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Full length article

A strategic niche management perspective on transitions to eco-industrial park development: A systematic review of case studies

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ABSTRACT

In recent decades, industrial park (IP) development has been an important practice for regional economic development for various geographies. Eco-industrial park (EIP) development, on the other hand, has been proposed as an alternative, considering environmental problems raised from the high number of agglomerated industries in IPs. Although there are some quite progressive EIP experiences that are globally distributed, IP development remains the mainstream industrial agglomeration model and has not yet experienced a transition into EIP development. The purpose of this article is both to understand and shed some light on how such a transition can be achieved through lessons from the EIP cases in the existing state of the art and to establish a research agenda that would elaborate on sustainability transitions into EIP development. To achieve these aims, a systematic literature review involving a case survey is conducted. A theoretical framework with an evolutionary perspective is developed drawing on EIP literature and strategic niche management (SNM) framework from sustainability transitions research. This connects two streams of research that have not been closely associated in the past. While synthesising 104 EIP cases from 24 countries, three analytical processes of SNM are considered: (i) articulation of expectations and visions, (ii) building of social networks, and (iii) learning activities. This article also discusses the development of local EIP experiments and EIP niche formation at different geographies. Based on this synthesis, policy implications are suggested and research implications are provided, stressing critical and interesting issues that have not yet had an explicit focus in the literature. This article enables cross-fertilisation across globally distributed EIP cases while adding to the critical mass in leveraging EIP development.

1. Introduction

The importance of agglomerated industries has been reflected in the development of industrial parks (IPs), which have experienced global popularity especially since the last quarter of the 19th century, when English economist Alfred Marshall coined the concept of industrial districts (1890/1920). Meanwhile, discourse on industrial agglomerations was widened to "capture the knowledge aspect" (Nuur, 2016) of development bringing innovation to the scene, which led to the phenomenon of *industrial clusters* (Porter, 1990) being used interchangeably with industrial districts. Then, as the idea behind developing industrial agglomerations has passed through different stages, faced new academic debates, and changed over time, the concepts of industrial district, industrial cluster, and industrial park have been used interchangeably (Côté and Cohen-Rosenthal, 1998; Vidova, 2010). In the present article we have chosen to focus on *industrial parks* as their development as a new system approach started relatively recently, in early 1970s (Kumar, 2005; Tylecote, 1995; Geng et al., 2008), and our focus is on the sustainability problematique of IP development and possibilities for next-generation IPs.

1.1. IP development and its problematique

IPs can be defined as systems of industrial actors within one location (Geng and Hengxin, 2009), based on a philosophy of obtaining advantages of potential common resources and services (Vidova, 2010; Fernández and Ruiz, 2009), such as infrastructure, transportation, management, recreational facilities, etc. IP development is "perceived as an integral part of regional development strategies of many countries worldwide" (Singhal and Kapur, 2002) and it has a crucial role in national and regional economic strategies (Fernández and Ruiz, 2009; UNIDO, 2012, 2014; Vidova, 2010; Liu and Côté, 2017). Naturally, IP

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development has been a mainstream feature of global industrial production systems. The number of IPs worldwide was between 12,000 and 20,000, according to data from 2001 provided in a report for UNEP (Francis and Erkman, 2001), approximately 3000 of which are in China (Liu and Côté, 2017).

While it has been claimed that IPs have the potential to function well in terms of efficiency, effectiveness, outcomes, etc. in order to drive for innovation, create new markets, mobilise local assets, and leverage the history and culture of a region while enhancing local development (Vidova, 2010; Ablonczy-Mihalyka and Keckkes, 2015; UNIDO, 2014; Fan et al., 2017), the environmental pillar of sustainable development has been missed out during their development, which has created pressure on the environment and as such relatedly on the society. Along with increasing awareness of sustainability concerns, negative environmental impacts from a concentration of large number of industries in IPs (Shi et al., 2010; Liu et al., 2017; Geng et al., 2008; Bai et al., 2014; Fernández and Ruiz, 2009; Côté and Liu, 2016; UNIDO, 2012; Gómez et al., 2018) have started to be discussed seriously. There would appear to be a need to integrate the economic, ecological, and social dimensions of IP development and transform these local scale industrial production systems considering regional, national, and even global ecological limitations (Wheeler, 2009).

In view of this, EIPs have been proposed as alternative IPs (Zhu et al., 2015; Wang et al., 2010) implementing "industrial ecology principles into existent and newly built industrial parks" (Farel et al., 2016) to address the sustainability–related problems (Gibbs et al., 2005; Cote and Hall, 1995; Erkman, 1997; Ehrenfeld, 2004) benefiting from the agglomerated nature of IPs (Bai et al., 2014).

1.2. EIP development

Industrial ecology, which Ehrenfeld (2004) once defined as "the science of sustainability", has been studied both as a policy tool and an academic theory (Daddi et al., 2016) with a motivation to provoke systemic transitions and to reduce environmental impacts by mimicking the principles of natural ecosystems (Erkman, 1997) to the industrial processes (Deutz and Gibbs, 2008; Panyathanakun et al., 2013). Development of EIPs has emerged as an inter-firm level application of industrial ecology, which was also referred as *industrial symbiosis* (Chertow, 2000). The initial philosophy behind industrial symbiosis was mutualistic interaction of different industries in a system for exchange of materials – water, energy, by-products, infrastructure, and natural habitat – resulting in economic, social, and environmental benefits (Lowe et al., 1995; Cote and Hall, 1995; Cossentino et al., 1996; USPCSD, 1996; Chertow, 1999, 2000). In time, industrial symbiosis has also been approached considering its social aspects revealing the importance of intangible resource exchanges (information, knowledge, and expertise), which has also facilitated the material resource exchanges (Gibbs, 2009; Lombardi and Laybourn, 2012).

Industrial symbiosis can benefit the advantages of agglomerations, which may ease the potential resource exchanges between industries (Chertow et al., 2008) and makes EIPs ideal next-generation sustainable IPs (Geng et al., 2008). EIP development can be followed both by designing/constructing new EIPs (that is, greenfield projects) and also by transforming existing IPs into EIPs (that is, brownfield projects) (Lambert and Boons, 2002). In the literature, the evolution of greenfield and brownfield EIP experiments has been addressed mainly by proposing three different models: (i) planned symbiosis (the build-and-recruit top-down model) (Chertow, 2007; Gibbs and Deutz, 2007); (ii) self-organising symbiosis (the bottom-up model) (Chertow, 2007; Chertow and Ehrenfeld, 2012); and (iii) facilitated symbiosis (facilitation by organisations and individuals) (Paquin and Howard-Grenville, 2012; Hewes and Lyons, 2008), which is a mixture of the top-down and bottom-up models.

EIP development has received global attention (Tiu and Cruz, 2017), especially after learning about the success of Kalundborg Symbiosis, which can be claimed to be the most influential EIP case for academia, policy-makers, and practitioners (Chertow, 2007; Branson, 2016). As expected, not all EIP cases are as influential and well-resulted as Kalundborg due to various reasons related to variety of involved actors and complex dynamics among them. Nevertheless, EIP development is a prevalent research topic in industrial ecology (Zhang et al., 2013; Yune et al., 2016). Both success and failure cases have been analysed in order to understand and extend the theory behind them, as well as for policy-making reasons.

1.3. Sustainability transitions to EIP development

Despite learnings based on extended research on various EIP cases, many regions continue to develop IPs (Geng and Côté, 2002; Côté and Liu, 2016) based on traditional ways of thinking that do not prioritise collective benefit through collaboration between industries for material and non-material exchanges, and instead favour the individual benefits of each firm (Lowe, 1997) concerning only individual performances.

In other words, EIP development has not substituted traditional IP development and IP development is still seen as strategic tool for local and regional development despite its sustainability problematique. Indeed, EIPs remain fringe sustainable practices and there are limited EIP initiatives distributed over different geographies, whereas IP development is still the mainstream logic. Apparently, there is resistance to potential transitions and this resistance stems from routines embedded in these industrial production systems. Therein lies the crux of the matter; how can EIP development become mainstream and how can such a transition from IP development into EIP development be achieved?

There are no concrete answers to those questions. In this vein, the EIP literature provides rich case studies that mostly focus on transitions of particular IPs into EIPs (Yu et al., 2014b; Shi and Yu, 2014; Mathews and Tan, 2011; Shi et al., 2010). However, there is a missing global systemic vision on a wider question of transitions into EIP development. Holding such a vision, we claim that the resistance can be overcome by correct interpretation of implications based on the understanding of development processes of existing EIP examples. Drawing lessons from past and present EIP examples would bring insights for future transitions into EIP development and these insights could be further elaborated through future research. Systematic literature review stands as a promising method for such an ambition especially considering the various EIP cases studied in EIP literature.

Therefore, the purposes of this article are (1) to understand and shed some light on how transitions into EIP development can be achieved through lessons from the EIP cases that have been studied in the existing state of the art; and (2) to establish a research agenda that would elaborate on sustainability transitions into EIP development.

In this review article, in order to understand better the EIP cases and also enrich the EIP literature with new insights, we intend to build a theoretical framework drawing upon a theoretical perspective called strategic niche management (SNM) (Kemp et al., 1998; Schot and Geels, 2008). SNM comes from another recently developed research stream, known as sustainability transitions (ST). In ST, scholars have developed middle-range theories and analytical frameworks (Geels, 2007) to study systemic sustainability transitions that hold a co-evolutionary view of society and technology with insights from evolutionary economics, sociology of technology, and history of technology and innovation studies (Geels, 2012; Markard and Truffer, 2008; Geels, 2010). The ST studies explore, describe and explain occurred, happening, or future potential transitions through co-evolution and interdependence of various system structures such as institutions, science, culture, technology, regulations, etc. (Geels, 2004; Coenen and Diaz Lopez, 2010; Smith et al., 2010; Truffer and Coenen, 2012).

Although both the EIP and ST literatures emphasise sustainability, systemic perspective, necessity of transitions, technological change, institutional change, broad range of actors and networks, etc., they

have not often been brought together; furthermore, EIPs, industrial ecology, and industrial symbiosis have not been often studied thoroughly drawing upon analytical frameworks provided by the ST field. Nevertheless, there are still some relevant EIP-related studies. Adamides and Mouzakitis (2009), Gibbs (2009) and Shi and Yu (2014) have drawn upon SNM, albeit partially. Adamides and Mouzakitis (2009) operationalised EIPs as strategic niches in industrial productions systems and analysed three well-known EIP initiatives to provide policy-level implications. Similarly, Gibbs (2009) approached EIPs as niches and provided generic analysis on the potential use of transition literature and particularly SNM framework for industrial ecology and industrial symbiosis research. Moreover, Shi and Yu (2014) borrowed concepts from ST and SNM studies and referred to EIPs as strategic niches. However, none of these studies have detailed analytical processes of SNM for the analysis of EIP development.

The remainder of this article is structured as follows. Section 2 presents the research objectives and research questions. It is followed by Section 3, which explains the theoretical framework combining SNM perspective with EIP development. In Section 4 the methodology is detailed and justified. That section also details how literature search was conducted, showing all search steps together with inclusion and exclusion criteria, as well as results of literature analysis, which covers meta-analysis of the selected articles focusing on their distribution over journals, years, and geography; this is presented to strengthen the background understanding of upcoming literature synthesis. Then, in Section 5, the literature synthesis is elaborated through re-interpretation of the EIP cases from the existing literature drawing upon the theoretical framework in order to take lessons to understand how IP development can experience a transition into EIP development. This section provides policy implications for sustainability transitions into EIP development and research implications for a future research agenda on EIP development. Finally Section 6 offers conclusions and a combined list of policy and research implications.

2. Research objectives

The industrial ecology literature has studied various EIP development initiatives from all around the world. Considering the rich EIP case studies available in the literature, we aim to learn from these cases how IP development can experience a transition into EIP development. A systematic literature review represents a proper method to do this by its facilitating capability to provide an overview of existing knowledge (Fischl et al., 2014; Tranfield et al., 2003).

There have already been some related literature review studies in the EIP literature. Therein, the researchers reviewed the literature with respect to identification and classification of industrial symbiosis indicators (Felicio et al., 2016); analysis of optimisation mechanisms for the design of EIPs (Boix et al., 2015); identification of different forms of eco-industrial networks that have the potential to advance environmental sustainability (Patala et al., 2014); analysis of the role of governmental policy in facilitating the development of industrial symbiosis (Jiao and Boons, 2014); analysis of the evolution of the industrial symbiosis research field and its embedding in industrial ecology through bibliometric and network analysis (Yu et al., 2014a); exploration of the methodological issues faced in the application of life cycle analysis to the various research questions arising from industrial symbiosis studies (Mattila et al., 2012); development of a theoretical framework for understanding the industrial symbiosis dynamics through which regional industrial systems change their connectiveness in an attempt to reduce their ecological impact (Boons et al., 2011); and development of EIPs as concrete realisations of the industrial symbiosis concept through a taxonomy of different material exchange types (Chertow, 2000).

To the best of our knowledge, no literature reviews have been conducted to date to understand how sustainability transitions into EIP development can be achieved. Elaborating such knowledge could reveal the ways in which EIP development processes can be influenced in desired transition directions rather than keeping them as frangible practices. Following that, our objective in this review article is twofold: (i) to understand and shed light on how transitions into EIP development can be achieved through lessons from the EIP cases that have been studied in the existing state of the art; and (ii) to establish a research agenda that would elaborate on sustainability transitions into EIP development. Following these objectives, the two following research questions are formulated:

Research question 1: What can be learnt from the existing state of the art on how transitions from IP development into EIP development can be achieved?
Research question 2: Which topics related to sustainability transitions into EIP development lack further investigation and offer opportunities for future research?

