. The sector-integrated group refers to those parks with multiple industrial sectors, especially the development zones, which are the main form of Chinese industrial park. The venous industrial park particularly refers to those resource recovery parks where environmental technology companies and firms making "green products" coexist. The sector-specific group refers to parks with primarily one main sector or correlated sectors (Geng et al., 2009).

Before 2006, the sector-specific EIP accounted for the largest percentage among the three kinds of industrial parks, including steel industry, cement industry and paper industry. In 2006, the award of EIP for Qingdao New World venous industry park[4] indicated that the venous industry become a new type of EIP in China. By the end of 2008, 30 national demonstration EIPs construction plan had been endorsed by MEP, including 20 sector-integrated EIPs, 9 sector-specific EIPs and 1 venous industry EIP. The development of sector-integrated EIP grew rapidly from 2006 to 2009, with even higher expanding rate after 2010 (Yu, 2015). By the end of 2015, there are already 126 national EIPs demonstration plans being endorsed, including 109 sector-integrated EIPs, 14 sector-specific EIPs and 3 venous industry EIPs (see Fig. 1).

Alongside with EIP development, the EIP standards also experienced several rounds of evolution. The development process of standard systems for Chinese EIPs is summarized in Table 1(MEP, 2016).

The new EIP standard (HJ/T274-2015) has already been enforced since 2016, while those already approved EIP_S are required to implement this new standard from January 1, 2019. In order to better understand the new EIP standard (HJ/T274-2015), the whole indicators

[2] State Environmental Protection Administration (SEPA) changed to Ministry of Environmental Protection (MEP) in 2008.

[3] The term "venous industry" (*静脉产业*) is widely used in China and Japan, and refers to resource recovery or secondary material industries. This is by analogy with the circulatory system: arteries carry oxygen-rich blood to the body, while veins return blood that has had its oxygen used up. The term 'venous' thus refers to secondary cycles of materials and energy, while 'arterial' industries are those engaged in primary flows of virgin materials.

[4] Due to environmental illegalty, Qingdao New World venous industry park was punished and removed the title of demonstration EIP in 2016. http://www.zhb.gov.cn/gkml/hbb/bgth/201612/t20161212_368966.htm

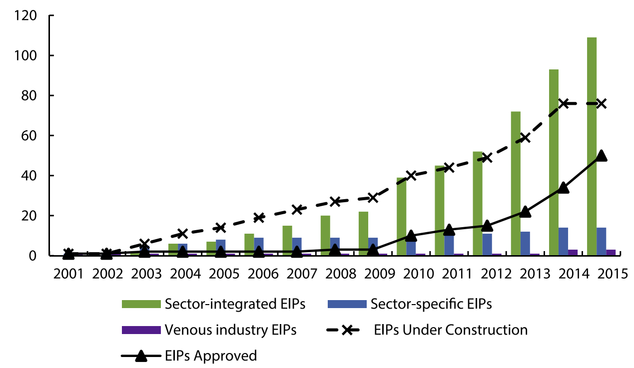

Fig. 1. China's EIPs development since 2001–2015. Modifed from Bai et al. (2014).

Table 1
EIP standards in China.

Date	Document
2006	1. Tentative Standard for Sector-specific Eco-industrial Parks (HJ/T273-2006) 2. Tentative Standard for Sector-integrated Eco-industrial Parks (HJ/T274–2006) 3. Tentative Standard for Venous Industry Based Eco-industrial Parks (HJ/T275-2006)
2009	Standard for Sector-integrated Eco-industrial Parks(HJ/T274-2009)
2012	Revised Standard for Sector-integrated Eco-industrial Parks (HJ/T274-2009)
2015	Standard for National Demonstration Eco-industrial Parks (HJ/T274-2015)

group are shown in Table 2. The added or modified items comparing with the previous versions are highlighted in bold value.

The standard for National Eco-industrial Parks (HJ/T274-2015) offers some detail of the calculation and explanations for each indicator. The calculation methods for some of the key indicators are illustrated in Table 3.

