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Article

Eco-Industrial Parks and Sustainable Spatial Planning: A Possible Contradiction?

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Abstract: The definition and the subsequent development of eco-industrial parks (EIPs) have been deeply based on the application of industrial ecology theory, which pays specific attention to metabolic exchanges within industrial processes to address a deep reduction of limited resource consumption and a minimization of waste production in the framework of a sustainable development approach. Despite the EIPs configurations being essentially based on the overall idea of sustainability, the problem of defining their proper location inside the territory and the consequent land use model, to minimize land consumption, have not always been central in the wide range of studies and practices concerning the EIPs. Nevertheless, the specific problem of a drastic reduction of land consumption at the EIP planning stage acquires a crucial role and, therefore, needs to be carefully assessed inside the perspective of sustainable urban development. In this framework, the paper firstly aims at facing the nontrivial relationship between the EIPs' theorizations and implementations and the reduction of land consumption by referencing specific studies and shared tools, where new developments have been favored despite the conversion and redevelopment of existing industrial parks; secondly, it focus on an Italian case study and its emblematic EIP planning processes, in order to deepen the contradictions between sustainable spatial planning and eco-industrial parks. Finally, some final conclusions will be presented, in order to integrate some main issues concerning the reduction of land consumption inside the more traditional EIP design processes.

Keywords: eco-industrial parks; industrial ecology; land consumption; urban regeneration; brownfield rehabilitation; sustainable planning

1. Introduction

As is well known, sustainable development has been defined as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" [1] (p. 8). The following debate about sustainable development has covered many issues related to different themes, such as population, agriculture and biodiversity, energy consumption, global warming, pollution and equity in access to resources, as well as urbanism and industry [2]. By mainly focusing our attention on these last two fields, if we firstly consider the relationship between sustainable development and urbanism, as already stressed at the famous "Sustainable Urban City Conference" held in Rio de Janeiro in 2000, the concept of sustainability applied to urban settings can be defined as the ability of the urban area and its region to continue to function at the quality of life levels desired by the community without restricting the options available to present and future generations and without causing adverse impacts inside and outside the urban boundary. In other words, the assumption of sustainability principles in the field of urban and spatial planning means the adoption of urban development models, which are aware of resource consumption and of the need to reduce environmental impacts [3]. In industrialized countries and mainly in Europe, this gave rise to urban regeneration, high urban densification policies and developing processes referring to the so-called "compact city" model [4]. At present, a compact city is considered as an impressive option to reduce the urban sprawl that has characterized urban development in the last century and that is currently argued to be no longer sustainable. The high soil consumption, urban congestion, rising of infrastructure costs and people's worsening health are just some of the effects due to urban sprawl [5]. Discussions about urban sprawl and the compact city model are strictly connected to land consumption, to be considered as the transformation of natural, open or agricultural land into urban land; in fact, soil is considered an even more scarce resource, which is conditioning urban and environmental sustainability [5]. Therefore, as asserted by some authors [6], it is widely accepted, in the field of land use policy, that the incessant consumption of open land demands intervention and regulation. Building upon greenfield areas is considered to be unsustainable by many planners, in particular when the regeneration or reuse of brownfield or greyfield land is possible, because it contributes to the exploitation of a non-renewable resource, namely soil, against the principle of sustainable urban planning. As some authors have stressed, soil consumption reduces the ability of nature to fulfil human requirements and, thus, impairs ecosystem services in various ways [7,8].

The problem of land consumption as a barrier to sustainable urban and spatial planning has been tackled not only by scholars and technicians, but also by politics and public administrations. In the European framework, for instance, at the EU level, many documents concerning sustainable land use planning, such as the European Landscape Convention (2000) [9], the European Spatial Development Plan (1999) [10], the Charter of European Planning (2013) [11] or the guidelines for the funding schemes of the common structural and agricultural policies, call for the reduction of land development.

At the national level, an array of different policies addressing the challenge of land consumption are being discussed in the different EU Member States. In Germany, the Netherlands and the UK, for instance, the discussion on strategies and instruments to inhibit the further growth of settlement areas is a high priority on the agenda of sustainable spatial politics.

Instead, since the 1990s, in the field of industrial production, the concepts of sustainable development and sustainability were acquired by the sciences concerning industrial production through the theorization and implementation of new and extremely innovative organizational and localizing models of industrial parks. Commonly denominated eco-industrial parks (EIPs), such industrial settlements are characterized first of all by ecological and environmental features that make it also possible to provide economic advantages [12]; therefore, they can also be considered "the next stage in the evolution of traditional manufacturing estates" [13]. As a matter of fact, unlike the traditional industrial districts, which base their aggregating model mainly on economic opportunities or simply decide to localize themselves in highly accessible areas, close to the main transport infrastructures, the eco-industrial parks call the common way of production into question by paying special attention to the management of environmental and resource issues, including energy, water and materials to meet the highest reduction of natural and non-renewable resources consumption, emissions and wastes [14]. In other words, they have been introduced as an alternative model for more sustainable industrial area planning; for this reason, it is desirable, if only from a theoretical point of view, that the implementation of eco-industrial parks will be in close relation with sustainable spatial planning principles, which are also very interested in non-renewable resources conservation, including soil, of course, and in guaranteeing a high quality of life, urban livability and ecosystem conservation, at the same time.