3. Theoretical framework

This article brings insights from ST research stream and particularly builds on the SNM framework, in which transitionary sustainable practices are approached as niche experiments. The SNM framework provides the grounds to analyse and understand niche experiments (Raven, 2005), which in some cases successfully challenge the unsustainable routines and in some cases remain as weak and frangible practices. In this article, EIP cases are conceptualised as strategic niche experiments that are expected to steer transitions to EIP development, and mainstream IP development can be thought as the logic of the existing industrial production systems, which is subject to sustainability transitions. When investigating the literature to answer the research questions, three “interrelated and mutually reinforcing” (Caniëls and Romijn, 2008) processes of the SNM approach are considered. These processes are (Schot and Geels, 2008; Raven, 2005; Weber et al., 1999):

(i) *articulation of expectations and visions*, which provides the grounds of interaction and gives direction to learning processes and lead to niche protection;
(ii) *building of social networks*, which creates mediums for interaction between related actors and facilitates learning; and
(iii) *learning activities*, which actually sustains the impact of niche experiments and changes the routines related to the socio-technical system subject to transition.

Considering three internal processes of SNM can be valuable while explaining and further understanding the development of greenfield and brownfield EIP niche experiments, and also the continuation of IP development due to embedded routines of mainstream actors. Such an understanding can provide clues on how to achieve sustainability transitions of IP development.

Fig. 1 provides an analytical illustration of the research conceptualisation of this article. This framework, with an evolutionary perspective, follows some theoretical standpoints that have emerged from both the ST and EIP literatures. In providing this framework, we connect two streams of research that have not been nurtured from each other very often.

In the EIP literature, EIP development has been mostly studied by scholars from industrial ecology, industrial symbiosis and regional science, drawing upon biological and ecological systems theory (Allenby and Cooper, 1994; Chertow and Ehrenfeld, 2012; Wright et al., 2009), having mostly an evolutionary perspective (Chertow and Ehrenfeld, 2012) and claiming that industrial ecology principles may lead to fundamental systemic transitions in technologies, industries and social life (Doranova et al., 2012; Machiba, 2010) through collaboration and interaction among multiple actors and networks in interaction with institutions (Gibbs, 2009).

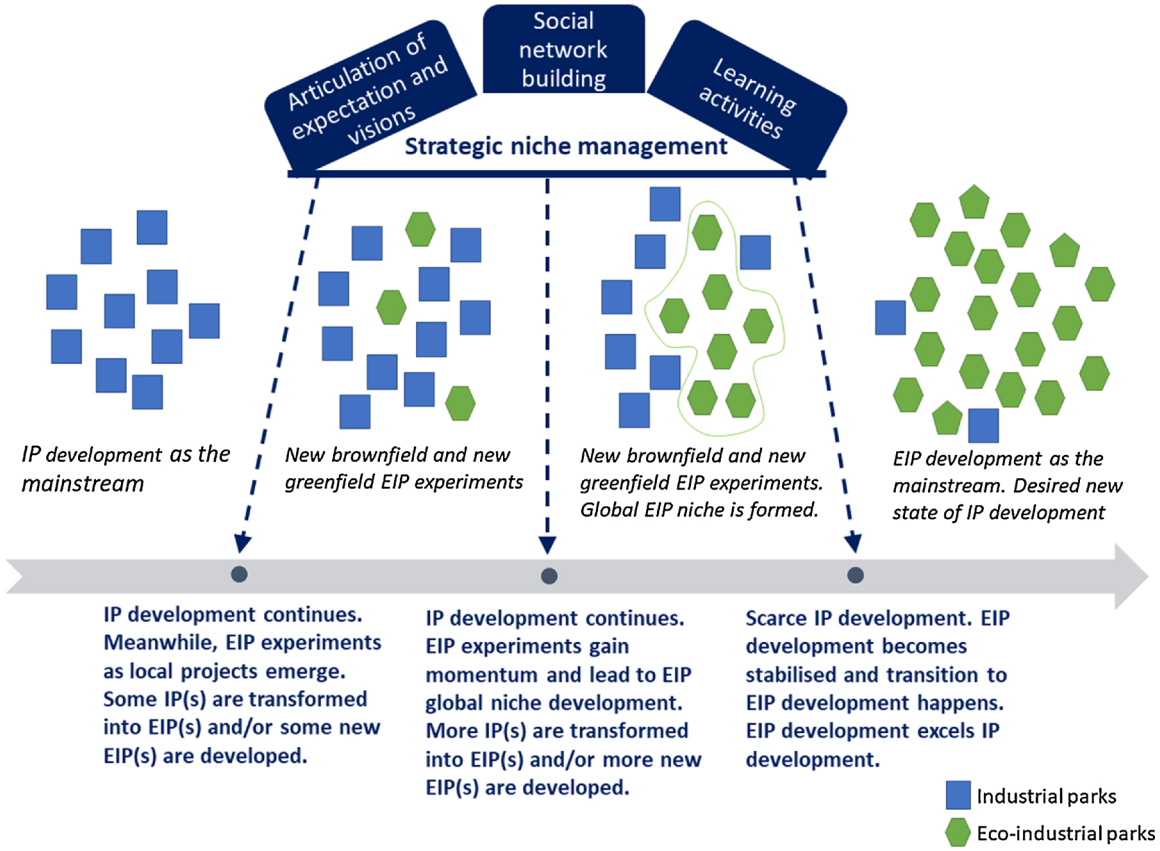

Fig. 1. Sustainability transitions of IP development into EIP development. Processes for SNM on evolution of EIP development; that is, EIP experiments as local projects, from local projects to global niches, and finally from global niches to EIP development as the mainstream. Authors' own elaboration based on Geels (2011), Schot and Geels (2008), Geels and Raven (2006), Chertow and Ehrenfeld (2012), Lambert and Boons (2002), and Gibbs (2009).

Here we emphasise that EIP development has an evolutionary perspective but consider EIP development more like a development trend that is expected to excel IP development, rather than focusing on evolution of industrial symbiosis in some specific EIP experiments (Chertow and Ehrenfeld, 2012; Paquin and Howard-Grenville, 2012; Baas and Boons, 2004; Domenech and Davies, 2011).

Referring to SNM studies (Schot and Geels, 2008; Caniëls and Romijn, 2008; Geels, 2011; Geels and Raven, 2006), we propose that proper combination and interaction between three internal niche processes can lead, firstly, to development of local greenfield and brownfield EIP experiments; secondly, to global EIP niche formation where there are still IPs but greenfield and brownfield EIP development gains some momentum; and, finally, to transitions into EIP development where EIPs excel IPs and EIP development becomes the mainstream. This evolution from local EIP experiments to global EIP niches and then from global EIP niches to sustainability transitions is conditioned and triggered by the three niche processes. Global EIP niches can be thought as accumulations of local EIP experiments and involve an emerging network that has similar or common concerns, problem agendas, expectations, visions, interests, etc.

Following Schot and Geels (2008), we suggest that three elements will be more effective at achieving sustainability transitions of IP development. These are (1) *expectations and visions* for EIP development, if they are specific enough and shared by various actors; (2) *network building*, if EIP networks are sufficiently broad and deep to articulate multiple views and to engage resources from the represented organisations; and (3) *learning processes*, if they are directed at both first-order learning (that is, observing, analysing the situation and learning facts and data) and second-order learning (that is, thinking of assumptions and values and changing behaviours and routines).

Finally, it is important to point out some theoretical assumptions behind the SNM framework that would not fit directly into EIP studies and its assumptions. Studies from ST and SNM are in favour of mainly radical technical innovations and take them to their research focus, whereas EIP development is also generous to incremental innovations that drive for systemic changes once accumulated. Indeed, realising EIPs does not specifically require introduction and diffusion of some particular technical product and process innovations such as wind energy, biogas, public transport systems, electric vehicle transport systems, etc., as usually studied by SNM scholars (Caniëls and Romijn, 2008). EIP development, as an industrial ecology in practice (Ehrenfeld and Gertler, 1997), is more about changing the industrial production routines through product, process and organisational innovations that may be achieved through institutional changes. Any physical or non-physical exchange between system members in EIPs is realised through an innovative solution and leads to an innovative solution as the result. The product or process innovation out of industrial symbiosis can be in an incremental or radical form depending on the exchange and its results. However, these innovations engaging various actors at the EIP level accumulates into systemic innovations.

4. Methodology

A systematic literature review (SLR) (Fischl et al., 2014; Petticrew and Roberts, 2006), including a case survey (Lucas, 1974), was chosen as the method of the present article due to the fact that EIP literature is rich in empirical case studies. We believe that extracting the EIP cases from the literature and re-interpreting them with a different theoretical perspective can provide valuable knowledge to elaborate on how transitions into EIPs can be achieved.

The case survey method enables us to have a rich set of case materials (Kivimaa et al., 2017; Newig and Fritsch, 2009) that have previously been generated for different research objectives under different research designs with different research perspectives. We were aware that the proper synthesis of such case material would require a smart bricolage ability, especially considering the "risk of bias in summarising" (Kivimaa et al., 2017) studies that we have not conducted (Petticrew and Roberts, 2006). Considering this, we have devoted enough time and commitment for the synthesis to benefit from the advantage of having numerous case studies, which would not have been possible through direct insight gathering from the primary sources.

In order to identify the cases from the literature, the SLR method was preferred for this study over a traditional or narrative literature review. Fink (1998) defined SLR as "a systematic, explicit and reproducible design for identifying, evaluating and interpreting the existing body of recorded documents". In more reflexive terms, the idea is to gather and re-interpret the earlier interpretations of EIP cases and present them in a new context (Alvesson and Skoldberg, 2009), developing new knowledge and addressing the objective of this article. The new context is the proposed theoretical framework, which builds on the SNM approach, as explained earlier. Following this methodology, diverse case studies could be brought together under a common theoretical framework.

In order to ensure thoroughness and rigour (Tranfield et al., 2003; Fischl et al., 2014), this article follows a solid SLR method with three concrete steps – (i) literature search, (ii) literature analysis, and (iii) literature synthesis – in order to use the existing knowledge effectively (Fischl et al., 2014).

The systematic literature review started with a literature search, where the crucial element was to choose the database(s) and the keyword(s) to be searched (Baker, 2000). Then, in the literature analysis step, selected studies were descriptively analysed in terms of various aspects related to journals, publication years, and geographical focus of studies. The EIP cases that would be further elaborated at the next step were also identified in this step.

Finally, in the literature synthesis, each EIP case was re-interpreted based on analytical processes of SNM as explained above. It is worth stating that none of the EIP cases included in that study were developed using SNM as the ex-ante prescriptive policy framework. Instead, we built on SNM as the underpinning of our theoretical framework, which is used as an ex-post analytical framework for re-interpretation in order to understand how transitions to EIP development can be achieved to derive some policy implications. The literature synthesis step covered the crucial discussions in line with the theoretical framework and led to various research implications about critical and interesting issues that require further investigation in the EIP literature. During the synthesis step of SLR, the units of analysis were the EIP cases in selected articles out of the literature search step, rather than the full article itself.

4.1. Literature search

In this step, the initial and crucial decision was related to selection of keywords. In the literature, the concept of EIPs refers to IPs having a focus on environmental and social pillars of sustainability through 'industrial ecology', or, more specifically, 'industrial symbiosis'. On the other hand, different studies in the literature refer to 'industrial parks" as 'local industrial productions systems', 'industrial districts', 'industrial clusters', 'industrial agglomerations', 'industrial estates', etc. Our interest is related to the potential transitions of IP development into EIP development through brownfield and greenfield projects. However, the literature also contains other studies, rather than EIP development, that focus on other ways of making IPs more sustainable. Including 'industrial parks' and its used synonyms as keywords in the literature search would bring all other sustainability solution possibilities for IPs. Doing so would be beyond the scope of this article, which argues that 'EIPs' would be a better possibility for addressing the problematique of sustainability concerns related to IP development. Therefore, three keywords were selected: 'eco-industrial' and its parent concepts 'industrial ecology' and 'industrial symbiosis'.

Web of Science was selected as the database because of its reputation as a useful and trustworthy source, as the oldest and most widely used database with rich and well-structured citation and bibliographic data dating back to 1900 (Mikki, 2009; Chadegani et al., 2013). Moreover, its coverage is mostly in English and it has a systematic and established journal selection criteria based on expert views, citation impact, international diversity, publication standards, etc.

Reviewing the literature through the search for the keywords 'eco-industrial', 'industrial symbiosis', or 'industrial ecology' in the title, keywords or abstracts of the articles in the Web of Science database rendered 3040 publications in English language for all years. The search was conducted on the 12th of December 2017. Filters on research domain to be 'social sciences' and document types to be 'articles' were then applied to the results, which decreased the number of publications to 1389. The review was limited to journal articles because they address a wider scientific audience and are subject to different forms of peer-review process, which increases the quality of the studies. Next, exclusion criteria, which are the measures to determine which articles will be excluded from the review, and inclusion criteria, which are the measures to determine which articles will be included in the review, were identified. Exclusion criteria were set to be elimination of articles related to technical studies, such as optimisation, programming, configuration development, emission reduction, specific production methods, quantification of performance, emergy analysis, etc. Inclusion criteria were set as articles that touch both social and technical aspects of EIPs and regional/local industrial symbiosis and industrial ecology. Taking these exclusion and inclusion criteria into consideration, titles and abstracts of the available articles were scrutinised; this step resulted in 115 articles for literature analysis. A further review was conducted over these 115 articles in order to identify the materialised EIP cases; that is, excluding those that are only at the proposal or planning stage, which would be re-interpreted during literature synthesis drawing upon SNM internal processes. This gave us 66 articles with a sample of 104 EIP cases. Finally, based on these articles, discussions on local EIP experiments, global EIP niche development and sustainability transitions into EIP development were built. The six-step procedure is illustrated in Fig. 2.