3.2. Enforcement of EIP standard

The management of EIP in China includes the process of application for EIP development, construction, EIP approval and certification, and follow-up examination (MEP, 2015). An EIP working group—-administrative office of national demonstrative EIP program is in charge of the EIP management, formed by officials from MEP and the Ministry of Commerce and Ministry of Science and Technology. The steps in the process are as follows:

(1) Industrial parks that are eager to be certified as EIPs need to first submit their development plan to the EIP administrative office. According to the current practices, the first planning stage tends to last for two or three years for those parks that have already conducted some eco-industrial development practices and obtained an ISO 14001-certified environmental management system for the EIP.
(2) Once the EIP development plan has been approved by the administrative office, intensive industrial symbiosis transformation needs to be conducted according to the EIP developing plan. Within 5 years after submission of the EIP development plan, industrial parks under EIP construction are allowed to apply for EIP approval. After careful inspection taken by the EIP administrative office, only those industrial parks with all the EIP standards qualified can finally be certified as EIPs (MEP, 2015).
(3) Both industrial parks under construction and certified need to hand over an annual performance evaluation report to the EIP administrative office, reporting their status against of each EIP standard criteria based on self-reported data. Furthermore, afterwards examination will be taken by the EIP administrative office. Three years after certification, part of the EIPs will be randomly selected for follow-up examination. Industrial parks found to be in breach of the standard will have their EIP certification revoked (MEP, 2016). The multistage, progressive EIP accreditation procedure is practically designed to deter the industrial parks that are mostly interested in promoting their public images, but lack genuine environmental commitment to actually implementing EIP development plans (Shi et al., 2012a, 2012b).

It is worth noting that the EIP program in China is entirely voluntary. Each industrial park interested in being recognized as an EIP had to take its own initiative in creating an EIP development plan and submitting its application to SEPA (Shi et al., 2012a, 2012b). In the past, MEP did not have tailored policy targeting EIP development, such as financial subsidy. In the latest EIP management plan however (MEP, 2015), the local government and bureau of environmental protection is required to set special funding or give tax preference for industrial parks under EIP construction or approved.

4. Analysis of EIP standard modification

4.1. Main changes and improvements of the standard system

As introduced, China's EIP standard systems have experienced several rounds of modification since first issued in 2006. In order to explore the changes, the previous standards including HJ/T273-2006, HJ/T274-2006, HJ/T275-2006, HJ/T274-2009 and HJ/T274-2012 are provided in our supplementary material. After a careful comparison of the indicators, the main changes of the series of standard systems are identified as follows.

Comparing HJ/T274-2009 with the Tentative Standard for sector-integrated EIP (HJ/T 274–2006), 5 indicators including "industrial added value per land unit", "reuse rate for reclaimed water", "elastic coefficient of energy consumption", "elastic coefficient of fresh water", and "implementation rate of cleaner production in key enterprises" are added. Furthermore, threshold values of indicator centralized processing rate are increased from ≥70% to 85% since 70% is no longer considered outstanding performances among industrial parks according to the site investigation of indicator designers. Other indicators are amended to better evaluate EIPs.

In the modification of EIP standard HJ/T274-2009 conducted in 2012, indicators "per-capital industrial added value" and "reuse rate for reclaimed water" were deleted (Tian et al., 2012; Fu, 2014). The compiler of the standard from the China Environmental Science Research Institute specifies that the indicator "reuse rate for reclaimed water" was deleted since the water resource in the southern China is relatively sufficient, which reduces incentives for use of reclaimed water for the industrial parks. The indicator "per-capital industrial added value" is just moved from the indicator system to fundamental conditions[5] to apply for EIPs.

The EIP standard HJ/T274-2015 experienced a substantial change comparing with the previous versions. In the following we will discuss the key improvements and the underlying reasons for the modification into HJ/T274-2015.

[5] According to EIP standard HJ/T274-2009, industrial parks aim to apply for EIPs have to meet some fundamental conditions, including (1) pass the certification of ISO 14000. (2) average growth rate of the industrial added value in the recent 3 years is no less than the average local level for industrial parks. (3) environmental pollution from each enterprise can meet the national and local standard, and there is no occurrence of serious environmental accident happened in the recent 3 years.

Table 2
Evaluation indicators for National Eco-industrial Parks (HJ/T274-2015).