Actually, if we analyze the EIP theorization and implementation, we notice that the reference to sustainable principles has mainly focused on (or "been limited to") industrial processes, *i.e.*, energy and mass exchanges, rather than spatial issues, which are also crucial to ensure a sustainable spatial development and, therefore, a reduction of land consumption. One of them is certainly the proper use of land within the framework of a strong reduction of land consumption and, consequently, if and when it is more suitable to prefer greenfield developments, in order to have a more effective organization of mass and energy interchanges among firms and strong impact reductions on the surrounding areas, rather than to accept lower performance mass and energy exchanges in favor of the renewal and remediation of existing industrial areas.

Starting from these preliminary assumptions, our paper will analyze EIP theories and development processes and compare them with urban policies concerning the reduction of land consumption, which often seem to be in conflict, although they are inspired by the same overall sustainability principle. Secondly, our paper will study the Italian context and especially an Emilia-Romagna case study to stress such a tendency and to define a specific planning approach that is more careful regarding the problems concerning land consumption, in order to reconcile EIP development and sustainable spatial planning.

2. Industrial Area Planning: From the More Traditional Models to the Innovative Eco-Industrial Parks

Planning and settlement models, which affected the development of industrial areas during the last few centuries, have always taken into account the need to provide the right location for industrial sites,

by conjugating the needs of production with optimal spatial settings and then with the needs of environmental protection. Namely, urban planning has been developed during the 19th Century, mainly following the industrialization phenomenon, which has produced wide changes and transformations of urban and spatial frameworks and has determined strong criticalities in terms of urban livability, because of the relevant polarization processes of the population in urban areas.

Primarily aiming at enhancing the quality of urban life, many planners and architects thought about new models of cities where the conflict between industrial development and urban life could be solved. Howard, Tony Garnier and Le Corbusier are only a few of the most famous planners who proposed new city models, where the urban pattern is organized on the basis of a more or less strong separation between residential and industrial functions. In particular, in 1928, Le Corbusier postulated the paradigm of the separation of the different urban functions, which became an important model for planning and developing most of the European cities. As Lambert and Boons stressed [15], this idea has been widely accepted since then, and it resulted in the forerunners of the traditional industrial parks. The first industries that settled in these industrial areas were those that were not compatible at all with residential areas. Somewhat larger industries took advantage of transport facilities, such as railway connections or inland navigation channels. Gradually, in industrialized countries, an increasing share of economic activities moved from the residential area to industrial parks; agricultural areas, which often possessed high cultural-historical and natural values and which should act as a buffer zone between built-up areas, were transformed into industrial areas at a high rate [5,16].

This development was further accelerated by those municipal policies aiming at developing many industrial areas through the zoning planning model, in order to enrich their territory and local economy and also thanks to the enhancement of car transport for employees and customers and truck transport for goods.

Consequently, the impacts of this kind of land use planning have been and are today sometimes alarming; furthermore, such a development, although seemingly favorable for the enterprises in the short term, results in serious disadvantages for both the economy and the environment in the long term. As Lambert and Boons observe in the Netherlands' context [15], inefficient land use causes severe logistic problems, as it multiplies the intensity of road traffic. Besides this, the attractiveness of the landscape gradually degrades, which also undermines the climate for investments in the long term. Furthermore, as many of the new industrial parks arise somewhere in between existing residential areas, they can act as catalysts for urban sprawl. These aspects illustrate the need to adopt a more sustainable approach in both planning and managing industrial parks.

2.1. Eco-Industrial Parks Theorization as a Response to the Sustainable Planning of Industrial Areas

Until the Seventies, industrial development had followed the classical model, where economic issues linked to profit and the continuous development of new technologies were considered the only purposes. Besides, as already stressed, the related localizing model had been mainly affected by the accessibility to the main transport infrastructures and strategic hubs and tended to delocalize industrial settlements far from urban areas. Later, by facing the forecasts of a forthcoming depletion of natural resources necessary to continue to foster economic development and provide for the wellness of the entire world's population, the need to develop new settlement models of industrial parks, which can lead to sustainable development, became essential.