4.2. Literature analysis

In this step, we conducted a meta-analysis of 115 selected articles for a quantitative representation of time and journal distribution of publications, as well as frequency of geographic locations studied in the articles. Moreover, we identified EIP cases that would be subjected further to literature synthesis. The full list of countries, together with references to the articles studying them, is attached as Appendix A.

Through analysis of number of articles published each year over a sample of 115 articles selected for analysis, we found that there has been a considerable and relatively stable interest in EIP development in social sciences research domain since 2007 (87%, n = 101). Starting from 2015 and peaking in 2016 (18%, n = 21), an increase was observed in the total number of articles published (see Fig. 3). Five journals represent the majority of the total sample (71%, n = 82). These are *Journal of Cleaner Production* (n = 51), *Journal of Industrial Ecology* (n = 15), *Journal of Environmental Management* (n = 6), *Sustainability* (n = 6), and *Regional Studies* (n = 4). The rest of the articles (n = 33) were published in 26 different journals related to the fields of environment, sustainability, technology, geography, urban planning, regional science and economics, indicating that eco-industrial development as a research topic has gained interest from scholars from different backgrounds and had the chance to be studied as an inter-disciplinary field. Fig. 4 presents the journals with more than one

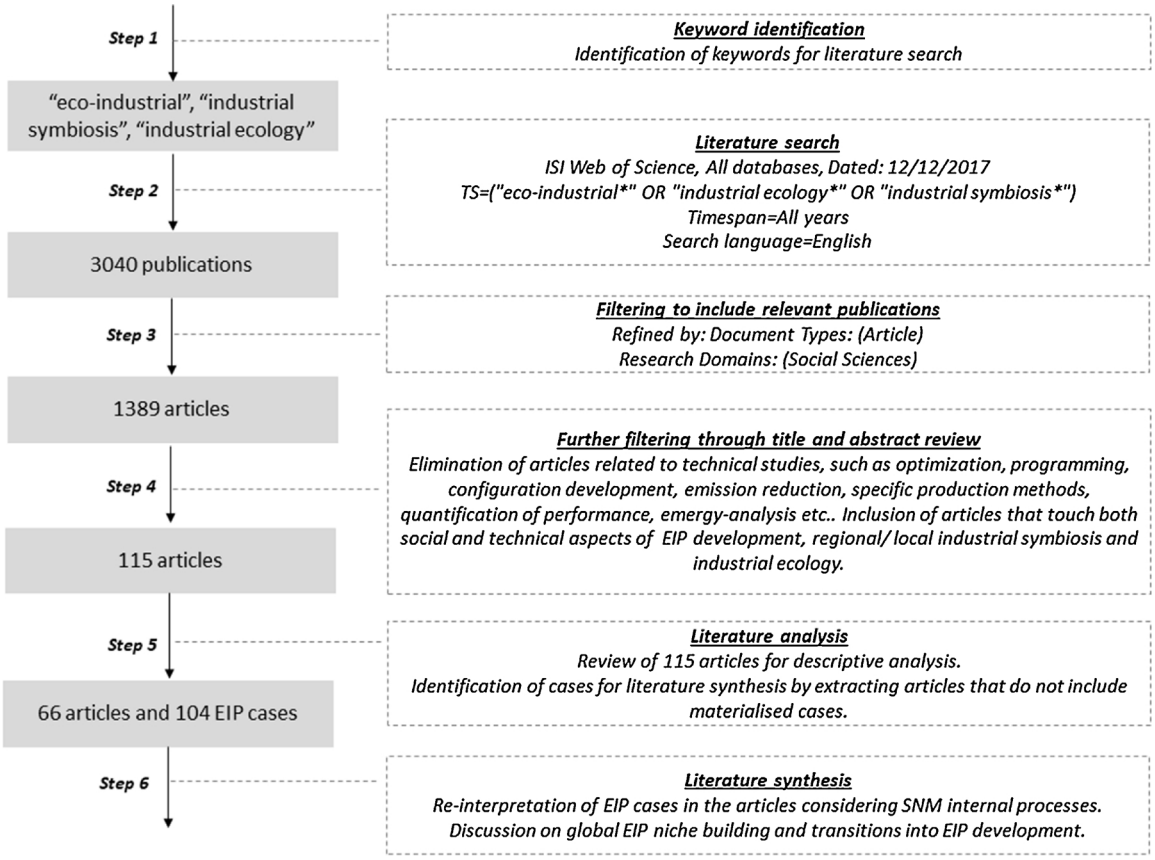

Fig. 2. Systematic literature review embedding a case survey in six steps.

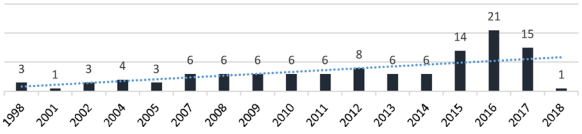

Fig. 3. Number of publications over years, n = 115.

publication within our literature analysis sample. Based on these analyses, it can be concluded that research on EIPs in social sciences domain stands still as a fresh line and may be enriched within interdisciplinary studies being operationalised in concepts from different social science theories. This enrichment would further extend our understanding of if and how transitions to EIP development can be achieved.

A picture of the geographical distribution of empirical contexts of the studies can reflect how the focus of different geographies on EIP development differs in intensity by looking at the frequency of countries studied in the article sample. To draw such a picture, the countries in focus were analysed and listed. The results showed that not all studies selected for literature analysis have specific geographical empirical contexts (n = 12). Still, it was observed that an importantly large sample of studies (n = 103) focused on analysis and interpretation of different aspects of EIP development in 31 different countries throughout the world. Among these studies, a relatively large number (n = 87) had a single-country focus, while some others (n = 16) have empirical contexts from multiple countries, as illustrated in Fig. 5.

Going further into the multi-country focus articles, new countries appear on the list, such as the United Kingdom, Ukraine, Switzerland,

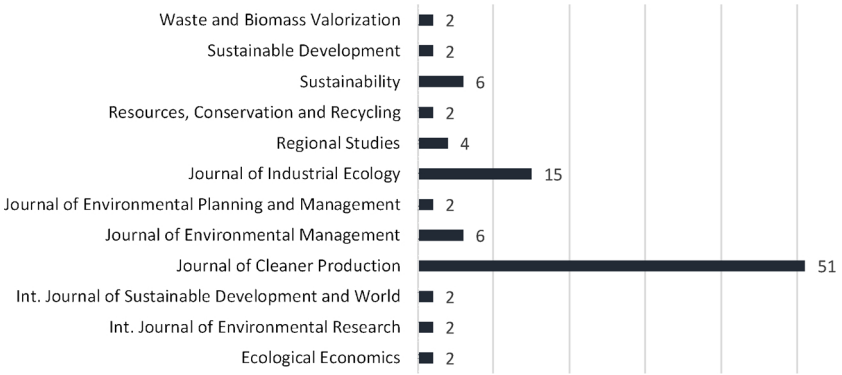

Fig. 4. Number of publications at most relevant journals, n = 115, included if > 1 article.

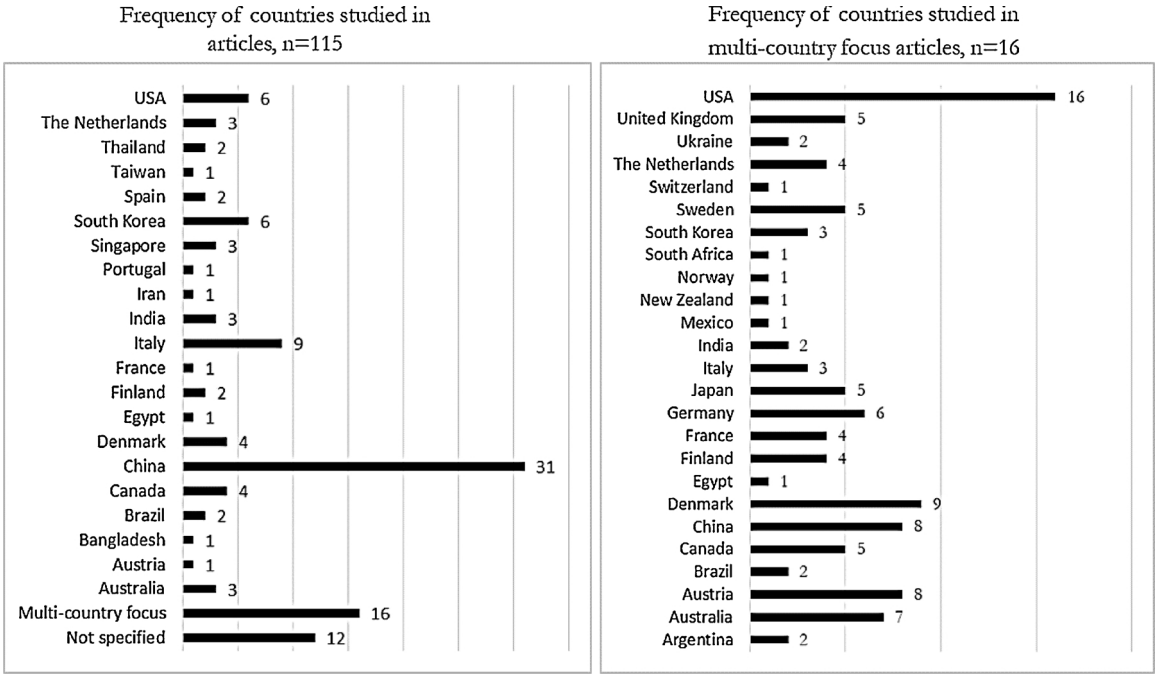

Fig. 5. Frequency of countries as empirical contexts studied in articles.

Sweden, South Africa, Norway, New Zealand, Mexico, Japan, Germany and Argentina. Moreover, when compared to other countries, Denmark, which has a benchmarked self-organised and perhaps the most cited EIP initiative (namely, Kalundborg EIP), has a relatively radical increase in its frequency of studies with a multi-country focus. This implies the interest in cross-comparison of cases with the best practices. The National Industrial Symbiosis Programme (NISP) of United Kingdom, as another benchmark example, also appears in the articles with a multi-country focus. However, NISP is not included in literature synthesis as it is a national-scale industrial symbiosis initiative. Articles with a multi-country focus provide experience and knowledge from and across different contexts, which arguably creates a more fruitful learning ground for readers.

As stated, the third step of our review is the synthesis of EIP cases from the selected literature studies. The frequency of countries focused on in each of the studies has already been presented but it is still necessary to list the EIP cases already interpreted in the literature. We have analysed each selected article thoroughly and identified all involved EIP cases. Articles that do not include already developed EIP cases, but instead analyse potential EIPs, have not been counted in the synthesis. However, articles that do not have specific EIP case analysis and instead have country-level analyses on different EIP development and management aspects based on the data collected from various EIP initiatives are included. Excluding such articles could have resulted in skipping crucial SNM processes' analysis for the EIP development in the related geographies as they provide insightful knowledge about the background of EIP development in the country under analysis. After applying these inclusion and exclusion criteria, the final EIP list was composed of 104 EIP cases from 24 countries studied in 66 articles. The global distribution of EIPs is illustrated in Fig. 6. Furthermore, list of identified EIP cases together with reference articles are given in Appendix B.

5. Literature synthesis

While re-interpreting identified EIP cases from the literature, three "interrelated and mutually reinforcing" (Caniëls and Romijn, 2008) processes of the SNM framework are considered, as explained in the theoretical framework. This section presents a learning outcome and discusses how EIP development has remained at the level of local projects in some geographies and evolved into EIP niche level in others. By doing so, we intend to elucidate how potential transitions from IP development into EIP development can be achieved and studied through giving policy and research implications.

5.1. Articulation of expectations and visions

Expectations from EIP development are strongly shaped by motivations of the involved actors; as there are various involved actors with different interests, expectations can vary, even within the same geography, and they are not clearly articulated most of the time. In general, however, motivation for the industries are almost always economic and whenever the EIP project does not seem economically feasible, the industry is not interested and firms do not prioritise the social and environmental potential of industrial symbiosis. Besides, industrial actors that do not have any related experience and are not equipped with enough background knowledge related to EIP development (Park et al., 2016) are not willing to initiate such experiments. On the other hand, expectations for governmental institutions, especially considering planned EIPs, are positive and motivated mostly by global pro-sustainability development landscape pressure, environmental pollution and resource scarcity problems at the regional or national levels and concerns related to sustaining country's industry in the international market. In the case of South Korea, for example, financially oriented motivation of industries is clearly articulated in various case studies, such as the *Ulsan* and *Macheon* experiments (Behera et al., 2012; Kim, 2007), whereas government has been developing ambitious top-down planned EIP development mechanisms while also considering the country's domestic context (Park et al., 2016; Park et al., 2008).