Groups	NO.	Indicators	Units	Standard	Remarks
Economic development	**1**	**The proportion of high tech enterprises output value of gross industrial output value**	%	≥**30**	At least one indicator shall reach the standard
	2	Industrial added value per capita	10^4¥/Person	≥15	
	3	**The average three-year growth rate of industrial added value**	%	≥**15**	
	4	**The proportion of remanufacturing industry added value of the gross industrial added value**	%	≥**30**	
Industrial symbiosis	**5**	**The added eco-industrial chain numbers after enforcing EIP demonstration program**	**Unit**	≥**6**	required
	6	Comprehensive utilization rate of industrial solid waste	%	≥70	At least one indicator shall reach the standard
	7	**Usage rate of renewable resources**	%	≥**80**	
Resource conservation	8	**Industrial added value per unit industrial land area**	Hundred million/Square kilometers	≥9	At least one indicator shall reach the standard
	9	**The average three-year annual growth rate of industrial added value per unit industrial land area**	%	≥6	
	10	**Elastic coefficient of comprehensive energy consumption**	–	-When annual growth rate of industrial added value in the EIP demonstration period is > 0: the value must be ≤0.6; -When annual growth rate of industrial added value in the EIP demonstration period is < 0: the value must be ≥0.6	required
	11	Energy consumption per unit of industrial added value	Metric ton of standard coal/10^4 RMB	≤0.5	At least one indicator shall reach the standard
	12	**Application ratio of Renewable energy**	%	≥**9**	
	13	**Elastic coefficient of fresh water consumption**	–	-When annual growth rate of industrial added value in the EIP demonstration period is > 0: ≤0.55; -When annual growth rate of industrial added value in the EIP demonstration period is < 0: ≥0.55	required
	14	Fresh water consumption per unit industrial added value	$m^3/10^4$RMB	≤8	At least one indicator shall reach the standard
	15	Recycling rate of industrial water	%	≥75	
	16	**Reuse rate of reclaimed water**	%	-Water deficient cities > 20%; -Jing-Jin-Ji areas > 30%; -Other areas > 10%	
Environmental protection	17	Rate of reaching the discharging standard for key pollution sources	%	Meet the standard	required
	18	**The conditions of national and local key pollutant emissions**	–	Meet the standard	required
	19	Frequency of severe environmental accidents	–	0	required
	20	**Completion degree of Environmental management strategies**	%	100	required
	21	Implementation rate of key enterprises' Clean production audit	%	100	required
	22	Centralized sewage treatment facilities	–	exist	required
	23	The completion rate of environmental risk prevention and control system	%	100	required
	24	Utilization rate of industrial solid waste(including hazardous wastes)	%	100	required
	25	Elastic coefficient of main pollutant emissions	–	-When annual growth rate of industrial added value in the EIP demonstration period is > 0: the value must be ≤0.3; -When annual growth rate of industrial added value in the construction period is < 0: the value must be ≥0.3	required
	26	The annual reduction rate of carbon dioxide emissions per unit industrial added value	%	≥3	required
	27	Waste water emission per unit industrial added value	$T/10^4$RMB	≤7	At least one indicator shall reach the standard
	28	Solid waste discharge per unit industrial added value	$T/10^4$RMB	≤0.1	
	29	Green cover percentage	%	≥15	required

(*continued on next page*)

Table 2 (*continued*)

Groups	NO.	Indicators	Units	Standard	Remarks
Information disclosure	30	Environmental information disclosure rate of key enterprises	%	100	required
	31	The completion degree of the ecological industry information platform	%	100	required
	32	Number of public education campaigns	Number/Year	≥2	required

Beijing-tianjin-hebei.

(1) "Three in one" EIP standard:

In comparison with the previous versions, the primary change in the new Standard for National Eco-industrial Parks is that the latest amendment (HJ/T274-2015) removed the classification of EIPs into three categories with specific indicator for each. The "three in one" system helps to avoid the confusion in the classification of EIP as in some instances sector-integrated EIP (with a primary industrial sector) could be also classified as sector-specific EIP(Zhu et al., 2014; Yan, 2015).

Furthermore, the scope of the standard is more comprehensive in the new version. The standards of sector-integrated EIP (HJ/T274-2009), sector-specific EIP (HJ/T273-2006) and venous EIP (HJ/T275-2006) contained four categories of indicators: 1) economic development, 2) material reduction and recycling, 3) pollution control, and 4) administrative and management indicators, with 26, 19 and 20 indicators respectively. The Standard for National Eco-industrial Parks (HJ/T274-2015) comprises five categories of indicators: 1) economic development, 2) industrial symbiosis, 3) resource conservation, 4) environmental protection and 5) information disclosure, with 32 indicators in total. In parallel, the threshold values of several indicators become more stringent since the previous thresholds are found can no longer represent the outstanding industrial parks for EIP candicates. For instance, requirement of fresh water consumption per unit industrial added value changed from ≤ 9 m^3/ ten thousand RMB to ≤ 8 m^3/ten thousand RMB. The minimal requirement of Waste water emission per unit industrial added value is modified from ≤ 8 t/ten thousand RMB to ≤ 7 t/ten thousand RMB.

