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# A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems

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ABSTRACT

In the last few years Circular Economy (CE) is receiving increasing attention worldwide as a way to overcome the current production and consumption model based on continuous growth and increasing resource throughput. By promoting the adoption of closing-the-loop production patterns within an economic system CE aims to increase the efficiency of resource use, with special focus on urban and industrial waste, to achieve a better balance and harmony between economy, environment and society. This study provides an extensive review of the literature of last two decades, with the purpose of grasping the main CE features and perspectives: origins, basic principles, advantages and disadvantages, modelling and implementation of CE at the different levels (micro, meso and macro) worldwide.

Results evidence that CE origins are mainly rooted in ecological and environmental economics and industrial ecology. In China CE is promoted as a top-down national political objective while in other areas and countries as European Union, Japan and USA it is a tool to design bottom-up environmental and waste management policies. The ultimate goal of promoting CE is the decoupling of environmental pressure from economic growth. The implementation of CE worldwide still seems in the early stages, mainly focused on recycle rather than reuse. Important results have been achieved in some activity sectors (e.g. in waste management, where large waste recycling rates are achieved in selected developed countries). CE implies the adoption of cleaner production patterns at company level, an increase of producers and consumers responsibility and awareness, the use of renewable technologies and materials (wherever possible) as well as the adoption of suitable, clear and stable policies and tools. The lesson learned from successful experiences is that the transition towards CE comes from the involvement of all actors of the society and their capacity to link and create suitable collaboration and exchange patterns. Success stories also point out the need for an economic return on investment, in order to provide suitable motivation to companies and investors. In summary, the CE transition has just started. Moreover, the interdisciplinary framework underpinning CE offers good prospects for gradual improvement of the present production and consumption models, no longer adequate because of their environmental load and social inequity, a clear indicator of resource use inefficiency.



## 1. Introduction

Over the last decade growing attention has been paid worldwide to the new concept and development model of Circular Economy, CE, with the aim to provide a better alternative to the dominant economic development model, so called "take, make and dispose" (Ness, 2008). The negative effects caused by the latter are threatening the stability of the economies and the integrity of natural ecosystems that are essential for humanity's survival. (EC, 2014a,b; Lett, 2014; Mazzantini, 2014; Park and Chertow, 2014; Su et al. 2013; Geng et al., 2012; UNEP, 2013a; Waughray, 2013; Ellen Macarthur Foundation, 2012; Preston, 2012; Stiehl and Hirth, 2012; Feng and Yan, 2007; Yuan et al., 2006; Yap, 2005).

So far many different CE studies (case studies, reviews, scientific reports, etc.) have been published worldwide (Yap, 2005; Andersen,

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2007; Feng and Yan, 2007; Charonis, 2012; Ellen Mac Arthur Foundation, 2012; Preston, 2012; Su et al., 2013; Lett, 2014; Naustdalslid, 2014; Prendeville et al., 2014; Club of Rome, 2015; Resource, 2015). A large number of these studies concern the implementation of CE in China. This country seems strongly committed and attracted by CE because of the huge environmental, human health and social problems posed by its very rapid and continuous economic development pattern (Yap, 2005; Fang et al., 2007; Feng and Yan, 2007; Geng and Doberstein, 2008; Geng et al., 2012; Mathews and Tan, 2011; Mazzantini, 2013; Su et al., 2013; UNEP, 2013a). Circular economy is seen as a new business model expected to lead to a more sustainable development and a harmonious society (Feng and Yan, 2007; Geng and Doberstein, 2008; Ness, 2008; Mathews and Tan, 2011; Europesworld, 2014; Lett, 2014; Naustdalslid, 2014). Sustainable development requires balanced and simultaneous consideration of the economic, environmental, technological and social aspects of an investigated economy, sector, or individual industrial process as well as of the interaction among all these aspects (FAO, 2002; Ren et al., 2013). Circular economy contributes positively to reconcile all the elements, thanks to its underlying rationale, mainly rooted in environmental and political (Birat, 2015) as well as economic and business aspects (Ellen Macarthur Foundation, 2012). CE promotes a more appropriate and environmentally sound use of resources aimed at the implementation of a greener economy, characterized by a new business model and innovative employment opportunities (Ellen Mac Arthur Foundation, 2012; Stahel, 2014), as well as by improved wellbeing and evident impacts on equity within and among generations in terms of both resource use and access: "*A world in which poverty is endemic will always be prone to ecological and other catastrophes*" (World Commission on Environment and Development, 1987).

CE has most often been considered only as an approach to more appropriate waste management. Such very limited point of view may lead CE to fail, in that some recycling, reuse or recovery options may either be not appropriate in a given context while instead fitting other situations and, more than that, some conversion options based on green chemistry and biotechnology may end up being much more expensive and impacting than the conventional technology addressed, which calls for prevention more than treatment. All in all, the challenge ahead towards a preventative and regenerative eco-industrial development (Geng et al., 2014a) is not a "more of the same" approach, calling for increased implementation of "green" technologies, but instead requires a broader and much more comprehensive look at the design of radically alternative solutions, over the entire life cycle of any process as well as at the interaction between the process and the environment and the economy in which it is embedded, so that the regeneration is not only material or energy recovery but instead becomes an improvement of the entire living and economic model compared to previous business-as-usual economy and resource management. CE has the potential to understand and implement radically new patterns and help society reach increased sustainability and wellbeing at low or no material, energy and environmental costs.

Finally, it should not be disregarded that sustainability patterns (such as CE) not only require innovative concepts but also innovative actors. In fact, due to the complexity of the sustainable development vision, most often its implementation needs to be supported by innovation designers and intermediaries who provide services and designs towards appropriate radical changes in both practices, policies and decision making tools (Golinska et al., 2015; Küçüksayraç et al., 2015).

Our primary aim in this review is to summarize and evaluate the literature pertaining Chinese CE implementation experiences and compare them with the European and Japanese as well as other worldwide experiences, to grasp similarities and differences among these geographical areas. We also provide a brief theoretical overview of CE, its origins, its underlying or foreseen economic models and its relationship to steady state and degrowth patterns that until now have challenged the present models of economic development. Our final purpose in this regard is to understand to what extent CE could be a solution to the need for reducing the environmental impacts of business-as-usual economic systems.

This study is structured as follows: Section 2 (Materials and Methods) provides details about the method used for literature mining and key characteristics of the studies selected for this review. The same section also provides an outline of CE origins, principles and models, as well as its relation with steady state, growth and degrowth patterns. Section 3 (Results) summarizes the implementation of CE worldwide on the basis of the published experiences at micro (company or consumer level), meso (eco-industrial parks) and macro (nations, regions, provinces and cities) levels in production, consumption and waste sectors as well as decoupling achievements, in China, Europe, other OECD (Japan and USA) and BRICS (Brazil, Russia, India, China, South Africa) countries. Section 4 (Discussion) discusses the main results emerged from literature and suggests directions for future research. Finally section 5 (Conclusions) highlights the key findings of the study.

## 2. Material and methods

The selection of published studies was performed according to several integrated criteria: (1) chronological order (from 2004 to 2014), (2) topics of interest (circular economy origins, principles, implementation at different scales (micro, e.g. company or consumer level; meso, e.g. eco-industrial parks level; macro, e.g. city, province, region, nation), (3) comparison to present economic growth and alternative patterns (steady state economy and economic degrowth), (4) problems and challenges. The literature search was performed in all web of science[1] databases and Sciencedirect,[2] by means of keywords such as "circular economy" (758 papers), "circular economy and cleaner production" (64 papers), "circular economy and eco-industrial park" (85 papers), "circular economy and zero waste" (26 papers), "circular economy and decoupling" (11 papers), "circular economy and rebound effect" (2 papers), "circular economy and sustainability" (85 papers). Duplicate papers in more than one category were excluded, totalling 1031 papers. A first selection was made based on the content of abstracts, the representativeness of which was also weighed on the basis of the authors' names (by excluding papers with similar content) and geographical area. In so doing, 155 most representative articles were selected and grouped according to the different topics of interest for our review. Fig. 1 provides a snapshot of the different groups of topics, focusing first on two conceptual groups (CE Models and CE principles) and then on how these concepts are investigated across three main "scales" (micro: single processes; meso: eco-industrial parks; and macro: local, regional and national economies). The main conclusions of the reviewed studies are reported in the Results section. As it can be seen from Fig. 1, a large part of selected articles deals with case studies of CE's implementation at different scales while only a

[1] https://apps.webofknowledge.com/UA_GeneralSearch_input.do?product=UA&search_mode=GeneralSearch&SID=Q1Uq4F77i8P4U9Z1YsY&preferencesSaved=.

[2] http://www.sciencedirect.com/.

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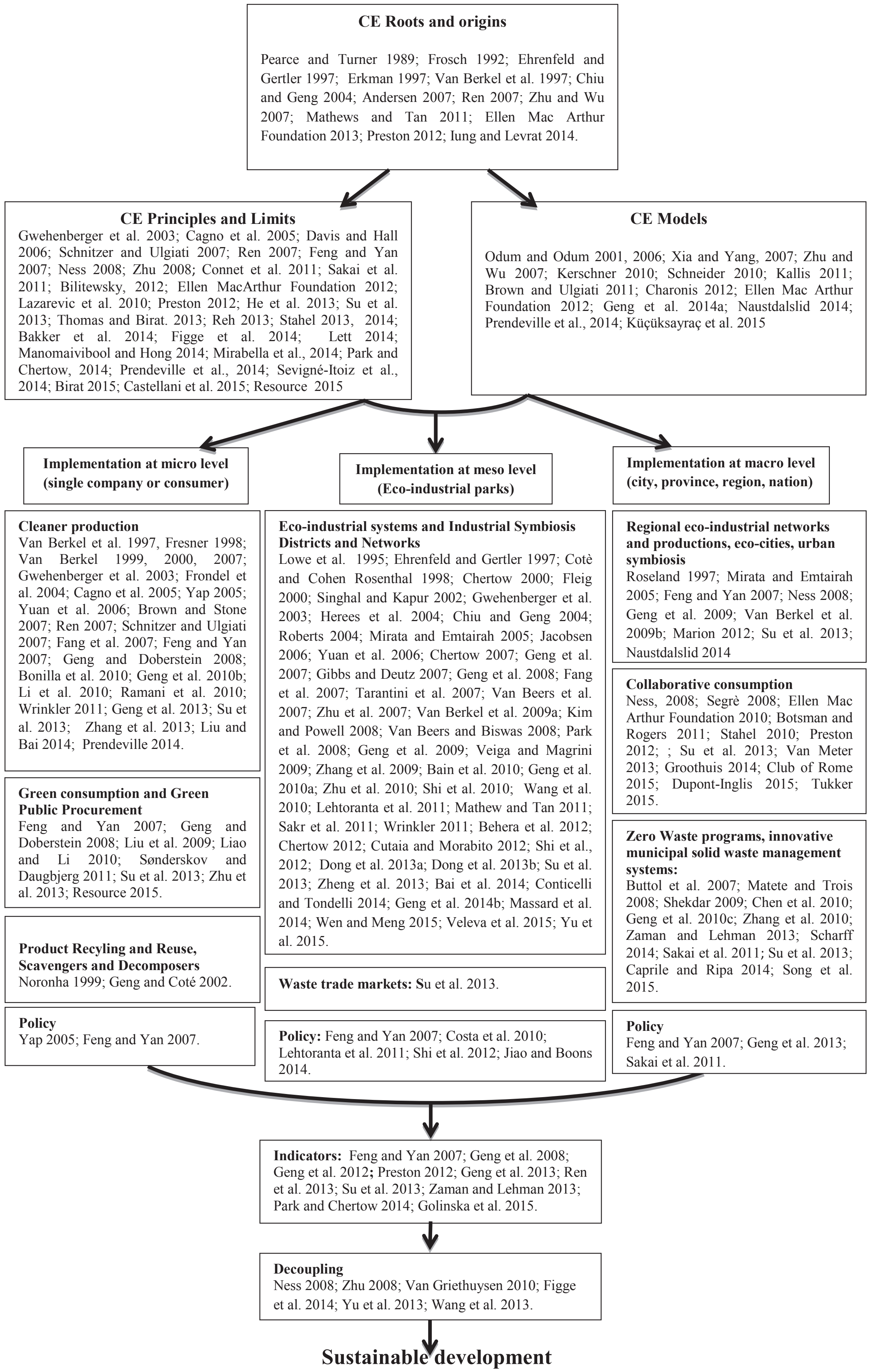


**Fig. 1.** Classification of reviewed studies according to the different subjects and categories converging to Circular Economy.

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few studies address the business model embedded in CE concepts and the need for decoupling resource use and economic growth. In a like manner, only a small number of published studies design or discuss CE indicators, therefore calling for additional research. Fig. 2 classifies the case studies on the basis of the investigated geographical proximity, with China (41 articles reviewed) showing the largest number of published articles about CE transition.

### 2.1. Origins of circular economy

The concept of circular economy traces back to different schools of thought. The environmental economists Pearce and Turner (1989) primarily introduced the concept of circular economic system building on previous studies of ecological economist Boulding (1966). Boulding's idea of economy as a circular system is seen as a prerequisite for the maintenance of the sustainability of human life on Earth (a closed system with practically no exchanges of matter with the outside environment). In their theoretical framework, Pearce and Turner (1989) explain the shift from the traditional open-ended economic system to the circular economic system as a consequence of the law of thermodynamics (Georgescu-Roegen, 1971) that dictate matter and energy degradation. According to these authors, three economic functions of the environment can be identified: provision of resources, life support system, sink for waste and emissions. Similar to other economic functions, these three basic functions should have a price. Most often, however, there is neither a price nor a market for environmental goods (such as air and water quality, public goods) even if they have a clear value or utility for individuals and societies. Diverse policy mixes, including regulations, economic instruments (e.g. environmental taxes) or voluntary measures aimed to fully internalize the externalities (e.g. producers responsibility) into the price of products, services or activities were designed to encourage a better use and conservation of resources, mitigation of environmental load as well as promotion of a transition to CE patterns (Andersen, 2007; Ren, 2007; Nuti, 2010; UNEP, 2015).

Roots of CE are also found in General Systems Theory (Von Bertanlaffy, 1950, 1968) and Industrial Ecology (Preston, 2012).

Beyond the Newtonian view of "organized simplicity", Von Bertalanffy (1950) proposed all organisms be considered as systems, the main characteristic being relationships among their components (László, 1972). In particular, the relationship between organizations and their environments can be seen as the main source of complexity and interdependence and often the whole has properties that cannot be known from analysis of the constituent elements in isolation (László, 1972), as the whole determines the behavior of the parts and not vice versa (Capra, 1995). As a consequence, the behavior of an economic agent or organization should be investigated within the systems of economic relationships of other agents in the economy (Delli Gatti and Gallegati, 2001). General Systems Theory (GST) therefore promotes holism, system thinking, complexity, organizational learning and human resource development (Capra, 1995; Odum, 1996; Swanson R.A., 2001; Jackson, 2003; Senge et al., 2010), all to be considered important premises of CE.

Industrial ecology, IE, emerged in opposition to the current conception that environmental impacts of industrial systems should be studied by keeping separate the source "industrial system" and the receptor of the impacts, "the environment". Industrial Ecology introduced a different perspective by analysing the industrial system and its environment as a joint ecosystem characterized by flows of material, energy and information as well as by provision of resources and services from the Biosphere (Erkman, 1997). Thus, IE consists of three pillars (Chiu and Geng, 2004): the first two are analytical and methodological, mainly aiming to grasp information on: "*how the industrial system works, how it is regulated, and its interaction with the biosphere*" (Erkman, 1997) and about its industrial metabolism (Ayres, 1989b), while the third one is proactive (Van Berkel et al., 1997), as IE can be used by companies to improve their performances or alternatively by policy makers for developing a roadmap to a more sustainable development (Graedel and Allenby, 1995; Chiu and Geng, 2004). At the basis of such improvement, in addition to a better conservation of virgin materials, a central role concerns appropriate waste management and its integration into the industrial production network as both material and energy source (Frosch, 1992). Industrial ecology promotes the transition from open to closed cycles of materials and energy thus leading to less wasteful industrial processes (Frosch, 1992; Erkman, 1997; Ehrenfeld and Gertler, 1997; Chiu and Geng, 2004; Andersen,

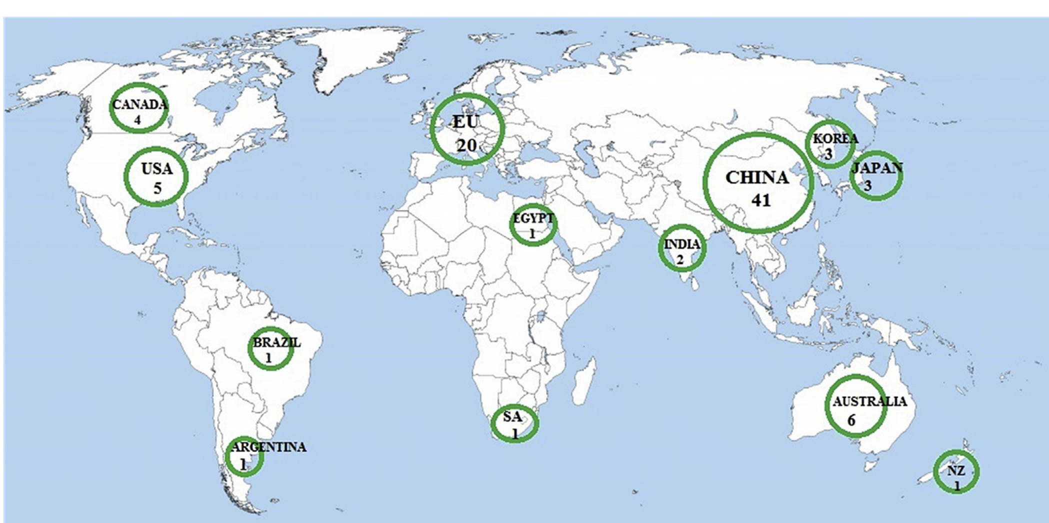


**Fig. 2.** Classification of reviewed case studies on the basis of the investigated geographical location. The diagram only refers to the articles selected for the present study, according to the sample described in the Introduction.