Furthermore, same-group actors at different geographies may have different expectations as well. In some EIP cases, industrial actors, such as *Kalundborg* (Valentine, 2016; Chertow, 2007; Branson, 2016), *Industrial Eco-System Project* (Lambert and Boons, 2002; Heeres et al., 2004) and *Kwinana* (Chertow and Ehrenfeld, 2012; Giurco et al., 2011; MacLachlan, 2013) took the lead in initiating successful symbiotic

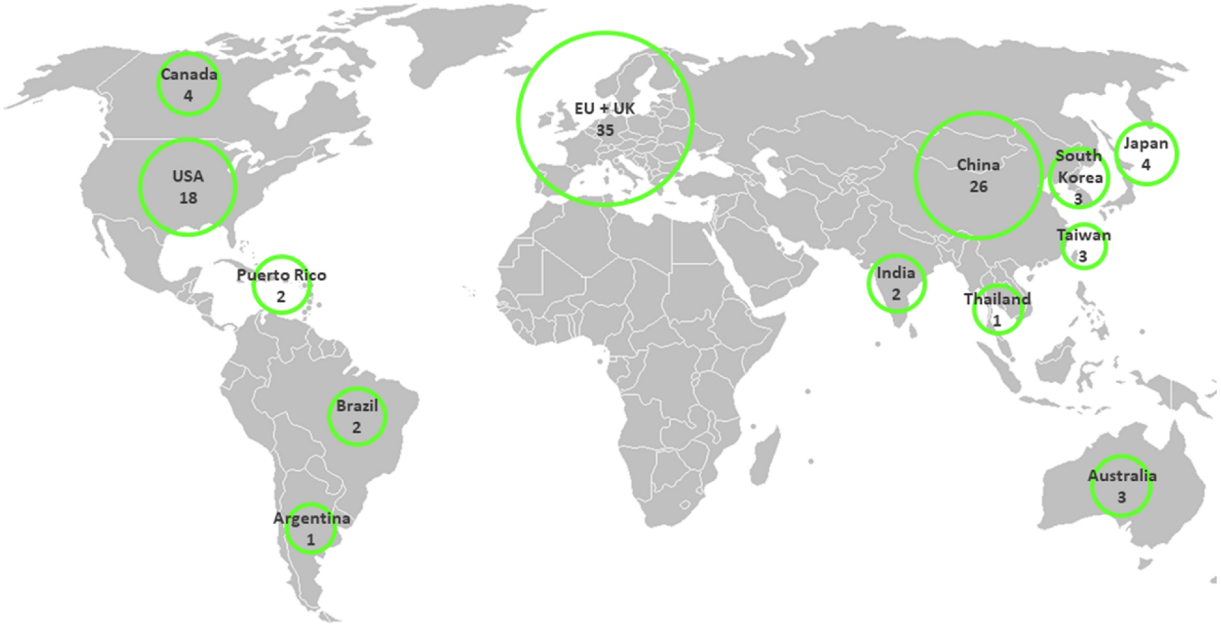

Fig. 6. Global distribution of the identified EIP cases. The number of EIP cases are indicated on the geographic location where they have been developed.

exchanges in collaboration with local and regional governmental institutions. They expected and then realised that industrial symbiosis could bring substantial economic and environmental profits and have been willing to invest in such projects.

Another important point is the importance of having common expectations from the EIP development. Even for a single EIP experiment, actors who have different interests and motivations may hold diverging expectations and may not communicate to each other clearly. Differences in motivations may lead to misunderstanding or arbitrary understanding of what an EIP is, especially when there is a lack of learning mechanisms. This problem is observed at the *Macheon* experiment (Kim, 2007), where government agents, industries and local citizens had different understandings about industrial symbiosis and developed different expectations from this specific EIP experiment, which threatened the aim and sustainability of the project.

Expectations of actors are highly interlinked with the vision of EIP development in related geography. Visions related to EIP development can be addressed through three evolution models proposed by the EIP literature: planned EIP, facilitated EIP and self-organised EIP. In the EIP literature, some leading scholars have discussed the importance of building upon existing and potential linkages within a locality (Gibbs and Deutz 2007), using existing strengths (Gibbs et al., 2005), identifying and uncovering existing symbiosis (Lambert and Boons, 2002; Chertow, 2007) in EIP development, and promoting self-organised and facilitated EIP models in this respect. However, it has been claimed that planning is still important if it is applied in the early stages of EIP development and if it is combined with a facilitated model to achieve long-term goals for eco-transitions (Yu et al., 2015a).

Despite this, a top-down approach leading to planned EIPs is prevalent in cases from North America, South America, Asia and Australia. Especially in USA and China, EIP development has been strongly guided by the government (Yu et al., 2015c; Gibbs and Deutz, 2005; Chertow, 2007), which has led to a higher number of EIP projects (see Fig. 6) when compared to all other countries. However, there are cases from these geographies where top-down planning was combined with a bottom-up approach and turned out to be a facilitated model, as in the cases of *Burnside* (Lambert and Boons, 2002), *Kawasaki* (Chertow and Ehrenfeld, 2012; Mathews and Tan, 2011; Farel et al., 2016), and *Central Gulf Coast* (Farel et al., 2016). The *Kwinana* case, as another exception, has been developed in a combined top-down and bottom-up fashion (Farel et al., 2016) as it was developed by the government as a greenfield site in 1952 but EIP practices were not planned and they 'happened over time' (MacLachlan, 2013).

In Europe there is a variety in EIP development visions where self-organising and facilitation mechanisms for brownfield EIP projects have been competing with planning trends for greenfield EIPs, which was not the case on the other above-mentioned regions. Bottom-up self-organised development as a result of voluntary cooperation has been followed at various European EIPs, such as *Styria* (Zhang et al., 2013; Chertow and Ehrenfeld, 2012; Chertow, 2007; Ashton et al., 2017), *Kalundborg* (Bellantuono et al., 2017; Lambert and Boons, 2002; Valentine, 2016; Chertow and Ehrenfeld, 2012; Branson, 2016; Gibbs et al., 2005), *Knapsack Chemical Park* (Farel et al., 2016), *BASF Verbund* (Farel et al., 2016), *Porto Marghera* (Mannino et al., 2015), *Bioraffinerie Les Sohettes* (Farel et al., 2016) and *Industrial Eco-System Project* (Lambert and Boons, 2002; Heeres et al., 2004). Although the trigger factors for these local projects were related to concerns of industries, facilitation mechanisms were introduced later through public and private organisations. On the other hand, for some other cases from Europe, such as *Biopark Terneuzen* (Farel et al., 2016), *Moerdjik* (Heeres et al., 2004; Farel et al., 2016), *Monthey*, *Norrkoping and Linkoping*, *Kymi* and *Deux Synthe* (Farel et al., 2016), bottom-up involvement has emerged later, leading to the facilitation model, although EIP mechanisms initially were introduced in a top-down fashion.

We have noticed that most of the EIP cases were established on a local vision built by expectations of particular actors targeted mostly at the transition of particular IPs for brownfield experiments or developing greenfield EIP projects. A broader long-term vision for transitions of IP development into EIP development only appears in countries where a top-down approach with national-level goals has been followed, such as China, South Korea, and Thailand through brownfield projects, and the USA, mostly through greenfield projects. However, brownfield projects from Asia using existing linkages and strengths within an IP have been more fruitful than the greenfield projects in the US (Chertow and Ehrenfeld, 2012). Moreover, more successful and sustained EIP experiments from those countries have been the ones that engaged in facilitation to keep EIP projects viable at later development stages, such as *Tianjin* and *Dalian* (Yu et al., 2015a), *Ulsan* (Behera et al.,

2012), and *Devens* (Veleva et al., 2015). In such experiments, a combination of top-down and bottom-up approaches have provided the background for interactions of the related actors to build networks under coordination activities provided by mostly public agents, which have also considered the need for learning processes in order to have diverging expectations and visions.

Moreover, the vision for EIP development also plays a crucial role with regard to protection of niche experiments in terms of regulatory, policy, and funding frameworks. Protection measures, such as tax regimes, environmental regulations, national policy programmes, financing incentives, and so on, condition and trigger, or in some cases even hinder EIP development, and decisions related to them are made at the political and often at national level. In this regard, integration of top-down planning into EIP development is observed to be critical. In geographies where, for EIP development, the government plays an initiator role (as in China, South Korea, Thailand, the US or Canada), or a facilitator role (as in Denmark, Australia, the Netherlands or Sweden), EIP experiments gain legitimacy and stability resulting from government support and protection. Furthermore, support from international landscape can also be beneficial for nurturing EIP experiments. In China, for instance, governments and industries have further participated in EIP development efforts through financial support from international development agencies like the United Nations Environmental Program (UNEP), the Asian Development Bank (ADB), and the Canadian International Development Agency (CIDA) (Geng et al., 2007). These international support mechanisms are also observed in experiments such as *Biopark Terneuzen* (Farel et al., 2016), *Deux Synthe* (Farel et al., 2016), *AvestaPolarit*, *Eco Dyfi*, *Ecotech* (Gibbs and Deutz, 2007) in which funding from European Union (EU) was received.

Policy implications

Based on the lessons learnt from the EIP cases, we suggest that top-down planning with a stronger focus on brownfield EIP experiments can provide promising conditions for governments to build specific expectations with specific motivations. Then, bringing in facilitation mechanisms that engage industries, research centres and citizens may lead to the convergence of motivations and shared expectations of wide variety of actors. Thus, an effective combination of a top-down and bottom-up approach stressing more brownfield projects through providing support and protection mechanisms would be more suitable considering the long-term vision required for transitions from IP development into EIP development.

Research implications

We propose following research implications related to expectations and visions for EIP development:

***Research implication 1*:** Evolving expectations and visions for EIP development covering a wide variety of related actors and their motivations requires an explicit focus of the EIP literature.

Research implication 2: A broader vision for transitions of IP development into EIP development in comparison to vision for transitions into particular EIPs has not been explicitly examined in the EIP literature.

5.2. Social network building

The network perspective in the EIP literature has been mostly addressed in reference to the development of industrial symbiosis exchange networks focusing on different aspects of network building, such as network connectedness and resilience through social network analysis (Zhang et al., 2013; Chopra and Khanna, 2014); networking behaviours of the firms in industrial symbiosis networks (Gibbs et al., 2005); social relationships and shared norms among actors in industrial symbiosis networks (Ashton and Bain, 2012); growth patterns for industrial symbiosis networks (Zhu and Ruth, 2014); embeddedness and proximity in industrial symbiosis networks (Schiller et al., 2014; Domenech and Davies, 2011); and the role of EIP coordinating bodies (Tessitore et al., 2015). These studies have provided important insights into the structure and dynamics of the industrial symbiosis networks. However, EIP development requires a wider constellation of actors including external institutions such as governmental bodies, regional and local development agencies, universities and research centres, local communities, non-governmental organisations (NGO) representing the community interests, etc., in order to involve multiple views and engage resources from different agents.

In the *Kalundborg* experiment, which is considered a benchmark EIP example by various scholars (Branson, 2016; Park et al., 2008; Chertow et al., 2008; Gibbs and Deutz, 2005), a social network was built among industries, coordinating body, local government, regulatory authorities, universities and research centres (Costa and Ferrao, 2010; Chertow, 2007; Valentine, 2016; Chertow and Ehrenfeld, 2012) and this wider network has conditioned the industrial symbiosis network within the park. This was the case for various other EIP experiments such as *Chamusca* (Costa and Ferrao, 2010), *Deux Synthe* (Farel et al., 2016), *Landskrona* (Park et al., 2008; Adamides and Mouzakitis, 2009), *Norrkoping and Linkoping* (Farel et al., 2016), *Kawasaki* (Chertow and Ehrenfeld, 2012; Mathews and Tan, 2011), *Ulsan* (Behera et al., 2012), *Daedok Technovalley* (Oh et al., 2005; Pilouk and Koottatep, 2017), *Northern Region Industrial Estate* (Panyathanakun et al., 2013), *Kwinana* (Giurco et al., 2011), and various Chinese EIPs including *Guigang Group* (Zhu and Côté, 2004; Fang et al., 2007), *Suzhou* (Yuan et al., 2010; Yu et al., 2015b), *Weifang Binhai* (Liu et al., 2015), *Tianjin* (Yu et al., 2014b), *Shanghai Chemical* (Yune et al., 2016; Zhang et al., 2009), *Dalian* (Yu et al., 2015a; Geng et al., 2008), *Rizhao* (Yu et al., 2015c), and *Qijiang* (Sun et al., 2017). Industrial symbiosis network within the park can then be considered as part of the wider EIP development network.

In the literature, a crucial structure of EIP development network has been considered as the coordinating body (Chertow and Ehrenfeld, 2012), which other articles referred to as the management body (Tessitore et al., 2015). The coordinating body in an EIP is generally responsible for strengthening networking, ensuring communication and information exchange among all of the network actors and especially among industrial actors in symbiosis network to facilitate the identification and establishment of symbiotic exchange potentials among the participating companies (Yu et al., 2015a) and more importantly among actors in the wider EIP development network. This role can be played by a private company, an industry association, or public authorities depending primarily on the expectations and visions of the EIP development in the concerned region. For instance, in China (Yu et al., 2015a), South Korea (Behera et al., 2012; Park et al., 2008) and Italy (Tessitore et al., 2015), where there is a national-level EIP development vision planned in a top-down manner, coordinating bodies are established and represented by public authorities. In contrast, coordinating bodies in EIP experiments like *Kwinana* (Chertow and Ehrenfeld, 2012), which have a mixture of top-down and bottom-up vision, demonstrate a more mixed structure for coordinating bodies that are composed of representation from the industrial actors, government and academia, and appreciate and communicate a wider range of articulated views.

Drawing on the articles included in literature synthesis, another important structure of the EIP development network appears to be a local champion (Chertow, 2007; Roberts, 2004; Heeres et al., 2004) for the purposes of goal setting and creating the actor network, which is in line with the SNM perspective (Caniëls and Romijn, 2008). Hewes and Lyons (2008) elaborated on the role of local champions in development of *Komsomolske* and *Cherkassey* EIPs in Ukraine, where the champions were locally embedded within the community. Although the local champions were explicit in these two EIP experiments, the role of local champions was deliberately unidentified in some other cases, such as *Industrial Eco-System* and *Rietvelden/Vutter Sustainable Revitilisation* experiments from the Netherlands, to avoid prejudice among industrial

actors, since many of them would be suitable for the task (Hewes and Lyons, 2008). The existence of local champions has been also favoured in EIP development in South Korea, where regional EIP centres established by the government act as local champions (Park et al., 2016); an exception is the *Ulsan* experiment, where the local champion was an academic researcher (Behera et al., 2012). Local champions in all those experiments promoted and strengthened bottom-up activities in order to gather all relevant actors for promoting social connections and developing trust in the EIP development networks.

