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Article

Environment in Industrial Ecology, Grasping a Complex Notion for Enhancing Industrial Synergies at Territorial Scales

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Abstract: Identifying the most relevant environment related indicators and how to make them available to decision-makers are current issues. Some seek to enhance their efficiency by means of methods such as aggregations or weighting. More fundamentally, in this chapter we question how industrial ecologists appropriate the notion of environment. On the basis of multidisciplinary research, we argue that, in contexts of geographically bounded networks of social actors forging industrial synergies, environmental questions should be posed from the viewpoint of the actors. Our work might aid to operationalize the complex notion of environment in such contexts, and constitutes a call to develop anthropocentric approaches to defining environmental indications followed by appropriated indicators.

Keywords: environment; industrial ecology; collective action; territorial ecology; environmental indication

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1. Introduction

In industrial ecology, *i.e.*, the field of study focusing on the relations between industrial systems and their environments, an increasing amount of indicators and methods are proposed in order to assess consequences of those industrial systems on the environment [1]. However, policy-makers may encounter difficulties grasping the tangibility and meaning of such a wide range of indicators [1].

Is that because the environment is too complex to be understood by actors? Or rather the environmental indications (via indicators) do not meet the actors' representation of the environment? When ex-ante environmental indications are supposed to serve decision-making processes, policy-makers are required to understand such indications. Our goal here is to decrypt, on the one hand the current epistemological basis of the environmental issue in industrial ecology, and on the other hand how it should eventually be amended, so that it meets requirements of networks of social actors.

2. Environment is a Polysemous and Complex Notion

Neither environment nor nature are absolute notions. According to Descola [2], the notion of nature does not make sense in some societies. He revealed the Achuar Indians, living in equatorial Amazon, consider they have family relationship with some plants and animals. This conception is completely different than the dualistic conception nature-society that inherits Christian societies [2].

Even in modern societies, there is no consensus on a single definition of environment. According to Theys [3] one can encounter at least three distinct conceptions of the environment:

(1) objective and biocentric, *i.e.*, a nature to be protected,
(2) subjective and anthropocentric, *i.e.*, a system of relations between humans and their surroundings,
(3) technocentric, as a list of limits and problems.

Those different conceptions of environment are conceivable, indeed, because environment is not an object per se, but refers to the relation object-subject [3]. These subject and object can differ and the relation object-subject, *i.e.*, the environment, can constitute several perspectives, in substance and in time. In certain decision-making contexts, this can lead to facing different environmental perspectives, leading to different environmental indications. Yet everyone does not share the same conception of the environment and policy-makers may encounter difficulties to grasp the meaning of environmental indications (via indicators) [1]. In addition, although environmental indications can be scientifically relevant, some may be perceived as biased or irrelevant by actors [4]. As a result, when looking at a plan or a program, European Commission recently stated [5] there is no standard set of environmental criteria to be assessed.

Recently, in particular interdisciplinary contexts, researchers strove to propose semantic framing of the notion of environment [6]. They highlighted how the notion of environment, which basically may refer to the same object, can differ from a discipline to another. For instance, economics considers notably the environment as a public-consumption good, and thus is a source of (economic) problems [7]; its scarcity is caused by competing uses for environmental goods and demands for its use, that are not all satisfied [7]. This perception of the environment is clearly different than the environment perceived by inhabitants [8].

3. Environment is Inherent in Industrial Ecology

Industrial ecology is both a multi-disciplinary and recent field of study. There are some who strove to define it. Among the firsts, Robert White [9] suggested it refers to "the study of the flows of materials and energy in industrial and consumer activities, of the effect of these flows *on the environment*, and of the influences of economic, political, regulatory, and social factors on the flow, use and transformation of resources". Likewise, Seager and Theis formulated an interesting proposition, defining industrial ecology "as a field of study (or branch of science) concerned with the interrelationships of human industrial systems and *their environments*" [10]. More recently, Boons and Howard-Greville, recognizing as normal that a developing scientific field is varying in perspective and method, proposed their own definition of industrial ecology as "the study of the material and energy flows resulting from human activities. This study provides the basis for developing approaches to close cycles in such a way that *ecological impact* of these activities is minimized" [11].