2007). The circular economy builds on IE's concepts for the analysis of industrial systems operation (industrial metabolism) and optimization (Iung and Levrat, 2014), scaling them up to an economy-wide system to establish a new model of economic development, production, distribution and recovery of products (Chiaroni and Chiesa, 2014). In CE, products and processes are redesigned to maximize the value of resources through the economy with the ambition to decouple economic growth and resource use (UTS, 2015).

It should be pointed out, however, that the research on CE implementation has been and still is mainly rooted on the IE idea of the analysis of benefits in terms of physical rather than monetary flows (Andersen, 2007; Mathews and Tan, 2011). It is important to mention that the benefits from recycling of materials tend to decrease until a cut-off point is reached where recycling could be environmentally or economically too expensive to provide a net benefit. In fact, CE cannot ensure 100 per cent recycling (Andersen, 2007), as also pointed out by Daly (1977) who suggested the impossibility for an economic system to be fully circular with products and energy turning back to raw materials forever, due to the entropy law. Zhu and Wu (2007) point out that CE should be embedded in a steady state economy framework. Focusing on China's economic dynamics, these authors support their claim based on the critical natural capital availability in China since the beginning of Chinese's industrial development. On the contrary, developed countries did not face natural resources restrictions during their initial stage of industrial development, and this is why neoclassical economics was the leading concept in these countries while it does no longer appear the be adequate for China and the World in the near future.

Finally, the Ellen Macarthur Foundation (2013) attributes to more recent theories such as regenerative design, performance economy, cradle to cradle, biomimicry and blue economy an important contribution for the further refinement and development of the concept of circular economy.

### 2.2. Principles and implementation of circular economy worldwide

Circular economy mainly emerges in the literature through three main "actions", i.e. the so called 3R's Principles: Reduction, Reuse and Recycle (Feng and Yan, 2007; Ren, 2007; Sakai et al., 2011; Preston, 2012; Reh, 2013; Su et al., 2013; Lett, 2014).

The Chinese CE promotion Laws define CE "*a generic term for the reducing, reusing and recycling activities conducted in the process of production, circulation and consumption*" (CCICED, 2008). This definition does not seem, however, consistent with China's practice of steady growth of production and consumption patterns within a national dimension. On the contrary, other countries such as Europe, Japan, USA, Korea and Vietnam seems to identify CE and its founding principles (3R) in more sectorial initiatives mainly related to waste management policies (see Sakai et al., 2011 for details). Their broader goal is the achievement of synergistic effects with national strategies towards landfill prevention, procurement of resources, reduction of GHG emissions and management of hazardous waste following circulation of materials (Sakai et al., 2011; Resource, 2015). On the other hand, because of trade-offs among policies, an integrated political approach (that could be built around CE) is required for addressing persistent, systemic environmental challenges (European Environment Agency, 2010, 2015).

Japan implemented CE since 1991 with the Law for Effective Utilization of Recyclables (IES, 2015) and, later on, the Japanese CE initiative (He et al., 2013; UNEP, 2013a). In Europe, CE primarily emerged in Germany in the early 1976 with the Waste Disposal Act, while at European Community level CE was promoted much later, by means of the Waste Directive 2008/98/EC (He et al., 2013) and more specifically with the Circular Economy Package (EC, 2014a,b).[3] United States seem still lacking of a relevant federal policy CE initiative, in spite of past regulations as the Resource Conservation and Recovery Act of 1976 (EPA, 2013) and the Pollution Prevention Act of 1990 (EPA, 2014; He et al., 2013). Most US States have also adopted since 1980s a solid waste management hierarchy placing reduction and reuse at the top of the hierarchy (Park and Chertow, 2014). Schemes for used oil, selective landfill bans on specific materials, minimum content laws, labelling laws, beverage containers recycling, and green labelling were also implemented (Davis and Hall, 2006; He et al., 2013). Other Asian countries as Korea and Vietnam have promoted important 3R policies. Korea issued the Waste Management Act (2007) and the Act on Promotion of Resources Saving and Recycling (2008) as the basis for material reuse, for a fee system for waste treatment, regulations on the use of one-way packaging and goods, a Food Waste Reduction Policy (EC, 2014c) and the Extended Producers Responsibility, EPR (Sakai et al., 2011). Vietnam has amended in 2005 the Environmental Protection Law and the National Strategy on Integrated Solid Waste Management with targets to 2025 and 2050 (Sakai et al., 2011), while Australia and New Zealand are now evaluating and accelerating an action agenda for the CE (Jewell, 2015; Sustainable Business Network, 2015).

The Reduction principle aims to minimize the input of primary energy, raw materials and waste through the improvement of efficiency in production (so called eco-efficiency) and consumption processes e.g. introducing better technologies, or more compact and lightweight products, simplified packaging, more efficient household appliances, a simpler lifestyle, etc. (Feng and Yan, 2007; Su et al., 2013). Eco-efficiency is mainly a business concept, focusing on the economic and environmental dimension of sustainability and disregarding the social dimension. On the contrary, the "resource efficiency" concept implies resource reduction and increasing economic and social well-being at the same time (Ness, 2008). On the production side, Figge et al. (2014) point out two basic ways in which companies can increase their eco-efficiency in production processes, i.e. keep or increase the value of products whilst also reducing their environmental impacts. This can be achieved by using fewer resources per unit of value produced and by replacing more harmful substances in favour of less harmful ones per unit of value produced.

The so-called Zero Emission Strategy (Tan et al., 2005; Mair and Marti, 2006; Jenkins, 2006; Schnitzer and Ulgiati, 2007; Figge et al., 2014) pursues the maximization of the value of goods coupled to zero (or decreased) environmental impacts.

The Reuse principle refers to "*any operation by which products or components that are not waste are used again for the same purpose for which they were conceived*" (EU, 2008). The reuse of products is very appealing in terms of environmental benefits as it requires fewer resources, less energy, and less labor, compared with the manufacture of new products from virgin materials (Castellani et al., 2015; WRAP, 2011) or even recycling or disposal. Castellani et al. (2015) showed that reuse of products avoids the emission of noxious substances as well as many other environmental impacts in the case of different items (clothes, books, furniture, glass, sideboard), by means of an LCA approach. The diffusion of reuse involves an increase of consumer demand for reused and

[3] The new version of the Package under study of the new European Commission compared to the original package should be more concerned on supporting CE as a new business strategy other than a waste management strategy, with the purpose of gaining more political success and aligning EU at the forefront of worldwide circular economy development (Resource, 2015).

remanufactured products, the design of durable products for multiple cycles of use as well as incentives for companies to favour take-back of products and the marketing of remanufactured products (Prendeville et al., 2014).

The Extended Producers Responsibility (EPR, Lindhqvist and Lidgren, 1990) was firstly proposed in Germany's legislation on packaging (1992), then in the Waste Directive of European Union (2008) and in the Korea Act on Resource Recycling of Electrical and Electronic Equipment and Vehicles (2008). It is an economic tool and a modern version of the polluter pay principle, that aims to enhance the circularity of products and materials (e.g. their reuse and recycling) acting on the producers side (Mancini, 2011; Bilitewsky, 2012; Sakai et al., 2011; Manomaivibool and Hong, 2014). This principle states that the costs of disposal and recovery must be transferred to the producers who will therefore have a strong incentive to reuse, recycle or dispose of waste materials. Additionally, Connett et al. (2011) argues that if a product cannot be reused, recycled or composted, then the industry should not produce such a product and consumers should not buy it. This last issue highlights the need for a shared responsibility among all stakeholders, including consumers, to achieve more ambitious results in terms of collection of waste to be reused or recycled. For example, contrary to European systems (as in the WEEE directive), the Japanese system, for electrical equipment, includes an enforced consumer's responsibility for returning products for recycling (Resource, 2015).

The Recycle principle refers to "*any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations*" (EU, 2008). Recycling of waste offers the opportunity to benefit from still usable resources and reduce the quantity of waste that need to be treated and or/disposed of, thus also decreasing the related environmental impact (Cagno et al., 2005; Zhu, 2008; Lazarevic et al., 2012, Birat, 2015). However, if a company or the society is able to recycle all its waste, it may not be interested in reducing the amount of waste (Gwehenberger et al., 2003).

Although Circular Economy is often identified with the recycling principle, it must be underlined that this may be the least sustainable solution compared to the other CE's principles (Reduction and Reuse) in terms of resource efficiency and profitability (Stahel, 2013, 2014). It is limited by nature (entropy law), material complexity and abuse (Stahel, 2013). Some waste materials are recyclable until a certain point or even unrecyclable. For example, cellulose fibers may be recycled 4–6 times, contrary to metals which are "unlimited manifold recycling" (Reh, 2013). Low levels of recycling are achieved for Rare Earth metals as it is hard to develop economies of scale (UNEP, 2013b; Prendeville et al., 2014) while some types of plastic waste are not recyclable due to the presence of contaminants as ink and metals (Prendeville et al., 2014). In this regard, some authors discuss the risks associated to the recycling of materials (Bilitewsky, 2012) and mixed materials (Stahel, 2013) and highlight the need for developing at global level an agreed-upon risk assessment for existing and new developed chemicals and products, excluding additional animal testing (Bilitewsky, 2012). Finally reuse, repair and remanufacturing have a local or regional dimension and are able to avoid or reduce packaging, transport costs and transaction costs through the maintenance of ownership, while recycling has a global dimension and works following the "*principles of industrial production, such as economies of scale, specialization and employing the cheapest labor*" (Stahel, 2013). These three principles, with some modifications, are also included in the waste hierarchy of European Waste directive 2008/98/EC (EU, 2008) since 1989 as well as in United States solid waste Agenda (Thomas and Birat, 2013; Bakker et al., 2014; Park and Chertow, 2014).

The 3R principles can be integrated by three additional principles developed within the Ellen Macarthur Foundation Report (2012). The first one, *appropriate design*, stresses on the importance of design stage in finding solutions to avoid waste discharge in landfills: "*Products are designed for a cycle of disassembly and reuse*". The second one introduces a *reclassification* of the materials into "technical" and "nutrients". The technical materials (as metals and plastics) are designed to be reused at the end of the life cycle while the nutrients or biological nutrients, that in general are non-toxic, "*can return safely to the biosphere or in a cascade of consecutive uses*". The third additional principle, "*renewability*", places renewable energy as the main energy source for circular economy, to reduce fossil energy dependence and enhance the adaptability (resilience) of the economic system towards oil negative effects (increase in oil prices, lack of supply, etc.).

Table 1 summarizes the main limits and challenges to CE development, with reference to the above mentioned CE principles.

### 2.3. Circular economy, a new business and development model

Circular economy is defined by Charonis (2012), in line with Ellen Macarthur Foundation vision (2012), as a system that is designed to be restorative and regenerative. This author considers CE as an "*alternative growth discourse*" and not an "*alternative to growth discourse*" (2012). In his study, Charonis also compared circular economy with degrowth (Schneider et al., 2010; Martinez-Alier, 2012; Demaria et al., 2013) and steady state (Daly, 2007) addressing key characteristics, similarities and differences. In particular, Charonis (2012) makes reference to the degrowth concept as proposed by Kallis (2011): "*a socially sustainable and equitable reduction (and stabilization) in a society's throughput where throughput denotes the materials and energy a society extracts, processes, transports and distributes, to consume and return back to the environment as waste*", as well as to the steady state economy description by Czech and Daly (2004): "*the one that undergoes neither growth nor recession, resulting in a constant rate of throughput*".

Circular economy, degrowth and steady state share a number of important principles and goals, in spite of the existence of non-negligible differences. These three frameworks share the request and aim for human society to operate within the ecological limits of our Planet contrary to what envisaged by business-as-usual, growth-oriented models. However, while the theoretical framework of degrowth and steady state has been highly developed, circular economy concepts are very recent and still require further refinement concerning the way they may affect population carrying capacity, employment, international trade, role of institutions, etc.

Most studies aimed at explaining the theoretical background of CE make first a distinction among neoclassical economics, steady state economics and circular economy. The mainstream economics (neoclassical) assumes a linear economy pattern and has been the theoretical foundation for economic development until recent. Neoclassical economics mainly focuses on efficient allocation of resources in the market and fails to provide analytical tools that take into account the limited and exhaustible nature of natural resources. The approach of steady-state economy seems to fill this gap, by trying to keep the economic activities within the constraints imposed by nature (same rate of resource consumption and resource use), while circular economy additionally suggests an economic model regulated according to the laws of the nature (networks of interacting components, exchange of material and energy flows, recycling patterns and, environmental mimicry).

CE operates around the neoclassical economy framework even if threats some of its key pillars; e.g. CE proposes a rethinking of

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**Table 1**
Main limits and challenges of transition to Circular Economy.

| Principles of CE | Limits or challenges | Reference |
|---|---|---|
| Design | Optimal product life scenario. | Bakker et al., 2014 |
| | Design for disassembly, reuse, recycling. | Wrinkler 2011; Ellen MacArthur Foundation 2012; Bakker et al., 2014 |
| | Design for durable products. | Bakker et al., 2014 |
| | Design for new business model of consumption. | Ramani et al., 2010; Bakker et al., 2014 |
| Reduction | Overcome rebound effect of eco-efficiency and eco-sufficiency strategies. | Figge et al., 2014 |
| Reuse | Technical maximum reusability of materials. | Park and Chertow 2014 |
| | Increase of consumer demand towards reuse of products and materials. | Prendeville et al., 2014 |
| | Development of take-back mechanisms from the companies. | Bilitewsky 2012 |
| | Ensuring repair and secondary use of products after their original use. | Bilitewsky 2012 |
| | Taxation based on non-renewable energy rather than labor and renewable energies | Stahel, 2010, 2013 |
| Recycle | Reinforcement of local markets of recycled materials. | Sevignè-Itoiz et al., 2014 |
| | Risks of global trade of materials. Plastic waste: unfeasibility due to the mixing of contaminants. | Bilitewsky 2012; Reh 2013 |
| | Cellulose: feasible until 4–6 times. | Reh 2013 |
| | Rare metals (lack of economies of scale). | UNEP 2013b; Prendeville et al., 2014 |
| | Food Waste: further transformations before being used requires high costs in research and development. | Mirabella et al., 2014 |
| | Appropriate LCA modelling for reuse and recycling. | Thomas and Birat 2013; Birat 2015 |
| Reclassification of materials into: Technical | Reuse after the first cycle | Ellen Macarthur Foundation 2012 |
| Nutrients | Safe return to the Biosphere or in a cascade of subsequent uses (biorefinery). | Ellen Macarthur Foundation 2012 |
| Renewable Energy | Increase their share compared to the share of fossil fuels. | Ellen Macarthur Foundation 2012 Preston 2012 |

ownership (as also degrowth and steady state do) in favour of models where products are leased to consumers, who become only users of a service. With regards to degrowth and steady state, Charonis (2012) also highlighted similarities in policy proposals e.g. employment, basic income, waste reduction, measures of progress, governance; he recognizes the complementarity between each other framework towards a possible alternative to the present economic growth model.

A comparison between steady state economics and circular economy theory was provided by Xia and Yang (2007). In their study, these authors discussed the lack of a suitable tool and theoretical framework in the mainstream economy for threating environmental and ecological problems. Furthermore, Xia and Yang (2007) also presented the fundamentals of steady state economics as "*steady-state economy represents the balance between two systems: material wealth system and human system, which cannot keep self-constant. Only when these two systems are kept at a low flow rate, a sustainable steady state may be achieved. As for the population system, a low flow rate means a low rate of birth and death, i.e. high life expectancy; as for wealth system, it means better commodity durability and less time spent on production as well as more leisure time*". The authors also pointed out that both steady-state and CE approaches share the principles of justice in resources use within and among generations implicit in the notion of sustainable development of the well-known Bruntland Commission Report "Our Common Future" (World Commission on Environment and Development, 1987). Moreover, steady state interprets the environmental problem from the point of view of matter and energy constraints imposed by the laws of thermodynamics, and advocates that economics should change its focus from the traditional issue of production and consumption to the problem of efficient circulation of biophysical resources, energy in particular.

A future steady state economy *"with a relatively stable, mildly fluctuating level of consumption"*, preceded by a transitory degrowth where economy operates within the Earth's ecological limits, is very appealing to the degrowth proponents as confirmed by the final declaration of the First International Degrowth Conference 2008. A degrowth pattern is looked at as a voluntary process, a planned and equitable transition to a state of lower production and consumption (Kallis, 2011; Schneider et al., 2010). It is unlikely to be imposed externally as a policy imperative (Schneider et al., 2010) even if it is claimed as an urgent need due to looming ecological limits including peak oil and gas (Davey, 2008). At the same time steady state or quasi steady state (Daly, 2007) could be challenged to deal with the continuous growth rate of population and by limited resources throughput at the global scale where many developing countries could growth and reduce poverty (Prendeville et al., 2014).

An interesting point of view is shown by Odum and Odum (2001, 2006). Based on Lotka (1922)'s maximum power principle, von Bertalanffy (1950, 1968)'s General Systems Theory and Holling (1986)'s studies on resilience and oscillating systems, these authors advocate that general systems principles of resource quality and availability force all kinds of organisms to "*program orderly descent and decession that is followed later by growth and succession again*" and claim that such a pulsing pattern is found "*in biochemical reactions, weather systems, seas, geological processes, ecosystems, relationships of stars, and appears to apply to human economies as well*". In particular, they identify four main stages of the pulsing cycle, namely (1) growth on abundant resources, with population and assets increase, low-efficiency and high-competition; (2) climax and steady-state, when the system reaches the maximum size allowed by the available resources and increases efficiency in order to take maximum advantage from them; (3) descent, with less resources available, population decrease, more recycling patterns and much higher efficiency; (4) low-energy restoration, with no-growth, consumption smaller than accumulation, and storage of resources for a new cycle ahead (Fig. 3). Within such vision, growth, steady state and degrowth appear as different stages of the same pulsing cycle, an unavoidable pattern of a system development, constrained by resource availability. The same authors claim that "*it appears to be a general principle that pulsing systems prevail in the long run…perhaps because they generate more productivity, empower, and performance than steady states or those that bloom and bust*" (Odum and Odum, 2006).

