

Taking into account social aspects for the development of industrial ecology on a territory

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ABSTRACT

Industrial ecology appears to be a significant means of reducing carbon dioxide emissions from industry. However, beyond flow management, eco-industrial parks can also contribute to a socio-economic transition on a regional scale. Usually, multi-criteria optimization models use economic and environmental criteria in the decision-making process. This article looks at the integration of social criteria in these models, and more broadly at the issues involved in measuring the social impact of an eco-industrial park. The aim of this article is to take a different approach to social indicators, by highlighting the key success factors of an eco-industrial park, such as cooperation within a collective but also between the different scales making up the system. This work is based on bibliographical research and semi-structured interviews with stakeholders in the field. What's more, the process of developing social indicators, particularly participatory ones, seems to be a strong catalyst in the construction of relationships and their dynamics. Finally, the metric of social indicators also has its limitations, which should be considered if we are to be able to address the various issues in a systemic way and potentially envisage other ways of taking into account the social aspect of an eco-industrial park.

Keywords: Eco-industrial park, social indicators, relational dimension, co-building

1. INTRODUCTION

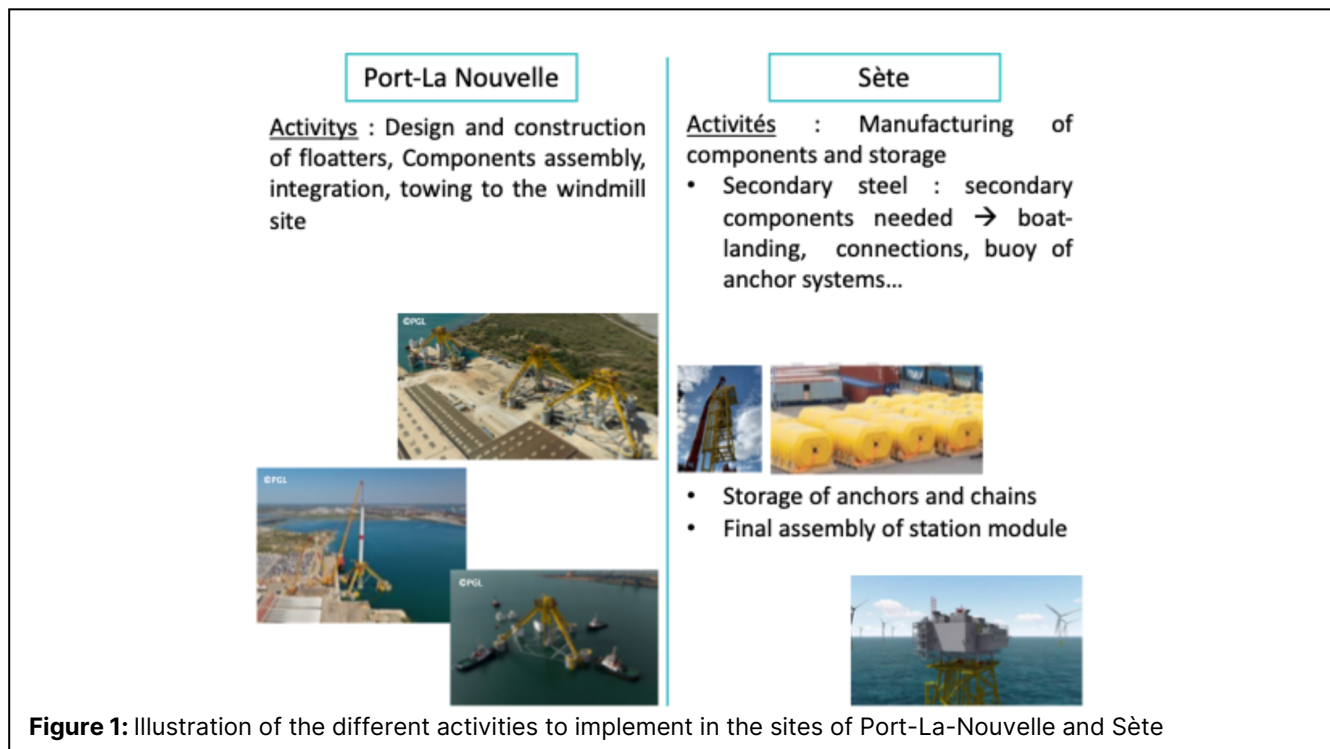
The technical, economic and environmental benefits of industrial ecology have already been demonstrated through multi-criteria optimization models [1]. Optimization models make possible to implement synergies according to economic and environmental criteria. Numerous studies have proposed several criteria such as: CO₂ emissions, Net Present Value or other economic ones, and today the reorganization of industry into eco-industrial parks appears to be a significant way of reducing carbon dioxide emissions into the atmosphere [2]. However, it appears less common to consider eco-industrial parks as an opportunity to modify socio-economic landscapes on a territorial scale.