EIPs were born to answer these urgent priorities, thanks to their innovative nature, able to conjugate environmental targets, such as the deep reduction of emissions and resource and energy consumption, with economic goals. One of the first and most famous definitions of an eco-industrial park was formulated by Lowe, Moran and Holmes [17] as "a community of manufacturing and service businesses seeking enhanced environmental and economic performance through collaboration in the management of environmental and resources issues including energy, water and materials. By working together, the community of businesses seeks a collective benefit that is greater than the sum of the individual benefit each company would have realized if it optimized its individual interests". Coˆte´ *et al.* [18] gave a more structured definition of an eco-industrial park as "an industrial system, which conserves the natural and economic resources; reduces production, material energy, insurance and treatment costs and liabilities; improves operating efficiency, quality, worker health and public image; and provides opportunities for income generation from use and sale of wasted materials". Again, Roberts [13] said eco-industrial parks are the subjects of increased interest, as governments, business and society seek solutions for the use and recycling of waste and emissions, and Lowe [19] adds that "Components of this approach include green design of park infrastructure and plants (new or retrofitted); cleaner production, pollution prevention; energy efficiency; and inter-company partnering. An EIP also seeks benefits for neighboring communities to assure that the net impact of its development is positive".

Ultimately, EIPs have enjoyed wide attention since their first theorizations, and today, worldwide industrial planners look at them with great interest, because they are considered as a real alternative to the traditional industrial parks that are worth investing in; as a matter of fact, since the early Nineties, when the "eco-industrial park" term was coined [20], many experiments have been carried out, first in the United Stated and Canada and, later, in Europe, Asia and South Africa, as well, thus giving rise to various interesting practices [21].

Eco-industrial parks are based on sciences deeply linked to sustainability: the discipline that mainly supported the implementation of the EIP concept was industrial ecology, based on principles like energy efficiency (to be regarded as the efficient use of natural resources in order to meet human needs), closed materials loops (in terms of balancing input and output by minimizing, through re-use, the total amount of industrial material that is landfilled or lost in intermediate processes) and, above all, industrial symbiosis (processes and industries are seen as interacting systems rather than isolated components in a system of material, energy and information flows) [22]. Such approaches, mainly based on firm-to-firm exchanges, describe only a few of the many possible features of an EIP. If we consider, for instance, the Chinese Circular Economy (CE), which was introduced in 1998 as a new sustainable development strategy, which integrates cleaner production and industrial ecology in a broader system encompassing industrial firms, many more planning strategies could be identified in the EIP implementations, such as, for instance, site development preserving local natural features, recruitment of companies committed to high resource efficiency and low pollution, management to support the financial, environmental and social success of EIP companies and a strong linkage to surrounding communities through economic development, social and environmental programs [19]. In this framework, a sort of ecological planning approach begins to make its way [23] toward leading the planning of industrial areas, which goes beyond the traditional "end of pipe" idea of pollution control and tries to foster "thinking like an ecosystem" [24].

More recently, a further ecological planning approach to implement EIPs has been proposed, mainly embedded into a spatial dimension. The new perspective, which is provided by landscape ecology [12,23], thus, is focused on a "spatial pattern intertwined with processes and changes" [25], looks at the spatial dimension of ecological flows, processes and changes on the human scale of landscapes and could be applied to an environment with intensive human disturbance.

Although both of the disciplines are strongly embedded into the idea of sustainability and pay specific attention to ecological and eco-systemic issues concerning eco-industrial park development, the adoption of landscape ecology or circular economy perspectives marks an emerging awareness about the role of spatial and localizing topics for sustainable industrial area planning and design. In any case, eco-systemic factors linked to metabolic processes seem to prevail in the theories at the base of EIP implementations, not to mention the different taxonomies of eco-industrial parks proposed by some scholars of environmental sciences, which are based on the types of material exchanges [26,27] or on the different types of symbiotic relationships among firms [28–30] and the outcomes of EIP implementations on the territory.

2.2. The Eco-Industrial Parks Planning in Practice

Under a planning point of view, the main difference between an EIP and a conventional industrial area could be synthesized in a higher environmental quality layout arrangement, good services and facilities for companies and employees, added ecological and technological infrastructures and integrated site management. Such requirements are well explained in many handbooks and methodologies dedicated to the planning of eco-industrial parks, which have also more or less explicitly shown the need to pinpoint the right spatial location of EIPs with reference to the disposal and the typology of the available areas. During the first EIP theorizations, Lowe *et al.* [17] already faced the issues concerning spatial location, and therefore, they implicitly introduced the issue of land consumption by recognizing three main types of EIP sites, with their strengths and weaknesses: virgin lands (greenfield sites), currently operating industrial parks and contaminated (brownfield) sites. Although an obvious predilection for greenfields emerges, because of the attitude that they provide the best conditions to carry out all industrial ecology's strategies, the authors have dedicated specific attention to the choice of brownfield renewal and rehabilitation in the framework of virgin land preservation.

