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INDUSTRIAL ECOLOGY, AN INNOVATIVE APPROACH SERVING SPATIAL PLANNING: THE EXAMPLE OF THE TOOL PRESTEO© (A PROGRAM TO RESEARCH SYNERGIES ON A TERRITORY)

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Summary: Industrial ecology is an interdisciplinary framework for designing and operating industrial systems as living systems interdependent with natural systems. This paper presents industrial ecology and its relevant territorial echoes. Our goal is to take advantage of these through the development of PRESTEO and the exploration of the cross-over between industrial ecology and social sciences such as spatial planning and territorial intelligence.

Keywords: industrial ecology, territory, territorial metabolism, spatial planning, sustainable development, tool

Mots clés : écologie industrielle, territoire, métabolisme territorial, aménagement, développement durable, outil.

Industrial Ecology, an Innovative Approach Serving Spatial Planning: the Example of the Tool PRESTEO© (A Program to Research Synergies on a Territory)

This paper aims at presenting the researches conducted by the company “Systèmes Durables” and the “Université de Toulouse II – Le Mirail” in the field of Industrial Ecology and Territorial Sciences. Industrial ecology is an interdisciplinary framework for designing and operating industrial systems as living systems interdependent with natural systems. The word 'industrial' does not only refer to industrial complexes but more generally to how humans use natural resources in the production of goods and services. This article deals with the genesis of the concept of industrial ecology and with how industrial ecology leads to the central concept of territory. Then it focuses on two particular means offered by industrial ecology that fits territorial needs. A conclusion and perspectives of future works end this paper.

1 GENESIS OF THE INDUSTRIAL ECOLOGY CONCEPT

One of the central principles of industrial ecology is the view that societal and technological systems are bounded within the biosphere, and do not exist outside of it. Ecology is used as a metaphor due to the observation that natural systems reuse materials and have a largely closed loop cycling of nutrients. Industrial ecology approaches problems with the hypothesis that by using similar principles as natural systems, industrial systems can be improved to reduce their impact on the natural environment as well. If individual industrial ecology acts had always been practiced as a result of common sense decisions, in the 1970s; a conceptualization of industrial ecology started to emerge. Erkman (Erkman, 1997) helps us to understand the construction of this notion during the last 40 years. This author describes the most important movements he noticed in his historical exploration of industrial ecology.

1.1 The 70s original soup

A first boiling point happens in the 1970s during which a few approaches developed concurrently and rather independently. In the theoretical field, systems ecologists were naturally among the first ones to perceive industrial systems as ecosystems. Studies of biogeochemical cycles, of regulation and interaction mechanisms with biosphere could clearly be pursued on these particular sets of living beings. In a more public intellectual field, the 1972 United Nations Conference on Human Environment started stimulating various organizations and persons. Among them was Robert Frosh, then a collaborator of United Nations Environment Program (UNEP) director. The main concerns here were practical and society oriented such as waste management, pollution control and material values. During these years natural world became a preoccupation and a topic of discussion. Coupling the environmental management questions of UNEP to this ambient context turned also into a path to industrial ecology.

The last significant movement of the 1970s happened in Japan. It had a very pragmatic and economy driven approach. Alerted by the huge cost of industrialization on the environment, the Ministry of International Trade and Industry (MITI), set up in the late 1960s an independent group to tackle this problem. Gathering experts of various domains, including consumer organization representatives, the mission was clearly to come up with alternatives to an economy dependant on physical resources. One main idea was to further develop the role of information and knowledge as wealth. A working group entitled “industry-ecology” was created after a first global state of the art. Though considered intellectually interesting the results of this group were not extended after 1973. Nevertheless basis of ecology were retained by MITI, with special emphasis on energy. Japan started big technological projects in the field of renewable energy. It was also the start of technological dynamics as grounding of Japanese approach.

1.2 The crystallization into industrial ecology

In the 1980s another, yet isolated, movement of industrial ecology occurred in Belgium. Inspired after *The Limits to Growth* (the Medows report to the Club of Rome), a group of six individuals with mixed backgrounds (biology, chemistry, economy) conducted a free-time collective work called *L’Écosystème Belgique*. Their thinking was published under the title *Essai d’Écologie industrielle*. One author said that this name had naturally inferred from their work. Their approach was to create a representation of Belgian economy in which the usual