The aim of this article is therefore to highlight the social impact that a territorial planification of cooperation can have on a territory and conversely. This impact will be assessed in a case study using social indicators such as job creation. This case study is about the development

of offshore wind energy expertise in the port of Port-La-Nouvelle in South of France with the port of Sète as a rear base. The aim is to assess the capacity of the port of Sète to host component manufacturing and anchor system storage activities, by evaluating the economic, environmental and social impacts of this approach. We will then highlight the criteria chosen and assess their relevance and limitations, particularly with regard to the social aspect.

To this end, we will define the needs and challenges of an industrial and territorial ecology approach with a relational and human point of view. Semi-directive interviews with players in the field and researchers who have studied this issue will enable us to highlight the complexity of this system and the parameters that determine its success.

In another time, we will examine the real added value of social indicators on this relational dimension, in particular by studying the way in which social indicators are implemented. Indeed, beyond the indicator itself, the



process chosen for its elaboration has a real influence on the indicator itself, as well as on the ability of users to appropriate it. We therefore need to consider which process seems most effective in enabling the use of social indicators to provide a new perspective on the context of an industrial and territorial ecology approach.

Finally, we will highlight the limits of metrics based on social indicators, and question their ability to capture a complex, multidimensional social environment [3]. We will also explore the possibility of using other concepts and tools to account for social reality, and assess their relevance to industrial and territorial ecology.

2. CASE STUDY

The proposed case study concerns the development of a regional port scheme with the port of Port-La-Nouvelle as a hub for floating offshore wind energy and the port of Sète as a rear base. The aim of the study is to assess the suitability of the port of Sète as a base for manufacturing components and storing anchoring systems (Figure 1). Various scenarios are proposed for evaluation, based on economic, environmental and social criteria.

In this article, we take one of the proposed activities as an example.

Components manufactured in Béziers need to be transported to Sète for finishing stages. Three transport scenarios are proposed:

- Road transport

- Rail transport
- River transport

The criteria presented in Table 1 will enable us to assess the impact of the three scenarios.

Table 1: Criteria chosen for the transport scenario

Economic criterion	Environmental criterion	Social criterion
C1 Transport costs	C2 Human health C3 Ecosystem quality C4 Resources	C5 Job creation

The environmental criteria were selected using the SIMAPRO life-cycle analysis software and the Eco-indicator 99 (E) V2.10 method, which uses end-point indicators. This method has been chosen because it allows for a limited number of criteria and therefore better readability of the results even if the uncertainty increases.

The social criterion was chosen in consultation with the actors of the region, which wanted to measure the contribution of this new activity in terms of employment and dynamization of their territory (attractivity).

The Electre I multicriteria decision aid methodology has been chosen to compare the different scenarios and to propose which one is the best compromise regarding the weights accorded to the criteria by the different actors.

3. RESULTS

Tables 2 and 3 show the performance matrix based on criteria reported on Table 1, with different weights affected for each player.

Table 2: Manufacturer's performance chart

Criteria	C1	C2	C3	C4	C5
Weights	3	2	1	2	2
Road	91	0,3	7,9	2,9	15
Rail	68	8,5	9,7	9,5	5
Waterway	62	6,3	9,7	8,2	10

Table 3: Local authorities' performance chart

Criteria	C1	C2	C3	C4	C5
Weights	1	1	1	1	6
Road	91	0,3	7,9	2,9	15
Rail	68	8,5	9,7	9,5	5
Waterway	62	6,3	9,7	8,2	10

The results that emerge from this study differ according to the weight attributed by the different stakeholders involved in the project.

According to ELECTRE approach and based on the weights affected using the different interviews, the best option is selected for each actor.

For manufacturers, rail transport is the preferred option, while for the general public, road transport is preferable.

From the point of view of social indicators, this method has its limits.

Firstly, in the context of a multi-criteria optimization model, the loss of qualitative information is very high. The context and its complexity are not taken into account. What's more, the job creation criterion is questionable, as it doesn't highlight the quality of the jobs and doesn't measure the real contribution to the region. We may well wonder what will happen to these jobs once the finishing activity is over.

In conclusion, this type of modeling, incorporating indicators with a social dimension, can be used to guide strategies. It also highlights the divergent viewpoints of stakeholders, thanks to the weights assigned to each criterion. This divergence of interests, objectivized by a mathematical model, can form the basis for discussion between stakeholders, and enable each to understand the stakes of the other. Nevertheless, we can't claim to take the social dimension of the situation into account. To understand social issues, we need to consider the context and its complexity. In order to emphasize and to understand the challenges into the consideration of social aspects in such territorial projects, we propose a new definition of the multi-actor compound of territorial projects.