The United Nations Environment Programme (UNEP) Handbook [31] was one of the first examples of structured guidelines for the location and design of industrial areas, inspired by the principles of industrial ecology. By referring to environmental problems joined to the development of industrial areas and according to the newer environmental policies, it provides localizing, planning and designing guidelines for new or existent industrial sites, even if greenfields seem to offer particular benefits. More recently, Fernandez and Ruiz [32] have proposed a conceptual descriptive model to locate sustainable industrial areas, based on a multi-criteria evaluation in order to analyze the suitability of different areas to locate a new industrial park. Although this model could also evaluate the suitability of the existing industrial areas, it does not assess what planning policy is better to pursue between the development of new areas and the rehabilitation and renewal of existent areas. Despite the above-mentioned examples being oriented toward integrating industrial ecology principles into the sustainable planning of industrial areas anyway, the aim of reducing land consumption still remains

quite in the background. Such an outcome is clearly inferred also by considering the interesting research proposed by Schlarb [33], where the main strategies concerning eco-industrial park implementations have been analyzed and effectively synthesized in Table 1.

Table 1. The main strategies for eco-industrial park (EIP) development (data from Schlarb [33]).

Main strategy	Specific criteria
• Resource recovery, pollution prevention and cleaner production	• Elimination of wasted energy, water and materials for cost savings within and among firms.
• Integration into natural ecosystems	• Define the carrying capacity of the site, and design within those limits. • Maintain the natural areas and indigenous vegetation as much as possible. • Retain natural drainage systems and use constructed or natural wetlands to purify industrial or storm-water run-off. • Increase the density of development. • Design energy-efficient sites and buildings. • Location of companies to achieve easier servicing and industrial symbiosis.
• Industrial clustering	• Networks of manufacturers developing cooperative relationships to optimize resources by clustering along a whole value chain.
• Sustainable ("green") design	• Increased energy efficiency through facility design or rehabilitation and renewable energy technologies. • Cogeneration or collecting and using otherwise "wasted" heat from the electrical generation process. • Energy cascading, which involves using residual heat from a primary process to provide heating or cooling to a later process. • Flexible building design for multiple uses. • Water cascading.
• Anchor tenant	• Establishing an eco-industrial park around one or more primary "anchor" tenant(s) as a way to create a more definable set of possible inter-connections.
• Life cycle assessment	• Minimizing resource use by streamlining design and including reusable or recyclable materials through technological innovation, material substitution and finding alternatives to by-product disposal through exchange relationships with other firms.
• Job training	• Optimizing labor resource efficiency by emphasizing the development of joint skills training programs for local residents.
• Environmental management systems	• Providing environmental area services, such as water and sewage management, hazardous waste treatment and disposal and environmental health and safety training for employees.
• Deconstruction and demanufacturing	• Recruiting firms involved in deconstruction, demanufacturing, dematerialization and other "decomposer" activities.
• Technological innovation and continuous environmental improvement	• Continual technological and design innovations that reduce the use of hazardous inputs and outputs in production and contribute to refining waste to a sufficient quality to become an input.
• Public participation and collaboration	• Adopting community-based planning tools to build relationships and inform planning efforts.

Although the pinpointed strategies cover a wide range of scientific fields, the planning issue concerning the reduction of land consumption is not really mentioned. Such an observation was implicitly expressed by Clinton in 1999 [34], when he said, "Industrial ecologists are just beginning to notice the relationships between land use patterns, transportation systems, and dissipative resource uses. They are much less willing than planners to accept a priori the position that compact cities are good and sprawl in all its forms is bad. Planners have already engaged in these debates (which are not fully resolved)". Instead, if we think of EIPs as an innovative example of an industrial area aimed at reducing non-renewable resource consumption and waste emissions in the environment, they necessarily have to assume also the aim of limiting the consumption of virgin land. Although the aim of a strong reduction of land consumption is not clearly mentioned among the targets for the "codified" eco-industrial park implementations, by looking at the first and most famous EIPs developed all around the world (see Table 2), the option to develop eco-industrial parks on greenfield does not seem to have necessarily led to brilliant outcomes, which instead have been achieved by some existent and gradually renewed industrial sites instead. This does not mean a compact settlement or an eco-industrial park has to give up wide public spaces and green areas, innovative urban infrastructures and facilities to be compact and, therefore, sustainable; furthermore, such equipment is generally not included within the idea of land consumption.

Table 2. The first and most famous EIPs and their current situation.

Name, State and/or Country	Original Site feature	Status	Notes
Brownsville, Texas (U.S.)	Greenfield	Not an EIP	
Burnside Park, Nova Scotia (CA)	Operating, with expansion	Open	
Cape Charles, Virginia (U.S.)	Greenfield	Not an EIP	
Chattanooga, Tennessee, (U.S.)	Brownfield	Not an EIP	
First Macrolotto of Prato, Italy	Operating, converted to an EIP	Open	Spontaneous/ self-organized system
Eco-industrial Park of Devens, Massachusetts (U.S.)	Brownfield	Open	
Kalundborg, Denmark	Operating, converted to an EIP	Open	Spontaneous/ self-organized system
Parc Industriel Plaine de l'Ain (PIPA), Lyon	Operating	Open	Spontaneous/ self-organized system