abstract money would be abandoned at the profit of materials and energy flows. Besides this the study was relying on the usual industrial production statistics. Very important observations were made by the team. First one regarded the 'disconnection' that had been introduced between potentially complementary or contiguous economic sectors. The typical example was steel production whose exportation outside Belgium was strongly encouraged without consideration for building more elaborated objects that could relate to metal-construction industry. It then became extremely dependant of the global market and did not serve domestic industry demands. A second case dealt with the evolution of agriculture. It had quitted the traditional model of integrated farming and feeding where harvest by-products fed animals whose dejections in return nurtured soils. In this pattern animal headcount keeps low, opposite to modern agriculture configuration. Authors observed that 'modernization' had disconnected farming and feeding, having livestock fed by industrial products prepared from abroad raw materials, whilst handling of the excrements becoming a waste management issue due to their accumulation at a single farm. The authors pointed that 'raw materials' and 'waste' were significant when circulation of materials in a system was not closed. Finally the authors concluded that the economic opening of Belgium had come in company of the ecological opening of physical resources cycles, had led to huge energy consumption mainly due to its inner organization and had caused pollution as a consequence of the new materials circulation. Unfortunately in the 1980s there was no interest in the messages of this group that later split apart.

The revival of the concept of industrial ecology happened in the early 1990s through two seniors of General Motors, Robert Frosh and Nicholas Gallopoulos. They are often referred to as the fathers of modern industrial ecology. In 1989 they were asked by the magazine Scientific American to contribute to a special issue on 'Planet Earth' with an article on manufacturing. They looked at several thoughts about the consequences of technology on industry and society, keeping unsatisfied (Gallopoulos, 2006). They wanted to go beyond the concept of 'industrial metabolism' of Robert Ayres that was not taking into account that "each process and network of processes must be viewed as a dependant and interrelated part of a large whole" (Frosh, Gallopoulos, 1992). Their 1989 paper suffered some editorial constraints cutting part of their text and changing the title of the paper from 'Towards an Industrial Ecosystem" to "Strategies for Manufacturing". And thus their second paper of 1992 is more often quoted. Their focus was clearly on manufacturing embedded in an economic and competitive world whilst stating that it exists more or less apparent opportunities to environmentally improve in that context. Industrial ecology was considered as an appropriate empirical framework to help internalize externalities. If the authors insisted on the analogy with natural food webs they also clearly stated that this analogy "is not perfect, but that much could be gained if the industrial systems were to mimic the best features of the biological analog" (Frosh, Gallopoulos, 1992). Encouraging the use of recycled materials, energy and products from mining to end of manufacturing chain, the authors asserted that this would decrease harmfull emissions and wastes. However, (Gallopoulos, 2006) stresses the difficulty to integrate and seamlessly close materials and energy loops at the inter-firm, inter-industry or inter-economy levels.

The reason why Frosh and Gallopoulos contribution raised interest was mainly due to the recognition of the two authors in business, engineering and even governmental audience. In addition, it was taken a step further and translated into business language by Hardin Tibbs. This person, contributed to spread a short business oriented version stamped by the very recognized business consultancy firms he worked for. Other persons started to write about the proposition of Frosh and Gallopoulos, starting a movement that is still ongoing today.

2 FROM INDUSTRIAL ECOLOGY TO TERRITORIES

2.1 Industrial ecology: various spatial and organizational levels

Nowadays, industrial ecology is mainly asked to concretely and pragmatically help solving problems in the domain of environmental management, production rationalization and spatial planning with often associated local work challenges. Application of industrial ecology concept ranges from a facility to a global scale. Marian Chertow (Chertow, 2000) had well depicted the services provided by industrial ecology according to the level at which it is used, as represented in Figure 1.

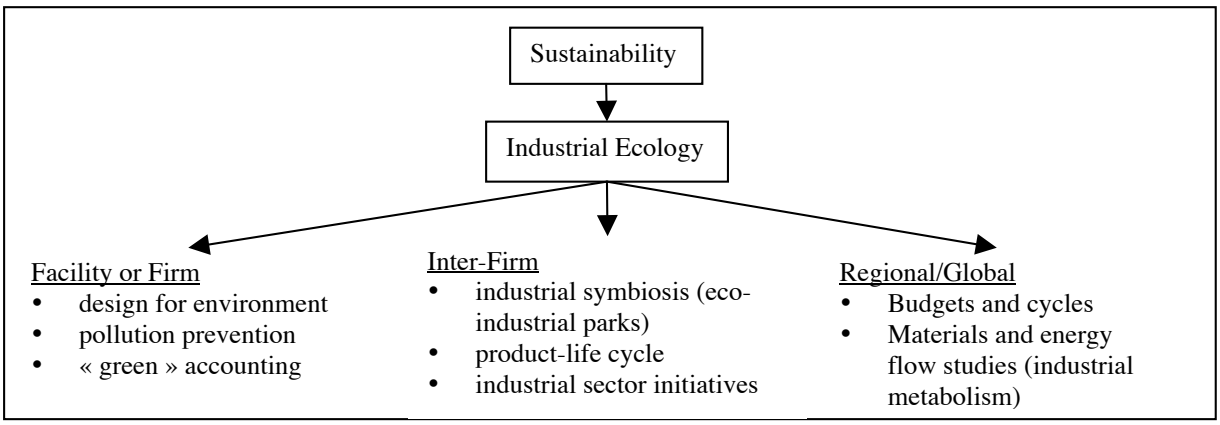

Figure 1 Industrial ecology operates at three levels (Chertow, 2000)