4. KEY FACTORS FOR ECO-INDUSTRIAL PARKS

Given the limitations of the above case study, we turned our attention to the needs and challenges of an eco-industrial park in the context of trying to imagine new synergies to enhance the attractiveness of a territory. Figure 2 shows the representation of the structure of an eco-industrial park with this multi stakeholder point of view.

This representation was drawn up on the basis of interviews with two consultancies specializing in industrial and territorial ecology, as well as with 5 industrial and territorial ecology coordinators employed by local authorities.

This representation reveals a complex, multidimensional system with 3 different strata:

- The operational level: made up of manufacturers and their internal ecosystems.
- Tactical level: the park and its key players (local community members, industrialists, park managers and institutions).
- Strategic level: with a more macro-systemic vision (politicians and external stakeholders).

It's interesting to note that some players belong to different scales, both tactical and strategic. For example, a farmer may generate flows that will feed the park. They will therefore be involved in the system, while at the same time having an activity outside the park. The aim of this diagram is to highlight the diversity of players with potentially divergent interests who are brought into contact with each other.

Following this observation, we asked ourselves what ingredients would enable this structure to operate on a good way.

Kalundborg is Europe's benchmark industrial ecology park. The success of this park seems to be linked, among other things, to good communication and the implementation of collaborative relationships between players [4]. What's more, following interviews with one employee of a private company, two park managers and five project managers, it seems obvious that it's socio-economic, human and organizational factors that either block or enable an industrial and territorial ecology approach to develop [5].

Figure 3 summarizes the keys to success identified by the players in the field, according to the park's life stage.

During the reflection phase, it became clear that a detailed analysis of the area was essential. This enables us to determine whether the area is economically and demographically dynamic enough to make such a project viable. The job market and local political will are also key factors.



Figure 2: Representation of an eco-industrial park as a multi-stakeholder system

In the start-up phase, the third-party player appeared to be a mainstay.

In the sustainability phase, the trio of communication, trust and cooperation is the key to a healthy collective. In fact, these 3 elements are essential at all stages of the process, and not just during the sustainment phase.

5. SOCIAL INDICATORS HELPFUL FOR ECO-INDUSTRIAL PARKS

Having highlighted the key social aspects that enable an eco-park to function, it seems worthwhile to examine the relevance of social indicators as a tool for steering such initiatives.

Social indicators can be approached from different angles. They can be used as external communication tools, evaluation and management tools, decision-making tools or impact measurement tools.

One of the angles chosen in this article concerns the notion of performative social sustainability indicators. These are indicators that raise the ambitious question “what kind of world do we want to create?” [3]. The performative approach allows us to adopt a “real relational orientation towards the causes and conditions that shape outcomes.”

This approach aims to question the system, the way

it works, as well as highlighting its dysfunctions. For example, this type of indicator can question the potential presence of a space for the expression of divergent points of view.

In addition, the previous chapter highlighted the importance of relationships within a collective, and in particular the need to build a climate of trust and cooperation led by a third-party actor who will be able to animate the industrial and territorial ecology approach throughout the life of the park. It therefore seems essential to pay particular attention to the stakeholders involved in this approach, and to give them the space to express their needs and interests. The method used to construct social indicators plays a decisive role in this process.

Indeed, a constructivist perception of social indicators makes it possible to involve eco-park stakeholders in the process. This involves understanding how individuals have constructed their vision of the world, and enables a more refined approach to the complexity of situations and therefore potential dysfunctions [6].

It turns out that a constructivist vision encourages the implementation of indicators via participatory processes that will enable stakeholders to appropriate these tools and perceive the benefits of using them. However, this approach involves qualitative methods such as interviews and narratives, which can be time-consuming to process.

Thinking	Launch	Sustainability
Area's economic structure	Third-party actor	Communication
Area's attractiveness	Relational skills of the third-party actor	Cooperation
Available natural resources	Event organisation	Trust
Local political determination	Involving manufacturers in the process	Economic viability of companies
Social acceptability	Project communication to the public	Taking risks
Grants	Grants	Ethics and responsibilities

Figure 3: Field analysis of keys to success

6. DISCUSSION

It seems that social indicators can bring real added value to the management of industrial and territorial ecology initiatives. They can give an account of a process and its malfunctions, and thus enable the implementation of corrective actions with the aim of developing the trust and cooperation essential to the smooth running of the system. By way of example, we can propose park-wide indicators such as: the composition of governance bodies, the organization and frequency of informal exchanges, the presence of a third-party actor, the existence of collective mediation, and the presence of rules for preserving the confidentiality of strategic data [7]. These indicators are intended to measure the collective dynamic and assess the framework conducive to secure exchanges enabling trust and cooperation.