The most successful examples of cooperation and mass and energy interchanges among firms, oriented toward reducing consumption and emissions, are observed in Kalundborg and the First Macrolotto of Prato, which are existent industrial sites where self-organized symbiotic processes among formerly settled firms were born and have progressively developed during the years without the provision of any site expansion to support environmental improvement programs. Otherwise, some new developments, where firm collection and their mutual exchanges were totally planned, have given disappointing outcomes. This is the case of the Brownsville pilot project, which has never achieved complete development and the outcomes of which were predetermined at the planning stage [35]. As some scholars have already observed [35–37], this seems to suggest that self-organized interchanges among firms have become a wider success than totally planned set-ups of areas and firms;

consequently, there is no contradiction between the need to pursue a strong reduction of land consumption and the need to provide the best conditions to maximize mass and energy interchanges among industrial processes and to minimize all of the negative impacts on ecosystems at the same time, because the best examples of EIPs are not directly affected by specific localization requirements.

In the following paragraph, an analysis of the Italian context is proposed to help the discussion concerning the relationship between sustainable spatial planning and EIP implementations. As a matter of fact, Italy has long since oriented toward developing and spreading sustainable industrial areas in its territory, even if with some delay with respect to other countries worldwide. At the same time, the Italian territory suffers from the significant phenomenon of land consumption, which has reached alarming levels in some regions; therefore, in the last few years, new regional policies oriented toward a strong reduction of land consumption have been developed.

3. The Development of EIPs in Italy and in the Emilia-Romagna Region and the Relationship with Land Consumption

In the years in which the first eco-industrial parks were born, in Italy, the implementation of EIPs remained a perspective, a political and industrial hope, to create the chance to renew the production process and industrial district planning. Only at the end of the last century, in 1998, did the Italian Government, by introducing the concept of eco-industrial parks, try to integrate sustainability principles in the production process. According to subsidiarity and local body autonomy principles, which began in the Seventies with the transfer of competences in the field of urban planning from the central State to the Regions, the National Government endowed the Regions with the responsibility to define criteria for locating, implementing and managing EIPs. At present, only eight Regions out of twenty have regulated this topic, providing specific laws and legislative hints; they are:

- Piemonte;
- Liguria;
- Emilia-Romagna;
- Toscana;
- Marche;
- Abruzzo;
- Puglia;
- Calabria.

Nevertheless, the idea of EIPs has gained interest among many other local bodies and authorities all over Italy, thanks to the spreading of the so-called “cluster approach”, which is peculiar to the Italian industrial sector and which finds a concrete application through the EIP model [38].

It is significant to verify what kind of planning prerequisites and localizing rules have been taken into account in the most relevant Italian EIPs developments; as a matter of fact, they could be crucial to define the most innovative planning strategies to implement eco-industrial parks in Italy.

To this end, by referring to an interesting national scale analysis led by the Ervet Agency of the Emilia-Romagna Region in 2010 and concerning the outcomes of the first EIP implementations, a map

of the most important industrial areas that are engaged in an EIP qualification process in the eight more advanced Regions has been drawn. These areas are listed in Table 3.

Table 3. Dimensional data of the 11 analyzed areas (data from the Ervet study, 2010 [38]).

NO.	Area	Region	Current extension (Ha)	Extension after expansion (Ha)	Type
1	Spip, Parma	Emilia-Romagna	133	560	Area to be expanded
2	Ponte Rizzoli, Bologna	Emilia-Romagna	46	113	Area to be expanded
3	Cairo Monte Notte, Savona	Liguria	42		Area to be completely developed
4	Carrodano, La Spezia	Liguria	4.5		Area to be completely developed
5	Brugnato, La Spezia	Liguria	7		Area with attitude to possible expansions
6	Zipa, Jesi	Marche	175	220	Area to be expanded
7	Monte San Vito, Ancona	Marche	14.4	34	Area to be expanded
8	Cherasco, Cuneo	Piemonte	3.5		Abandoned area to be rehabilitated
9	Pianvallico, Firenze	Toscana	46	57	Area to be expanded
10	Navicelli, Pisa	Toscana	74	120	Area to be expanded
11	I Macrolotto, Prato	Toscana	150		Existent and totally developed area
	Total extensions		6954	1104	

By looking at the EIPs development in the analyzed territories, it is easy to detect that, on the one hand, the specific rules and processes for the EIPs' diffusion are mainly focused on defining proper technical requirements for new industrial site development; on the other hand, planning policies mainly address expanding or regenerating the existent areas, as is stressed by the case studies collected in Table 3 (in particular, the industrial areas in grey are affected by wide expansions, which have been planned just to foster the environmental rehabilitation of the pre-existing areas). Such attitudes are mainly due to a progressive depletion of greenfields; therefore, the development of industrial sites in Italy tends to go towards the enlargement of existent industrial areas rather than new expansions. Secondly, they are conditioned by other urban and spatial planning policies constantly oriented toward ensuring environmental sustainability applied to the territory and needing, therefore, a strong limitation of urban sprawl. Consequently, the development of lesser performing EIPs under the mass and energy exchanges point of view can be expected, but actually, planning of these areas is oriented towards a possible reduction of land consumption, which is a phenomenon involving most part of the Italian territory, with higher intensity just in the more industrialized regions.