The pulsing paradigm may help achieve a better understanding of the potential role of CE within an economic dynamics. To some extent, it would be partially misleading to consider CE as a

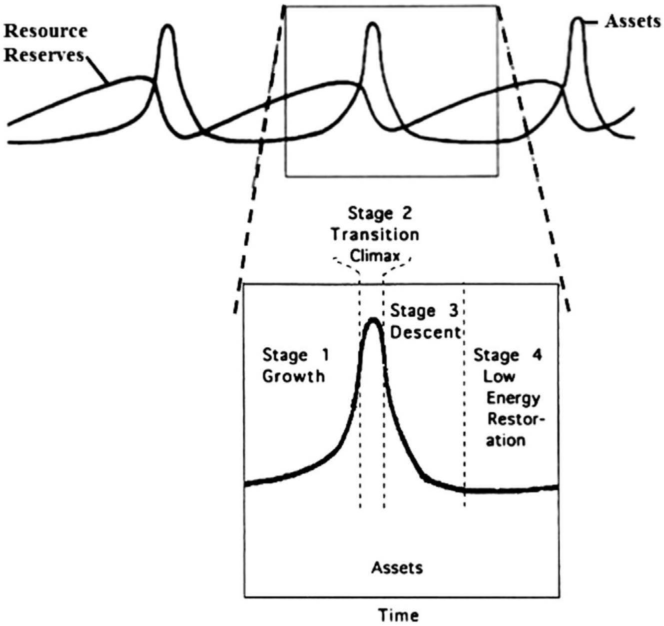


**Fig. 3.** The pulsing paradigm according to Odum and Odum (2001, 2006). In a pulsing dynamics, the first stage (growth) is characterized by high net yields, low efficiency and increasing load on environment; in the transition, steady-state phase, a declining growth rate is accompanied by low net yields, increasing efficiency, decreasing environmental loads; during degrowth, no net yields are achieved, efficiency reaches its maximum possible value to get the most out of less resources available, environmental loads keep decreasing due to less resource use. Finally, a phase of resource restoration occurs, for a new cycle ahead. CE contributes to transition and degrowth phases, while is not requested in growth and restoration stages.

new economic model similar to growth, degrowth and steady state, with focus placed on the trend of economy's size and performance. More than a trend-based model, CE may rather be considered a way to design an economic pattern aimed at increased efficiency of production (and consumption), by means of appropriate use, reuse and exchange of resources, and do more with less. In order to do so, production and consumption systems need to be structured in such a way that their component processes are capable to benefit from resource exchange and interaction among components. As a consequence, according to Odum and Odum's pulsing paradigm, focus should be placed on the potential contribution of the CE framework to the different stages of the economic and societal dynamics. Within a pulsing paradigm framework, efficiency is unimportant in the growth phase (think of the low efficiency, around 3–4%, of the Watt's steam engine coal-powering the UK industrial revolution (Ayres, 1989a,b), while it becomes useful to extend the duration of the steady-state phase, and crucial to allow a smooth descent in the perhaps unavoidable (although uncertain in time) degrowth phase.

## 3. Results

Circular Economy in China and worldwide seem to follow very different patterns. CE in China is a direct outcome of the national political strategy (top down approach), and its implementation is structured following both a horizontal and a vertical approach (Feng and Yan, 2007). Chinese national governmental policy aims to transform not only the industry but also the socioeconomic organization of the society at all levels (Naustdalslid, 2014). The top down approach of the Chinese national strategy is also reflected on the instruments used, that are mainly of "command and control" rather than market based (Friends of Europe, 2014) as in the European, Japanese or American policies (EU, 2013; UNEP, 2013a; EPA, 2015).

On the contrary, the transition towards CE in Europe mainly seems to be occurring as a bottom up approach, e.g. from the initiatives of environmental organizations, civil society, NGOs, etc. All these economic actors call for greener products and adequate legislation try to involve both private companies and public authorities in a virtuous cycle (Brown and Stone, 2007; Naustdalslid, 2014). In Japan a comprehensive and close collaboration among the civil society, the public sector and manufacturers characterize the CE transition (EC, 2014c; IES, 2015).

The vertical approach in China implies the shift of CE from the low level of analysis – micro – (company or single consumer level) to the higher hierarchical levels – meso – (e.g. eco-industrial parks) and macro (cities, provinces and regions) while the horizontal dimension implies a link between "*industries, urban infrastructures, cultural environment, and the social consumption system*" (Feng and Yan, 2007). Several Chinese studies analyse CE implementation following both horizontal and vertical approach (Yuan et al., 2006; Feng and Yan, 2007; Ren, 2007; Geng and Doberstein, 2008; Su et al., 2013) while the literature of other countries presents case studies of application of CE at one single level only, most often the meso level.

### 3.1. Circular economy at micro level

#### 3.1.1. CE implementation in production sectors: the emergence of ecodesign and cleaner production

The adoption of a circular economy program entails that a company carries out different strategies to improve the circularity of its production system and also cooperates with other companies over the supply chain for the achievement of a more effective circular pattern (Wrinkler, 2011).

Within company's production processes, eco-design or green design (Wrinkler, 2011) and design for environment (DFE) (Van Berkel et al., 1997; Ramani et al., 2010) as well as cleaner production (CP) are the main strategies, to be considered as preparatory towards CE. Design for environment and cleaner production are strictly in relation among each other. Actually, cleaner production includes three interrelated practices as pollution prevention (PP), toxic use reduction (TUR) and design for environment (DFE) (Van Berkel et al., 1997). Both DFE and eco-design "*blend environmental aspects into product design and development at product conception to enhance environmental performance throughout its lifecycle*". The design stage is relevant in that the relative sustainability of the product mainly depends on the choices made in the early design stage (Ramani et al., 2010), in order to avoid that the reduction of some impacts could translate into an increase of other types of impacts (e.g. the abatement of toxic substances might increase energy use which could in turn cause a negative impact on environment) (Prendeville et al., 2014). Moreover issues regarding "*disassembly, disposability without negative environmental impacts, ease of distribution and return, durability, reliability and customer success*" should also be included as relevant to CE (Sherwin and Evans, 2000; Wrinkler, 2011; Prendeville et al., 2014). Finally, ecodesign renders more environmentally friendly products and processes while at the same time keeps high quality standards and product's performances (Van Berkel et al., 1997; Graedel and Allenby, 2003; Ramani et al., 2010).

For energy using products the European Union adopted in 2005 an eco-design directive to provide a coherent and integrated framework for mandatory eco-design minimum requirements applied to energy using products (EC, 2012a). The first results of this Directive suggest its effectiveness in improving energy efficiency of some products (EC, 2012b). In China, a survey by Yu et al.

(2008) found a low applicability of eco-design in the electric and electronic product sector, while Fang et al. (2007) point out a wider application of principles of industrial ecology to design for environment in the subsidiaries of multinational corporations such as Motorola, BASF, Mitsubishi and Lucent Technologies, as compared to the companies within the domestic industrial system.

Globally, cleaner production is considered an essential strategy towards CE (Bilitewsky, 2012) and sustainable development (Van Berkel, 2000; Brown and Stone, 2007) in that CP introduces cleaner products, processes and services with the aim to reduce waste and emissions flows as well as to prevent the use of non-renewable and harmful input flows (Van Berkel et al., 1997; Van Berkel, 2007; EC, 1997; Frondel et al., 2004; Gwehenberger et al., 2003; UNEP, 2013a). In some cases CP is the first important strategy towards the achievement of CE goals (Van Berkel, 1999; Li et al., 2010). Brown and Stone (2007) state that the introduction of cleaner production provides fuels for a change in the way the relationship between business and the environment is perceived. In detail, CP relies on the *continuous* application of *an integrated, preventive* environmental strategy towards *processes, products and services* in order to increase overall economic efficiency and reduce damage and risks for humans and the environment (Van Berkel et al., 1997; Van Berkel, 2000; Fresner, 1998; Li et al., 2010; UNEP, 1990; Brown and Stone, 2007; UNIDO, 2013).

Moreover, the efficiency and effectiveness of CP strategies depends on the institutional framework where they are introduced (Van Berkel, 1999; Geng et al., 2010b; Zhang et al. 2013; Liu and Bai, 2014) and on the capacity and farsightedness of decision makers to develop and implement proactive, integrated policies and strategies stimulating societies to manage all resources in more sustainable ways (Van Berkel, 1999; Schnitzer and Ulgiati, 2007; Bonilla et al., 2010).

Cleaner Production was more extensively promoted and adopted in China compared to other methods for environmental management, in particular after the “Cleaner Production Promotion Law” in 2002 (Geng et al. 2010b, 2012 Su et al. 2013). This law, defined by Yap (2005) as “*concise, unambiguous and comprehensive in scope*”, has been one of the policy responses to the huge environmental problems generated by the fast Chinese economic development. Actually, cleaner production practices formally started more than ten years before the promulgation of “CP promotion law” of 2002 with the creation of the China National Cleaner Production Centre. Li et al. (2010) report in their study that 5000 industries have introduced cleaner production in China and that important improvements in energy conservation have been achieved at national level in Chinese process industries. Geng et al. (2013) evidence that large financial resources are invested in CE pilot projects involving the application of clean production techniques in specific sectors. As the number of enterprises in China is very high, in the order of 40 million, strong efforts are needed towards the removal of existing barriers to CP implementation for a higher CE diffusion (Yap, 2005; Geng et al. 2010b; Zhang et al. 2013).

### 3.1.2. *CE in the consumption sector: consumers' responsibility and green public procurement*

The promotion of consumers responsibility is crucial for enhancing the purchase and use of more sustainable products and services (Feng and Yan, 2007; Geng and Doberstein, 2008; Su et al., 2013).

Functional instruments for green consumers are specific information and labelling systems covering food, non-food products as well as services. The labelling systems are sharply developing across all continents (EPA, 1998): in Europe (EC, 2013), Asia (Liu et al., 2009; Liao and Li, 2010), Northern and Southern Americas (UNEP, 2011) and Australia. Governmental involvement in labelling schemes is an important factor for increasing confidence of consumers towards these instruments (Sønderskov and Daugbjerg, 2011). In European Union, the EU Ecolabel, from its launch in 1992, has awarded 1300 licenses on non-food products and services and today it can be found on about 17,000 products (EC, 2013). Products identified by an Eco-label should satisfy strict environmental criteria established by a panel of experts, consumer organizations and industry on the basis of the environmental impacts of the product in the whole life cycle. Green consumption in public sector is another important policy tool, stimulating the uptake of more environmentally friendly products and services. It can be introduced by setting and including “green” requirements before awarding public contracts (EC, 2010). This tool is as much as important for its contribution if we think that e.g. in EU27 public procurement accounted for about 19.9% of EU Gross Domestic Product in 2009 (EU, 2012). In China the public procurement expenditure is also relevant (Zhu et al., 2013). GPP schemes are also implemented in Japan, Taiwan, Korea, Malaysia and USA (Resource, 2015). A recent survey in EU27 on ten product/service groups showed that the development of green public procurement, GPP, is encouraging even if not yet satisfactory (EU, 2012). Different institutional hurdles, some of which country specific and more commonly across countries, prevent further development of GPP worldwide (UNEP, 2013c). The latter would require a coherent international framework of agreed and recognized principles and assessment systems of GPP's sustainability including a set of indicators to monitor and evaluate GPP activities by policy makers, purchasers and suppliers (UNEP, 2013c).

### 3.1.3. *CE in waste management: recovery of resources and environmental impact prevention*

Waste management has been considered in the past simply a way to get rid of the waste materials by landfilling or incinerating. This is still the dominant disposal pattern worldwide, in so generating a huge loss of valuable resources and very heavy environmental impacts. Recently, a new way to look at waste is emerging, that recognizes waste management as a recovery of resources and environmental impact prevention. In so doing, waste management becomes an important sub-sector of circular economy, with the emergence of new typologies of operators and processes, among which the so-called “scavengers” and “decomposers”, referring to companies capable to extract resources out of waste by applying innovative recovery technologies. It is worth noting that in the natural world “scavengers” and “decomposers” are fundamental organisms in each ecosystem and its food chain. They contribute to keep the community clean by processing dead organic matter and nurture plants with essential substances.

Scavengers collect the waste resources on site within companies or in other points of the disposal chain and redistribute them into the system to companies that can reuse or recycle such materials making their work easier. After the collection of waste materials, some of the scavengers perform dismantling, sorting, and transport to the decomposers in a form that is readily accessible for them to process. The decomposers in turn transform or recycle waste resources into new materials or as fractions of the same input flows for which they were initially designed (Noronha, 1999; Geng and Coté, 2002). Scavengers and decomposers can be further classified as specialist or generalist ones, according to their specialization to deal with only one type or more types of materials. The stability of a company relies on the availability of different materials for its activity and more than one scavenger or decomposer company (Geng and Coté, 2002).

### 3.2. Circular economy at meso level

The CE actions within this level only refer to the production side involving the development of eco-industrial parks, industrial symbiosis districts and networks, as well as other related productive networks denominations (Yuan et al., 2006; Chertow, 2012, 2000; Su et al., 2013). In these industrial systems, industries that traditionally work as separate entities, become engaged in complex interplays of resource exchange (material, water, energy and by-products), so called "industrial symbiosis", with the purpose of achieving economic and environmental benefits (Lowe et al., 1995; Chertow, 2000). "*The essence of industrial symbiosis is taking full advantage of by-product utilization, while reducing residual products or treating them effectively. The term is usually applied to a network of independent companies that exchange by-products and possibly share other common resources*" (Zhu et al., 2007).

The industrial symbiosis has traditionally been a research field within industrial ecology. While industrial ecology focuses at all levels of analysis (facility level, inter-firm level, regional and global level), the industrial symbiosis refers at inter-firm level because it involves physical exchanges among several organizations (Chertow, 2000) that do not necessarily take place within the "*strict boundaries of a "park,"*". (Chertow, 2000). As the distance among participant industries increases energy demand, this implies that Eco-industrial Parks are planned where a suitable mix of production units is able to minimize the waste and emissions of the whole facility (Gwehenberger et al., 2003).

The international experiences of industrial symbiosis can be mainly traced back to both top down (Eco-Industrial Parks – EIP -, e.g. in US, Canada and Asia) and bottom up (industrial symbiosis districts or industrial ecosystem as Kalundborg) strategies, on the basis of the fact that the former are the result of a preventive planning and design while the latter derive from spontaneous agreements among the participant companies (Cutaia and Morabito, 2012).

Besides China, dealt with in the next section with more details, several EIPs cases can be identified worldwide (Sakr et al., 2011), in USA (Herees et al., 2004; Gibbs and Deutz, 2007; Chertow, 2007; Veleva et al., 2015), Canada (Cotè and Cohen-Rosenthal, 1998; Fleig, 2000), India (Singhal and Kapur, 2002; Bain et al., 2010), Korea (Kim and Powell, 2008; Behera et al., 2012), Japan (Van Berkel et al., 2009a), Australia (Roberts, 2004; Van Beers et al., 2007; Van Beers and Biswas, 2008), Brazil (Veiga and Magrini, 2009), Egypt (Sakr et al., 2011), thanks to a growing body of scientific literature (Bai et al., 2014). The EIP of Kalundborg (Denmark) is one of the most analysed examples in the international literature (Ehrenfeld and Gertler, 1997; Chertow, 2000, 2007; Jacobsen, 2006; Van Berkel et al., 2009a; Mathews and Tan, 2011) even if there are many other cases of EIPs in European countries (as in UK, Netherlands, Finland, Germany, Austria, Italy etc.). Some of them are in operation, others are planned or in pilot phases (Tarantini et al., 2007; Lehtoranta et al., 2011; Sakr et al., 2011; Conticelli and Tondelli, 2014; Massard et al., 2014). The Kalundborg industrial complex gradually shifted towards an EIP structure as an example of a bottom up approach of industrial symbiosis. It originated from the idea of a few managers, in the late '60s, who discovered the opportunity of obtaining economic benefits from by-products exchanges (Heeres et al., 2004). Over time, both the extent and quality of symbiosis links among five co-located companies and the local municipality evolved, from low value to high value by-products (Chertow, 2000; Jacobsen, 2006; Mathews and Tan, 2011), under the aim of firms to achieve an economically profitable use of their by-products and minimize the costs of abidance to new and more rigorous environmental regulations (Ehrenfeld and Gertler, 1997; Chertow, 2007). However, the participants industries in Kalundborg recognized the environmental effects of their activities after a decade from its foundation (in the '80s) and the international awareness of the achieved results only emerged in the '90 s at the Conference for Sustainable Development of Rio de Janeiro (Chertow, 2000, 2007). Similar results are reported for a case in Styria (Austria) where the participant companies were found unaware of the additional environmental benefits (Schwarz and Steininger, 1995, 1997) and for a Finnish case (Korhonen et al., 1999) that was labelled as "industrial ecology" or "industrial symbiosis" only after the intervention of a third party (Chertow, 2007; Sakr et al., 2011). The economic benefits arising from symbiotic exchanges in an EIP can be summarized as direct (e.g. revenues from selling by-products, reduced costs from avoided discharge fees or disposal costs, reduced costs deriving from substituting virgin energy and materials with alternative feedstock obtained at lower prices) and indirect. The latter regard the avoidance of investments, increase of supply security and flexibility, better reputation, innovation, operational resiliency, and ability to attract and retain employees (Ehrenfeld and Gertler, 1997; Herees et al., 2004; Mirata and Emtairah, 2005; Jacobsen, 2006; Veleva et al., 2015).

Undoubtedly, the evolution of EIP's development faces many challenges. New problems and trends are also emerging on the practical foundations of an EIP. For example Zhu et al. (2010) evidence the need to select optimal companies for the purpose of assuring stability and efficiency to the EIP itself, while Veleva et al. (2015) argue that eco-industrial parks are less concerned about physical exchanges of materials, energy, water and by-products in favour of sharing more about infrastructure and knowledge, joint sourcing, building local supply chain and reducing the risks from weather and other business disruptions.