Policy implications

Relying on experiences related to network building from the articles, we propose that the network perspective in EIP development should be widened, aiming at a combination of industries, which form the industrial symbiosis network, and external actors such as government bodies, research institutes, universities, informal institutes like industrial associations and NGOs. A perspective on such a wider EIP development network would be broad and deep enough to reflect multiple views. Moreover, networking building can be more efficient if it is guided by a coordinating body that ensures all actors communicate effectively, and also if it is supported by local champions that facilitate interaction and trust development among network actors. Clearly, vision for EIP development constructed through top-down and/or bottom-up approaches should impact the variety in actor structure, their interactions, or existence of coordinating body or local champions.

Research implications

We arrive at the following research implications considering social network building:

***Research implication 3*:** Structures of broader networks for EIP development, which involves not only industrial actors in symbiosis networks but also external institutions such as governmental bodies, university and research institutes, NGOs, industrial associations, local community, etc., and the interaction among them remain underexplored in EIP literature.

***Research implication 4*:** The EIP literature lacks an understanding of the correlation between the EIP development visions, tailored by top-down, bottom-up, and mixed approaches, and network building characteristics, related to involved actors and their interactions.

5.3. Learning activities

Learning has a crucial role in sustaining niches at the level of single niche experiments or a set of demonstrations experiments (Schot and Geels, 2008). Despite this, it has not found an explicit interest in EIP literature. A deeper look into the articles has been necessary to synthesise cases with respect to learning activities embedded in their evolution path.

The depth and breadth of learning processes – that is, first-order or second-order learning – are found to be related to characteristics of EIP development networks. When the EIP development networks are broad and connect various EIP experiments, as in countries like China, where there is a top-down approach for vision on national-level transitions into EIP development, second-order learning seems to be more likely. One reason for this is the "structured repeated visioning" (Schot and Geels, 2008) through various EIP experiments under the protection of the same umbrella programmes, such as the National Demonstration EIP Program (NDEIP) and the National Demonstration Circular Economy Zone Program (NPCEZ) in China (Zhang et al., 2010). Another reason is related to the high number of EIP cases, which were initiated and protected by these programmes through concurrent experimentation, and aggregation of learning outcomes from these experiments. For instance, Chinese governmental organisations have, since the beginning of the 21st century, been accumulating knowledge through monitoring results from different EIP experiments and have been facilitating learning for IPs by disseminating this knowledge through publications and by exchanging lessons via useful capacity-building events such as seminars, forums, workshops, trainings, business meetings, etc., as well as dissemination through media. However, there is still a lack of a learning system in China with a common platform for information sharing and communication among IPs, and such a system would create the knowledge and practice sharing network among all IPs and EIPs (Zhu et al., 2015).

We also observed that network diversity, both in industrial symbiosis networks and wider EIP development networks, enhances learning processes. Considering industrial symbiosis networks that are centred on one or a few major industries, the absence of diversity may "hinder learning and critical reflection about the experiment" (Weber et al., 1999). This was the case in *Porto Marghera* (Mannino et al., 2015) in Italy, a failed EIP experiment in which high dependency on a single industry reduced the diversity and thus the learning for the resilience of the network.

Indeed, the experiments from the literature show that heterogeneity in terms of sectoral and size differences inside the park facilitates favourable contexts, especially for observing, analysing and learning from the facts and data with a focus on technological issues; that is, first-order learning. Communication and disseminations events as capacity-building measures, organised by coordinating bodies, anchor tenants, local champions, environmental agencies, or governmental institutions, have provided mediums for first-order learning in many EIPs, such as *Burnside* (Lambert and Boons, 2002), *ValuePark Schkopau* (Liwarska-Bizukojc et al., 2009), *Devens* (Veleva et al., 2016), *Kwinana* (MacLachlan, 2013), *Kalundborg* (Branson, 2016), *Guigang Group* (Zhu and Côté, 2004), *Suzhou* (Yu et al., 2015b), *Weifang Binhai* (Liu et al., 2015), *Xi'an High-Tech* (Shi and Yu, 2014), *Dalian*, *Tianjin*, (Yu et al., 2015a), *Qijiang* (Sun et al., 2017), *Ebara* (Bellantuono et al., 2017), *Kokubu* (Bellantuono et al., 2017), *Ulsan* (Behera et al., 2012), and *Northern Region Industrial Estate* (Panyathanakun et al., 2013). Information systems technologies can also be important tools to facilitate the exchange of information and materials, as in cases such as *Chamusca* (Costa and Ferrao, 2010), *Landskrona*, (Adamides and Mouzakitis, 2009), *Tianjin*, *Kalundborg*, etc. Then, repetition and accumulation of first-order learning over time, as in the cases of *Devens*, *Kwinana*, and *Kalundborg*, led to the rethinking of assumptions and changing of production routines in such EIPs (that is, second-order learning), where not only technological issues but also social, managerial and organisational network features were addressed.

Another important aspect of learning in niche building is related to transfer of experiences and lessons from one experiment to other places (Weber et al., 1999) as such cross-fertilisation across experiments can occur (Caniëls and Romijn, 2008). In that respect, the *Kalundborg* case stands as the most influential EIP experiment (Branson, 2016; Chertow et al., 2008; Deutz and Gibbs, 2008) and served as a reference benchmark learning centre for the development of various other EIP experiments (Adamides and Mouzakitis, 2009; Chertow and Ehrenfeld, 2012) distributed over wide geographies (Gibbs et al., 2005; Park et al., 2008). In view of this, international collaborations can play a role in terms of knowledge transfer and co-creation, such as in the *Suzhou* experiment where knowledge from experience in Singapore has been adopted by China for EIP development; the *Biopark Terneuzen* experiment (Farel et al., 2016), which was a part of an international project funded by the European Union by international partners; or national-level EIP development programmes in countries like China (NDEIP and NPCEZ) (Bai et al., 2014), South Korea (National Plan for Eco-industrial Park Development) (Park et al., 2016), or Thailand (Development of Eco-Industrial Estates and Networks Project) (Pilouk and Koottatep, 2017), for which governmental organisations have been collaborating

with international institutes and experts.

Policy implications

In light of these aspects, we argue that learning activities and processes require an explicit focus in EIP development as they sustain the impact of EIP experiments during their evolution over time. If first-order learning can be achieved continuously via capacity-building measures for actors in industrial symbiosis networks and wider EIP development networks, it can accumulate into second-order learning, which facilitates the viability of an EIP experiment and also the emergence of expectations and visions for EIP development at wider geographies. Network characteristics like diversity, connectedness and size also have an influence on learning activities. Moreover, cross-fertilisation across EIP experiments from different places is crucial so the experiments can learn from each other.

Research implications

We arrive at following research implications related to learning activities:

Research implication 5: Learning activities, processes or mechanisms have received little attention in the EIP literature. The existing analytical levels, or processes related to learning for analysis and development of sustainability niche experiments from other research streams such as ST can be used and adapted to EIP development.

Research implication 6: Transfer of learning from one experiment to other places is considered important for EIP development. However, it has received scant attention in the existing EIP literature and requires further investigation.

5.4. Local EIP experiments, global EIP niche formation and transitions

EIP development as a sustainability strategy has organisational characteristics and requirements that are close to the characteristics and requirements of the existing mainstream industrial development but also promises substantial changes in the management and operational logics of IPs and industries located in and around IPs in the long-term. Various EIP experiments at different geographies have shown that an operating EIP can be the result of evolution over decades (Mathews and Tan, 2011). Although EIP development does not require a radical divergence from the development patterns of IPs, EIP experiments from the literature revealed that it could not have gained its internal momentum rapidly and easily and at various geographies. Instead, it stayed at local isolated experiments level, like most of the strategic niche experiments (Schot and Geels, 2008), and often did not lead to niche formation and obviously could not replace the IP development trend and lead to a transition.

Although SNM as a policy tool suggests that niches are assumed to emerge through collective actions by bottom-up approaches (Schot and Geels, 2008), the review of EIP experiments from the literature, building on SNM as an ex-post analytical tool, has demonstrated that the most promising EIP niche development is observed at geographies where top-down planning mechanisms were more prevalent, such as China, South Korea and the US. However, even when the top-down planning runs as the main trigger for EIP development, the necessary role of facilitating, enabling, coordinating the networks for EIP development (Chertow and Ehrenfeld, 2012) indicates the analytical and practical importance of combination of top-down and bottom-up mechanisms.

In China, since the Ministry of Environmental Protection (MEP) initiated EIP projects in 2001, a total of 108 projects – mostly brownfield but also a few greenfield proposals – have been approved and 31 of those have met the criteria and become EIPs (Liu et al., 2017); meanwhile, the MEP has been collaborating with other governmental agencies like the Ministry of Commerce (MOC), the Ministry of Finance (MOF), the National Development and Reform Commission (NDRC) and the Ministry of Science and Technology (MOST). This governmental-level collaboration, having positive expectations about EIP development in China, has provided spaces for experimentation (Shi and Yu, 2014) and triggered various IPs to apply to be an EIP, as well as greenfield EIP projects through well-established two programmes, NDEIP and NPCEZ, that have practical quantitative evaluation indicators. However, having two national-level programmes, one focusing on EIP development with a more ecological perspective, and the other focusing on circular economy for IPs with a more economic perspective, has created a blurred understanding about what an EIP is and how to become one (Zhang et al., 2010).

The present article included 26 EIP Chinese experiments. Chinese experience shows that brownfield experiments have been more popular (Bai et al., 2014) and successful (Shi et al., 2012) than greenfield experiments. Although many EIPs in China still struggle with challenges related to technologies, management and regulations, at the national level, we would argue that China provides the most nurturing environment for EIP niche formation considering the number of experiments, which is the highest globally (see Fig. 6), ongoing protection policies of the Chinese Government and a rich set of different sectors involved in projects (Fang et al., 2007), including mining, metallurgy, electric power, chemicals and petro-chemicals, construction materials, general mechanics, electronics, transportation, airplane manufacture, textiles, paper, beer, alcohol and pharmaceuticals. However, compared to other international EIPs, Chinese EIPs are observed to be more dependent on the Central Government for design, management, and financial support (Ghisellini et al., 2016). This may be problematic if and when the government decided to withdraw the niche protection as suggested by the SNM literature (Caniëls and Romijn, 2008; Kemp et al., 1998) as strong on-going protection can restrict autonomous, bottom-up learning processes (Weber et al., 1999). To date, Chinese government have provided continuous support for EIP development since 2001 when the first EIP projects were started (Jiao and Boons, 2017). This support could be strengthened by adding more financial support and enforcing the supervisory task of coordinating agencies for approved EIPs (Zhang et al., 2010). Moreover, a learning system with a common platform for information sharing and communication would promote experiences from benchmark EIPs (Zhu et al., 2015), such as *Tianjin*, *Guigang Group* and *Dalian*, and strengthen the niche formation process in China.

EIP development in other Asian countries (n = 13) also followed EIP development in a similar vision as in China. The top-down approach is observed to be prevalent in Japan through the Eco-town Programme (Pilouk and Koottatep, 2017), South Korea through the National Plan for EIP Development (Park et al., 2016), Taiwan through the Green Economy Program (Li et al., 2015), Thailand through the Development of Eco-Industrial Estates and Networks Projects and Community-Based Eco-Industrial Estate Framework (Panyathanakun et al., 2013), and also in India (Ashton and Bain, 2012; Bellantuono et al., 2017), although a national level programme has not been observed in the Indian cases.

Synthesis of the 18 EIP experiments from the US involved in this review have revealed that EIP development has not been particularly fruitful. These projects were outcomes of a strong top-down push in 1996 from the President's Council for Sustainable Development through a task force for creating various greenfield EIP projects. However, experiments remained at the level of local projects and even they could not sustain themselves for years and industrial actors

generally remained passive throughout the project lifetimes (Heeres et al., 2004). The reason for this was claimed to be the central planning, with attempts to even predetermine IP tenants, which did not end in organic systems (Chertow and Ehrenfeld, 2012). However, more fruitful EIP experiments from Puerto Rico (n = 2), integrating top-down strategies into bottom-up initiatives (Chertow et al., 2008; Chertow, 2007), demonstrated evolving notable industrial symbiosis exchanges over time.

Compared to other continents, Europe has the longest list of EIP cases (n = 35), which indicates on-going momentum for continuous development of EIPs. Inspiring experiments can be observed in Europe (examples include *Kalundborg*, *Ecopark Hartberg*, *Styria*, *Rantasalmi*, *ValuePark Schkopau*, *Chamusca*, *Landskrona*, *Industrial Eco-System Project*, *Rietvelden/Vutter Sustainable Revitilisation*, *Moerdjik, Biopark Terneuzen*, *Komsomlske* and *Cherkassey*). Still it is difficult to identify a promising EIP niche building in any European country; instead, EIP experiments have remained isolated events without bridges in between. Even *Kalundborg*, which is considered to be the benchmark EIP example, did not repeat, even in Denmark, and there have been no other Danish cases. Similar EIP experiments in Denmark may have led to the niche formation, but *Kalundborg* remained a unique local experiment in the country. Considering this, local government organisations have recently launched new projects to extend industrial symbiosis mind-set to other locations of municipal oversight (Valentine, 2016). Expanding this approach of Danish local government, a learning system at the European level that could facilitate cross-fertilisation between these distributed experiments by disseminating information and building wider EIP development networks may support EIP niche building at both the specific country level and the continent level.