By still analyzing the eleven industrial areas, although forecasts of expansion do not involve the majority of the areas, the extent of the expansions is generally substantial; that is why we can speak about a possible and not a real reduction of land consumption: if we consider the total amount of the areas appointed to be eco-industrial parks, the planned extensions are about 160% of the existent areas;

this percentage grows to 225% if we only consider the six areas with planned expansions. This means that such expansions double the dimension of the existent areas; consequently, we can consider that land consumption is implicitly, but clearly, present, even though not very sprawling, inside the planning provisions concerning the Italian eco-industrial parks.

Finally, we conclude that the 11 best examples of Italian eco-industrial parks have shown that planning choices and economic development strategies are mainly oriented toward the renewal of the existent industrial sites rather than the development of new areas, but a general and steady expansion of existent areas is fostered, as well. Such opposing outcomes do not only affect the implementation of the EIP model. Furthermore, traditional industrial areas often tend to grow as existent areas enlarge. Therefore, land use consumption is not a phenomenon that is only due to the development of EIPs. The real issue is that the EIP model should have a greater and deeper awareness about the problem of land consumption than traditional industrial site planning. This expansion policy of industrial sites may appear further controversial if we then consider the most recent recessive trends, which have been piquing the interest of the European economy and, especially, the Italian one and which have produced many scattered abandoned industrial buildings: today, these could be an interesting option to localize new industrial firms instead.

Such contradictions could be due to a lack of national policies that define the essential principles for sustainable spatial planning to be carried out at regional and local scales. As a matter of fact, in Italy, the debate about land use policies has been developed primarily at the regional level: the National Town planning law, which regulates the general planning of the Italian territory dates to 1942, and only recently has the Italian Government proposed a new national law concerning the limitation of land use, which, however, is still under the examination of Parliament. In this framework, a deeper analysis of a specific regional context could be significant to deepen the reasons for these contradictions and to pinpoint positive synergies. The case study of the Emilia-Romagna Region has been chosen because it has already developed innovative laws and policies concerning both sustainable spatial planning policies and EIP implementations.

The Emilia-Romagna Region Case Study

As we have already seen, the Emilia-Romagna Region is one of the eight regions with its own laws and regulations concerning EIP implementations and management. Therefore, it defines and regulates the EIPs at the regional level though its Urban Planning Law n. 20/2000 [39]. According to its contents, EIPs should guarantee a higher environmental quality with respect to environmental thresholds set by law, by means of the adoption of environmental prevention and control principles and sustainability objectives. More specifically, the development of new regional EIPs or the conversion of existing industrial areas into EIPs is based on coherence with land use characteristics and the equipment of the park, with technologically well-advanced infrastructures and facilities, to be managed in an integrated way.

The Emilia-Romagna context is also an interesting example under the sustainable spatial planning point of view: as a matter of fact, again, Urban Planning Law n. 20/2000 introduced, one year before the European directive n. 42/2001 [40],the obligation to subject each plan or program concerning the environment and territory to a strategic environmental assessment (SEA). Furthermore, by considering

the land use issues, the Emilia-Romagna Region has long been involved in encouraging policies oriented toward more and more reduction of land consumption.

The same law, n. 20/2000, its revision with Law n. 6/2009 [41] and the bill concerning land consumption, which is currently under discussion, have introduced and consequently strengthened the battle against land consumption, by including the need to "plan the consumption of virgin land only when there are no other alternatives generated by the conversion, regeneration or reorganization of existent urban areas" (Law n. 6/2009, art. 2) [42] among the general aims of planning. In other words, today, in Emilia-Romagna, there is a widespread recognition that the limitation of land consumption is crucial to achieve the aims of improving the quality of life, the health of settlements and the overall sustainability of the regional spatial and environmental policies. As a matter of fact, with regards to land consumption, the Urban Planning Law assigns precise tasks to the provincial plans, which have to:

- Fix land use criteria and limits and conditions for the consumption of virgin land;
- Activate regeneration processes by the rehabilitation of abandoned areas and in order to reduce urban sprawl and virgin land consumption.

By analyzing the data concerning land consumption that has occurred in Emilia-Romagna during the first decade of the 21st Century (see Table 4), actually such aims seem to be mostly ignored. As a matter of fact, between 2001 and 2011, the increase of the regional urban areas, which are taken into account to measure the regional land consumption, has been substantial; that is, about 9.9% (the national average is about 8.8%) [42].

Table 4. Land consumption in Emilia-Romagna between 2001 and 2011, by Province (datasource: Istat).