*Eco-industrial development in China*

The EIP concept was primarily introduced in China at the end of 1990s (Fang et al., 2007; Zhang et al., 2009; Shi et al., 2012) and kept developing quickly at research, political and practical level (Fang et al., 2007; Shi et al., 2012). At political level, the Chinese State Environmental Protection Administration (SEPA) started to promote EIPs and Industrial Symbiosis as models of industrial and technological development alternative to the ones based on an end of pipe pollution approach. In particular the take up of EIPs has been encouraged to face the problem of polluting industrial development zones (Chiu and Geng, 2004; Geng et al., 2008; Shi et al., 2012). Since the beginning of the development of a new industrial park program, SEPA has been in charge of the approval of EIPs' applications to become part of the National Demonstration EIP's Program (Shi et al., 2012; Jiao and Boons, 2014).

China is trying to develop its own model of EIPs (within the theoretical framework of industrial ecology) in order to properly account for the different political, socio-economic and environmental context compared to the rest of the World (Chiu and Geng, 2004; Fang et al., 2007).

The intention of pursuing the feature of "new" in the EIPs' development is confirmed by the definition of the Ministry of Environmental Protection that defines an EIP as a new type of industrial park that emphasizes the establishment of an industrial symbiosis network composed of varied industries (by-products exchange, water and energy cascading, and information sharing among firms), in addition to including all the features of a traditional industrial park. The main goals of an EIP are the realization of closed loops, the minimization of waste and overall eco-efficiency improvements by applying the principles of cleaner production, industrial ecology and circular economy. Most importantly, is the introduction of a group of criteria and indicators for each type of EIPs (sector specific, sector integrated and venous) classified into different categories: economic development, material reduction and recycling, pollution monitoring and park management (Geng et al., 2008). However, the system of indicators should be improved by moving beyond measuring the overall efficiency of the EIP towards informing about issues pertaining e.g. the level of symbiosis and diversity in the EIP as well as the links between the EIPs and the local socio-economic context in which the EIP is embedded (Geng et al., 2008, 2012).

From 2001 to 2011 China has developed the largest National EIP network consisting of the approval of 60 National Trial EIPs (Fig. 4). Among them the three Ministries have assessed the progress made in the implementation of 15 National Trial EIPs (Shi et al., 2012). Within the 60 National Trial EIPs, 48 are mixed industrial parks and 11 are sectorial industrial parks (as sugar-making, metallurgical, mining, coal-based chemical, and petrochemical industries) while only one National Trial EIP is a resource recovery park (or so-called venous industrial parks where companies turn waste into reusable resources and again to new products) (Geng et al., 2008; Shi et al., 2012). The performances of some of the EIPs that are part of the National Trial EIPs (approved and assessed or only approved) have been carefully analysed by many authors as described in the following.

Geng et al. (2007) analysed the planning and application of an integrated solid waste management system in Tianjin Economic Development Area, TEDA (the largest industrial park of China) introduced in 2003 to maximize resource use and minimize the waste produced and their costs of disposal. In the same period, the TEDA started an EIP project to increase higher cost efficiency by sharing common services, transports and infrastructure linking the companies of TEDA. The planning of integrated solid waste management required the description of waste flows at company, EIP and regional levels. For example at company level cleaner production programs were introduced within all the companies of the EIP for the purpose of minimizing the total amount of waste. At EIP level the planning was focused on creating the network of industrial symbiosis activities (by-products exchange) among the companies. It also implied the search for new scavengers and decomposers for the establishment of the network. The research also evaluated the potential economic (e.g. costs savings in resource use, increase of revenues from the sale of waste), environmental (e.g. ease of virgin materials exploitation and reduction of waste quantity as well as decrease of waste' amount disposal to landfill) and social benefits (e.g. improved public health by reducing solid and hazardous waste, employment opportunities for local scavengers and decomposers companies, etc.) from the introduction of the integrated solid waste management system. Still about TEDA, Shi et al. (2010) further deepen on the process of investments in environmental management actions (aimed at involving multinational companies operating in the park and maintaining its competitiveness and leading position in China as an industrial park). In November 2000 TEDA obtained the ISO 14001 certification for the entire industrial park and in the same year it has been designated by SEPA as one of the National ISO 14001 Demonstration Zones. Finally in 2008 TEDA became one of the three first Trial EIPs of the National Demonstration Program. The research identified 81 inter-firm symbiotic relationships over a period of 16 years involving utility, automobile, electronics, biotechnology, food and beverage, and resource recovery clusters. Of the 81 symbiotic exchanges the material exchanges accounted for the highest share (76%).

Yu et al. (2015) analysed the role of Government and other factors affecting Industrial Symbiosis (IS) performances through the analysis of the evolution of IS in the Eco-Industrial Park Rizhao Economic Technological Development Area (REDA). The study identified 31 IS practices mainly related to by-products exchanges (90% of the total) while water exchanges and energy accounted for 6% and 4%, respectively. The latter types of symbiosis are more difficult to establish because they require the investment of heavy infrastructures. Moreover, the authors evidence that the content,


**Fig. 4.** Overview of approved eco-industrial parks (EIPs) within the National EIP Program up to December 2010 in China. Source: Mathews and Tan 2011.

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type and stability of symbiosis streams depend on cleaner production activities implemented with the goal of minimal use of raw materials and energy as well as minimal production of waste and emissions. Finally the main reasons for companies to establish IS were economic (recovering of the costs in environmental investments, cost saving from virgin material substitution and transport, business visibility and social identity, social responsibility of enterprises). In this context stricter environmental standards, tax cut and refund policies on resource use and financial subsidises positively stimulated the IS development.

The emergy method (environmental support demand; Odum 1988, 2000; Geng et al., 2013) is used by Geng et al. (2010a) to investigate the sustainability of the second largest Chinese Industrial Park located in Dalian region (Dalian Economic Development Zone, DEDZ) in the year 2006, when the park started its conversion to the Eco-Industrial Park status, by introducing cleaner production activities (at company level) and by-product exchange (at the interfirm level). In 2006 about 83% of the waste produced by the Industrial Park was collected and recycled while about half (46.5%) was reused and recycled within the EIP. Very interesting in the study is the introduction of a new indicator capturing the emergy savings due to the replacement of input resources by means of reuse or recycle of waste. The emergy method was also used to evaluate the overall performance of EIP activities and the industrial symbiosis established at Shenyang Economic and Technological Development Zone (SETDZ). The latter presented its application for the status of EIP within the National Trial EIP program on 2011. On September 26, 2013, the SETDZ EIP plan passed the national onsite evaluation organized by the Ministry of Environmental Protection. The study found that industrial symbiosis provides relevant environmental and economic benefits. The latter could potentially increase by further expanding the existing synergies: the reuse of treated wastewater from local wastewater treatment, reuse of sludge from wastewater treatment as a fertilizer, the reduction of coal energy dependency and its substitution with renewable energies such as wind energy (Geng et al., 2014b). For the same EIP, Dong et al. (2013a) assessed the carbon footprint by means of a hybrid Life Cycle Assessment calculating a total amount of 15.29 Mt $CO_2$ released in 2007. Upstream (55.42%) and downstream (0.02%) impacts contributed to more than the half of the total carbon footprint of the EIP compared to direct impacts onsite (44.57%). Chemical and manufacturing industries were found responsible of the highest lifecycle carbon footprints.

Finally, two studies compared Chinese EIPs with other international EIPs. The first one (Mathews and Tan, 2011) compared some Chinese EIPs (Guigang group, Pigmei, Lubei, Suzhou, Tianjin) with the international counterparts of Kalundborg (Denmark), Kwinana (Australia), Ulsan (Korea), Kawasaki (Japan). Results evidence that the eco-industrial parks initiatives can be applied to improve the existing industrial parks in order to transform the value chain from linear to closed-loop. Moreover, the transition to an EIP occurs over decades introducing primarily cleaner production and pollution control strategies and gradually broadening the symbiosis. Compared to the international eco-parks the Chinese parks perform with a lower number of synergies and are more dependent by the Government both for design, support and management of the EIPs activities and their financial support (Mathews and Tan, 2011). In a latecomer perspective of analysis the higher role of government in China is important at the early stage of development of EIPs to overcome barriers that latecomers may face (e.g. access to established markets and technologies in the face of high competition). The same latecomer perspective allows to better grasp the rapid and high development of EIPs compared to the slower and smaller numbers in developed countries (Mathews and Tan, 2011). A second study (Zheng et al., 2013) compared selected Chinese EIPs (Guangxi, Xinjiang, Tianjin, Lubei) and their international counterparts (Kalundborg, Styria, Kitakyushu, Choctaw) by means of density and network degree-of-centralization metrics and then categorized the EIPs into three different types: dependence-oriented (Guangxi, Xinjiang, and Kalundborg), equality-oriented (Choctaw and Lubei), and nested–oriented complexes (Kitakyushu, Tianjin, and Styria) in so assessing differences and similarities. The authors proposed the establishment of new symbiosis paths for all the investigated eight industrial symbiosis estates, from the perspective of analysing their deficiencies in structural characteristics and calculated the effectiveness of these new linkages.

### 3.3. Circular economy at macro level

Circular economy development in cities, provinces or regions involves the integration and the redesign of four systems: the industrial system (e.g. changing the size of companies from small to large or the phase-out of the heavy polluting enterprises in favour of light economic activities as related to high-tech industries, tourism or culture) the infrastructure system delivering services (transportation and communication systems, water-recycling systems, clean energy and electrical power lines, etc.), the cultural framework and the social system (Mirata and Emtairah, 2005; Feng and Yan, 2007; Ness, 2008; Naustalslid, 2014).

#### 3.3.1. Eco-cities

The concept of eco-town was born in the eighties in USA within Urban Ecology mission and was aimed to redesign cities according to more ecological concepts (Roseland, 1997). The well-known Japanese eco-towns Governmental program developed since 1997 involved urban and industrial centres in symbiosis projects thanks to their geographical proximity (Van Berkel et al., 2009b). In that way both zero emissions goals (concept that virtually emphasizes the full use of waste flows in the economic system) and economic benefits have been achieved given the challenges of shortage of landfills and the need of revitalizing local industry texture (Van Berkel et al., 2009b). From the adoption of the Eco-town programme in 1997 a number of 26 eco-towns were created in Japan, by approving their eco-town plans. Eco-towns also received subsidies to invest in innovative recycling projects. Moreover, the projects granted with subsidies generated further and even higher no-subsidized projects and provided public (e.g. environmental quality) and private benefits (e.g. profits of enterprises). The success of such programs is due to legal, social, economic and technological factors, such as the evolving legislative framework towards the adoption of a recycling oriented society, the shared responsibility of society over the need for environmental protection, the reduction of enterprise's risks and capital expenditure by means of subsidies, the diversification of enterprise's activities, and the improvement of technological capacity within particular industrial sectors (Van Berkel et al., 2009b).

Other examples of eco-cities can be found in Europe, such as in Germany, Sweden and UK (EU-ASIA, 2014) as well as in China, where the literature evidences more than one hundreds of eco-city projects (Marion, 2012). Beijing, Shanghai, Tianjin and Dalian in the last years implemented eco-city pilot projects with the aim of investigating the evolution of CE in terms of resource efficient use (e.g., indicators of energy intensity per GDP and water intensity per capita), municipal waste production, waste treatment and reclamation (rate of waste water treatment, rate of industrial solid waste reuse) (Geng et al., 2009; Su et al., 2013). From 2005 to 2010 in the four mentioned eco-cities the highest reductions have been observed in energy and water consumption indicators. Tianjin was the best performing city, in particular within the energy and waste management categories. The major drivers of performance improvement have been the Government intervention in highly pollutant and energy consuming industrial sectors, by means of heavy industry relocation, the introduction of regulations for polluting sectors and the highest availability of energy efficient technologies and equipment in the four eco-cities referred to above, compared to other Chinese cities. Moreover, the Dalian municipality has encouraged and in some cases required the manufacturing companies to adopt cleaner production strategies and the EMS ISO 14001 standard[4] while for water it promoted programs for improving water management from both supply and demand sides (e.g., the collection of rainwater in rural and urban areas, the use of seawater for cooling, the introduction of desalinization technologies, the minimization of water use in industrial and residential sector, etc.) (Geng et al., 2009).

### 3.3.2. Collaborative consumption models

Collaborative consumption models are recognized as one of the best available options on consumer side to shift from the present business-as-usual model to CE (Ness, 2008; Preston, 2012; Van Meter, 2013). Collaborative models (e.g. sharing, bartering, lending, trading, renting, gifting) are based on a shared ownership among multiple consumers. For example, when renting the consumer has no ownership of the product but has only the right to use it by paying a charge (Ness, 2008; Ellen MacArthur Foundation, 2010; Preston, 2012; Van Meter, 2013). As the ownership is at the core of our present consumption model, the loss of ownership is one of the strongest potential barriers that could limit the development of such systems (Tukker, 2015).

Besides renting, other solutions are lending, bartering and gifting (Segrè, 2008; Preston, 2012; Ellen MacArthur Foundation, 2010). Because of the various approaches of these activities, their goal can range from profit, non-profit or both. Presently, collaborative consumption is adopted in car-sharing, in website-based networks sharing different products (music, textbooks, fashion, and art, among others). Consumer's lifestyle keeps changing, by reducing the environmental impacts associated to consumption activities (e.g. in North America members of car-sharing reduced by 30% their driving time compared to the period they owned a personal car) and promotes social cohesion (Ness, 2008; Preston, 2012). Rather than a marketing trend, it is instead a crucial factor towards sustainable development (Botsman and Rogers, 2011) and circular economy, as also recently recognized by the European Economic and Social Committee (EESC, 2014). However, consumers need to be located within a certain community or location (e.g. big cities) or should be part of a larger network for easy access to such schemes (Preston, 2012).

These consumption models are the basis for an improved performance of circular economy, as theorized by Stahel (2010). In his study the author evidenced the advantages in terms of higher employment and resource-efficiency of a business model mainly based on selling services instead of selling products as the present business model. As a consequence Governments, in western economies should accelerate their taxation policies towards taxing more strongly the use of non-renewable resources instead of taxing renewable resources as labor (Club of Rome, 2015). Obviously, this fact creates an indirect strong barrier to the development of circular economy (Groothuis, 2014) as CE is perfectly aligned with the development of the bio-economy and the transition towards bio-based rather than fossil based products (Dupont-Inglis, 2015).

### 3.3.3. Innovative waste management and zero-waste programmes

Waste production and management issues increase when a society further develops. The problem is also worsened by globalization (Song et al., 2015). In urban centres municipal solid waste are mainly disposed of in landfills, recycled or recovered. Due to increasing environmental problems and landfill constraints the prevention of waste is gaining more attention in particular in populous cities and countries such as Japan with limited landfill and natural resource capacity (Buttol et al., 2007; Geng et al., 2010c). Caprile and Ripa (2014) showed by means of LCA that through prevention, recycling or recovering (separate collection) it is possible to reduce substantially the environmental impacts compared to disposal in landfills. Moreover as shown by the case of Kawasaki (Japan), innovative Municipal Solid Waste Management (MSWM) through urban symbiosis seems to fulfil the need for reducing the amount of waste as well as natural resources procurement (Geng et al., 2010c). In China, given its fast development, the problem of waste is also very urgent to address (Sakai et al., 2011). Chinese CE Promotion Law is also one of the political responses to waste management problems. The effectiveness of CE Promotion Law requires improvements in different waste sectors, such as Waste Electrical and Electronic Equipment (WEEE) and Municipal Solid Waste Management, while more attention in waste management policies should also be paid to imported recycled materials (Sakai et al., 2011).

Ideally CE transition seems to imply the objective of pulling all waste down to zero (EC, 2014a). Some cities, given their critical role in resource use (Ramsar, 2012), have established zero waste programmes (Song et al., 2015; Zerowaste Europe, 2014). One of these programs is analysed in its implementation steps in Durban (South Africa) by Matete and Trois (2008). According to the authors the investigated model has potential to lead close to zero waste, even if a total recycling is impossible for all types of materials (e.g. paper). They also evidence that a successful implementation of the model depends on the participation rate of the households. Following the ideal goal of zero waste, Zaman and Lehmann (2013) propose the Zero Waste Index for three big cities: Adelaide, Stockholm and San Francisco with the aim to measure waste management performances and to forecast potential raw resources demand and emissions savings. The calculation of the index aims to overcome the limits of the waste sorting rate (one of the most common indicators used by the municipalities to measure the current performances of waste management systems), introducing aspects of waste prevention. The zero waste index quantifies the potentialities of virgin materials of being substituted by the waste management city system. Results show that among the three cities Adelaide generated the highest amount of waste per capita (681 kg) while Stockholm the least (480 kg). San Francisco achieved the best value of zero waste index: 0.51, meaning that about half of the city municipal waste materials were recovered and potentially replaced the demand for virgin materials. On the contrary, Stockholm only achieved an index of 0.17 because of the high use of incineration that prevents the possibility to recover large amounts of virgin materials, energy and water and to achieve GHG emissions savings. It should be noted that San Francisco achieved the greater energy and greenhouse gas savings, as well as greater water savings, than the other cities.

The zero waste goal is also included within the European Union policy, as indicated by the 7th Environment Action Program, with the aim to: "virtually eliminate landfilling by 2020" (EU, 2013), while the Landfill Directive, 1999/31/EC (EC, 1999) only required the EU Member States to reduce the landfilling of "biodegradable municipal waste" to less than 35% of the amount produced in 1995. Some EU Member States (Austria, Belgium, Denmark, Germany and Netherlands) already achieved the targets indicated by the EU

[4] ISO 14001: http://www.iso.org/iso/home/standards/management-standards/iso14000.htm.

Landfill Directive. For example, only 3% of the total waste produced in The Netherlands is still landfilled. The use of different instruments (tax, bans, and regulations) contributed to the low landfilling rates, in particular landfill taxes. However, paradoxically, as discussed by Scharff (2014), the transition towards a low landfilling rate generated different side-effects related to the maintenance of economic, environmental and social sustainability of the remaining landfills, rendering impossible their final dismissing because of the need to recover the financial losses. To avoid these problems, Scharff (2014) highlights the importance of planning the required landfill capacity and the reorganization of the landfill sector, also to prevent waste disposal abroad and huge costs to the society, instead of to the polluter. Finally, Shekdar (2009) analyses solid waste management (SWM) systems in Asian countries, evidencing key features of SWM in some of them related to the stage of development of the country: Japan, South Korea, Taiwan and Singapore (developed), Thailand and Indonesia, China and India (developing). In the first four countries, strong efforts were made towards the elimination of landfilling and increasing recycling rates. Waste management systems services (collection, transportation, processing and disposal) are well organized and citizens' awareness over SWM as well as the expectations towards such service are high. In the second group of countries, the SWM system, even evolving through a better management (e.g. recycling is an established and organized commercial activity) seems facing many problems towards the improvement of the quality of the SWM service systems.