One can admit that the field of industrial ecology is evolving, even turning into a multifaceted field [12]. However, environmental concern is an inherent aspect of the field. In spite of the fact that the concepts of industrial ecology were already discussed some decades before the term appeared in literature in the early 1990s [13], the field emerged, notably after the publication of "Strategies for Manufacturing" by Frosch and Gallopoulos [14]. The authors highlighted that the "traditional model of industrial activities", that are organized in linear supply-chains without recycling process, generates collateral consequences, such as ozone destruction, global warming and even the death of people. Frosch and Gallopoulos called for more efficient and integrated models in order to "reduce the impact of industry on the environment". According to Bourg [15], industrial ecology even became an important field "precisely because anthropogenic energy and material flows cause unfavorable *environmental change*". This redundant aspect is thus the core of the field of industrial ecology.

4. Contribution of Social Sciences in Industrial Ecology

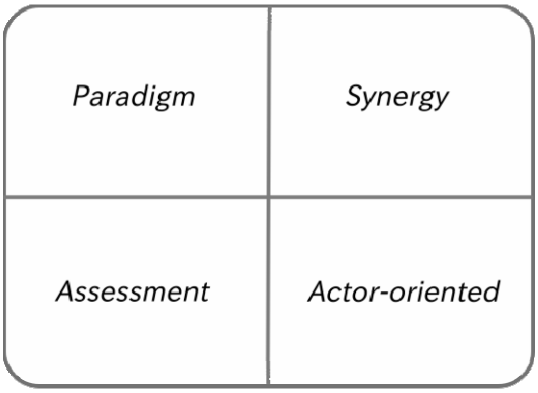
At its beginning, industrial ecology was the cup of tea of economists and engineers, such as Robert U. Ayres, Robert Frosch, Nicholas Gallopoulos. The "study of flows of materials and energy in industrial activities", according to White [9], seems to implicate human actors only indirectly. As highlighted by Boons and Howard-Grenville [11], industrial ecology benefited mostly from contributions with technological and scientific emphasis. In fact, if the main issue is *how* flows are evolving without considering *why*, the actors' contributions remain inevitably secondary [16]. But the idea that acquiring information would systematically lead to its application, was not verified by social science based research [11]. According to them, realizing industrial synergies requires considering the social context in which the synergies are supposed to occur. The consideration of social sciences in industrial ecology emerged, notably in France where the *écologie indutrielle et territoriale* (see Box 1) has come to dominate [12]. Figure 1 illustrates a schematic representation of the four representations of industrial ecology such as proposed by Bahers [12].

Chertow and Ashton [17] highlighted that indeed, industrial symbiosis does not take place when social issues are not appropriated. In fact, through industrial synergies, one can hypothesize that actors seek to enhance their situations or solve common problems [17]. We meet such kind of approach in the *collective actions* theories [18]. Thus in certain way industrial-symbiosis are kind of collective actions [19] in which actors seek to enhance their situation, to solve common purposes. Chertow and Ashton [17] concluded that "those forms of collective action cannot be engaged without interaction and development and strengthening of trust" that emerges from the sharing of values [19].

Box 1. Tentative of translation of *écologie industrielle et territoriale*.

The *écologie industrielle et territoriale* appeared in France in early 2000s [20]. It comes from a rapprochement notably between industrial ecologists and (social) geographers [21]. The latters associate the term *territoire* to a geographical area inseparable from its inhabitants [22]. This association comes from ethologists that assimilated territorial behavior of species to a territory [22].
In English, the term territory is mainly used to refer to political subdivisions of land. However, as industrial ecologists, we could refer to the ecologists' vocabulary. According to Encyclopaedia Britannica [23], a territory (in ecology) is likewise defined through a group which exhibits a territorial behavior. On that basis, we think that the description of Boons and Howard-Grenville under the label "industrial ecologies that are geographically bounded network of social actors" could fit with the term *Territorial Industrial Ecology*.

Figure 1. Fourfold viewpoint of industrial ecology, according to Bahers [12]. The paradigm part refers to a call to change linear industrial systems, towards more closed-loop ecosystems. Synergy refers to the operationalization of the paradigm, that one calls industrial-symbiosis through closed-loops of matter and energy. Assessment refers to the quantification of industrial activities. Under this label, we encompass analysis of materials and products throughout their life-cycle. The fourth part, named actor-oriented, calls another interdisciplinary field that includes social sciences into the study of industrial synergies.