(2) Supplement industrial symbiosis criteria:

Industrial symbiosis is defined as encouraging traditionally separate industries to adopt a collective approach building competitive advantage by incorporating physical exchange of materials, energy, water and by-products into their business processes (Chertow, 2000). The essence of industrial symbiosis is the trade of by-products and waste among enterprises such as the case of Kalundborg in Denmark (Shi et al., 2012a, 2012b; Geng et al., 2016). The previous versions of EIP standard systems did not include any indicator regarding industrial symbiosis. The new standard includes indicators on evaluating the level of materials exchange at EIP level. The added indicator "The added new eco-industrial chain project numbers after enforcing EIP demonstration program" can help to encourage the tenant enterprises to seek the potential network of industrial symbiosis with others, which will facilitate the network establishment of industrial symbiosis. The indicator "Usage rate of renewable resources" included in the new EIP standard (HJ/T274-2015) can help to emphasize the regeneration and reutilization of renewable resources under the network of industrial symbiosis. The supplement of industrial symbiosis criteria can undoubtedly encourage and better evaluate the industrial symbiosis actions in industrial parks.

(3) Involve environmental risk control indicators:

The extensive applications of hazardous materials such as ammonia together with deficient management have caused several risk accidents. The fire and explosion accident happened in August 2015 in Tianjin Binhai New Area was found to have been caused by irregular management of hazardous materials[6]. Reviewing of the previous three versions of standards found that there was no indicator regarding the control or manage of these hazardous materials or environmental risk accidents. Given this circumstance, the supplement indicator such as "The completion rate of environmental risk prevention and control system" and "Frequency of severe environmental accidents in enterprises" in the new EIP

[6] More information of the Tianjin Binhai New Area accident in 2015 can be found in http://news.sohu.com/s2015/tjbaozha/

Table 3
Calculation method for some new indicators.

No. (No. in Table 2)	Indicators	Calculation formula
1 (3)	The average three-year growth rate of industrial add value (%)	[(Industrial added value of the year(10^4 RMB)/Industrial added value before three years(10^4 RMB)$^{1/3}$-1] × 100%
2 (4)	The proportion of remanufacturing industry output value of the gross industrial output value (%)	= output value from remanufacturing industry (10^4RMB)/ gross industrial output value (10^4RMB) × 100%
3 (6)	Comprehensive utilization rate of industrial solid waste (%)	Comprehensive utilization amount of industrial solid wastes(t)/[Total production amount of industrial solid wastes(t) + storage amount of industrial solid wastes in previous years(t)] × 100%
(10)	**Elastic coefficient of comprehensive energy consumption**	Annual growth rate of comprehensive energy consumption/ annual growth rate of industrial added value in the EIP demonstration period
4 (21)	Implementation rate of key enterprises' clean production audit (%)	number of key enterprises adopting clean production audit numbers/number of key enterprises × 100%
5 (25)	Elastic coefficient of main pollutant emissions	The average annual growth rate of key pollutant emissions during EIP construction period (%)/The average annual growth rate of industrial added value In which, The average annual growth rate of key pollutant emissions = [(emission amount of pollutant in EIP certified year(metric ton)/ emission amount of pollutant in baseline year (metric ton))$^{1/\text{ acceptance year } - \text{ base year}}$ −1] × 100%

Comprehensive utilization amount is defined as the total amount of solid waste reused in the industrial park in each year, including the solid waste produced within the industrial park, input from the outside of the industrial park, and stored industrial solid wastes produced in previous years.

standard (HJ/T274-2015) aims to prevent and control the environmental risk issue to a certain extent.

(4) Include more environmental indicators:
The new EIP standard (HJ/T274-2015) set more comprehensive environmental indicators by setting indicator “Elasticity coefficient of main pollutant emissions”, targeting relative decoupling of resource consumption and pollutants emission along with economic growth. Here the key pollutants refer those under national overall volume control-−COD, SO_2, NH_3, etc. Under the circumstance that the air pollution is still serious in China, the added environmental indicators can help better monitoring the environmental pollution and encouraging pollution control in the EIP. Meanwhile, with the supplementary indicator “The annual reduction rate of carbon dioxide emissions per unit industrial added value”, CO_2 emission reduction is also evaluated in the new EIP standard. Feedback from China Environmental Science Research Institute declares that the supplement CO_2 indicator is a positive response to China's commitment of Carbon peak before 2030.