At another geography, the few EIP experiments (n = 3) from South America (Bellantuono et al., 2017) also remained as isolated experiments and did not succeed in changing the strategies of mainstream actors involved in IP development, although they did receive governmental support through a top-down approach. This situation may be claimed to be similar in Australia, considering the low number of EIP experiments (n = 3) identified in the literature. However, the *Kwinana* experiment, which followed a combination of top-down and bottom-up approaches, has been one of the most studied EIPs due to its successful reputation on how it has been evolved into an EIP even though industrial symbiosis was not planned or foreseen when *Kwinana* was originally established as a greenfield site (MacLachlan, 2013). In this respect, *Kwinana* has been influential for other EIP experiments at different locations.

Policy implications

Based on the information gathered from EIP experiments in this synthesis, we observed that the general trend of EIP development appears to remain at the stage of local projects and is not connected to a broader strategy to develop EIP niches in most of the countries. Still, it can be claimed that the countries that developed national-level protection programmes for the transition of IPs at the country level into EIPs have made a greater contribution to global niche building. Drawing on the SNM perspective, we suggest that isolated EIP experiments can be further developed into niches by interconnecting similar experiments or expanding them beyond the local level by means of effective policy mechanisms whereby common visions can be formulated through network management by enabling learning and exchanging lessons learnt from different experiments.

Research implications

Finally, we arrive at the following research implications related to global EIP niche building and transitions into EIP development:

Research implication 7: Although various case studies related to EIP development have been conducted, concepts such as niche experiments or global niche building have not been examined in EIP literature. Theoretical frameworks for examining various single EIP experiments for sustainability transitions of IP development are missing in the literature.

Research implication 8: So far, the ST stream and EIP development literatures have not been often studied together. However, it would be fruitful for EIP development research to bring in insights from different theoretical frameworks in ST literature while learning from other sustainability practices that have been the objects of ST studies.

6. Conclusion

Certainly, EIPs are sustainable practices and transitions into EIP development are not easy to realise. Existing actors in industrial production systems have a tendency to resist fundamental changes in their operational and production routines, and this brings lock-ins in the existing systems. For this reason, IP development still is very popular despite its problematique related to environmental sustainability concerns. Transforming existing IPs into EIPs or developing new EIPs instead of IPs are not often the options that the related actors choose. Therein lies the crux of the matter: How can EIP development become mainstream and how can such a transition from IP development into EIP development be achieved?

While there is no one specific answer to these complex questions, we argue that there is a lot to learn from the rich EIP case studies available in the literature and we can contribute to the EIP literature using different perspectives. In this vein, our objective in this article was twofold: (i) to understand and shed some light on how transitions into EIP development can be achieved through lessons from the EIP cases that have been studied in the existing state of the art; and (ii) to establish a research agenda that would elaborate on transitions into EIP development with the aim of bringing a sustainability transitions perspective to the EIP literature. To accomplish these aims, we systematically analysed the EIP literature and synthesised the identified 104 EIP cases from 24 countries.

To conceptually guide the literature synthesis, we developed a theoretical framework following certain theoretical standpoints from the ST and EIP literatures. From the ST field, we mainly built on the SNM framework with a particular focus on its three interlinked niche processes (Schot and Geels, 2008; Smith and Raven, 2012; Kemp et al., 1998), while considering the differentiation between local and global niche levels (Geels and Raven, 2006). We integrated the SNM framework into the EIP literature with an evolutionary perspective for conceptual elaboration of the sustainability transitions to EIP development. In doing so, we connected the EIP literature and ST field, which have not been nurtured from each other very often.

Drawing on the developed theoretical framework for understanding and re-interpretation of the identified EIP cases, we completed the literature synthesis considering four conceptual building blocks: articulation of expectations and visions; building of social networks; learning activities; and local EIP experiments, global EIP formation and transitions. Based on our learning from the existing state of the art with regard to these conceptual blocks, we arrived at some policy implications regarding how to achieve sustainability transitions into EIP development (see Table 1). We recognise that there are no universally correct policy implications and that each geographical context needs to consider the local constraints before implementing any policy implication. Therefore, we have carefully derived these implications so that they can offer enough flexibility to

Table 1
Policy implications and research agenda with potential avenues for future research.

Policy implications	Research agenda
Articulation of expectations and visions: Top-down planning with a stronger focus on brownfield EIP experiments can provide promising conditions for governments to build specific expectations with specific motivations. Then, bringing in facilitation mechanisms that engage industries, research centres and citizens may lead to the convergence of motivations and shared expectations of wide variety of actors. Thus, an effective combination of a top-down and bottom-up approach stressing more brownfield projects through providing support and protection mechanisms would be more suitable considering the long-term vision required for transitions from IP development into EIP development.	***Research implication 1*:** Evolving expectations and visions for EIP development covering a wide variety of related actors and their motivations requires an explicit focus of the EIP literature. ***Research implication 2:*** A broader vision for transitions of IP development into EIP development in comparison to vision for transitions into particular EIPs has not been explicitly examined in the EIP literature.
Social network building: The network perspective in EIP development should be widened, aiming at a combination of industries, which form the industrial symbiosis network, and external actors such as government bodies, research institutes, universities, informal institutes like industrial associations and NGOs. A perspective on such a wider EIP development network would be broad and deep enough to reflect multiple views. Moreover, networking building can be more efficient if it is guided by a coordinating body that ensures all actors communicate effectively, and also if it is supported by local champions that facilitate interaction and trust development among network actors. Clearly, vision for EIP development constructed through top-down and/or bottom-up approaches should impact the variety in actor structure, their interactions, or existence of coordinating body or local champions.	***Research implication 3*:** Structures of broader networks for EIP development, which involves not only industrial actors in symbiosis networks but also external institutions such as governmental bodies, university and research institutes, NGOs, industrial associations, local community, etc., and the interaction among them remain underexplored in EIP literature. ***Research implication 4*:** The EIP literature lacks an understanding of the correlation between the EIP development visions, tailored by top-down, bottom-up, and mixed approaches, and network building characteristics, related to involved actors and their interactions.
Learning activities: Learning activities and processes require an explicit focus in EIP development as they sustain the impact of EIP experiments during their evolution over time. If first-order learning can be achieved continuously via capacity-building measures for actors in industrial symbiosis networks and wider EIP development networks, it can accumulate into second-order learning, which facilitates the viability of an EIP experiment and also the emergence of expectations and visions for EIP development at wider geographies. Network characteristics like diversity, connectedness and size also have an influence on learning activities. Moreover, cross-fertilisation across EIP experiments from different places is crucial so the experiments can learn from each other.	***Research implication 5:*** Learning activities, processes or mechanisms have received little attention in the EIP literature. The existing analytical levels, or processes related to learning for analysis and development of sustainability niche experiments from other research streams such as ST can be used and adapted to EIP development. ***Research implication 6***: Transfer of learning from one experiment to other places is considered important for EIP development. However, it has received scant attention in the existing EIP literature and requires further investigation.
Local EIP experiments, global EIP formation and transitions: Isolated EIP experiments can be further developed into niches by interconnecting similar experiments or expanding them beyond the local level by means of effective policy mechanisms whereby common visions can be formulated through network management by enabling learning and exchanging lessons learnt from different experiments.	***Research implication 7:*** Although various case studies related to EIP development have been conducted, concepts such as niche experiments or global niche building have not been examined in EIP literature. Theoretical frameworks for examining various single EIP experiments for sustainability transitions of IP development are missing in the literature. ***Research implication 8***: So far, the ST stream and EIP development literatures have not been often studied together. However, it would be fruitful for EIP development research to bring in insights from different theoretical frameworks in ST literature while learning from other sustainability practices that have been the objects of ST studies.

be tailored and further detailed considering the geographical space and scale on which they can be followed. Moreover, deriving policy implications in this article should be seen as an attempt to provide a global perspective on EIP development for connecting various geographies through network building activities so that they can learn from each other to articulate the expectations and visions guiding a common agenda for sustainability transitions of IP development.

We argue that the theoretical framework and the synthesis presented in this article are crucial steps towards examining EIP development from the perspective of sustainability transitions. In line with this, we derived some research implications for guiding the future research related to EIP development in that respect (see Table 1).

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Appendix A

*LA = Literature analysis; LS = Literature synthesis; Articles included in literature synthesis are at grey shaded rows.

LA Nr	Author	Name	Journal	Studied geography	LS Nr
1	(Ribeiro, et al., 2018)	An integrated approach towards transforming an industrial park into an eco-industrial park: the case of Salaise-Sablons	Journal of Environmental Planning and Management	France	
2	(Taddeo, et al., 2017)	The Development of Industrial Symbiosis in Existing Contexts. Experiences from Three Italian Clusters	Ecological Economics	Italy	
3	(Fraccascia, et al., 2017)	Rethinking Resilience in Industrial Symbiosis: Conceptualization and Measurements	Ecological Economics	China Denmark	
4	(Liu, et al., 2017)	Comprehensive development of industrial symbiosis for the response of greenhouse gases emission mitigation: Challenges and opportunities in China	Energy Policy	China	1
5	(Chen, et al., 2017)	Clustering enterprises into eco-industrial parks: Can interfirm alliances help small and medium-sized enterprises?	Journal of Cleaner Production	China	
6	(Bellantuono, et al., 2017)	The organization of eco-industrial parks and their sustainable practices	Journal of Cleaner Production	Austria, Denmark, Finland, France, Germany, UK, Italy, Spain, Sweden, Canada, USA, Argentina, Brazil, China, Japan, India, Australia	2
7	(Li, et al., 2017)	The vulnerability of industrial symbiosis: A case study of Qijiang Industrial Park, China	Journal of Cleaner Production	China	
8	(Pilouk & Koottatep, 2017)	Environmental performance indicators as the key for eco-industrial parks in Thailand	Journal of Cleaner Production	Thailand	3
9	(Hwang, et al., 2017a)	Green business park project management: Barriers and solutions for sustainable development	Journal of Cleaner Production	Singapore	
10	(Ceglia, et al., 2017)	Critical elements for eco-retrofitting a conventional industrial park: Social barriers to be overcome	Journal of Environmental Management	Brazil	
11	(Boons, et al., 2017)	Industrial Symbiosis Dynamics and the Problem of Equivalence	Journal of Industrial Ecology	not specified	
12	(Hwang, et al., 2017b)	Identifying Critical Success Factors for Green Business Parks: Case Study of Singapore	Journal of Management in Engineering	Singapore	
13	(Jiao & Boons, 2017)	Policy durability of Circular Economy in China: A process analysis of policy translation	Resources Conservation and Recycling	China	
14	(Liu & Côté, 2017)	A Framework for Integrating Ecosystem Services into China's Circular Economy: The Case of Eco-Industrial Parks	Sustainability	China	4
15	(Ashton, et al., 2017)	Life and Death of Industrial Ecosystems	Sustainability	Denmark, Australia, Austria, USA	5
16	(Sun, et al., 2017)	Coordination of Industrial Symbiosis through Anchoring	Sustainability	China	6
17	(Veleva, et al., 2016)	Benchmarking eco-industrial park development: the case of Devens	Benchmarking – An International Journal	USA	7
18	(Vahidi, et al., 2016)	Challenges and Opportunities of Industrial Ecology Development in Iran	International Journal of Environmental Research	Iran	
19	(Horváth & Harazin, 2016)	A framework for an industrial ecological decision support system to foster partnerships between businesses and governments for sustainable development	Journal of Cleaner Production	not specified	
20	(Park, et al., 2016)	A review of the National Eco-Industrial Park Development Program in Korea: Progress and achievements in the first phase, 2005-2010	Journal of Cleaner Production	South Korea	8
21	(Ghisellini, et al., 2016)	A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems	Journal of Cleaner Production	Canada, USA, EU, Brazil, Argentina, Egypt, South Africa, India, China, Australia, South Korea, Japan, New Zealand	9
22	(Hwang, et al., 2016)	Causal relationship of eco-industrial park development factors: a structural equation analysis	Journal of Cleaner Production	South Korea	
23	(Guo, et al., 2016)	Evaluation of promoting industrial symbiosis in a chemical industrial park: A case of Midong	Journal of Cleaner Production	China	10