To summarize, in order to facilitate industrial symbiosis, actors must share a common basis of values. As the environment is inherent in industrial ecology, these common values should concern environmental values as well. However, we saw previously that the environment is a complex notion that can be understood in different ways. For industrial ecology to effectively induce industrial symbiosis it is therefore essential that the underlying research and its reporting respect the (regionally) prevalent perceptions.

5. Use of the Notion of Environment in Industrial Ecology

As we saw previously, environmental concerns occupy a central position in industrial ecology. However, the conceptual object *environment* is to the best of our knowledge never presented nor discussed, as if it was obvious. Bearing in mind that environment is a well-defined notion, one may ask "What is the environment considered in industrial ecology?"

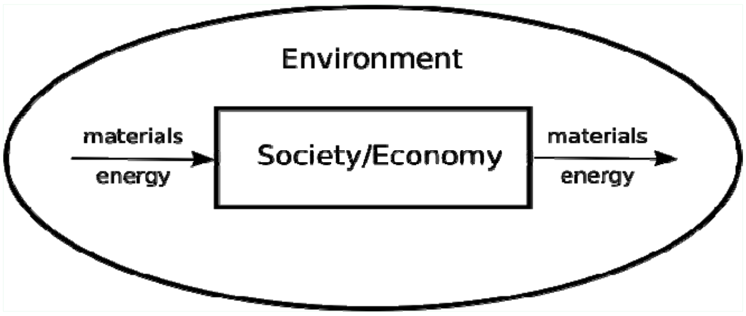
In fact, when *environment* is mentioned in industrial ecology, it is by means of an intermediate such as *impact* or *changes*, and one refers to *nature*, *biosphere*, *ecosystems* or even *resources*. Indeed, as we saw above, the environment constitutes an object of research in itself, although it is not part of the field of industrial ecology as such. In the following we will strive to unravel how the notion of environment is appropriated in industrial ecology, through the most common tools, that are material flow analysis (MFA) [24] and life-cycle assessment of products (LCA) [25].

In industrial ecology we study the functioning of industrial system and their interaction with the environment. *Environment* is then systematically explicitly mentioned, and one refers to it by means of:

- flows of matter and energy that quit industrial systems and are exchanged with the environment,
- and impacts on the environment.

The former is pretty much used in the context of MFA for instance (Figure 2), while the latter is used in the context of (LCA).

Figure 2. Schematic representation "The economy/environment system", according to [24].