### 3.4. Decoupling economic growth from environmental impacts

Both in Europe and China the circular economy is seen as an intermediate objective towards the ultimate goal of decoupling economic growth from resource consumption (Zhu, 2008; EC, 2012c). Although EU and China appear to be two typical case studies, we cannot neglect other applications of circular economy in other countries of the world.

#### 3.4.1. Decoupling in Europe

Some countries in Europe have reached both relative decoupling and absolute decoupling in some sectors. Denmark and Sweden decoupled fossil fuels consumption, while Slovakia decoupled the municipal waste production and England and Germany the land take.

In Denmark relative decoupling was achieved in agricultural production and fertilizer use, in Ireland with plastic bags and in Iceland for some fish stocks (Prokop et al., 2011; Dynamix Project, 2013, 2014). Additional experiences of absolute decoupling in other countries are also discussed by Yu et al. (2013), such as: Domestic Extraction Use (DEU) in Germany, France, the United Kingdom, Italy and Canada; Total Energy Consumption (TEC) in Germany, $CO_2$ emissions in Germany, France and the United Kingdom). Europe seems to strive towards absolute decoupling; there is the risk that only relative decoupling can be achieved due to the so-called “rebound effect”, that is the risk for eco-efficiency strategies at micro level that improvements in productivity of resources do not translate into a reduction of resource use, but rather into an increase of them (Ness, 2008). However, some cases of absolute decoupling seem to confirm the hypothesis by Figge et al. (2014) that rebound effects are not a certainty in all sectors, although they frequently occur. These authors also found that eco-sufficiency strategies (consisting in reducing what is produced or consumed in absolute terms) are not neutral to rebound effects. If both of these strategies are unable to reduce resource use, the final result would unavoidably be an overall reduction of economic activity (Figge et al., 2014) as theorized by the de-growth movement. However, up to now, as argued by Van Griethuysen (2010), our society showed to be unable to give up its “growthmania”, even if the “*growth-based development path has lead our society to a general collapse*”.

#### 3.4.2. Decoupling in China

The eco-efficiency trends of resource use, energy consumption and pollutant emissions, relative and absolute decoupling of environmental pressure from economic growth and their dynamics (in terms of analysis of major drivers) in China was investigated by Yu et al. (2013). Their findings pointed out that from 1978 to 2010, the trend of resource efficiency (measured by GDP/DEU[5] and GDP/TEC[6]) kept increasing mainly due to the high growth of GDP, while DEU and TEC increased to a lower extent. The same pattern is observed for the eco-efficiency trend of pollutant emissions (to air: $CO_2$, $SO_2$, soot; water: waste water, COD[7] ammonia nitrogen) that mainly improved because of the higher growth of GDP compared to the one of pollutant emissions. Absolute decoupling in China was found for COD, while relative decoupling only for wastewater, $SO_2$, $CO_2$, TEC and DEU. The major drivers of change reveal that the trend of energy efficiency (GDP/TEC) has been affected positively by technology (phase out obsolete technologies from 2003) and negatively by structural changes (due to the sharp increase of the fraction of heavy industries output to the total industrial output in particular from 2000 to 2010).

#### 3.4.3. Decoupling worldwide

A smaller number of case studies in other countries worldwide showed no significant differences from the two “approaches” above considered. Absolute decoupling of Domestic Extraction Use (DEU) was also explored by Wang et al. (2013) in Japan. Decoupling indicators for resource use ($D_r$) and emissions ($D_e$) are used to distinguish between absolute ($D_r \geq 1$), relative ($0 < D_r < 1$) and non-decoupling ($D_r < 1$) for two BRICS countries (China and Russia), Japan and United States during 2000–2007 to examine decoupling conditions of domestic extraction of materials, energy use and sulphur dioxide emissions from Gross Domestic Product (Wang et al., 2013). The main results of their work show that Japan and the United States were more successful in decoupling $SO_2$ emissions from GDP than material and energy use, compared to the BRICS countries. These findings could be explained by the different development stages and different economic growth rates between the formers and the latter.

## 4. Discussion

### 4.1. Theoretical background of CE

From our extensive analysis of literature worldwide the CE concept shows to be rooted in very diverse theoretical backgrounds: ecological economics, environmental economics, industrial ecology. Since its very beginning, CE presented itself as an alternative model to the neoclassical economic both from a theoretical and practical point of view as it acknowledges the fundamental role of environment, as well as its functions and the interplay between the environment and the economic system. Moreover, CE looks at the environment as an example to emulate for redesigning the production activities, in particular industrial or

[5] Gross Domestic Product, GDP/Domestic Extraction Used, DEU (in the study measured in tons).

[6] Total Energy Consumption, TEC (in the study measured in units of standard coal equivalents).

[7] Chemical Oxygen Demand.

development patterns. As a consequence, as in the natural environment, in CE "*nothing that contains available energy or useful material is lost*" (Frosch, 1992). One of the innovative and core principles of CE – inherited from industrial ecology – is that waste at the end of their life should be released to the industrial food web, both as material and energy flows. Their inclusion in the design of products and processes allows to close the material and energy cycle (closed loop), maximize waste use, minimize the use of virgin materials and the release of noxious materials to the environment.

So far the promotion of the concept of CE in China and worldwide seems mainly based on the industrial ecology theoretical framework and pillars (analytical, methodological, proactive) even if not everywhere the principles of industrial ecology are well known and implemented (Chiu and Geng, 2004). The published literature is rich with studies that analyse physical performances and trends of use of different types of materials and energy by-products, industrial symbiosis patterns, and resource use indicators (Jacobsen, 2006; Van Berkel et al., 2009a; Geng et al., 2010a; Shi et al., 2010; Wang et al., 2010; Mathews and Tan, 2011; Yu et al., 2013; Dong et al., 2013a,b; Li et al., 2013; Geng et al., 2014b; Sevigné-Itoiz et al., 2014; Wen and Meng, 2015; Yu et al., 2015). On the contrary a few studies deal with the analysis of economic aspects of CE (Andersen, 2007) or its theoretical economic framework (Andersen, 2007; Xia and Yang, 2007; Zhu and Wu, 2007; Charonis, 2012; Naustalslid, 2014). Among these, it is interesting to note that while in the European literature CE operates within environmental economics that is a subfield of neoclassical economics (Charonis, 2012; Naustalslid, 2014), in China CE is identified within the ecological economics framework. The latter is considered much more consistent with Chinese industrial development stage, that has been addressing since the beginning the problem of natural resource scarcity (Xia and Yang, 2007; Zhu and Wu, 2007).

### 4.2. Political background of CE

At political level we found that very diverse policies and economic instruments (taxes, environmental permits, financial subsidizes) are used worldwide. Contrary to Europe, USA, Japan, in China the CE implementation is promoted within a national programme as it is considered part of a wider policy for socioeconomic transformation and development, capable of ensuring harmony between society and environment (Naustdalslid, 2014). The achievement of a harmonious society seems to characterize the CE political context of China compared to the other countries as Europe, Japan or USA. In the latter economic areas, CE is mainly recognized as a strategy for waste management or for implementation of environmental policies at the maturity stage of economic development (Ren, 2007). In EU the political importance of a CE development has been increasing in the last few years, as it can be ascertained from the Manifesto of resource efficiency (EC, 2012c), the European Resource Efficiency Platform (EREP) (2012) and the EU Circular Economy Package (EC, 2014a,b). In Japan the transition towards CE started earlier with two important laws in 1991 and 2000 while in USA at the moment a relevant federal policy law towards CE seems still lacking. Also Australia and New Zealand are on the way of defining its CE transition while Korea and Vietnam have included relevant 3R policies in their political agenda.

### 4.3. CE patterns across scales

It is important to mention that even if there is recognition of a hierarchy among the 3R principles, the transition towards CE, at practical level, seems more concerned with recycling rather than reuse, the leading principle of CE according to Stahel (2013). Reuse could contribute to reduce the environmental impacts as well as to revitalize the competitiveness of local economies and improve the well-being of particular segments of population (Stahel, 2013; Castellani et al., 2015). Its wider role is essential given the limits and risks of recycling in the global market (Bilitewsky, 2012; Stahel, 2013, 2014) to fully accomplish with the objective of absolute decoupling. Recycling activities should be promoted on a more local dimension compared to global, to avoid the loss of key resources in industry sector (Sevignè-Itoiz et al., 2014) while CE and policies should focus on each recycled material since the different level of recycling achieved by materials (Birat, 2015).

#### 4.3.1. CE implementation at micro level

At micro level the transition towards CE implies the adoption of cleaner production and eco-design. As eco-design takes into account all the environmental impacts of a product since the earliest stages of design, it has the potential to improve the circular economy approach by favouring the improvement of material and resource use (Sherwin and Evans, 2000; Prendeville et al., 2014). In Chinese Eco-Industrial Parks, cleaner production is the starting point for individual companies to engage towards CE. The introduction of cleaner production provides environmental benefits and economic benefits to companies, as it reduces the amount of waste produced and the costs of disposal. The adoption of cleaner production patterns should be planned in such a way as to balance its isolated process nature by means of better integration into other environmental strategies of a company, an industrial system or the entire society. Moreover its adoption is not easy to monitor as CP can be applied to processes, products and services. Some data about its diffusion are available only for some European countries, U.S.A, Canada, Japan and China. Finally, the effectiveness of cleaner production to promote CE and address environmental problems as well as its larger adoption strictly depend on the context and also on the capacity of public authorities to stimulate an increase of the responsibility of producers towards a continuous improvement of environmental performances. In turn, the enhancement of consumers' responsibility contributes to further strengthening that virtuous cycle. In this regard, environmental labelling is increasing worldwide also supported by public authorities as in the case of EU Ecolabel. The diffusion of products marked with the environmental labelling as well as the increase of Green Public Procurement strategies are very encouraging aspects.

#### 4.3.2. CE implementation at meso level

The implementation of CE at meso level regards the introduction of EIPs initiatives. The latter provide the opportunity to improve environmental performances within industrial areas as shown by the investigated case studies on EIPs in Europe, China and other countries. However, even if there are several initiatives in Europe, the attention was mainly placed on the Kalundborg industrial symbiosis system. Instead, in China a much wider range of case studies is reported, showing the environmental performances of EIPs also in a CE perspective, through different types of environmental assessment methods. Results show that in several cases (e.g. Tianjin) industrial symbiosis and environmental improvement are carried out at EIP level. Some trends of symbiosis such as the ones in electronics and automotive sectors are of particular concern as they regard the outsourcing of low value added and polluting activities, and need to be addressed appropriately by the public authorities (Shi et al., 2012). The adoption of a life cycle perspective in the supply chain of the symbiosis carried out by an EIP is important for the correct evaluation of the environmental performances of an EIP.

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Moreover, due to market mechanisms (price of by-products) industrial symbiosis among companies may fail, evidencing that economic feasibility is a decisive factor in the adoption of symbiosis mechanisms and achievement of environmental improvements.

#### 4.3.3. CE implementation at macro level

Finally, the implementation at macro level (e.g. in cities) shows interesting improvements of CE aspects, as in Japanese and Chinese eco-cities, zero waste programs, as well as CE indicators (e.g. zero waste index). On the consumption side, monitoring collaborative consumption experiences (e.g. car sharing) seems to suggest that the quality of consumption patterns affects the environmental impacts. In the waste management sector at national level, the case of Netherlands shows that it is possible to achieve a high recycling rate, while also evidencing how it is difficult to move towards CE, to close the material loop and dismiss the landfills. Finally, as above mentioned, in both European Union and China the transition towards CE should lead to the decoupling of environmental pressure from economic growth while other countries as Japan, USA, India, Brazil and Russia are also aimed to the decoupling. So far absolute decoupling has been achieved, in Europe and China, only for some production patterns, sectors and materials, evidencing that the scale factor affects the performance of the economic systems (e.g. the increase of the Gross Domestic Product, GDP) more than offsetting the increase of efficiency (GDP/DEU or GDP/TEC).

### 4.4. Summarizing CE development, advantages and disadvantages

This review evidenced features and progresses of CE patterns in some countries and geographical areas. Because of different development stages and country specific constraints, European Union Japan and USA (post-industrialization stage) and China (mid-industrialization stage), the main areas and countries of CE development, evidence unique features in circular economy patterns. In the former, CE policies and actions are mainly identified within waste area as they emerged in response to the increasing problem of waste management (Ren, 2007; Geng et al., 2010c). Industrial pollution with the introduction of cleaner technologies was partially resolved (Ren, 2007). Instead, China is facing a phase of industrial development that has no precedents in the history of the former countries. Its primary aims within CE is the adoption of a new business model that integrates cleaner production and the development of eco-industrial parks, considered as the more critical sectors to address (Ren, 2007). The large industrialization, rapid urbanization, change of consumption patterns and population growth lead to a rapid increase of the amount of waste leading China in 2004 to be the largest Municipal Solid Waste generator (Chen et al., 2010; Zhang et al., 2010). While the amount of MSW per capita is still lower in China (250 kg) than in 27 European countries (512 kg), Japan (380 kg) and USA (720 kg) (Environment European Agency, 2009; OECD Statistics, 2010), landfilling remains in China the dominant means of disposal of MSW (Chen et al., 2010; Zhang et al., 2010) practically preventing the possibility of closing material cycles in CE perspective. Instead, the industrial waste collection rates are higher in China (67% in 2010) and much closer to the ones of developed countries (90% in 2010) (Song et al., 2015).

The circular economy, beyond the present model of production and consumption, helps optimize natural resource use through efficiency increase towards a transition from open to closed cycles of materials and energy and to less wasteful industrial processes (Frosch, 1992; Erkman, 1997; Ehrenfeld and Gertler, 1997; Chiu and Geng, 2004; Andersen, 2007). CE prevents the loss of valuable materials as suggested by Mirabella et al. (2014) and supports the concepts put forward by Park and Chertow (2014) and Zaman and Lehmann (2013) of waste as a potential resource. The Ellen Mac Arthur Foundation's Report rejects the concept itself of waste. For this to happen, their use at the end of life cycle should be planned in the design phase (Ellen Macarthur Foundation, 2012). Prendeville et al. (2014) evidences that this latter stage acquires and plays a central role in CE reinforcing its benefits (mainly focused on resource use) as eco-design aims to reduce all environmental impacts in the life cycle of a product. The adoption of a cradle to cradle perspective embedded in CE while preventing the loss of valuable materials allows a reduction of the costs for the companies and municipalities, due to a reduction of the problem of waste management (Mirabella et al., 2014; Geng et al., 2010c) as well as to a reduction of the externalities for the society (lower pollution), new jobs opportunities (Ellen Macarthur Foundation, 2012; Club of Rome, 2015) and increased welfare for low income households (Castellani et al., 2015). This is because the reuse and remanufacturing activities are labour intensive instead of resource intensive as in the present linear model of production and consumption (Stahel, 2013). In turn the reduction of dependence on natural resources, in particular non-renewables means a lower exposure of the economy to the negative effects of resource prices shocks (Ellen Macarthur Foundation, 2012; Preston, 2012; Lett, 2014).

Generally at meso level the development of eco-industrial parks and industrial symbiosis under “CE philosophy” are source of environmental (lower material and energy resources consumption and lower water, air and soil pollution) and economic advantages (e.g. lower costs for raw materials substitution and lower treatment costs) (Chertow, 2007; Zhu et al., 2007; Van Beers and Biswas, 2008; Park et al., 2008; Van Berkel et al., 2009a,b; Geng et al., 2010a; Shi et al., 2010; Wang et al., 2010; Behera et al., 2012; Wen and Meng, 2015; Yu et al., 2015). Several studies (Ehrenfeld and Gertler, 1997; Singhal and Kapur, 2002; Jacobsen, 2006; Herees et al., 2004; Zheng et al., 2013) quantify (or estimate) the actual and potential benefits (Zheng et al., 2013) obtained from industrial exchanges in Kalundborg in terms of annual resource savings (water, fuel and chemicals), waste and emissions avoidance. For China, in crucial economic sectors as iron/steel industry, Dong et al. (2013b) evidence that it is possible to exploit energy, water, by products and waste exchanges enhancing resource and energy efficiency, reducing pollutant's emissions of the EIP and the external linked facilities as well as of the urban communities. In fact, urban solid waste can be used by the EIP and the excess of metallurgy energy of the EIP can feed urban heating systems (Dong et al., 2013b). In the successful experiences of urban symbiosis in Japan of the Eco-Town Program establishing 26 Eco-Towns, Van Berkel et al. (2009) highlight that the program other than providing environmental and socio-economic benefits contributed to the advance of technology in recycling as new processes for complex waste streams along with advanced options for commodity plastics. Other experiences of symbiosis among industries and local municipalities and their social benefits (employment, district heating and waste disposal) are also cited by Lehtoranta et al. (2011) in the relevant Finnish pulp and paper industries.

As the companies mainly engage in EIP projects with the purpose of gaining economic benefits (Ehrenfeld and Gertler, 1997; Singhal and Kapur, 2002; Herees et al., 2004; Chertow, 2007; Park et al., 2008; Lehtoranta et al., 2011; Sakr et al., 2011; Behera et al., 2012; Massard et al., 2014), environmental benefits are side-effects of their choices (Heeres et al., 2004) often uncovered (Chertow, 2007; Bain et al., 2010). As a consequence, the engagement in EIPs and industrial symbiosis and CE as well are considered a disadvantage for companies (as reported by Shi et al. (2010) for the automotive sector) whenever the IS projects are not convenient economically. Many authors stress therefore the importance for public authorities of creating the adequate support to companies through policies, national EIP initiatives, environmental legislative framework, economic instruments (taxes, subsidies) for the development and advance of EIPs and IS as well as policies removing the hurdles that prevent the safe reuse of by-products and informing companies about the benefits of IS, improvement of the cooperation among stakeholders, adequate infrastructures (rails and roads) and services (as research centres and EIP coordinating centres), promotion of a cleaner production approach among individual facilities, education programmes to support EIP's take up (Cotè and Cohen-Rosenthal, 1998; Roberts, 2004; Desrochers, 2004; Van Beers et al., 2007; Park et al., 2008; Veiga and Magrini, 2009; Van Berkel et al., 2009a, b; Bain et al., 2010; Costa et al., 2010; Shi et al., 2010; Lehtoranta et al., 2011; Behera et al., 2012; Bai et al., 2014; Veleva et al., 2015; Yu et al., 2015).