(5) Provide optional indicators:
The previous EIP standard system is made up by a system of compulsory indicators. In the current modified standard, optional indicators have also been included. Feedback from the drafting committee of HJ/T274-2009–China Environmental Science Research Institute indicated that the offering of optional indicators can involve more industrial parks with different development characteristics. Among the total 32 indicators, 17 are obligatory ones and 15 are optional ones. At least 23 indicators need to reach the standard for the industrial park to pass the EIP evaluation. For instance, in the category of economic development, only one indicator is required to be met among the four indicators. Industrial symbiosis, resource conservation and environmental protection also include optional indicators, leaving the category “information disclosure” with only obligatory indicators.

(6) Give flexibility in the indicator targets:
In order to provide more flexibility and ensure more consistent evaluation, the new EIP standard system (HJ/T274-2015) gives some flexibility in setting the targets for a number of indicators based on different contextual conditions. Among the 32 indicators, three elasticity coefficient indicators (elastic coefficient of energy consumption, elastic coefficient of fresh water consumption and elastic coefficient of main pollutant emissions) and reuse rate of reclaimed water give distinct indicator criteria depending on the economic circumstances of the park. For instance, in the previous standard for sector-integrated EIP (HJ/T274-2009), the energy consumption elasticity coefficient is required to meet the target“ **<** 0.6″. In HJ/T274-2015, the criterion is adjusted taking into account the annual growth rate of industrial added value in the EIP demonstration period. The new standard system requires that when the growth rate of added value is > 0, then the corresponding standard is ≤0.6; if the annual growth rate of industrial added value in the EIP demonstration period is **<** 0, then the corresponding standard is ≥0.6″. In other instances, targets are established taking into account of regional characteristics.

4.2. Shortcomings and outlook of the EIP standard development

Although many positive changes and improvement have been identified, there are still some shortcomings exist in the new EIP standard. Based on the feedback from compilers of the standard in the China Environmental Science Research Institute, EIP administrative office and academic resarchers in the EIP fields, the potential improvement for promoting the EIP standard is discussed in the following:

(1) Further improve the industrial symbiosis indicators:
It is a significant improvement since the new EIP standard (HJ/T274-2015) has absorbed three indicators to evaluate industrial symbiosis actions in EIP. However, our respondent comment that the indicator “number of symbiotic linkages established after the park's EIP development has been approved by the EIP administrative office formally” can only reflect the eco-industrial chain numbers without assessing the practical benefits resulting from industrial symbiosis. In order to fill this gap, economic contribution resulted from industrial symbiosis should be considered in EIP evaluation. In addition, industrial symbiosis should not be limited to solid waste or renewable resource as the existing indicators instructed. Energy sharing measures such as waste heat recovery and reuse should also be encouraged and involved in the EIP evaluation. Furthermore, our respondent suggest industrial symbiosis behaviors outside the industrial park should also be evaluated and encouraged since EIP should ideally make use of opportunities for material or energy exchange with the local community. The review finds that the existing eco-efficiency indicators focus only on the firms and activities within the designated industrial park. It would be desirable to develop new indicators to clarify how designated industrial parks are linked to other areas and how the industrial symbiosis actions in and outside the EIP can promote the local sustainable development. This concept, termed as urban symbiosis, recognizes the use of municipal solid waste as inputs to industries for example

(Dong et al., 2014).

(2) Include social benefit evaluation indicators:
The practical implementation of EIP will involve and have implications on environmental, economic and social dimensions. Thus, a systematic evaluation on various aspects should be addressed. Analysis of several existing industrial park cases reveals that no symbiosis or utility sharing can materialize even if physical features are all present but social factors are lacking (Valenzuela-Venegas et al., 2016). However, the published new EIP standard (HJ/T274-2015) does not include any social benefit evaluation indicator. Considering social responsibility is quite important for both enterprises and industrial parks, it is quite necessary to include social benefit evaluation indicators such as "Occupational Health and Safety", "employment rate", "employees' average wage earnings" and "the degree of public awareness and participation" for evaluating EIPs.

(3) Strengthen the reduction action evaluation:
The 3Rs (Reduce, Reuse and Recycle) are a core principle for circular economy, also is the key rule guiding EIP construction (Su et al., 2013). Among the 3Rs, reduction namely prevention is the most important objective (Akenji et al., 2016). Indicators reviewing the new EIP standard (HJ/T274-2015) found that only energy and water consumption burden per industrial added value are considered–"Comprehensive energy consumption per unit industrial added value" and "Fresh water consumption per unit industrial added value". The lack of any broader reduction evaluation indicator could become an incentive for enterprises preferring recycling and reuse based solutions over the more preferable prevention and source reduction solutions integrated into the design of products and in production process. Thus, it is quite urgent to involve reduction monitoring and evaluation indicators for assessing EIPs. A key would be to start monitoring materials more systematically, in line with e.g the 2008 OECD manual on measuring material flows and resource productivity, and to strengthen efforts to boost markets for secondary resources.