24	(Notarnicola, et al., 2016)	Industrial symbiosis in the Taranto industrial district: current level, constraints and potential new synergies	Journal of Cleaner Production	Italy	
25	(Felicio, et al., 2016)	Industrial symbiosis indicators to manage eco-industrial parks as dynamic systems	Journal of Cleaner Production	not specified	
26	(Valentine, 2016)	Kalundborg Symbiosis: fostering progressive innovation in environmental networks	Journal of Cleaner Production	Denmark	11
27	(Taddeo, 2016)	Local industrial systems towards the eco-industrial parks: the model of the ecologically equipped industrial areas	Journal of Cleaner Production	Italy	
28	(Geng, et al., 2016)	Recent progress on innovative eco-industrial development	Journal of Cleaner Production	not specified	
29	(Branson, 2016)	Re-constructing Kalundborg: the reality of bilateral symbiosis and other insights	Journal of Cleaner Production	Denmark	12
30	(Daddi, et al., 2016)	Regional policies and eco-industrial development: the voluntary environmental certification scheme of the eco-industrial parks in Tuscany (Italy)	Journal of Cleaner Production	Italy	13
31	(Côté & Liu, 2016)	Strategies for reducing greenhouse gas emissions at an industrial park level: a case study of Debert Air Industrial Park, Nova Scotia	Journal of Cleaner Production	Canada	14
32	(Dong, et al., 2016)	Towards preventative eco-industrial development: an industrial and urban symbiosis case in one typical industrial city in China	Journal of Cleaner Production	China	
33	(Layton, et al., 2016)	Industrial Ecosystems and Food Webs: An Expansion and Update of Existing Data for Eco-Industrial Parks and Understanding the Ecological Food Webs They Wish to Mimic	Journal of Industrial Ecology	Denmark	
34	(Velenturf & Jensen, 2016)	Promoting Industrial Symbiosis: Using the Concept of Proximity to Explore Social Network Development	Journal of Industrial Ecology	not specified	
35	(Farel, et al., 2016)	Sustainable Manufacturing Through Creation and Governance of Eco-Industrial Parks	Journal of Manufacturing Science and Engineering-Transactions of the ASME	Denmark, South Korea, Australia, Switzerland, France, USA, Japan, The Netherlands, China, Finland, Germany, Sweden, Austria	15
36	(Yune, et al., 2016)	Greening Chinese chemical industrial park by implementing industrial ecology strategies: A case study	Resources Conservation and Recycling	China	16
37	(LeBlanc, et al., 2016)	Potential for Eco-Industrial Park Development in Moncton, New Brunswick (Canada): A Comparative Analysis	Sustainability	Canada	
38	(Yu, et al., 2015c)	Evolution of industrial symbiosis in an eco-industrial park in China	Journal of Cleaner Production	China	17
39	(Yu, et al., 2015b)	From an eco-industrial park towards an eco-city: a case study in Suzhou, China	Journal of Cleaner Production	China	18
40	(Liu, et al., 2015)	Implementing a three-level approach in industrial symbiosis	Journal of Cleaner Production	China	19
41	(Puente, et al., 2015)	Industrial symbiosis opportunities for small and medium sized enterprises: preliminary study in the Besaya region (Cantabria, Northern Spain)	Journal of Cleaner Production	Spain	
42	(Qu, et al., 2015)	Sustainable development of eco-industrial parks in China: effects of managers' environmental awareness on the relationships between practice and performance	Journal of Cleaner Production	China	
43	(Mannino, et al., 2015)	The decline of eco-industrial development in Porto Marghera, Italy	Journal of Cleaner Production	Italy	20
44	(Veleva, et al., 2015)	Understanding and addressing business needs and sustainability challenges: lessons from Devens eco-industrial park	Journal of Cleaner Production	USA	21
45	(Li, et al., 2015)	Building green supply chains in eco-industrial parks towards a green economy: Barriers and strategies	Journal of Environmental Management	China	22
46	(Patnaik & Poyyamoli, 2015)	Developing an eco-industrial park in Puducherry region, India - a SWOT analysis	Journal of Environmental Planning and Management	India	
47	(Zhu, et al., 2015)	Barriers to Promoting Eco-Industrial Parks Development in China: Perspectives from Senior Officials at National Industrial Parks	Journal of Industrial Ecology	China	23
48	(Yu, et al., 2015a)	What Makes Eco-Transformation of Industrial Parks Take Off in China?	Journal of Industrial Ecology	China	24
49	(Tessitore, et al., 2015)	Eco-Industrial Parks Development and Integrated Management Challenges: Findings from Italy	Sustainability	Italy	25

50	(Iacondini, et al., 2015)	Feasibility of Industrial Symbiosis in Italy as an Opportunity for Economic Development: Critical Success Factor Analysis, Impact and Constrains of the Specific Italian Regulations	Waste and Biomass Valorization	Italy	
51	(Madsen, et al., 2015)	Industrial Symbiosis Exchanges: Developing a Guideline to Companies	Waste and Biomass Valorization	not specified	
52	(Schiller, et al., 2014)	Analyzing networks in industrial ecology - A review of Social-Material Network Analyses	Journal of Cleaner Production	not specified	
53	(Bai, et al., 2014)	Insights on the development progress of National Demonstration eco-industrial parks in China	Journal of Cleaner Production	China	26
54	(Yu, et al., 2014b)	Process analysis of eco-industrial park development - the case of Tianjin, China	Journal of Cleaner Production	China	27
55	(Jiao & Boons, 2014)	Toward a research agenda for policy intervention and facilitation to enhance industrial symbiosis based on a comprehensive literature review	Journal of Cleaner Production	China	28
56	(Patala, et al., 2014)	Towards a broader perspective on the forms of eco-industrial networks	Journal of Cleaner Production	not specified	
57	(Shi & Yu, 2014)	Eco-Industrial Parks from Strategic Niches to Development Mainstream: The Cases of China	Sustainability	China	29
58	(MacLachlan, 2013)	Kwinana Industrial Area: agglomeration economies and industrial symbiosis on Western Australia's Cockburn Sound	Australian Geographer	Australia	30
59	(Zhang, et al., 2013)	Social network analysis and network connectedness analysis for industrial symbiotic systems: model development and case study	Frontiers of Earth Science	Denmark, USA, Japan, Austria, China	31
60	(Panyathanakun, et al., 2013)	Development of eco-industrial estates in Thailand: initiatives in the northern region community-based eco-industrial estate	Journal of Cleaner Production	Thailand	32
61	(Spekkink, 2013)	Institutional capacity building for industrial symbiosis in the Canal Zone of Zeeland in the Netherlands: a process analysis	Journal of Cleaner Production	The Netherlands	
62	(Romero & Ruiz, 2013)	Framework for Applying a Complex Adaptive System Approach to Model the Operation of Eco-Industrial Parks	Journal of Industrial Ecology	Norway, USA, China, Austria, Canada, Australia	
63	(Conticelli & Tondelli, 2013)	Application of Strategic Environmental Assessment to Eco-Industrial Parks: Raibano Case in Italy	Journal of Urban Planning and Development	Italy	
64	(Gregson, et al., 2012)	Territorial Agglomeration and Industrial Symbiosis: Sitakunda-Bhatiary, Bangladesh, as a Secondary Processing Complex	Economic Geography	Bangladesh	
65	(Behera, et al., 2012)	Evolution of 'designed' industrial symbiosis networks in the Ulsan Eco-industrial Park: 'research and development into business' as the enabling framework	Journal of Cleaner Production	South Korea	33
66	(Taddeo, et al., 2012)	Implementing eco-industrial parks in existing clusters. Findings from a historical Italian chemical site	Journal of Cleaner Production	Italy	
67	(Ashton & Bain, 2012)	Assessing the "Short Mental Distance" in Eco-Industrial Networks	Journal of Industrial Ecology	India	34
68	(Shi, et al., 2012)	China's Quest for Eco-industrial Parks, Part II Reflections on a Decade of Exploration	Journal of Industrial Ecology	China	35
69	(Boons & Spekkink, 2012)	Levels of Institutional Capacity and Actor Expectations about Industrial Symbiosis	Journal of Industrial Ecology	The Netherlands	
70	(Chertow & Ehrenfeld, 2012)	Organizing Self-Organizing Systems	Journal of Industrial Ecology	Denmark, USA, China, South Korea, Australia, Austria, The Netherlands, UK	36
71	(Wells & Zapata, 2012)	Renewable Eco-industrial Development A New Frontier for Industrial Ecology	Journal of Industrial Ecology	not specified	
72	(Sakr, et al., 2011)	Critical success and limiting factors for eco-industrial parks: global trends and Egyptian context	Journal of Cleaner Production	Egypt	
73	(Giurco, et al., 2011)	Developing industrial water reuse synergies in Port Melbourne: cost effectiveness, barriers and opportunities	Journal of Cleaner Production	Australia	37

74	(Zamorano, et al., 2011)	Diagnosis and proposals for waste management in industrial areas in the service sector: case study in the metropolitan area of Granada (Spain)	Journal of Cleaner Production	Spain	
75	(Lehtoranta, et al., 2011)	Industrial symbiosis and the policy instruments of sustainable consumption and production	Journal of Cleaner Production	Finland	
76	(Boons, et al., 2011)	The dynamics of industrial symbiosis: a proposal for a conceptual framework based upon a comprehensive literature review	Journal of Cleaner Production	China, UK, Australia, Japan, USA, Ukraine	
77	(Mathews & Tan, 2011)	Progress Toward a Circular Economy in China The Drivers (and Inhibitors) of Eco-industrial Initiative	Journal of Industrial Ecology	China	38
78	(Wang, et al., 2010)	Pursuing sustainable industrial development through the eco-industrial parks Three case studies of China	Annals of the New York Academy of Sciences	China	39
79	(Yuan, et al., 2010)	Improving Competitive Advantage with Environmental Infrastructure Sharing: A Case Study of China-Singapore Suzhou Industrial Park	International Journal of Environmental Research	China	40
80	(Desrochers & Leppala, 2010)	Industrial Symbiosis: Old Wine in Recycled Bottles? Some Perspective from the History of Economic and Geographical Thought	International Regional Science Review	not specified	
81	(Costa & Ferrao, 2010)	A case study of industrial symbiosis development using a middle-out approach	Journal of Cleaner Production	Portugal	41
82	(Shi, et al., 2010)	Developing country experience with eco-industrial parks: a case study of the Tianjin Economic-Technological Development Area in China	Journal of Cleaner Production	China	42
83	(Zhang, et al., 2010)	Eco-industrial parks: national pilot practices in China	Journal of Cleaner Production	China	43
84	(Elabras Veiga & Magrini, 2009)	Eco-industrial park development in Rio de Janeiro, Brazil: a tool for sustainable development	Journal of Cleaner Production	Brazil	
85	(Adamides & Mouzakitis, 2009)	Industrial ecosystems as technological niches	Journal of Cleaner Production	Denmark, Germany, Sweden	44
86	(Liwarska-Bizukojc, et al., 2009)	The conceptual model of an eco-industrial park based upon ecological relationships	Journal of Cleaner Production	Austria	45
87	(Geng, et al., 2009)	Assessment of the National Eco-Industrial Park Standard for Promoting Industrial Symbiosis in China	Journal of Industrial Ecology	China	46
88	(Wright, et al., 2009)	Diversity and Connectance in an Industrial Context The Case of Burnside Industrial Park	Journal of Industrial Ecology	Canada	47
89	(Zhang, et al., 2009)	Comparative analysis of socio-economic and environmental performances for Chinese EIPs: case studies in Baotou, Suzhou, and Shanghai	Sustainability Science	China	48
90	(Geng, et al., 2008)	Evaluating the applicability of the Chinese eco-industrial park standard in two industrial zones	International Journal of Sustainable Development and World Ecology	China	49
91	(Park, et al., 2008)	Strategies for sustainable development of industrial park in Ulsan, South Korea - From spontaneous evolution to systematic expansion of industrial symbiosis	Journal of Environmental Management	South Korea	50
92	(McManus & Gibbs, 2008)	Industrial ecosystems? The use of tropes in the literature of industrial ecology and eco-industrial parks	Progress in Human Geography	not specified	
93	(Deutz & Gibbs, 2008)	Industrial Ecology and Regional Development: Eco-Industrial Development as Cluster Policy	Regional Studies	USA	51
94	(Chertow, et al., 2008)	Industrial Symbiosis in Puerto Rico: Environmentally Related Agglomeration Economies	Regional Studies	Puerto Rico	52
95	(Hewes & Lyons, 2008)	The Humanistic Side of Eco-Industrial Parks: Champions and the Role of Trust	Regional Studies	Ukraine, USA	53
96	(Gibbs & Deutz, 2007)	Reflections on implementing industrial ecology through eco-industrial park development	Journal of Cleaner Production	USA, UK, Italy, Finland, France, Germany, Austria, The Netherlands, Sweden, Denmark	54
97	(Fang, et al., 2007)	Industrial sustainability in China: Practice and prospects for eco-industrial development	Journal of Environmental Management	China	55

98	(Chertow, 2007)	Uncovering industrial symbiosis	Journal of Industrial Ecology	USA, Canada	56
99	(Kim, 2007)	Building an eco-industrial park as a public project in South Korea. The stakeholders' understanding of and involvement in the project	Sustainable Development	South Korea	57
100	(Geng, et al., 2007)	Empirical analysis of eco-industrial development in China	Sustainable Development	China	58
101	(Haskins, 2007)	A systems engineering framework for eco-industrial park formation	Systems Engineering	not specified	
102	(Gibbs & Deutz, 2005)	Implementing industrial ecology? Planning for eco-industrial parks in the USA	Geoforum	USA	59
103	(Oh, et al., 2005)	Eco-Industrial Park Design: a Daedeok Technovalley case study	Habitat International	South Korea	60
104	(Gibbs, et al., 2005)	Industrial ecology and eco-industrial development: A potential paradigm for local and regional development?	Regional Studies	USA, UK, Italy, Finland, France, Germany, Austria, Denmark, Sweden, Germany	61
105	(Yang & Lay, 2004)	Applying ecosystem concepts to the planning of industrial areas: a case study of Singapore's Jurong Island	Journal of Cleaner Production	Singapore	
106	(Heeres, et al., 2004)	Eco-industrial park initiatives in the USA and the Netherlands: first lessons	Journal of Cleaner Production	The Netherlands	62
107	(Zhu & Côté, 2004)	Integrating green supply chain management into an embryonic eco-industrial development: a case study of the Guitang Group	Journal of Cleaner Production	China	63
108	(Roberts, 2004)	The application of industrial ecology principles and planning guidelines for the development of eco-industrial parks: an Australian case study	Journal of Cleaner Production	Australia	64
109	(Geng & Côté, 2002)	Scavengers and decomposers in an eco-industrial park	International Journal of Sustainable Development and World Ecology	Canada	65
110	(Singhal & Kapur, 2002)	Industrial estate planning and management in India - an integrated approach towards industrial ecology	Journal of Environmental Management	India	
111	(Lambert & Boons, 2002)	Eco-industrial parks: stimulating sustainable development in mixed industrial parks	Technovation	Canada, The Netherlands, USA	66
112	(Korhonen, 2001)	Regional industrial ecology: examples from regional economic systems of forest industry and energy supply in Finland	Journal of Environmental Management	Finland	
113	(Martin, et al., 1998)	Applying industrial ecology to industrial parks: An economic and environmental analysis	Economic Development Quarterly	USA Mexico	
114	(Carr, 1998)	Choctaw Eco-Industrial Park: an ecological approach to industrial land-use planning and design	Landscape and Urban Planning	USA	
115	(Chertow, 1998)	Waste, industrial ecology, and sustainability	Social Research	Denmark	