Finally, circular economy also requires producers and consumers to become more active participants in the recycling or reuse of products, forgetting about the passive “throwaway” culture of the linear economy (Shah, 2014). It should not be disregarded that given the limits in recycling it is unlikely that CE could continue to maintain quantitative economic growth forever. According to Georgescu-Roegen (1971): “*not only growth, but also a zero-growth state, even a declining state which does not converge toward annihilation, cannot exist forever in a finite environment*”. Nevertheless, as we discussed in section 3.3, CE should be seen as a transition to a new and different business model, where wellbeing is decoupled by resource consumption. CE could help the transition to a degrowth path (less resource use with increasing wellbeing) that seems inevitable in particular in industrialized economies having surpassed ecological limits (Kerschner, 2010). As suggested by Kerschner (2010) economic degrowth in the North could implement a path for achieving the goal of a globally equitable lower steady state economy, by allowing some more economic growth in the South. In this perspective CE can be seen as an advantage by degrowth supporters and a disadvantage by the ones advocating continuous quantitative economic growth. On the other hand, so far environmental and social dimensions of sustainability have attracted less interest compared to the economic sphere and need the right recognition. A shift is then needed, in particular in developed countries, towards a more qualitative development model, as could be the CE, where people live equitable within planet's carrying capacity as suggested by Brown and Ulgiati (2011).

### *4.5. Future research options*

The perspectives of CE are huge and appealing. An overall increase of knowledge of theoretical and practical framework of circular economy, CE, as well as the monitoring of the presently existing projects at the different levels are fundamental for advancing CE progresses in Europe, China and worldwide. The most important aspect, i.e. the one that still seems to need improvement, is the knowledge and awareness of European producers and consumers, because of the important role devoted to producers and consumers responsibility in European policies. The same aspect is certainly important in other countries and China, but CE awareness seems to be more analysed only in China, at least based on literature.

At a micro level, only a few studies deal with the diffusion, adoption and effects of cleaner production. In particular, the research on design needs to be oriented to understand the effects of CE business and consumption models implying the selling of a service (instead of a product) or its leasing, refurbishment and remanufacturing (Ramani et al., 2010; Bakker et al., 2014). To this purpose research on motivation of consumer's purchases and replacement of still functioning products with new ones is also needed, to help designers to better match consumers choices and needs (Ramani et al., 2010). The role of scavengers and decomposers also requires a better investigation at all levels. Diverse types of scavengers and decomposers companies are well established in Europe where recycling activities are highly developed and recycled materials markets are actively operative (specially for paper, glass, steel, among others).

At the meso level the development of EIPs and the adoption of industrial symbiosis, IS, require further investigation in European countries, where most studies only focus on Kalundborg case, disregarding other options or achieved results. This would provide additional knowledge on IS to public authorities, in order to enhance the shift of existing, poorly integrated industrial areas to the principles of industrial ecology and circular economy. The role of the public sector is of paramount importance in promoting the adoption of new symbiosis initiatives as well as CE advancing over time (Lehtoranta et al., 2011).

Continuity, i.e. stability of normative framework and market opportunities, is another key feature of IS that need to be further investigated. Companies rely on the need to maintain economic profitability of their activities and investments in IS when market mechanisms (e.g. increase of prices of by-products provided by a company to another) discourage the adoption of IS. In this regard appropriate instruments rewarding positive externalities need to be tailored to provide tools to policy makers.

It should not be disregarded the need for assessing the environmental performances of IS on a life cycle basis, with regard to the upstream and downstream impacts of the entire network (Martin et al., 2015). Sokka et al. (2011) showed that by only considering direct emissions and resource use by the symbiosis network, more than the 50% of the total impacts are neglected.

Finally, at the macro level it would be extremely important to evaluate the evolution of projects, legislation, and awareness in cities, regions and overall nations. This would provide feedback information to policy makers about the soundness of the policies adopted by far.

## 5. Conclusions

The final purpose of this extensive worldwide literature review was to understand to what extent CE could be a solution to the need for reducing the environmental impacts of business-as-usual economic systems. Although the implementation of CE worldwide is still at an early stage of development, CE provides a reliable framework towards radically improving the present business model towards preventive and regenerative eco-industrial development as well as increased wellbeing based on recovered environmental integrity. However, only a limited number of countries have taken preliminary actions towards CE and a stronger commitment is still required. At both theoretical and practical levels CE is mainly rooted in environmental economics and industrial ecology, with a high emphasis on technological innovation in the form of cleaner technologies as well as on recycling rather than reuse. The latter is a key principle in CE and should be prioritized with adequate policies. Moreover, the high emphasis on increasing resource efficiency is not fully consistent with the often claimed need for decreasing resource use as well as the high reliance on non-renewable resources.

With reference to the so-called Odum and Odum's pulsing paradigm, with long time-scale oscillating waves of growth and descent, it seems evident that the same policies and strategies that apply to growth phases may not be the best options in transition and descent stages. As a consequence, CE is not an appropriate tool for growth-oriented economic systems (i.e. cannot be claimed to support further economic growth), where efficiency is not the “winning card” and the rebound effect and market competition are likely to diminish the potential benefits of increased efficiency.

Instead, in steady-state oriented economic systems as well as in a possible future descent stage of some economies worldwide, CE efficiency and environmental protection would become crucial factors to orient policies for the transition to new production and consumption patterns, capable to delay the descent and allow a smoother transition to different and more environmentally sound lifestyles and socio-economic dynamics.

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## References

Andersen, M.S., 2007. An introductory note on the environmental economics of the circular economy. Sustain. Sci. 2, 133–140.
Ayres, R.U., 1989a. Technological Transformations and Long Waves, p. 13. http://webarchive.iiasa.ac.at/Admin/PUB/Documents/RR-89-001.pdf.
Ayres, R.U., 1989b. Industrial metabolism: theory and policy. In: Ayres, R.U., Simonis, U.K. (Eds.), Industrial Metabolism: Restructuring for Sustainable Development. United Nations University Press, Tokyo.
Bai, L., Qiao, Q., Yao, Y., Guo, J., Xie, M., 2014. Insights on the development progress of national demonstration eco-industrial parks in China. J. Clean. Prod. 70, 4–14.
Bain, A., Shenoy, M., Ashton, W., Chertow, M., 2010. Industrial symbiosis and waste recovery in an Indian industrial area. Resour. Conserv. Recycl. 54, 1278–1287.
Bakker, C., Wang, F., Huisman, J., Den Hollander, M., 2014. Products that go round: exploring product life extension through design. J. Clean. Prod. 69, 10–16.
Behera, S.K., Kim, J.-H., Lee, S.-Y., Suh, S., Park, H.-S., 2012. Evolution of 'designed' industrial symbiosis networks in the Ulsan eco-industrial park: 'research and development into business' as the enabling framework. J. Clean. Prod. 29–30, 103–112.
Bilitewsky, B., 2012. The circular economy and its risks. Waste Manag. 32, 1–2.
Birat, J.-P., 2015. Life cycle assessment, resource efficiency and recycling. Metall. Res. Technol. 112 (206), 1–24.
Bonilla, S.H., Almeida, C.M.V.B., Giannetti, B.F., Huisingh, D., 2010. The roles of cleaner production in the sustainable development of modern societies: an introduction to this special issue. J. Clean. Prod. 18, 1–5.
Botsman, R., Rogers, R., 2011. What's Mine Is Yours. The Rise of Collaborative Consumption. Harpers Collins Publishers.
Boulding, K., 1966. The economy of the coming spaceship earth. In: Daly, H., Freeman, W.H. (Eds.), (1980). Economics, Ecology, Ethics: Essay towards a Steady State Economy, San Francisco.
Brown, G., Stone, L., 2007. Cleaner production in New Zealand: taking stock. J. Clean. Prod. 15, 716–728.
Brown, M.T., Ulgiati, S., 2011. Understanding the global economic crisis: a biophysical perspective. Ecol. Model. 223, 4–13.
Buttol, P., Masoni, P., Bonoli, A., Goldoni, S., Belladonna, V., Cavazzuti, C., 2007. LCA of integrated MSW management systems: case study of the Bologna district. Waste Manag. 27, 1059e1070.
Cagno, E., Trucco, P., Tardini, L., 2005. Cleaner production and profitability: analysis of 134 industrial pollution prevention (P2) project reports. J. Clean. Prod. 13, 593–605.
Capra, F., 1995. The Web of Life: a New Scientific Understanding of Living Systems. Anchor Books, New York.
Caprile, D., Ripa, M., 2014. A life cycle assessment of landfilled municipal solid waste in Argentina: the influence of waste composition on greenhouse gases emissions and other impacts. J. Environ. Account. Manag. 2 (2), 141–159.
Castellani, V., Sala, S., Mirabella, N., 2015. Beyond the throwaway society: a life cycle-based assessment of the environmental benefit of reuse. Integr. Environ. Assess. Manag. 11 (3), 373–382.
CCICED, 2008. Circular Economy Promotion Law of the People's Republic of China. Available: http://www.bjreview.com.cn/document/txt/2008-12/04/content_168428.htm (accessed 19.10.13.).
Charonis, G., 2012. Degrowth, steady state economics and the circular economy : three distinct yet increasingly converging alternative discourses to economic growth for achieving environmental sustainability and social equity. In: World Economic Association Sustainability Conference 2012. Available: http://sustainabilityconference2012.worldeconomicsassociation.org/wp-content/uploads/WEASustainabilityConference2012_Charonis_Alternative-Discourses-to-Economic-Growth.pdf (accessed 19.10.13.).
Chen, X., Geng, Y., Fujita, T., 2010. An overview of municipal solid waste management in China. Waste Manag. 30, 716–724.
Chertow, M.R., 2000. Industrial symbiosis: literature and taxonomy. Annu. Rev. Energy Environ. 25.
Chertow, M.R., 2007. Uncovering industrial symbiosis. J. Ind. Ecol. 11 (1), 11–30.
Chertow, M.R., 2012. Industrial symbiosis. Encycl. Earth. Available: http://www.eoearth.org/view/article/153824/ (accessed 09.10.13.).
Chiaroni, D., Chiesa, V., 2014. La rivoluzione possibile che va oltre il riciclo (in Italian). Available: http://www.ilsole24ore.com/art/impresa-e-territori/2014-11-04/la-rivoluzione-possibile-che-va-oltre-riciclo-114618.shtml?uuid=ABm2fAAC (accessed 22.05.15.).
Chiu, A.S.F., Geng, Y., 2004. On the industrial ecology potential in Asian developing countries. J. Clean. Prod. 12, 1037–1045.
Club of Rome, 2015. The Circular Economy and Benefits for Society, Swedish Case Study Shows Jobs and Climate as Clear Winners. Available: http://www.clubofrome.org/cms/wp-content/uploads/2015/04/Final-version-Swedish-Study-13-04-15-till-tryck-ny.pdf (accessed 22.06.15.).
Connett, P., Ercolini, R., Lo Sciuto, P., 2011. Rifiuti Zero una rivoluzione in corso. Dissensi Edizioni, ISBN 9788896643136.
Conticelli, E., Tondelli, S., 2014. Eco-industrial parks and sustainable spatial planning: a possible contradiction? Adm. Sci. 4, 331–349. http://dx.doi.org/10.3390/admsci4030331.
Costa, I., Massard, G., Agarwal, A., 2010. Waste management policies for industrial symbiosis development: case studies in European countries. J. Clean. Prod. 18, 815–822.
Coté, R.P., Cohen-Rosenthal, E., 1998. Designing eco-industrial parks: a synthesis of some experiences. J. Clean. Prod. 6 (3–4), 181–188.
Cutaia, L., Morabito, R., 2012. Ruolo della simbiosi industriale per la green economy. Energia, Ambiente e Innovazione. ENEA (in Italian), available: http://www.enea.it/it/produzione-scientifica/pdf-eai/speciale-green-economy/simbiosi-industriale.pdf (accessed 18.08.14.).
Czech, B., Daly, H.E., 2004. The steady state economy: what it is, entails, and connotes. Wildl. Soc. Bull. 32, 598–605.
Daly, H.E., 1977. The Steady-state Economy. The Sustainable Society: Implications for Limited Growth. Praeger, New York and London, pp. 107–114. Available: http://www.amalthys.com/greenpath/019steadystate.html (accessed 22.03.15.).
Daly, H.E., 2007. Ecological Economics and Sustainable Development: Selected Essays Pf Herman Daly. Edward Elgar Publishing, Cheltenham.
Davey, B., 2008. The de-growth economy and lifestyles. In: Proceedings of the First International Conference on Economic De-growth for Ecological Sustainability and Social Equity, 282–285, Paris.
Davis, G.G., Hall, J.A., 2006. In: Circular Economy Legislation, the International Experience. Executive Summary. Available: http://www.google.it/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0CCkQFjAB&url=http%3A%2F%2Fsiteresources.worldbank.org%2FINTEAPREGTOPENVIRONMENT%2FResources%2FCircularEconomy_Legal_IntExperience_ExecSummary_EN.doc&ei=C0FgVevzOKi6ygPN-YP4CQ&usg=AFQjCNGY8lIa9coTkGMoELZbYy6zHtxFNw (accessed 23.05.15.).
Delli Gatti, D., Gallegati, M., 2001. Macroeconomia: fatti, teorie, politiche. Giappichelli, Torino (in Italian).
Demaria, F., Schneider, F., Sekulova, F., Martinez-Alier, J., 2013. What is degrowth? From an activist slogan to a social movement. Environ. Values 22, 191–215.
Desrochers, P., 2004. Industrial symbiosis: the case for market coordination. J. Clean. Prod. 12, 1099–1110.
Dong, H., Geng, Y., Xi, F., Fujita, T., 2013a. Carbon footprint evaluation at industrial park level: a hybrid life cycle assessment approach. Energy Policy 57, 298–307.
Dong, L., Zhang, H., Fujita, T., Ohnishi, S., Li, H., Fujii, M., Dong, H., 2013b. Environmental and economic gains of industrial symbiosis for Chinese iron/steel industry: Kawasaki's experience and practice in Liuzhou and Jinan. J. Clean. Prod. 59, 226–238.
Dupont-Inglis, J., 2015. In: Circular Economy: All Eyes on the Juncker Commission's Next Move. Available: http://suschem.blogspot.it/2015/04/circular-economy-all-eyes-on-juncker.html (accessed 24.06.15.).
Dynamix Project, 2013. Dynamix Policy Mix Evalutation. Reducing Land Sealing in Germany. Available: http://dynamix-project.eu/sites/default/files/Land_Germany.pdf (accessed 23.08.14.).
Dynamix Project, 2014. Case Studies Report and Case Studies on Decoupling. Available: http://dynamix-project.eu/case-study-report-and-case-studies-decoupling (accessed 23.08.14.).
EC, European Commission, 1997. Review of Cleaner Production. Available: http://ec.europa.eu/environment/enveco/eco_industry/pdf/annex2.pdf (accessed 23.05.15.).
EC, Official Journal of the European Communities, L182/1. 1999. Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste.
EC, European Commission, 2010. Green Public Procurement. Available: http://ec.europa.eu/environment/gpp/pdf/brochure.pdf (accessed 08.10.13.).
EC, European Commission, 2012a. Ecodesing Your Future. How Ecodesign Can Help the Environment by Making Products Smarter. Available: http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/files/brochure_ecodesign_en.pdf (accessed 12.10.13.).
EC, European Commission, 2012b. Evaluation of the Ecodesign Directive (2009/125/EC). Available: http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/review/files/ecodesign_evaluation_report_executive_summary_en.pdf (accessed 26.09.13.).
EC, European Commission, 17/12/2012c. Manifesto for a Resource-efficient Europe. MEMO 12/989/, available: http://europa.eu/rapid/press-release_MEMO-12-989_en.htm (accessed 25.09.13.).
EC, European Commission, 2013. EU Ecolabel for Consumers. Available: http://ec.europa.eu/environment/ecolabel/eu-ecolabel-for-consumers.html (accessed 15.10.13.).