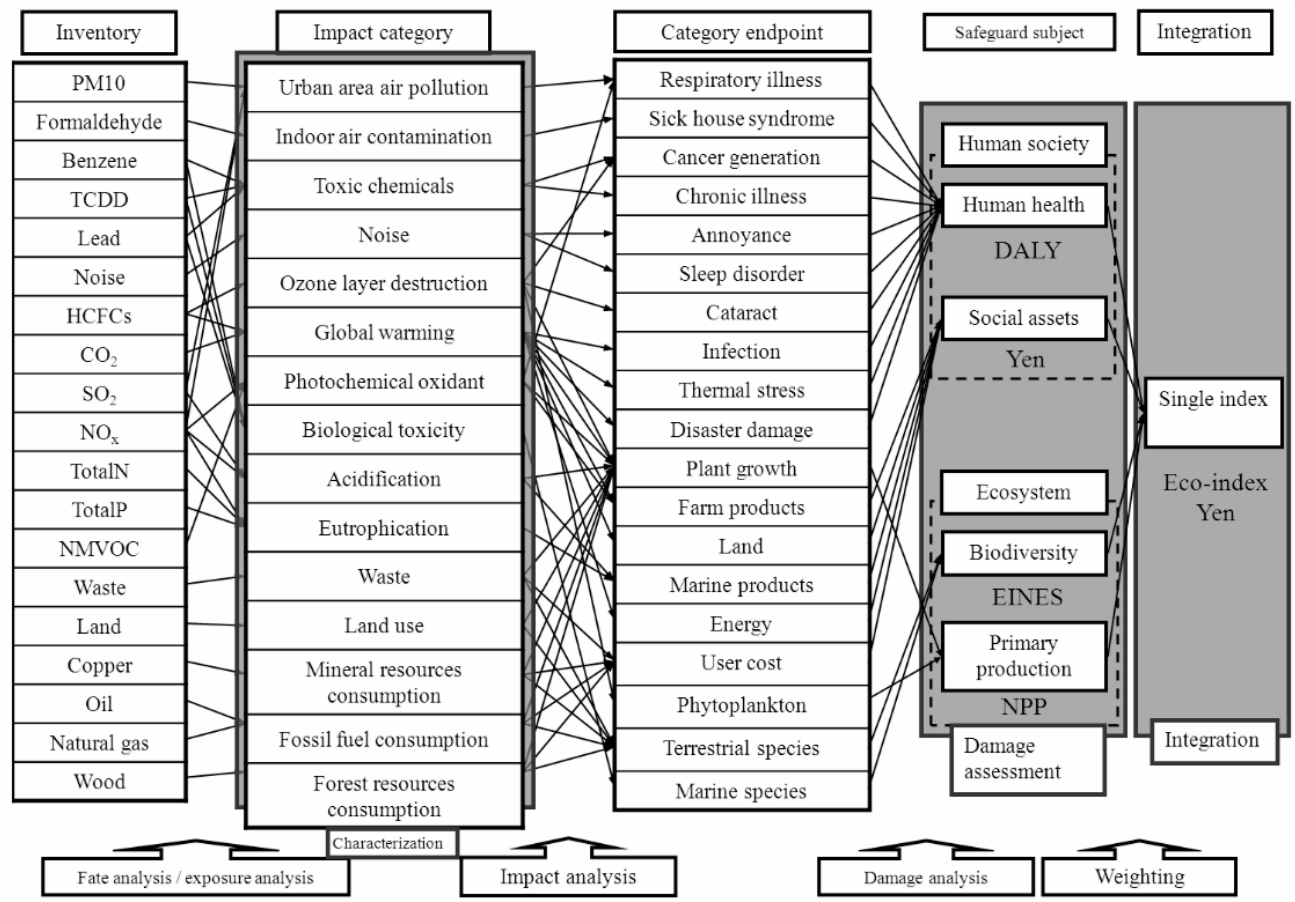
In the first approach, the subject of study is the square and the input and output arrows, but not the environment as such. In the second approach, *i.e.*, *impacts on the environment*, the *environment* should *a fortiori* be more explicitly defined. Indeed, it is not out of the scope of study, but it is part of what is to be assessed. In order to grasp how the notion is used, let us make a retrospective of the epistemological basis of life-cycle environmental impact assessment (LCIA).

When we have a look at products or services through their life-cycle, the flows of matter and energy linked to the life-cycle stages are likely to occur, in a global market, at anytime and anywhere [26]. Thus, resulting environmental changes engendered by industrial activities, potentially occur anywhere at any time and at different scales as well. These industrial and environmental characteristics, somehow, have to be treated by tools for environmental assessment, among which LCA is up to now a framework of reference.

The LCA framework was built in a way that its scope covers environmental changes "at all scale levels, including the local scale" [27]. It was said, however, that environmental impacts potentially occurring at local scales would be well treated by other analytical tools. Indeed, the way chosen to develop the *impact categories* was to start with global categories, and then to go down in scale, up to the lower scale [27]. The concept of *Area of Protection* (AoP) was created for that purpose [27]. This concept refers to "entities that we want to protect" [28] and are mainly: human health, natural environment and natural resources [28,29]. The *environmental impacts* and *damages*, or mid- and endpoints, are a web of interconnected characterization model (see Figure 3).

In the above sketched representation, most impact categories proposed refer to limits and problems, such as human health (DALY: disability-adjusted life years), damage to biodiversity (EINES: expected increase in the number of extinct species). Since LCA is designed for environmental assessment of products, practitioners may be willing to compare across impact categories, prioritizing among the indications, in order to choose the best alternative. To do that, the LCIA do not count only on natural sciences, but the pathways are based on social sciences and economics as well [29]. All those points are clear characteristics of a *technocentric environment* as described by Theys [3].

Figure 3. Outlines of the environmental mechanisms (substances-impacts-damages-weighting), according to Japanese life-cycle impact assessment method LIME2 [30].