(4) Provide incentives for promoting EIPs:
Within the current Chinese EIP management system, there is no economic incentive policy for EIPs. Based on the feedback from our respondent, several incentive approaches are feasible to motivate industrial parks. For instance land preference policy, tax discount for EIPs and involved enterprises, and administrative suppport for EIP enterprises. Some local environmental protection agencies are also trying to establish specific foundation for supporting eco innovation movement. Top-down incentive policies and local attempts are both desirablefor promoting EIPs development in China.

5. Concluding remarks

China is the only country establishing and practicing national EIP standard and indicators (Cote and Liu, 2016). Reflection on the experience indicates that development of practical quantitative assessment indicators for EIPs has been a crucial factor for the ongoing success of China's national demonstration EIP program. Up to date, EIP standard in China has already experienced several round of revision since the first rounds of declaration in 2006. In 2015, MEP released the new standard for national demonstration EIP (HJ/T274-2015) to replace the previous standards of sector-integrated EIP, sector-specific EIP and the venous industry EIP.

This study gives a review of China's EIP standard systems, and undertakes an analysis of the new released EIP standard. Comparing with indicators of previous three standard systems, the newly released EIP standard (HJ/T274-2015) has obvious improvements. Most of the previous shortcomings (e.g. Vague and intricate indicators, and lack of industrial symbiosis indicators) discussed by scholars like Geng et al. (2008, 2009, 2012) have been modified to some extent. Besides these improvements, environmental risk control indicators and more comprehensive environmental indicators are also amended in the new EIP standard (HJ/T274-2015), as environmental pollution and effective risk prevention and control remain as significant challenge in China.

Through the review and analysis of China's EIP standard, the circumstance of how China is conducting EIP management with guiding criteria is clearly shown. With accurate and programmatic indicators, EIP development can be better promoted along with efficient monitoring and evaluation. For the years ahead we propose the inclusion of more material-oriented indicators to unleash the potential of resource efficiency and boost markets for secondary resources. Such shift is likely to be in line with a more saturating Chinese economy whose demand for primary materials is likely to flatten (Bleischwitz et al, forthcoming) as well as with broader attempts in such direction in both Europe and China (McDowall et al., 2017).

China's experience of setting EIP standards and indicators may provide lessons for other countries' attempt to develop industrial estate indicators and designate such parks towards eco-innovation strategies. In order to observe and effectively promote EIP more widely at an international and global scale, there are some remaining research questions that need further exploration, for instance, how will the existing EIP indicators and the proposed flexibility actually be applied across parks, and what lessons can be learned? What are the lessons for designing any national EIP standards in either more top-down EIP mode countries e.g. US, Canada and Asia, or more bottom-up EIP mode countries e.g. European countries (Ghisellini et al., 2016)? What may speak in favour of an international EIP standard, and what would be core indicators? What are broader lessons for eco-innovation performance of industries and countries?

After all this article should allow scholars to learn about recent progress in Chinese EIP programand we believe the EIP development at the global range can have a bright future with extensive investigation and analysis to come.

Acknowledgements

The research work of this paper was supported by a grant from the National Natural Science Foundation of China (No.71403170, No.71325006, No. 71461137008) as well as through a grant from UK ESRC (ES/L015838/1). Many thanks for the feedback from Dr. Minghui Xie from China Environmental Science Research Institute. We also appreciate the comments from the editor and three anonymous reviewers.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:10.1016/j.resconrec.2018.09.013.