Province	**Extension of urbanized areas (urban centers, small settlements, industrial sites)**				
	Areas extension (km^2)		Increase/ decrease (km^2)	Land consumption (Ha/day)	Variation (%)
	2001	2011	2001–2011	2001–2011	2001–2011
Bologna	285.4	328.3	+42.9	1.17	+15.0
Ferrara	158.4	168.7	+10.3	0.28	+6.5
Forl ìCesena	133.9	146.7	+12.8	0.35	+9.5
Modena	225.6	239.6	+14.09	0.38	+6.2
Parma	177.3	202.4	+25.1	0.69	+14.2
Piacenza	117.9	133.9	+16.0	0.44	+13.6
Ravenna	152.2	163.6	+11.4	0.31	+7.5
Reggio Emilia	213.8	225.2	+11.4	0.31	+5.4
Rimini	97.1	106.4	+9.3	0.26	+9.7

A not so irrelevant part of the increases of urbanized areas listed in Table 4 is due to industrial uses: the data concerning provincial industrial sites indicate diffuse and wide increases of industrial settlements, which occurred both as extensions of existent areas and as new developments (see Table 5). Fifteen percent of these areas are EIPs (see Table 6).

Table 5. Industrial settlements in Emilia-Romagna, by Province (data source: Ervet and MOAPnet (Monitoraggio Aree Produttive di Modena)).

Province	Existent areas extension (Ha)	Extension of areas expansion (Ha)	Total areas (Ha)	% of extended areas against existent areas
Bologna	5187	0	5187	0%
Ferrara	2169	1016	3185	47%
Forl ìCesena	1554	697	2251	45%
Modena	5226	1161	6387	22%
Parma	2423	365	2788	15%
Piacenza	1537	905	2442	59%
Ravenna	2718	1093	3811	40%
Reggio Emilia	3183	719	3902	23%
Rimini	820	267	1087	33%
Total	24,817	6223	31,040	25%

Table 6. Eco-industrial parks in the Emilia-Romagna Region, by Province (data source: Ervet 2010 [38]).

Province	No. of EIPs	Surface (Ha)
Bologna	5	616
Ferrara	4	399
Forl ìCesena	2	532
Modena	4	517
Parma	3	629
Piacenza	3	513
Ravenna	3	707
Reggio Emilia	3	465
Rimini	3	421
Total	30	4,799

To justify this trend, it is important to consider the regional urban policies concerning industrial sites, which are mainly developed at the provincial scale. In the provincial coordination spatial plans of the nine Provinces of Emilia-Romagna, a general trend to reduce agricultural land consumption is pursued by favoring the regeneration and the rehabilitation of abandoned areas rather than the development of new urban settlements, as addressed by the Regional Law; however, the strongest demands of the possible delocalization of existent industrial activities in more accessible areas near the main transport infrastructures has been compiled at the same time, in the name of a better rationalization of the whole existent industrial system [43].

Therefore, also in the Emilia-Romagna Region, where the urban debate concerning sustainability issues is already very advanced, the conflict between industrial and economic development and sustainable use of environmental and spatial resources is still evident. What Campbell called the

"resource conflict" [44]—that is to say the tension between the economic utility of natural resources in industrial society and their ecological utility in the natural environment—does not seem to be completely solved even with the EIPs' introduction.

4. Discussion and Conclusions

By considering what has emerged by the general dissertation concerning EIP implementations and especially by the case study analysis, some mismatch between the EIPs' features concerning the ecosystem organization of the industrial processes and the localizing and planning choices can be perceived. Nevertheless, the failures of the EIP implementations do not seem to have any relationship with this lack of synergy; they suggest new controversial issues to be addressed in order to reconcile spatial sustainability principles with the environmental sustainability of industrial processes.

The first contradicting issue consists of the fostering of an extremely innovative planning and management model of industrial areas, based on ecosystem opportunities, but developed through a still traditional planning and localizing model. As clearly emerged in the regional case study, in every provincial plan, industrial delocalization options or wide site enlargements are preferred rather than deep reconversions of existent industrial sites or fostering strategies oriented toward optimizing the existent supplies of industrial sites through the revitalization of partially or totally abandoned sites; this happens because the improvement of site accessibility, commonly considered a fundamental requirement for traditional industrial site localization, is normally preferred to the reduction of urban growth. The need to ensure good accessibility to industrial sites and, consequently, to reduce traffic congestion and air pollution in the surrounding living areas is beyond a doubt a fundamental requisite for sustainability; nevertheless, it could become a way to bypass or overlook the obligation to regenerate urbanized land before using virgin land, also in territories where land consumption is clearly restricted, as in the Emilia-Romagna Region.