Although the LCIA method focuses on limits and problems, it is partly based on an objective conception of the environment. According to Theys, a noticeable characteristic of such an approach is that it is difficult to determine how far the environmental mechanisms should be assessed. Those limits, indeed, are not obvious at all; for instance the second version of the LIME methodology has got five *impact categories* and three *category endpoints* more than the previous version [29]). However, this new version of the method does not suggest other "Safeguard subject" (also named "Areas of Protection" in the previous version); the environmental endpoints remain the same. Instead, new environmental mechanisms complete the whole system. This enhancement is not a technocentric feature, but a path towards a more objective estimation. In addition, a biocentric approach leads to question the scales of time and space that are the most relevant to be assessed. Actually these issues were questioned within the community working on LCA [29]. For instance, given the complexity of natural ecosystems and their interactions with different trophic levels, "only the approach addressing the population diversity level seems sufficiently mature for application in LCIA" [28].

Another example of that objective and biocentric approach, are indications about biodiversity, which is described by means of quantity of species [28]. This typically does not stem from a technocentric conception. A loss of biodiversity inherits from an objective conception, of a set of natural objects. It is another evidence of that *objective and biocentric conception*.

To conclude, the conception of the environment in industrial ecology is somehow hybrid. It presents aspects from both technocentric and biocentric approaches. While it can be scientifically relevant, a weakness of the latter is nevertheless that it may be only loosely related to what stakeholders, in the industrial ecology process, perceive as (their) environment [3].

6. Perception of Consequences

According to sociologists, people act intentionally in consideration of future consequences [31]. This fact was theorized by the economist J.R. Commons who held that people act considering their *futurity, i.e.*, the perception of the consequences of their actions. Regarding environmental consequences, Boon [32] highlighted that point, *i.e.*, humans react in response to their *perception* of environmental impacts rather than environmental impacts *per se*.

When Bourg says that "industrial ecology even became an important field precisely because anthropogenic energy and material flows cause unfavorable *environmental change*" [15], what is unfavorable and for whom? This is not about a biocentric viewpoint, but about risks run by human society. Actually it can be unfavorable for a myriad of groups ranging from communities concerned with biodiversity or climate change, to those of whom their immediate environment is at stake, e.g., local actors or inhabitants [33]. The latter are certainly concerned by global-scale consequences, but are affected in a different way. That is what we concluded in the previous section regarding the conception of the environment in industrial ecology, *i.e.*, a technocentric or a biocentric environment, can be far from what people perceive as their environment.

7. An Anthropocentrical Viewpoint for Territorial Contexts

The environment is inherent in the field of industrial ecology. It is its *raison d'être*. The environment is, nevertheless, a polysemous and complex notion that is the subject of different conceptualizations [3]. Throughout the development of tools and methods for assessing environmental consequences of industrial activities, the notion of environment has so far been approached from both technocentric and biocentric viewpoints. However, those conceptions are not obvious for people while compared to their surrounding environment.

We have seen, however, that notably the sharing of values between actors is of great importance for enhancing industrial synergies, especially in territorial contexts [34], that are akin to collective actions. In such contexts, environmental consequences that would potentially be induced by the industrial symbiosis should be revealed by means of indications that meet the environmental perspectives of the actors. In territorial contexts of industrial ecology (or *territorial industrial ecology*), *i.e.*, involving social actors (with their own representations of the environment) of geographically bounded industrial networks, environmental consequences should thus respect a conceptual framework built to represent the environment of the local actors. As in ethnoecology, we have to consider what people "know" about environmental issues [32]. For such a purpose we should have a look at the third conception of the environment Theys [3] described. In this conception, the environment is based exclusively on the relation "subject-object", in which the subjects can be individuals, societies, institutions, or even the economy-wide. According to Theys, the impacts of nature on humans, *i.e.*, object-to-subject, are to be considered insofar as humans perceive them, or their activities are concerned.

Although this subjective anthropocentric conception of the environment seems to be suitable with contexts of *territorial industrial ecology*, there would be some difficulties to operationalize it [3]. Indeed, since this anthropocentric conception can be subjective up to individuals, it may be difficult to develop a general approach to sketch environmental indications, not tuned to specific uses or contexts. Such a method should overcome interferences of different values and might base on the crossroad of different disciplines, such as anthropology, economics and geography [3].

8. Conclusions

The interdisciplinary field of research of industrial ecology is intimately related to environmental awareness by engineers, scientists and policymakers who co-defined them [3]. Meanwhile, one among the goals of industrial ecology is the enhancing of industrial symbioses, thus reducing environmental impacts. However, the actors' environmental materiality on their territory is not known *a priori*. This materiality is to be elaborated with the actors' (industrials, scientists, policymakers, inhabitants) environmental representations—that may diverge—and thus requires both interdisciplinary and anthropocentric conceptual tools and participatory approaches. Such a combination might aid to establish relevant environmental indicators prior to their assessment.