References

Akenji, L., Bengtsson, M., Bleischwitz, R., Tukker, A., Schandl, H., 2016. Ossified materialism: introduction to the special volume on absolute reductions in materials throughput and emissions. J. Clean. Prod. 132, 1–12.
Bai, L., Qiao, Q., Yao, Y., Guo, J., Xie, M.H., 2014. Insights on the development progress of national demonstration eco-industrial parks in China. J. Clean. Prod. 70, 4–14.
Boons, F., Chertow, M., Park, J., Spekkink, W., Shi, H., 2017. Industrial symbiosis dynamics and the problem of equivalence. J. Ind. Ecol. 21 (4), 938–952.
Chertow, M.R., 2000. Industrial symbiosis: literature and taxonomy. Annu. Rev. Energy Environ. 25, 313–337.
Chiu, A.S.F., 2001. Ecology, system, and networking: walking the talk in Asia. J. Ind. Ecol. 5 (2), 6–8.
Cote, R.P., Cohen-Rosenthal, E., 1998. Designing eco-industrial parks: a synthesis of some experiences. J. Clean. Prod. 6 (3-4), 181–188.
Cote, R.P., Liu, Z., 2016. Eco-Industrial Park Performance Standards and Indicators and the Circular Economy Report. Devens, Massachusetts USA.
Dong, H.J., Ohnishi, S., Fujita, T., Geng, Y., Fujii, M., Dong, L., 2014. Achieving carbon emission reduction through industrial & urban symbiosis: a case of Kawasaki. Energy 64, 277–286.
Ehrenfeld, J., Gertler, N., 1997. Industrial ecology in practice: the evolution of interdependence at Kalundborg. J. Ind. Ecol. 1 (1), 67–79.
Fang, Y.P., Cote, R.P., Qin, R., 2007. Industrial sustainability in China: practice and prospects for eco-industrial development. J. Environ. Manage. 83 (3), 315–328.