However, beyond the mere proposal of indicators, their development process seems to be the most impactful contribution. Indeed, the inclusion of stakeholders in their construction generates exchanges that encourage the expression of each party's issues. This space for dialogue is itself a creator of the collective: "The dialogue process must be seen as much more than a selection of indicators. Above all, it creates an opportunity for collective learning and debate between stakeholders, enabling them to perceive the range of issues at stake, and to learn what is important to others, and why." This iterative process of discussion, revision, and validation of indicators not only refines the assessment tools but also

strengthens relationships among actors, promoting a culture of transparency, cooperation, and shared governance.

Industrial and territorial ecology can thus be seen as a means of "providing a technical, organizational, or economic response to a challenge felt by the players involved (public and private). Industrial Ecology is therefore no longer an objective in itself (as has often been the case during the many experiments carried out in France), but it constitutes an innovative solution to resolve a problem relating to the management of waste, a resource, energy production, or even the economic development of the territory" [8]. The contextualization of these indicators within the framework of industrial ecology implies that their impact extends beyond operational efficiency and includes socio-economic resilience. By adopting this perspective, stakeholders can integrate social sustainability considerations into their strategies, ensuring that industrial symbiosis initiatives align with broader societal values.

Nevertheless, indicators generate "a simplification of complex social realities into abbreviated symbols for easy communication." This simplification can facilitate the implementation of rather top-down forms of governance, which will focus their attention on the consumer and the market and turn away from questions about the social sustainability of the system such as "worker well-being, industrial equity, and engaged, positive relationships with external communities." The risk of reductionism highlights the need for reflexivity in indicator design. If indicators merely serve to rationalize existing power structures or validate pre-established narratives, they

may obscure deeper systemic issues and reinforce inequitable dynamics.

The political nature of the indicator then needs to be questioned, as claiming that it only describes and analyzes is a mistake. An indicator is a choice, a choice to make certain realities visible and others invisible. It is important to clearly identify the intention behind the choice of indicators and to iteratively question their meaning and objectives. This vigilance is a way of shedding light on manipulative commercial practices, known as Greenwashing. Indeed, isn't taking social issues into account a way for industries to justify themselves and show that they are "repairing," thereby feeding the myth of sustainable development? If social indicators are merely used as a performative mechanism rather than a genuine tool for progress, they risk being reduced to symbolic gestures rather than catalysts for substantive change.

Furthermore, the integration of social indicators into industrial and territorial ecology can serve as a bridge between quantitative and qualitative assessment frameworks. Traditional environmental and economic models rely heavily on measurable data, but social dimensions require interpretive approaches that capture the nuances of human interactions, trust, and collaboration. Thus, a hybrid methodology that combines quantitative metrics with qualitative insights is necessary to ensure a holistic understanding of industrial ecosystems. This would enable a more inclusive evaluation process that incorporates the lived experiences of various stakeholders.

This study constitutes a key step in our process of developing a generic methodology to design and optimize flows in eco-industrial parks. Indeed, when taking into account several criteria in an optimization model, environmental and economic aspects are the most commonly used and the most easily quantified. The social criterion, however, is more important at a territorial scale and can vary significantly depending on the different actors involved. This study shows which criteria can be chosen and emphasizes the need to conduct preliminary interviews before formulating the problem. Engaging with stakeholders early in the process ensures that the indicators reflect the diversity of perspectives, allowing for a co-built and contextually relevant problem formulation.

Ultimately, the development of social indicators in industrial and territorial ecology is not merely an exercise in measurement but a fundamental practice of participatory governance. As industry and policymakers seek to balance ecological imperatives with economic viability, the social dimension must not be relegated to the background. The success of eco-industrial initiatives depends on the extent to which they integrate social trust, cooperation, and equity into their core frameworks. By fostering inclusive dialogue, continuously refining indicators, and ensuring their alignment with real-world social dynamics, we can create industrial ecosystems that are not

only efficient and sustainable but also just and resilient.

7. CONCLUSION AND PERSPECTIVES

An eco-industrial park cannot function without particular attention to the links between the various players. Communication, trust and cooperation are the foundations of an effective collective. Social indicators can be used to assess the parameters conducive to this type of climate. We have also found that their participative elaboration has a strong potential to transform the collective.

Ultimately, social indicators in the context of industrial and territorial ecology raise questions about the management of common goods within a territory. The governance of the commons can be approached in ways other than metrics. Elinor Ostrom's work sets out fundamental principles for the management of common goods [9]. Moreover, the notion of principles and values [10] can also be seen as an alternative to social indicators. The idea here is to focus on the collective's values, what it wishes to defend and the principles that will flow from them.

These different avenues of reflection lead the collective, in our case an eco-park, to question the social impact it wishes to have on a micro, meso and macro scale.

In conclusion, this reflection on social indicators highlights a profound question: what impact do we wish to have on the world?

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