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Author Contributions

François Dumoulin is the main author of the article. Tom Wassenaar supervised the research and proofread the article. All the authors approved the final version.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Bosch, P.; Büchele, M.; Gee, D. *Environmental Indicators: Typology and Overview*; European Environment Agency: Copenhagen, Denmark, 1999; p. 19.

2. Descola, P. L'anthropologie et la question de la nature. In *L'environnement en perspective*; Abélès, M., Charles, L., Jeudy, H.-P., Kalaora, B., Eds.; L'Harmattan: Paris, France, 2000; pp. 61–83. (In French)
3. Theys, J. Trois conceptions irréductibles de l'environnement. In *Écologies urbaines*; Coutard, O., Lévy, J.-P., Eds.; Economica: Paris, France, 2010; pp. 15–38. (In French)
4. Svarstad, H.; Petersen, L.K.; Rothman, D.; Siepel, H.; Wätzold, F. Discursive biases of the environmental research framework DPSIR. *Land Use Policy* **2008**, *25*, 116–125.
5. European Commission. Report from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, on the Application and Effectiveness of the Directive on Strategic Environmental Assessment (Directive 2001/42). Available online: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52009DC0469 (accessed on 14 February 2013).
6. Morel, V.; Deboudt, P.; Deldrève, V.; Longuépée, J.; Maillefert, M.; Masson, É.; Meur-Férec, C.; Petit, O.; Zuindeau, B. Les risques environnementaux: Lectures disciplinaires et champs de recherche interdisciplinaires. In *Risque environnemental et action collective—Application aux risques industriels et d'érosion côtière dans le Pas-de-Calais*; Petit, O., Herbert, V., Eds.; Lavoisier: Paris, France, 2010; pp. 7–30.(In French)
7. Siebert, H. *Economics of the Environment. Theory and Policy*, 7th ed.; Springer-Verlag: Berlin/Heidelberg, Germany, 2008; p. 333.
8. Lolive, J. Mobilisations environnementales. In *Écologies urbaines*; Coutard, O., Lévy, J.-P., Eds.; Economica: Paris, France, 2010; pp. 276–301. (In French)
9. White, R. Preface. In *The Greening of Industrial Ecosystems*; Allenby, B., Richards, D.J., Eds.; National Academies Press: Washington, DC, USA, 1994.
10. Seager, T.P.; Theis, T.L. A uniform definition and quantitative basis for industrial ecology. *J. Clean. Prod.* **2002**, *10*, 225–235.
11. Boons, F.; Howard-Grenville, J. Introduction the social embeddedness of industrial ecology. In *The Social Embeddedness of Industrial Ecology*; Boons, F., Howard-Grenville, J., Eds.; Edward Elgar: Cheltenham, UK; Northampton, MA, USA, 2011; pp. 3–27.
12. Bahers, J.-B. *Dynamiques des filières de récupération-recyclage et écologie territoriale: L'exemple du traitement des déchets d'équipements électriques et électroniques (DEEE) en Midi-Pyrénées*; Université de Toulouse: Toulouse, France, 2012. (In French)
13. Erkman, S.; Ramaswany, R. *Applied Industrial Ecology: A New Platform for Planning Sustainable Societies*; AICRA Publishers: Bangalore, India, 2003; p. 159.
14. Frosch, R.A.; Gallopoulos, N.E. Strategies for Manufacturing. *Sci. Am.* **1989**, *261*, 144–152.
15. Bourg, D. Industrial ecology—Philosophical and political meanings. In *Perspectives on Industrial Ecology*; Bourg, D., Erkman, S., Eds.; Greenleaf Publishing: Sheffield, UK, 2003; pp. 58–61.
16. Ehrenfeld, J. A critical view on the social science contribution to industrial ecology. In *The Social Embeddedness of Industrial Ecology*; Boons, F., Howard-Greville, J., Eds.; Edward Elgar: Cheltenham, UK; Northampton, MA, USA, 2011; pp. 257–272.