Another controversial issue concerns the mismatch between the traditional model of EIPs and the real implementations of sustainable industrial districts. By still considering the theoretical models of EIPs proposed by handbooks, laws or codes dedicated to their implementation, a common trend to consider a unique type of EIP, defined by clear, well-traced boundaries and, therefore, based on a co-location approach, is noticeable in all of the mentioned international and local examples. According to this model, even if the interventions of the expansion and rehabilitation of the existent areas involved in the EIP qualification processes are more frequent than new eco-industrial park developments, soil consumption reduction remains an unreached goal, like in the described case of the Emilia-Romagna Region. Actually, eco-industrial parks can have very different configurations, without losing their main features linked to sustainable production. According to Roberts [13], there could be eco-industrial parks where industries share waste materials or dispensed energy to industries in the same or nearby locations, but also networked eco-industrial park systems where manufacturing industries and clusters spread over the territory develop synergies through networks, as well as spatial association. Chertow [37] defines five types of industrial symbiosis depending on the spatial scale of the exchange opportunities: from waste exchange in a single industrial process to exchanges among firms organized "virtually" across a broader region. The already mentioned circular economy approach also stresses this issue by basing its implementation on three main levels of action, depending on the

spatial scale of the by-product exchange cluster: the individual firm level, where higher efficiency has been reached through cleaner production, industrial ecology and ecological modernization strategies; the second level, where the main objective is to develop an eco-industrial network that will benefit both regional production systems and environmental protection; and the third level, where the aim is to develop eco-cities, eco-municipalities or eco-provinces [45]. All of these contributions call the more traditional definitions of an eco-industrial park and even industrial symbiosis and industrial ecology into question, as remarked also by Lombardi and Laybourn [46], which remove the requirement for co-location from their proposed definition of industrial symbiosis.

Another more recent phenomenon goes along with this new, more flexible point of view concerning the idea of an eco-industrial park: the greater part of the most industrialized European regions have, on the one hand, a surplus of planned or already partially developed industrial areas and, on the other hand, a fragmented, but very conspicuous, stock of disused industrial buildings and spaces, which are not affected by any pre-determined valorization programs and policies. Therefore, the very fragmented and sprawling availability of industrial sites could be concealed by an eco-industrial cluster model anyway, because the different industrial activities involved do not necessarily have to be near each other to ensure high environmental performance. Such a "dispersed" configuration may decrease the actual discrepancy between planning choices, which are followed by very long realization times, and the demands for changes expressed by economic sectors, which need to have very flexible and fast responses. Hence, today, the great attention towards new eco-industrial park planning and design shown by handbooks and methods dedicated to EIP implementations could be considered rather anachronistic.

Such considerations lead to presuming that the conflict between eco-industrial park planning and virgin land conservation can be solved, but this needs a more evolved theoretical model of EIPs, and the concomitant laws and rules for its implementation, to make it less rigid with respect to the effective interchange demands among firms and to face the localization problems under a more effective and innovative point of view. If we look at the most successful examples of EIPs, which were born by bottom-up demands (as Kalundborg and First Macrolotto of Prato have shown), an *a priori* definition of possible synergies among firms, which frequently are hypothetical, because they are not already settled in a given area, would not be an effective strategy. What instead is needed is to define a path to build trusty relationships and interchange opportunities among firms that are already settled in a given area or interested in entering into a firm's network.

Besides new theoretical models of EIP, more effective approaches to plan sustainable industrial sites, which may keep environmental and ecological spatial planning features together, could be used, helping practitioners who have to face the problem of locating and planning sustainable industrial sites all around the world. An interesting example is the already mentioned European strategic environmental assessment (SEA) [22], based on the integration of impact reduction inside land, environmental and sectorial planning tools, in order to analytically assess at the earliest phases of the industrial areas' localization and planning what is better to pursue and how, between a strong reduction of land consumption and high environmental performance in the framework of the sustainable planning of industrial sites. The SEA procedure may compare, for instance, different planning choices among new developments, the expansion or rehabilitation of existent industrial sites, taking into account the specific ecological and environmental requirements of the EIPs at the same time.

Finally, moving towards a more flexible model of clusters and more effective planning approaches is crucial also, because we have to deal with the fragmented availability of industrial lots and areas produced by fluctuating economic phases, which can offer an impressive alternative to traditional expansions and, furthermore, to new developments, which are very risky investments to be no longer carried out in a recessive framework, as many European countries still present. As a matter of fact, the effects of the economic crisis, which still persist, have created new awareness concerning the fragility and instability of our economic system: at present, the most evolved Western economies are experiencing a financial and economic stagnation phase; therefore, new substantial land use changes from natural to, even if sustainable, industrial use seems to be unacceptable; by considering the wide amount of partially operant industrial areas, the need, which however is still rather low, at least in Italy, to have new sustainable industrial sites could be widely fulfilled by the regeneration of existent areas rather than new developments. This would allow one to have a dual advantage: on the one hand, to go on to spread innovative sustainable industrial areas models; and on the other hand, to pursue sustainable land use by the effective re-use of urbanized land without compromising virgin land and ecosystems.

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Author Contributions

The authors are listed in alphabetical order; their contributions are equal.

Conflicts of Interest

The authors declare no conflict of interest.

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