Boons et al. (2017), Boons and Spekkink (2012), Carr (1998), Ceglia et al. (2017), Chen et al. (2017), Chertow (1998), Conticelli and Tondelli (2013), Desrochers and Leppala (2010), Dong et al. (2016), Elabras Veiga and Magrini (2009), Fraccascia et al. (2017), Geng et al. (2016), Geng et al. (2009), Gregson et al. (2012), Guo et al. (2016), Haskins (2007), Horváth and Harazin (2016), Hwang et al. (2017a), Hwang et al. (2017b), Hwang et al. (2016), Iacondini et al. (2015), Korhonen (2001), Layton et al. (2016), LeBlanc et al. (2016), Lehtoranta et al. (2011), Li et al. (2017), Madsen et al. (2015), Marshall (1920), Martin et al. (1998), McManus and Gibbs (2008), Notarnicola et al. (2016), Patnaik and Poyyamoli (2015), Puente et al. (2015), Qu et al. (2015), Ribeiro et al. (2018), Romero and Ruiz (2013), Sakr et al. (2011), Spekkink (2013), Taddeo (2016), Taddeo et al. (2012), Taddeo et al. (2017), Vahidi et al. (2016), Velenturf and Jensen (2016), Wells and Zapata (2012), Yang and Lay (2004), and Zamorano et al. (2011).

Appendix B

*Countries of EIP cases are given next to EIP names in form of abbreviations as stated by International Organization for Standardization.

Nr	Name of the case and references	Nr	Name of the case and references
1	Burnside EIP (CA) (Bellantuono, et al., 2017; Lambert and Boons, 2002; Geng and Côté, 2002; Wright et al., 2009; Chertow, 2007)	53	Moerdjik EIP Project (NL) (Heeres et al., 2004; Farel et al., 2016)
2	Alberto (CA) (Chertow, 2007)	54	Biopark Terneuzen (NL) (Farel, et al., 2016)
3	Debert Air Industrial Park (CA) (Côté and Liu, 2016)	55	Komsomlske (UA) (Hewes and Lyons, 2008)
4	Innovista (CA) (Bellantuono, et al., 2017)	56	Cherkassey (UA) (Hewes and Lyons, 2008)
5	Fairfield, Baltimore (USA) (Chertow, 2007; Heeres et al., 2004)	57	European Sites ABLE Project (UK) (Gibbs and Deutz, 2007)
6	Brownsville Regional Industrial Symbiosis Project (USA) (Bellantuono et al., 2017; Chertow, 2007; Heeres et al., 2004)	58	AvestaPolarit (UK) (Gibbs and Deutz, 2007)
7	Cape Charles Sustainable Technologies Industrial Park (USA) (Bellantuono et al., 2017; Gibbs and Deutz, 2005; Chertow, 2007; Heeres et al., 2004; Deutz and Gibbs, 2008; Gibbs and Deutz, 2007)	59	Eco Dyfi (UK) (Gibbs and Deutz, 2007)

8 Central Gulf Coast Project (USA) (Gibbs and Deutz, 2005; Farel, et al., 2016; Gibbs and Deutz, 2007)
9 Riverside EIP, Burlington, Vermont (USA) (Chertow, 2007)
10 Green Institute EIP, Minneapolis, Minnesota (USA) (Chertow, 2007)
11 Stonyfield Londonderry EIP, Londonderry, New Hampshire (USA) (Gibbs and Deutz, 2005; Chertow, 2007; Deutz and Gibbs, 2008; Gibbs and Deutz, 2007)
12 Red Hills Ecoplex, Mississipi (USA) (Gibbs and Deutz, 2005; Deutz and Gibbs, 2008; Gibbs and Deutz, 2007)
13 Ecolibrium, Computer and lectronic Disposition, Austin, Texas (USA) (Gibbs and Deutz, 2005; Deutz and Gibbs, 2008; Gibbs and Deutz, 2007)
14 Front Royal, Eco-Office Park, Virginia (USA) (Gibbs and Deutz, 2005; Deutz and Gibbs, 2008; Gibbs and Deutz, 2007)
15 Dallas EIP, Texas (USA) (Gibbs and Deutz, 2005; Deutz and Gibbs, 2008; Gibbs and Deutz, 2007)
16 Triangle J, North Carolina (USA) (Chertow, 2007)
17 Phillips Eco Enterprise Center, Minnesota (USA) (Gibbs and Deutz, 2005; Deutz and Gibbs, 2008; Gibbs and Deutz, 2007)
18 Bassett Creek, Minnesota (USA) (Gibbs and Deutz, 2005; Gibbs, 2008; Deutz, 2007)
19 Devens (USA) (Bellantuono et al., 2017; Veleva et al., 2015; Veleva et al., 2016; Deutz, 2005; Lyons, 2008; Gibbs, 2008; Deutz, 2007)
20 Campbell Industrial Park, Hawaii (USA) (Ehrenfeld, 2012)
21 Jacksonville, Florida (USA) (Ehrenfeld, 2012)
22 Choctaw, Oklahoma (USA) (Zhang et al., 2013)
23 Puerto Rico – Guayama (PR) (Ehrenfeld, 2012; Chertow, 2007; Farel et al., 2016; Chertow et al., 2008)
24 Puerto Rico – Barceloneta (PR) (Chertow, 2007; Chertow et al., 2008; Ashton et al., 2017)
25 La Cantabrica (AR) (Bellantuono et al., 2017)
26 Paracambi (AR) (Bellantuono, et al., 2017)
27 Santa Cruz (AR) (Bellantuono et al., 2017)
28 Ecopark Hartberg (AT) (Bellantuono et al., 2017; Farel et al., 2016; Liwarska-Bizukojc et al., 2009)
29 Styria (AT) (Zhang et al., 2013; Ehrenfeld, 2012; Chertow, 2007; Ashton et al., 2017)
30 Kalundborg Symbiosis (DK) (Bellantuono et al., 2017; Zhang et al., 2013; Boons, 2002; Valentine, 2016; Ehrenfeld, 2012; Branson, 2016; Gibbs et al., 2005; Ashton et al., 2017) (Deutz, 2005; Park et al., 2008; Ferrao, 2010; Chertow, 2007; Farel et al., 2016; Tan, 2011; Mouzakitis, 2009; Zhang et al., 2009; Chertow et al., 2008; Gibbs, 2008)
31 Kymi (FI) (Farel et al., 2016)
32 Rantasalmi (FI) (Bellantuono et al., 2017)
33 Uimaharju (FI) (Bellantuono et al., 2017)
34 Deux Synthe (FR) (Farel et al., 2016)
35 Ecosite du Pays de Thau (FR) (Deutz, 2007)
36 Bioraffinerie Les Sohettes (FR) (Farel et al., 2016)
37 Arbois Mediterranee (FR) (Bellantuono, et al., 2017)
38 Artois-Flandres (FR) (Bellantuono et al., 2017)
39 Plaine de l'Ain (FR) (Bellantuono et al., 2017)
40 ValuePark Schkopau (DE) (Bellantuono et al., 2017; Liwarska-Bizukojc et al., 2009)
60 Ecotech (UK) (Gibbs and Deutz, 2007)
61 Humber Industrial Symbiosis Project (UK) (Gibbs and Deutz, 2007)
62 Crewe Business Park (UK) (Bellantuono et al., 2017)
63 The Guigang Group/ The Guitang Group (CN) (ellantuono et al., 2017; Zhang et al., 2013; hu and Côté, 2004; Chertow and Ehrenfeld, 2012; Chertow, 2007; Mathews and Tan, 2011; Farel et al., 2016; Fang et al., 2007)
64 The Pingdingshan Coal Mining Group (CN) (Mathews and Tan, 2011)
65 The Lubei Group (CN) (Zhang et al., 2013; Fang et al., 2007; Mathews and Tan, 2011)
66 The Suzhou Industrial Park (SIP) (CN) (Yuan et al., 2010; Yu et al., 2015b; Mathews and Tan, 2011; Zhang et al., 2009; Fang et al., 2007)
67 Suzhou Hi-Tech Development Zone (CN) (Fang et al., 2007)
68 Yantai Development Zone (CN) (Fang et al., 2007)
69 Guiyang – Kaiyang (CN) (Fang et al., 2007)
70 Hai-Hua / Weifang Coastal Development Zone / Weifang Binhai Economic-Technological Development Area (BEDA) (CN) (Liu et al., 2015; Fang et al., 2007)
71 Tianjin Economic-Technological Development Area (TEDA) (CN) (Bellantuono et al., 2017; Zhang et al., 2013; Yu et al., 2015a; Yu et al., 2014b; Yu, 2014; Ehrenfeld, 2012; Fang et al., 2007; Geng et al., 2009; Shi et al., 2010; Tan, 2011; Geng et al., 2008; Farel et al., 2016)
72 Fuzhou Economic and Technological Development Area (FEDA) (CN) (Yu, 2014)
73 Xi'an High-Tech Zone (CN) (Yu, 2014)
74 Baotou National Ecological Industrial Demonstration Park (BNEIDP) (CN) (Fang et al., 2007; Zhang et al., 2009)
75 Huangxing (CN) (Zhang et al., 2013; Fang et al., 2007)
76 Shanghai Chemical Industry Park (SCIP) (CN) (Yune et al., 2016; Zhang et al., 2009)
77 Dalian Economic Development Zone (DEDZ) (CN) (Yu et al., 2015a; Fang et al., 2007; Geng et al., 2008)
78 Shenyang Economic and Technological Development Zone (SETDZ)(CN) (Ghisellini et al., 2016)
79 Dafeng EIP Project (CN) (Wang et al., 2010)
80 Nanhai EIP Project (CN) (Fang et al., 2007; Wang et al., 2010)
81 Lubei EIP Project (CN) (Wang et al., 2010)
82 Fushun (CN) (Fang et al., 2007)
83 Midong Chemical Industrial Park (MCIP) (CN) (Guo et al., 2016)
84 Rizhao Economic and Technology Development Area (REDA) (CN) (Yu et al., 2015c)
85 Xinjiang Shihezi EIP (CN) (Zhang et al., 2013)
86 Shanghai Wujing EIP (CN) (Zhang et al., 2013)
87 Qijiang Industrial Symbiosis Park (CN) (Sun et al., 2017)
88 Nanning Sugar Co (CN) (Bellantuono, et al., 2017)
89 EBARA Corporation (JP) (Bellantuono et al., 2017)
90 Kawasaki (JP) (Ehrenfeld, 2012; Tan, 2011; Farel et al., 2016)
91 Kitakyushu (JP) (Zhang et al., 2013)
92 Kokubu (JP) (Bellantuono et al., 2017)

41 Knapsack Chemical Park (DE) (Farel et al., 2016)
42 BASF Verbund (DE) (Farel et al., 2016)
43 Porto Marghera (IT) (Mannino et al., 2015)
44 Torino Enviornmental Park (IT) (Bellantuono et al., 2017)
45 Chamusca (PT) (Ferrao, 2010)
46 Lopez Soriano (ES) (Bellantuono et al., 2017)
47 The Landskrona Industrial Symbiosis (SE) (Park et al., 2008; Mouzakitis, 2009)
48 Norrkoping and Linkoping (SE) (Farel et al., 2016)
49 Vreten Park (SE) (Bellantuono et al., 2017)
50 Monthey (CH) (Farel et al., 2016)
51 Industrial Eco-System Project (NL) (Boons, 2002; Heeres et al., 2004)
52 Rietvelden/Vutter Sustainable Revitilisation Project (NL) (Heeres et al., 2004)
93 The Nanjangud Industrial Area (IN) (Bain, 2012)
94 Naroda (IN) (Bellantuono et al., 2017)
95 Ulsan EIP (KR) (Ehrenfeld, 2012; Park et al., 2008; Farel et al., 2016; Tan, 2011; Behera et al., 2012)
96 Daedok Technovalley Development Project (KR) (Oh et al., 2005)
97 Macheon Industrial Park (KR) (Kim, 2007)
98 Lin-Hai Industrial Park – China Steel Corp. (TW) (Li et al., 2015)
99 Da-Yuan Industrial Park – Cheng Loong Corp. (TW) (Li et al., 2015)
100 Lin-Yuan Industrial Park – Formosa Plastic Corp. (TW) (Li et al., 2015)
101 Northern Region Industrial Estate (TH) (Panyathanakun et al., 2013)
102 Kwinana Industrial Area (KIA) (AU) (Bellantuono et al., 2017; MacLachlan, 2013; Giurco et al., 2011; Ehrenfeld, 2012; Chertow, 2007; Farel et al., 2016; Tan, 2011; Ashton et al., 2017)
103 Gladstone Industrial Area (AU) (Chertow, 2007)
104 Synergy Industrial Park (AU) (Park et al., 2008)

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