Fleig, A.K., 2000. Eco-Industrial Parks: A Strategy Towards Industrial Ecology in Developing and Newly Industrialised Countries. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Federal Republic of Germany.
Fu, L.N., 2014. Research on Ecological Transformation of Industrial Park and Its Eco-Efficiency. Central South University, Hunan.
Geng, Y., Cote, R., 2003. Environmental management system at industrial park level in China. J. Environ. Manage. 31 (6), 784–794.
Geng, Y., Zhang, P., Cote, R., Qi, Y., 2008. Evaluating the applicability of the Chinese eco-industrial park standard in two industrial zones. Int. J. Sust. Dev. World. 15 (6), 543–552.
Geng, Y., Zhang, P., Cote, R., Fujita, T., 2009. Assessment of the national eco-industrial park standard for promoting industrial symbiosis in China. J. Ind. Ecol. 13 (1), 15–26.
Geng, Y., Fujita, T., Chen, X.D., 2010. Evaluation of innovative municipal solid waste management through urban symbiosis: a case study of Kawasaki. J. Clean. Prod. 18, 993–1000.
Geng, Y., Fu, J., Sarkis, J., Xue, B., 2012. Towards a national circular economy indicator system in China: an evaluation and critical analysis. J. Clean. Prod. 23, 216–224.
Geng, Y., Sarkis, J., Ultiati, S., Zhang, P., 2013. Measuring China's circular economy. Science 339, 1526–1527.
Geng, Y., Sarkis, J., Ulgiati, S., 2016. Sustainability, Well-Being, and the Circular Economy in China and Worldwide 6278. pp. 73–76 (supplement).
Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. J. Clean. Prod. 114, 11–32.
Kim, D., Powell, J.C., 2008. Comparison of eco-industrial development between the UK and Korea. EU-Korea Conf. Sci. Technol. 124, 443–454.
Lai, B.J., 2013. Research on Environmental Performance index of Eco-Industrial Park Development in China. Tsinghua University, Beijing.
Liu, J.Y., Qiao, Q., Yao, Y., Guo, Y.W., 2007. A study on evaluation index system of eco-industrial parks: Sector-integrated eco-industrial parks. Mod. Chem. Ind. 7, 58–61 (in Chinese).
Lowe, E., 1997. Creating by-product resource exchanges: strategies for eco-industrial parks. J. Clean. Prod. 5, 57–65.
Massard, G., Jacquat, O., Zurcher, D., 2014. International Survey on Eco-Innovation Parks. Learning from Experiences on the Spatial Dimensions of Eco-Innovation. Federal Office for the Environment and the ERA-NET Eco-INNOVERA. Bern. Environmental Studies No.1402.
Mathews, J., Tan, H., 2016. Lessons from China. Nature 531, 440–442 (Special issue on the circular economy).
McDowall, W., Geng, Y., Huang, B.J., Bartekova, E., Bleischwitz, R., Turkeli, S., Kemp, R., Domenech, T., 2017. Circular economy policies in China and Europe. J. Ind. Ecol. 21, 3651–3661.
MEP, 2009. Ministry of Environmental Protection (MEP) of the People'S Republic of China. HJ/T274-2009. (Access on 20 October 2016). http://www.zhb.gov.cn/gkml/hbb/bgg/201208/t20120809_234561.htm.
MEP, 2015. Ministry of Environmental Protection (MEP) of the People's Republic of China, 2015. HJ/T274-2015. (Access on 10.20 October 2016). http://bz.mep.gov.cn/bzwb/other/qt/201512/t20151224_320149.htm.
MEP, 2016. Ministry of Environmental Protection (MEP) of the People's Republic of China, Management of Follow-up Examination of EIP. 2016. (Access on 20 October 2016). http://www.mep.gov.cn/gkml/hbb/bgth/201602/t20160215_330241.htm.
Park, H.S., Rene, E.R., Choi, S.M., Chiu, A.S.F., 2008. Strategies for sustainable development of industrial park in Ulsan, South Korea - from spontaneous evolution to systematic expansion of industrial symbiosis. J. Environ. Manage. 87 (1), 1–13.
Park, J.M., Park, J.Y., Park, H.S., 2016. A review of the national eco-industrial park development program in Korea: progress and achievements in the first phase, 2005-2010. J. Clean. Prod. 114, 33–44.
Roberts, B.H., 2004. The application of industrial ecology principles and planning guidelines for the development of eco-industrial parks: an Australian case study. J. Clean. Prod. 12 (8-10), 997–1010.
Shi, L., Liu, G.G., Guo, S.P., 2012a. International comparison and policy recommendation on the development model of industrial symbiosis in China. Acta Ecol. Sinica 32 (12), 3950–3957.
Shi, H., Tian, J.P., Chen, L.J., 2012b. China's quest for eco-industrial parks, part I. J. Ind. Ecol. 16 (5), 8–10.
Song, X.Y., Shen, J., 2015. The ecological performance of eco-industrial parks in shandong based on principal component analysis and set pair analysis. Resour. Sci. 37 (3), 0546–0554.
Su, B.W., Heshmati, A., Geng, Y., Yu, X.M., 2013. A review of the circular economy in China: moving from rhetoric to implementation. J. Clean. Prod. 42, 215–227.
Tian, J.P., Liu, W., Li, X., Lai, B.J., Chen, L.J., 2012. Study of eco-industrial Park development Mode in China. China Popul. Resour. Environ. 22 (7), 60–66.
Tian, J.P., Liu, W., Lai, B.J., Li, X., Chen, L.J., 2014. Study of the performance of eco-industrial park development in China. J. Clean. Prod. 64, 486–494.
UNEP, 1997. The Environmental Management of Industrial Estates. UNEP Industry and Environment. United Nations Environmental Programme (UNEP), Paris, France.
Valenzuela-Venegas, G., Salgado, J.C., Díaz-Alvarado, F.A., 2016. Sustainability indicators for the assessment of eco-industrial parks: classification and criteria for selection. J. Clean. Prod. 133, 99–116.
Van Beers, D., Corder, G., Bossilkov, A., Van Berkel, R., 2007. Industrial symbiosis in the Australian minerals industry: the cases of kwinana and gladstone. J. Ind. Ecol. 11 (1), 55–72.
Van Berkel, R., 2007. Cleaner production and eco-efficiency initiatives in Western Australia 1996–2004. J. Clean. Prod. 15 (8-9), 741–755.
Van Berkel, R., Fujita, T., Hashimoto, S., Geng, Y., 2009. Industrial and urban symbiosis in Japan: analysis of the eco-Town program 1997–2006. J. Environ. Manage. 90 (3), 1544–1556.
Yan, M., 2015. Research on the Index System of Regulatory Detailed Planning of Cheng De Industrial Park According to the Industrial Characteristics. Southwest University of Science and Technology, Sichuan.
Yu, F., 2015. Patterns, Driving Factors and Environmental Benefits Evaluation of Industrial Symbiosis in Industrial Parks. Shandong University, Shandong.
Yu, C., Dijkema, G.P.J., de Jong, M., 2014. What makes eco-transformation of industrial parks take off in China? J. Ind. Ecol. 19 (1), 441–456.
Zhang, L., Yuan, Z.W., Bi, J., 2010. Eco-industrial parks: national pilot practices in China. J. Clean. Prod. 18, 504–509.
Zhu, Q.H., Cote, P., 2004. Integrating green supply chain management into an embryonic eco-industrial development: a case study of the guitang group. J. Clean. Prod. 12 (8-10), 1025–1035.
Zhu, Q.H., Lowe, E., Wei, Y., Barnes, D., 2007. Industrial symbiosis in China: a case study of the guitang group. J. Ind. Ecol. 11 (1), 31–42.
Zhu, Q.H., Geng, Y., Sarkis, J., Lai, K.H., 2014. Barriers to promoting eco-industrial parks development in China. J. Ind. Ecol. 19 (3), 457–467.