EC, European Commission, 2014a. MEMO, Questions and Answers on the Commission Communication "Towards a Circular Economy" and the Waste Targets Review. Available: http://europa.eu/rapid/press-release_MEMO-14-450_en.htm (accessed 11.07.14.).
EC, European Commission, 2014b. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Towards a Circular Economy: a Zero Waste Programme for Europe. COM, p. 398.
EC, European Commission, 2014c. Scoping Study to Identify Potential Circular Economy Actions, Priority Sectors, Material Flows and Value Chains. Available: http://www.ieep.eu/assets/1410/Circular_economy_scoping_study_-_Final_report.pdf (accessed 03.07.15.).
EESC, European Economic and Social Committee, 2014. Collaborative Consumption: New Opportunities for Consumers and Businesses on the EU Market. Available: http://www.eesc.europa.eu/?i=portal.en.press-releases.30595 (accessed 22.02.15).
Ehrenfeld, J., Gertler, N., 1997. Industrial ecology in practice. The evolution of interdependence at Kalundborg. J. Ind. Ecol. 1 (1), 67–79.
Ellen Macarthur Foundation, 2010. Services, Not Goods. Available: http://www.ellenmacarthurfoundation.org/circular-economy/circular-economy/services-not-goods (accessed 10.09.13.).
Ellen Macarthur Foundation, 2012. Towards the Circular Economy. Available: http://www.ellenmacarthurfoundation.org/business/reports (accessed 10.09.13.).
Ellen Macarthur Foundation, 2013. The Circular Model – Brief History and School of Thought. Available: http://www.ellenmacarthurfoundation.org/circular-economy/circular-economy/the-circular-model-brief-history-and-schools-of-thought (accessed 10.10.13.).
EPA, US Environmental Protection Agency, 1998. Environmental Labelling: Issues, Policies and Practices Worldwide. Available: http://www.epa.gov/oppt/epp/pubs/wwlabel3.pdf (accessed 05.05.15.).
EPA, US Environmental Protection Agency, 2013. Resource Conservation and Recovery Act. Available: http://www.epa.gov/agriculture/lrca.html (accessed 05.05.15.).
EPA, US Environmental Protection Agency, 2014. Summary of the Pollution Prevention Act. Available: http://www2.epa.gov/laws-regulations/summary-pollution-prevention-act (accessed 05.05.15.).
EPA, US Environmental Protection Agency, 2015. Economic Incentives. Available: http://yosemite.epa.gov/EE%5Cepa%5Ceed.nsf/webpages/EconomicIncentives.html (accessed 06.05.15.).
Erkman, S., 1997. Industrial ecology: an historical view. J. Clean. Prod. 5 (1–2), 1–10.
EU, 2008. Official Journal of EU, L 312, 19.11.2008. Directive 2008/98/EC of the European Parliament and of the Council of 19 november 2008 on waste and repealing certain directives. Available: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:312:0003:0030:en:PDF.
EU, 2012. The Uptake of Green Public Procurement in the EU-27. Prepared by: Centre for European Policy Studies (CEPS): Andrea Renda, Jacques Pelkmans, Christian Egenhofer, Lorna Schrefler, Giacomo Luchetta, Can Selçuki. College of Europe (Core Team), Jesus Ballesteros, Anne-Claire Zirnhelt. Available: http://ec.europa.eu/environment/gpp/pdf/CEPS-CoE-GPP%20MAIN%20REPORT.pdf (accessed 22.02.15.).
EU, 2013. Official Journal of EU, L 354/171 Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Programme to 2020 "Living well within the limits of our Planet". Available: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013D1386&from=EN (accessed 23.08.14.).
EU-ASIA, 2014. Eco-cities. Sharing European and Asian Best Practices and Experiences. Available: http://www.eu-asia.eu/publications/eco-cities/ (accessed 19.03.15.).
European Environment Agency, 2009. Municipal Waste Generation (CSI 016/WST 001). Assessment published Dec 2011, available: http://www.eea.europa.eu/data-and-maps/indicators/municipal-waste-generation/municipal-waste-generation-assessment-published-4 (accessed 29.06.15.).
European Environment Agency, 2010. The European Environment, State and Outlook 2010, Synthesis. Available: http://www.eea.europa.eu/soer/synthesis/translations/lambiente-in-europa-2014-stato/# (accessed 25.06.15.).
European Environment Agency, 2015. The European Environment State and Outlook 2015, Executive Summary. Available: http://www.eea.europa.eu/soer-2015/synthesis/report/0c-executivesummary (accessed 24.06.15.).
Europesworld, 2014. The Circular Economy Is the Basis of a New Industrial Policy. Available: http://europesworld.org/2014/06/15/the-circular-economy-is-the-basis-of-a-new-eu-industrial-policy/#.VQCon5VARdg (accessed 11.03.15.).
Fang, Y., Coté, R.P., Qin, R., 2007. Industrial sustainability in China: practice and prospects for eco-industrial development. J. Environ. Manag. 83, 315–328.
FAO, Food and Agriculture Organization, 2002. Guidelines for the Integration of Sustainable Agriculture and Rural Development. The concept of SARD, available: http://www.fao.org/docrep/w7541e/w7541e04.htm (accessed 08.08.15.).
Feng, Z., Yan, N., 2007. Putting a circular economy into practice in China. Sustain. Sci. 2, 95–101.
Figge, F., Young, W., Barkemeyer, R., 2014. Sufficiency or efficiency to achieve lower consumption and emissions? The role of rebound effect. J. Clean. Prod. 69, 216–224.
Flieg, A.-K., 2000. A Strategy towards Industrial Ecology in Developing and Newly Industrialised Countries. Available: http://www.meso-nrw.de/toolkit/Downloads/etc-11.pdf (accessed 23.05.15.).
Fresner, J., 1998. Cleaner production as a means for effective environmental management. J. Clean. Prod. 6, 171–179.
Friends of Europe, 2014. Circular Economy Scaling up Best Practices Worldwide. Available: http://www.friendsofeurope.org/media/uploads/2014/10/FoE-Report-Circul-WEB-18-08-2014-4.pdf (accessed 23.05.15.).
Frondel, M., Horbach, J., Rennings, K., 2004. End-of-Pipe or Cleaner Production? An Empirical Comparison of Environmental Innovation Decisions across OECD Countries. ZEW Discussion Papers, No. 04–82.
Frosch, R.A., 1992. Industrial ecology: a philosophical introduction. Proc. Natl. Acad. Sci. U. S. A. 89, 800–803.
Geng, Y., Coté, R.P., 2002. Scavengers and decomposers in an eco-industrial park. Int. J. Sustain. Dev. World Ecol. 9 (4), 333–340.
Geng, Y., Doberstein, B., 2008. Developing the circular economy in China: challenges and opportunities for achieving "leapfrog development". Int. J. Sustain. Dev. World Ecol. 15, 231–239.
Geng, Y., Zhu, Q., Haight, M., 2007. Planning for integrated solid waste management at the industrial park level: a case of Tianjin, China. Waste Manag. 27, 141–150.
Geng, Y., Zhang, P., Cotè, R.P., Fujita, T., 2008. Assessment of the national eco-industrial park standard for promoting industrial symbiosis in China. J. Ind. Ecol. 13, 15–26.
Geng, Y., Zhu, Q., Doberstein, B., Fujita, T., 2009. Implementing China's circular economy concept at regional level: a review of progress in Dalian, China. Waste Manag. 29, 996–1002.
Geng, Y., Zhang, P., Ulgiati, S., Sarkis, J., 2010a. Emergy analysis of an industrial park: the case of Dalian, China. Sci. Total Environ. 408, 5273–5283.
Geng, Y., Xinbei, W., Qinghua, Z., Hengxin, Z., 2010b. Regional initiatives on promoting cleaner production in China: a case of Liaoning. J. Clean. Prod. 18, 1502–1508.
Geng, Y., Tsuyoshi, F., Chen, X., 2010c. Evaluation of innovative municipal solid waste management through urban symbiosis: a case study of Kawasaki. J. Clean. Prod. 18, 993–1000.
Geng, Y., Fu, J., Sarkis, J., Xue, B., 2012. Towards a circular economy indicator system in China: an evaluation and critical analysis. J. Clean. Prod. 23, 216–224.
Geng, Y., Sarkis, J., Ulgiati, S., Zhang, P., 2013. Measuring China's circular economy. Science 339 (6127), 1526–1527.
Geng, Y., Fujita, T., Park, H.-S., Chiu, A., Huisingh, D., 2014a. Call for papers: towards post fossil carbon societies: regenerative and preventative eco-industrial development. J. Clean. Prod. 68, 4–6.
Geng, Y.Z., Xue, B., Dong, H., Fujita, T., Chiu, A., 2014b. Emergy based assessment on industrial symbiosis: a case study on Shenyang economic and technological development zone. Environ. Sci. Pollut. Res. 21, 13572–13587.
Georgescu-Roegen, N., 1971. The Entropy Low and the Economic Process. Cambridge Mass. Harward University Press.
Gibbs, D., Deutz, P., 2007. Reflections on implementing industrial ecology through eco-industrial park development. J. Clean. Prod. 15, 1683–1695.
Golinska, P., Kosacka, M., Mierzwiak, R., Werner-Lewandowska, K., 2015. Grey decision making as a tool for the classification of the sustainability level of remanufacturing companies. J. Clean. Prod. 105, 28–40.
Graedel, T.E., Allenby, B.R., 1995. Industrial Ecology. AT&T, Prentice Hall, New Jersey, pp. 8–10, 93–6.
Graedel, T.E., Allenby, B.R., 2003. Industrial Ecology, second ed. Prentice Hall, New York.
Groothuis, F., 2014. Tax Shift Is the Key to the Circular Economy and Jobs. Available: www.huffingtonpost.com/femke-groothuis/tax-shift-is-key-to-a-cir_b_6373014.html (accessed 24.06.15.).
Gwehenberger, G., Erler, B., Schnitzer, H., 2003. In: A Multi – Strategy Approach to Zero Emissions. Article Presented at Technology Foresight Summit 2003, Budapest 27–29 March 2003. United Nations Industrial Development Organization. http://www.unido.org/.
He, P., Lü, F., Zhang, H., Shao, L., 2013. Recent developments in the area of waste as a resource, with particular reference to the circular economy as a guiding principle, in waste as a resource 2013. In: Hester, R.E., Harrison, R.M. (Eds.), Issues in Environmental Science and Technology No 37. The Royal Society of Chemistry 2013, ISBN 978-1-84973-668-8.
Heeres, R.R., Vermeulen, W.J.V., De Walle, F.B., 2004. Eco-industrial park initiatives in the USA and the Netherlands: first lessons. J. Clean. Prod. 12, 985–995.
Holling, C.S., 1986. Resilience of ecosystems; local surprise and global change. In: Clark, W.C., Munn, R.E. (Eds.), Sustainable Development of the Biosphere. Cambridge University Press, Cambridge, pp. 292–317.
IES, The Institution of Environmental Sciences, 2015. The Circular Economy in Japan. Available: https://www.the-ies.org/analysis/circular-economy-japan (accessed 05.05.15.).
Iung, B., Levrat, E., 2014. Advanced maintenance services for promoting sustainability. Procedia CIRP 22, 15–22.
Jackson, M.C., 2003. Systems Thinking: Creative Holism for Managers. Wiley, p. 378. ISBN 0-470-84522-8.
Jacobsen, B.N., 2006. Industrial symbiosis in Kalundborg, Denmark; a quantitative assessment of economic and environmental aspects. J. Ind. Ecol. 10, 239–255.
Jenkins, H., 2006. Small business champions for corporate social responsibility. J. Bus. Ethics 67, 241–256.
Jewell, C., 2015. Action Agenda for a Circular Economy Released at World Resource Forum. Available: http://www.circulareconomyaustralia.com/blog/2015/6/3/action-agenda-for-a-circular-economy-released-at-world-resources-forum (accessed 02.07.15.).

Jiao, W., Boons, F., 2014. Toward a research agenda for policy intervention and facilitation to enhance industrial symbiosis based on a comprehensive literature review. J. Clean. Prod. 67, 14–25.
Kallis, G., 2011. In defence of degrowth. Ecol. Econ. 70, 873–880.
Kerschner, C., 2010. Economic degrowth vs. steady-state economy. J. Clean. Prod. 18, 544–551.
Kim, D., Powell, J.C., 2008. Comparison of eco-industrial development between the UK and Korea. Spring. Proc. Phys. 124, 443–454.
Korhonen, J., Wihersaari, M., Savolainen, I., 1999. Industrial ecology of a regional energy supply system: the case of Jyväskylä Region. J. Greener Manag. Int. 26, 57–67.
Küçüksayraç, E., Keskin, D., Brezet, H., 2015. Intermediaries and innovation support in the design for sustainability field: cases from the Netherlands, Turkey and the United Kingdom. J. Clean. Prod. 101, 38–48.
László, E., 1972. The Relevance of General Systems Theory: Papers Presented to Ludwig von Bertalanffy on his Seventieth Birthday, p. 185.
Lazarevic, D., Aoustin, E., Buclet, N., Brandt, N., 2012. Plastic waste management in the context of a European recycling society: comparing results and uncertainties in a life cycle perspective. Resour. Conserv. Recycl. 55, 246–259.
Lehtoranta, S., Nissinen, A., Mattila, T., Melanen, M., 2011. Industrial symbiosis and the policy instruments of sustainable consumption and production. J. Clean. Prod. 19, 1865–1875.
Lett, L.A., 2014. Las amenazas globales, el reciclaje de residuos y el concepto de economia circular. Riv. Argent. Microbiol. 46 (1), 1–2.
Li, H., Bao, W., Xiu, C., Zhang, Y., Xu, H., 2010. Energy conservation and circular economy in China's process industries. Energy 35, 4273–4281.
Li, N., Zhang, T., Liang, S., 2013. Reutilisation-extended material flows and circular economy in China. Waste Manag. 33, 1552–1560.
Liao, C., Li, J., 2010. Green Consumption in China and Green Marketing Options for Thule. Thesis for the Degree in Master of Science in Management, available: http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=1624842&fileOId=2435891.
Lindhqvist, T., Lidgren, K., 1990. Modeller för Förlängt producentansvar (Model for Extended Producer Responsibility). In: Ministry of the Environment, Från vaggan till graven – sex studier av varors miljöpåverkan [From the Cradle to the Grave – Six Studies of the Environmental Impacts of Products] (7–44). Ministry of the Environment, Stockholm (DS1991:9).
Liu, Y., Bai, Y., 2014. An exploration of firms' awareness and behavior of developing circular economy: an empirical research in China. Resour. Conserv. Recycl. 87, 145–152.
Liu, Q., Li, H-m., Zuo, X-l., Zhang, F-f., Wang, L., 2009. A survey and analysis on public awareness and performance for promoting circular economy in China: a case study from Tianjin. J. Clean. Prod. 17, 265–270.
Lotka, A.J., 1922. Contribution to the energetics of evolution. Natural selection as a physical principle. Proc. Natl. Acad. Sci. 8, 147–155.
Lowe, E., Moran, S., Holmes, D., 1995. A Fieldbook for the Development of Eco-industrial Parks. Report for the U.S. Environmental Protection Agency. Indigo Development International, Oakland (CA).
Mair, J., Marti, I., 2006. Social entrepreneurship research: a source of explanation, prediction, and delight. J. World Bus. 41, 36–44.
Mancini, A., 2011. Responsabilità estesa del produttore: tra riduzione e qualità del materiale raccolto (in Italian). Available: http://www.ecodallecitta.it/notizie.php?id=107193 (accessed 27.09.13.).
Manomaivibool, P., Hong, J.H., 2014. Two decades, three WEEE systems: how far did EPR evolve in Korea's resource circulation policy? Resour. Conserv. Recycl. 83, 202–212.
Marion, A., 2012. Chinese Eco-cities: the Implementation of a New Economic Model? Available: http://ecocitynotes.com/2012/06/chinese-eco-cities-new-economic-model/ (accessed 15.10.13.).
Martin, M., Svensson, N., Eklund, M., 2015. Who gets the benefits? An approach for assessing the environmental performance of industrial symbiosis. J. Clean. Prod. 98, 1–9.
Martinez-Alier, J., 2012. Environmental justice and economic degrowth: an alliance between two movements. Capital. Nat. Social. 23, 51–73.
Massard, G., Jacquat, O., Zürcher, D., 2014. International Survey on Eco-innovation Parks. Learning from Experiences on the Spatial Dimension of Eco-innovation, p. 310. Federal office for the environment and the ERANET ECO-INNOVERA, Bern. Environmental studies no. 1402.
Matete, N., Trois, C., 2008. Towards zero waste in emerging countries – a South African experience. Waste Manag. 28, 1480–1492.
Mathews, J.A., Tan, H., 2011. Progress towards a circular economy: the drivers and inhibitors of eco-industrial initiative. J. Ind. Ecol. 15, 435–457.
Mazzantini, U., 2013. La Cina divora materie prime: secondo l'ONU è il più grande consumatore mondiale. Green Report.it, available: http://www.greenreport.it/news/consumi/la-cina-divora-materie-prime-secondo-lonu-e-il-piu-grande-consumatore-mondiale/ (accessed 24.09.13.).
Mazzantini, U., 2014. Rivoluzione a Davos, il big business mondiale vuole l'economia circolare. Available: http://www.greenreport.it/news/consumi/rivoluzione-a-davos-il-big-business-mondiale-vuole-leconomia-circolare/ (accessed 10.02.14.).
Mirabella, N., Castellani, V., Sala, S., 2014. Current options for the valorization of food manufacturing waste: a review. J. Clean. Prod. 65, 28–41.
Mirata, M., Emtairah, T., 2005. Industrial symbiosis networks and the contribution to environmental innovation: the case of the Landskrona industrial symbiosis programme. J. Clean. Prod. 13, 993–1002.
Naustdalslid, J., 2014. Circular economy in China – the environmental dimension of the harmonious society. Int. J. Sustain. Dev. World Ecol. http://dx.doi.org/10.1080/13504509.2014.914599.
Ness, D., 2008. Sustainable urban infrastructure in China: towards a factor 10 improvement in resource productivity through integrated infrastructure system. Int. J. Sustain. Dev. World Ecol. 15, 288–301.
Noronha, J., 1999. Scavengers and Decomposers in an Industrial Park System: a Case Study of Burnside Industrial Park. Thesis for the Degree of Master of Environmental Studies, available: http://www.collectionscanada.gc.ca/obj/s4/f2/dsk1/tape8/PQDD_0022/MQ50081.pdf.
Nuti, F., 2010. Valutazione economica e beni ambientali, i primi passi. (in Italian). In: Ecoscienza. Available: http://www.arpa.emr.it/cms3/documenti/_cerca_doc/ecoscienza/ecoscienza2010_2/giovanetties2_10.pdf (accessed 29.08.14.).
Odum, H.T., 1988. Self organization, transformity and information. Science 242, 1132–1139, 1988.
Odum, H.T., 1996. Environmental Accounting: Emergy and Environmental Decision Making. John Wiley and Sons, New York, p. 370.
Odum, H.T., 2000. Handbook of Emergy Evaluation: a Compendium of Data for Emergy Computation Issued in a Series of Folios. Folio No.2 – Emergy of Global Processes. Center 161 for Environmental Policy, Environmental Engineering Sciences. Univ. of Florida, Gainesville, p. 16. http://www.emergysystems.org/.
Odum, H.T., Odum, E.C., 2001. A Prosperous Way Down. University Press of Colorado, Boulder, Co.
Odum, H.T., Odum, E.C., 2006. The prosperous way down. Energy 31, 21–32.
OECD Statistics, 2010. OECD Factbook 2013: Economic, Environmental and Social Statistics. Available: http://www.oecd-ilibrary.org/sites/factbook-2013-en/09/02/02/index.html;jsessionid=t2m0lu3gcdyf.x-oecd-live-02?itemId=/content/chapter/factbook-2013-71-en&_csp_=9dbcbf247d0a7eab384f33292fc60d63 (accessed 29.06.15.).
Park, J.J., Chertow, M., 2014. Establishing and testing the "reuse potential" indicator for managing waste as resources. J. Environ. Manag. 137, 45–53.
Park, H.-S., Rene, E.R., Choi, S.-M., Chiu, A.S.F., 2008. Strategies for sustainable development of industrial park in Ulsan, South Korea—from spontaneous evolution to systematic expansion of industrial symbiosis. J. Environ. Manag. 87, 1–13.
Pearce, D.W., Turner, R.K., 1989. Economics of Natural Resources and the Environment. Hemel Hempstead, Harvester Wheatsheaf, London. Italian edition 1991 by Il Mulino, Bologna.
Prendeville, S., Sanders, C., Sherry, J., Costa, F., 2014. Circular Economy: Is it Enough? Available: http://www.edcw.org/sites/default/files/resources/Circular%20Ecomomy-%20Is%20it%20enough.pdf (accessed 10.07.14.).
Preston, F., 2012. A Global Redesign? Shaping the Circular Economy. Briefing Paper. Available: http://www.chathamhouse.org/sites/default/files/public/Research/Energy%20Environment%20and%20Development/bp0312_preston.pdf (accessed 22.08.14.).
Prokop, G., Jobstmann, H., Schönbauer, A., 2011. Overview of Best Practices for Limiting Soil Sealing or Mitigating its Effects in EU-27. April 11, 2011, final report to the European Commission. Environment Agency Austria, p. 24. http://ec.europa.eu/environment/soil/sealing.htm.
Ramani, K., Ramanujan, D., Bernstein, W.Z., Zhao, F., Sutherland, J., Handwerker, C., Choi, J.-K., Kim, H., Thurston, D., 2010. Integrated sustainable life cycle design: a review. J. Mech. Des. 132, 0910041–1-091004-15.
Ramsar, 2012. The Ramsar Convention on Wetlands. Background and Context to the Development of Principles and Guidance for the Planning and Management of Urban and Peri-urban Wetlands (COP11 DR11). Available: http://www.ramsar.org/pdf/cop11/doc/cop11-doc23-e-urban.pdf (accessed 13.08.14.).
Reh, L., 2013. Process engineering in circular economy. Particuology 11, 119–133. Resource, 2015. Circular economy – State of the Nations. Available: http://www.resource-event.com/Uploads/Resource%202015%20Circular%20economy%20State%20of%20the%20Nations.pdf (accessed 24.06.15.).
Ren, Y., 2007. The circular economy in China. J. Material Cycles Waste Manag. 9, 121–129.
Ren, J., Manzardo, A., Toniolo, S., Scipioni, A., 2013. Sustainability of hydrogen supply chain. Part I: identification of critical criteria and cause-effect analysis for enhancing the sustainability using DEMATEL. Int. J. Hydrog. Energy 38, 14159–14171.
Resource, 2015. Circular Economy – State of the Nations. Available: http://www.resource-event.com/Uploads/Resource%202015%20Circular%20economy%20State%20of%20the%20Nations.pdf (accessed 03.07.15.).
Roberts, B., 2004. The application of industrial ecology principles and planning guidelines for the development of eco-industrial parks: an Australian case study. J. Clean. Prod. 12, 8–10.
Roseland, M., 1997. Dimensions of the eco-city. Cities 14 (4), 197–202.
Sakai, S., Yoshida, H., Hirai, Y., Asari, M., Takigami, H., Takahashi, S., Tomoda, K., Peeler, M.V., Wejchert, J., Schmidt-Unterseh, T., Ravazzi Douvan, A., Hathaway, R., Hylander, L.D., Fischer, C., Oh, J.G., Jinhui, L., Chi, N.C., 2011. International comparative study of 3R and waste management policy developments. J. Material Cycles Waste Manag. 13, 86–102.
Sakr, D., Baas, L., El-Haggar, S., Huisingh, D., 2011. Critical success and limiting factors for eco-industrial parks: global trends and Egyptian context. J. Clean. Prod. 19, 1158–1169.
Scharff, H., 2014. Lanfill reduction experience in The Netherlands. Waste Manag. 34, 2218–2224.
Schneider, F., Kallis, G., Martinez-Alier, J., 2010. Crisis or opportunity? Economic degrowth for social equity and ecological sustainability: introduction to this special issue. J. Clean. Prod. 18, 511–518.