17. Chertow, M.R.; Ashton, W.S. The social embeddedness of industrial symbiosis linkages in Puerto Rican industrial regions. In *The Social Embeddedness of Industrial Ecology*; Boons, F., Howard-Grenville, J., Eds.; Edward Elgar: Cheltenham, UK; Northampton, MA, USA, 2011; pp. 128–151.
18. Froger, G.; Méral, P. Des mécanismes de l'action collective aux perspectives pour les politiques d'environnement. In *Gouvernance 2. action collective et politique d'environnement*; Helbing & Lichtenhahn: Basel, Switzerland, 2002; pp. 9–24. (In French)
19. Beaurain, C.; Brullot, S. L'écologie industrielle comme processus de développement territorial: Une lecture par la proximité. *Rev. d'Économie Rég. Urbaine.* **2011**, *2*, 313–340. (In French)
20. Barles, S. Écologie Urbaine, Écologie Industrielle, Écologie Territoriale. In *Écologies urbaines*; Coutard, O., Lévy, J.-P., Eds.; Economica: Paris, France, 2010; pp. 61–83. (In French)
21. Moine, A. Le territoire comme un système complexe: Un concept opératoire pour l'aménagement et la géographie. *Espace. Geogr.* **2006**, *35*, 115–132. (In French)
22. Le Berre, M. Territoires. In *Encyclopédie de Géographie*; Bailly, A., Ferras, R., Pumain, D., Eds.; Economica: Paris, France, 1995; pp. 601–622. (In French)
23. Encyclopaedia Britannica. Territory. Available online: http://www.britannica.com/EBchecked/topic/588355/territory (accessed on 31 August 2013).
24. Eurostat. *Economy-wide Material Flow Accounts and Derived Indicators*; Office for Official Publications of the European Communities: Luxembourg, 2001; p. 85.
25. International Organization for Standardization. *Environmental Management—Life Cycle Assessment—Principles and Framework*; British Standards Institution: London, UK, 2006.
26. Guinée, J.B.; Gorrée, M.; Heijungs, R.; Huppes, G.; Kleijn, R.; de Koning, A.; van Oers, L.; Wegener Sleeswijk, A.; Suh, S.; Udo de Haes, H.A. *Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards*; Springer: Dordrecht, The Netherlands, 2002; p. 692.
27. Udo de Haes, H.A.; Jolliet, O.; Finnveden, G.; Hauschild, M.; Krewitt, W.; Müller-Wenk, R. Best available practice regarding impact categories and category indicators in life cycle impact assessment. *Int. J. Life Cycle Assess.* **1999**, *2*, 167–174.
28. European Commission. *International Reference Life Cycle Data System (ILCD) Handbook: Framework and Requirements for Life Cycle Impact Assessment Models and Indicators*, 1st ed.; Publications Office of the European Union: Luxembourg, 2010; p. 116.
29. Pennington, D.W.; Potting, J.; Finnveden, G.; Lindeijer, E.; Jolliet, O.; Rydberg, T.; Rebitzer, G. Life cycle assessment part 2: Current impact assessment practice. *Environ. Int.* **2004**, *30*, 721–739.
30. Itsubo, N.; Inaba, A. *LIME2. Life-cycle Impact Assessment Method Based on Endpoint Modeling*; Life-Cycle Assessment Society of Japan: Tokyo, Japan, 2012. Available online: http://lca-forum.org/english/ (accessed on 28 August 2013).
31. Strathman, A.; Gleicher, F.; Boninger, D.S.; Edwards, C.S. The consideration of future consequences: Weighing immediate and distant outcomes of behavior. *J. Personal. Soc. Psychol.* **1994**, *66*, 742–752.
32. Boons, F. Ecology in the social sciences. In *The Social Embeddedness of Industrial Ecology*; Boons, F., Howard-Greville, J., Eds.; Edward Elgar: Cheltenham, UK; Northampton, MA, USA, 2011; pp. 28–47.

33. Ioppolo, G.; Heijungs, R.; Cucurachi, S.; Salomone, R.; Kleijn, R. Urban Metabolism: Many Open Questions for Future Answers. In *Pathways to Environmental Sustainability: Methodologies and Experiences*; Salomone, R., Saija, G., Eds.; Springer International Publishing: Cham, Switzerland, 2014; pp. 23–32.
34. Ioppolo, G.; Saija, G.; Salomone, R. From coastal management to environmental management: The sustainable eco-tourism program for the mid-western coast of Sardinia (Italy). *Land Use Policy* **2013**, *31*, 460–471.