Schnitzer, H., Ulgiati, S., 2007. Less bad is not good enough. J. Clean. Prod. 15, 1185–1189.
Schwarz, E.J., Steininger, K.W., 1995. The Industrial Recycling-network Enhancing Regional Development. Research Memorandum #9501. Department of Economics, University of Graz, Graz, Austria.
Schwarz, E.J., Steininger, K.W., 1997. Implementing nature's lesson: the industrial recycling network enhancing regional development. J. Clean. Prod. 5, 47–56.
Segrè, A., 2008. Elogio allo spreco (in Italian). Edizioni Missionarie Italiane, Bologna.
Senge, P.M., Smith, B., Kruschwitz, N., Laur, J., Schley, S., 2010. The Necessary Revolution: How Individuals and Organizations Are Working Together to Create a Sustainable World. Broadway Books, The Crown Publishing Group, New York, ISBN 978-0-385-51904-5, p. 406. www.crownpublishing.com.
Sevignè-Itoiz, E., Gasol, C.M., Rieradevall, J., Xavier, Gabarell, X., 2014. Environmental consequences of recycling aluminum old scrap in a global market. Resour. Conserv. Recycl. 89, 94–103.
Shah, V., 2014. The Circular Economy's Trillion-dollar Opportunity. Available: http://www.eco-business.com/news/circular-economys-trillion-dollar-opportunity/ (accessed 30.06.15.).
Shekdar, A.V., 2009. Sustainable solid waste management: an integrated approach for Asian countries. Waste Manag. 29, 1438–1448.
Sherwin, C., Evans, S., 2000. Ecodesign innovation: is "early" always "best"?. In: International Symposium on Electronics and the Environment, pp. 112–117.
Shi, H., Chertow, M., Song, Y., 2010. Developing country experience with ecoindustrial parks: a case study of the Tianjin economic-technical development in China. J. Clean. Prod. 18, 191–199.
Shi, H., Tian, J., Chen, L., 2012. China's quest for eco-industrial parks, part I, history and distinctiveness. J. Ind. Ecol. 16 (1), 8–10.
Singhal, S., Kapur, A., 2002. Industrial estate planning and management in India—an integrated approach towards industrial ecology. J. Environ. Manag. 66, 19–22.
Sokka, L., Pakarinen, S., Melanen, M., 2011. Industrial symbiosis contributing to more sustainable energy use – an example from the forest industry in Kymenlaakso, Finland. J. Clean. Prod. 19, 285–293.
Sønderskov, K.M., Daugbjerg, C., 2011. The state and consumer confidence in eco-labeling: organic labeling in Denmark, Sweden, the United Kingdom and the United States. Agric. Hum. Val. 28, 507–517.
Song, Q., Li, J., Zeng, X., 2015. Minimizing the increasing solid waste through zero waste strategy. J. Clean. Prod. 104, 199–210.
Stahel, W., 2010. The Performance Economy, second ed. Palgrave-MacMillan, London. 350 pages, ISBN 978-0-230-58466-2 (first edition 2006).
Stahel, W.R., 2013. Policy for material efficiency – sustainable taxation as a departure from a throwaway society. Phyl. Trans. R. Soc. A 371, 20110567. http//dx.doi.org/10.1098/rsta.2011.0567.
Stahel, W.R., 2014. Reuse Is the Key to the Circular Economy. Available: http://ec.europa.eu/environment/ecoap/about-eco-innovation/experts-interviews/reuse-is-the-key-to-the-circular-economy_en.htm (accessed 16.05.15.).
Stiehl, C., Hirth, T., 2012. Vom additiven Umweltschutz zur nachhaltigen Produktion. Chem. Ing. Tech. 84, 963–968.
Su, B., Heshmati, A., Geng, Y., Yu, X., 2013. A review of the circular economy in China: moving from rethoric to implementation. J. Clean. Prod. 42, 215–277.
Sustainable Business Network, 2015. Accelerating the Circular Economy in New Zealand. Available: http://sustainable.org.nz/what-we-do/transformation-areas/accelerating-the-circular-economy-in-new-zealand/ (accessed 03.07.15.).
Swanson, R.A., 2001. Assessing the Financial Benefits of Human Resource Development. Basic Books, Perseus Books Group, Cambridge, ISBN 978-0-738-20457-4, p. 198. www.basicbooks.com.
Tan, W.-L., Williams, J., Tan, T.-M., 2005. Defining the 'social' in 'social entrepreneurship': altruism and entrepreneurship. Int. Entrepreneursh. Manag. J. 1, 353–365.
Tarantini, M., Di Paolo, A., Dominici, A., Peruzzi, A., Dell'Isola, M., 2007. Linee guida per l'insediamento e la gestione di aree produttive sostenibili. ENEA, Ente per le Nuove Tecnologie, l'Energia e l'Ambiente, ISBN 88-8286-186-4.
Thomas, J.–S., Birat, J.–P., 2013. Methodologies to measure the sustainability of materials – focus on recycling aspects. Rev. Métall. 110, 3–16.
Tukker, A., 2015. Product services for a resource-efficient and circular economy – a review. J. Clean. Prod. 97, 76–91.
UNEP, 1990. Resource Efficient and Cleaner Production. Available: http://www.unep.fr/scp/cp/ (accessed 01.09.14.).
UNEP, 2011. Promotion of Eco-labelling in Latin America through Knowledge Exchange and Capacity Training. Available: http://hqweb.unep.org/south-south-cooperation/case/casedetails.aspx?csno=51 (accessed 05.05.15.).
UNEP, United Nations Environment Programme, 2013a. Resource Efficiency: Economics and Outlook for China. Available: http://www.unep.org/pdf/China_Resource_Efficiency_in_English_2013.pdf (accessed 24.09.13.).
UNEP, United Nations Environment Programme, 2013b. Metals Recycling: Opportunities, Limits and Infrastructure. http://www.unep.org/resourcepanel/Publications/MetalRecycling/tabid/106143/Default.aspx (accessed 12.08.14.).
UNEP, 2013c. Sustainable Public Procurement. A Global Review. Available: http://www.unep.org/resourceefficiency/Portals/24147/SPP_Full_Report_Dec2013_v2%20NEW%20(2).pdf (accessed 05.05.15.).
UNEP, United Nations Environment Programme, 2015. Economic Instruments. Available: http://www.unep.org/regionalseas/marinelitter/other/economics/ (accessed 07.03.15.).
UNIDO, United Nations Development Organization, 2013. Benefits of Cleaner Production. Available: http://www.unido.org/en/what-we-do/environment/resource-efficient-and-low-carbon-industrial-production/cp/benefits.html (accessed 11.10.13.).
UTS, 2015. What Will a Circular Economy Look like in Australia. Available: http://www.uts.edu.au/research-and-teaching/our-research/institute-sustainable-futures/news/what-will-circular-economy (accessed 05.05.15.).
Van Beers, D., Biswas, W.K., 2008. A regional synergy approach to energy recovery: the case of the Kwinana industrial area, Western Australia. Energy Convers. Manag. 49, 3051–3062.
Van Beers, D., Corder, G., Bossilkov, A., Van Berkel, R., 2007. Industrial symbiosis in the Australian minerals industry: the cases of Kwinana and Gladstone. J. Ind. Ecol. 11 (1), 55–72.
Van Berkel, R., 1999. Building a Cleaner World: Cleaner Production, its Role in Australia, Lessons from Overseas, and its Future Applications. John Curtin International Institute. Think Tank Meeting 2 March 1999.
Van Berkel, R., 2000. Sustainable development and cleaner production in minerals and energy production. In: Sixth International Symposium on Environmental Issues and Waste Management in Energy and Mineral Production, Calgary, Alberta, Canada, May 30 – June 2, 2000.
Van Berkel, R., 2007. Cleaner production and eco-efficiency initiatives in Western Australia 1996-2004. J. Clean. Prod. 15, 741–755.
Van Berkel, Willems, E., Lafleur, M., 1997. The relationship between cleaner production and industrial ecology. J. Ind. Ecol. 1, 51–65.
Van Berkel, R., Fujita, T., Shisuka, H., Fujii, M., 2009a. Quantitative assessment of urban and industrial symbiosis in Kawasaki, Japan. Environ. Sci. Technol. 43, 1271–1281.
Van Berkel, R., Fujita, T., Hashimoto, S., Geng, Y., 2009b. Industrial and urban symbiosis in Japan: analysis of the Eco-Town program 1997–2006. J. Environ. Manag. 90, 1544–1556.
Van Griethuysen, P., 2010. Why are we growth-addicted? The hard way towards degrowth in the involutionary western development path. J. Clean. Prod. 18, 590–595.
Van Meter, B., 2013. Collaborative Consumption : what it Means and How it Works available : http://greenopedia.com/article/collaborative-consumption-what-means-why-awesome (accessed 14.10.13.).
Veiga, L.B.E., Magrini, A., 2009. Eco-industrial park development in Rio de Janeiro, Brazil: a tool for sustainable development. J. Clean. Prod. 17, 653–661.
Veleva, V., Todorova, S., Lowitt, P., Angus, N., Neely, D., 2015. Understanding and addressing business needs and sustainability challenges: lessons from Devens eco-industrial park. J. Clean. Prod. 87, 375–384.
Von Bertalanffy, L., 1950. An outline of general system theory. Br. J. Phil. Sci. 1, 134–165.
Von Bertalanffy, L., 1968. General System Theory. G. Braziller Publ, New York, p. 295.
Wang, Z., Shi, L., Hu, D., Xu, Y., Sun, D., 2010. Pursuing sustainable industrial development through the ecoindustrial parks. Ann. N. Y. Acad. Sci. 1195, E145–E153.
Wang, H., Hashimoto, S., Yue, Q., Moriguchi, Y., Lu, Z., 2013. Decoupling analysis of four selected countries. J. Ind. Ecol. 17 (4), 618–629.
Wen, Z., Meng, X., 2015. Quantitative assessment of industrial symbiosis for the promotion of circular economy: a case study of the printed circuit boards industry in China's Suzhou new district. J. Clean. Prod. 90, 211–219.
Waughray, D., 2013. Davos 2013: Circular Economy Offers Opportunities for Latin America. The Guardian. Available: http://www.theguardian.com/sustainable-business/davos-2013-circular-economy-opportunities-latin-america (accessed 24.08.13.).
World Commission on Environment and Development, 1987. Our Common Future Available:. http://www.un-documents.net/ocf-ov.htm (accessed 05.05.15.).
WRAP, Waste and Resources Action Programme, 2011. A Methodology for Quantifying the Environmental and Economic Impacts of Reuse. Available: http://www.wrap.org.uk/sites/files/wrap/Final%20Reuse%20Method.pdf (accessed 04.07.15.).
Wrinkler, H., 2011. Closed-loop production systems – a sustainable supply chain approach. CIRP J. Manuf. Sci. Technol. 4, 243–246.
Xia, P., Yang, H., 2007. Re-reading steady-state economy: calm thinking on hot circular economy. China Popul. Resour. Environ. 17 (3), 20–23.
Yap, N.U., 2005. Towards a circular economy: progress and challenges. Green Manag. Int. 50, 11–24.
Yu, J.Q., Hills, P., Weldford, R., 2008. External producer responsibility and eco-design changes: perspectives from China. Corp. Soc. Responsib. Environ. Manag. 15, 111–124.
Yu, Y., Chen, D., Zhu, B., Hu, S., 2013. Eco-efficiency trends in China, 1978–2010: decoupling environmental pressure from economic growth. Ecol. Indic. 24, 177–184.
Yu, F., Han, F., Cui, Zhaojie, C., 2015. Evolution of industrial symbiosis in an eco-industrial park in China. J. Clean. Prod. 87, 339–347.
Yuan, Z., Bi, J., Moriguichi, Y., 2006. The circular economy; a new development strategy in China. J. Ind. Ecol. 10, 4–8.
Zaman, A.U., Lehmann, 2013. The zero waste index: a performance measurement tool for waste management systems in a "zero waste city". J. Clean. Prod. 50, 123–132.
Zerowaste Europe, 2014. Closing the Loop of Materials, Phasing Out Toxics & Emissions. Our Network, available: http://www.zerowasteeurope.eu/zw-groups-in-europe/. accessed 2270372015.

Zhang, H., Hara, K., Yabar, H., Yamaguchi, Y., Uwasu, M., Morioka, T., 2009. Comparative analysis of socio-economic and environmental performances for Chinese EIPs: case studies in Baotou, Suzhou, and Shangai. Sustain. Sci. 4, 263–279.
Zhang, D.Q., Tan, S.K., Gersberg, R.M., 2010. Municipal solid waste management in China. Waste Manag. 91, 1623–1633.
Zhang, B., Yang, S., Bi, J., 2013. Enterprises' Willingness to Adopt/Develop Cleaner Production Technologies: an Empirical Study in Changsu, China.
Zheng, H., Zhang, Y., Yang, Z., Liu, G., Su, M., Chen, B., Meng, X., Li, Y., 2013. Exploring improvement paths for eight industrial symbiosis complexes throughout the world. J. Environ. Account. Manag. 1 (3), 295–306.
Zhu, D., 2008. Background, pattern and policy of China for developing circular economy. Chin. J. Popul. Resour. Environ. 6 (4), 3–8.
Zhu, D., Wu, Y., 2007. Plan C: China's development under the scarcity of natural capital. Chin. J. Popul. Resour. Environ. 5 (3), 3–8.
Zhu, Q., Lowe, E.A., Wei, Y., Barnes, D., 2007. Industrial symbiosis in China, a case study of the Guitang group. J. Ind. Ecol. 11 (1), 31–42.
Zhu, L., Zhou, J., Cui, Z., Liu, L., 2010. A method for controlling enterprises access to an eco-industrial park. Sci. Total Environ. 408, 4817–4825.
Zhu, Q., Geng, Y., Sarkis, J., 2013. Motivating green public procurement in China: an individual level perspective. J. Environ. Manag. 126, 85–95.