Facility or firm level is out of our consideration in this paper, whilst the regional and global aspects will be evoked in section 3.1. Industrial symbiosis and eco-industrial parks are the most popular case of industrial ecology at the inter-firm level. Typical cases of industrial symbiosis are substitution of a raw material with a waste/by-product generated at another firm or mutualisation of firm efforts around a material or energy flow. Information about implementing such industrial ecology is available in (Adoue, 2007). It is interesting to remark that eco-industrial park is itself a multiple levels notion and not only the case of municipal working areas. According to the famous taxonomy proposed by Chertow (Chertow, 2000), five types of material exchanges can be distinguished, among which the last types refer respectively to "among local firms that are not collocated" and to "among firms organized "virtually" across a broader region". Indeed, opportunities of industrial symbiosis had been researched and implemented with success at the regional level in locations such as the Rhine-Neckar region, Germany and the district of Orange, US (Duret, 2004) and in the broad regions of Kwinana and Gladstone, Australia (van Berkel & al, 2006).

The work conducted in these cases is firms centric. It means that it focuses on voluntary companies and their good will to provide information that is often considered business critical by convenience. This is a first type of difficulty. The primary step is thus creating interest and confidence from enterprises to have them collaborate. Then the materials and energy flows information is gathered in a database that is exploited in order to figure out potential exchanges of interest for the engaged parties. Note that some regions or countries also offer waste exchange site without necessarily being part of any industrial ecology broader initiative (CCIP & al or CTTÉI, 2008). Nevertheless the habit of using and trading substances that had once been called waste is not yet installed in mentalities. In both the American and Australian above cases, authors mentioned that interesting environmental and economic benefits occurred. However, the economic gain is also a pervert friend. The Australian authors point well the fact that despite being in desert area reuse of industrial water in place of drinking water isn't popular among industrials due to the low price of network water.

It appears that industrial ecology has mainly been considered in practice through these various levels as physical resources flows optimization succeeding to accounting of materials. The accounting uses from facility bookkeeping to global statistics (see industrial metabolism section) according to the level at which it is needed and the available information. On another side efforts are also punctually put on developing technologies supporting by-product reuse in the field of waste science. The accounting, though essential to capture the way the system works, is a bit restrictive of the numerous dimensions of industrial ecology. This leads us to the questions of what is needed to properly handle industrial ecology complexity.

2.2 Industrial ecology: a multidisciplinary approach

Industrial ecology as a scientific field has the ambition of understanding how an industrial society functions in relation to its natural surrounding. Biosphere is then recognized as the essential substrate of most human activities. The methodology derives from the studies of ecosystems and strongly relies on the systemic approach. Dealing with human society industrial ecology needs also to integrate human sciences to reach comprehension, pertinence and tools to drive industrial ecosystems towards sustainable balance within the existing biosphere limits. Though some works exist industrial ecology is not yet spread within all the appropriate fields. This is what we would like to contribute to change in showing the potential mutual benefits between industrial ecology and territorial intelligence.

So far the main pillars of industrial ecology have been the principles of Ecology of ecosystems, the knowledge of biosphere provided by the science of Nature and the technology skills of Engineering to transform waste into reusable by-products or to optimize for environment chains of production and chains of supply (of energy and physical resources). When having an industrial symbiosis idea, the actors also need to check its robustness towards existing regulation, logistics, economic viability, population acceptance. This is usually done on case by case basis. Little works exist in these domains though they are concerned. Nevertheless this is slowly changing and some references can be found in (Diemer and Labrune, 2007) or in the sources quoted in the next paragraph.

Industrial ecology impacts Economy with its challenge of activity relocalization, of new cooperation model between firms and change in the value of waste. Economy can also bring nutrients to industrial ecology with its understanding of scaling factors or competing style for instance. Management theories handling aspects of coordination, networking and supply chain is surely valuable too. Social sciences could be used to catch industrial ecology as a cultural phenomenon as some suggested. Other authors such as (Ashton, 2008) mobilize sociology to study new interaction schemes between actors and how it impacts industrial symbiosis. Philosophers are also interested in industrial symbiosis and the paradigms it brings or what it means to take Nature as a model for human societies. Even Law starts to know industrial ecology through its industrial platform consequences (Gautier-Sicari, 2006). Finally the paper "Uncovering Industrial Ecology" (Chertow, 2007) evokes a clear benefit of industrial ecology from territorial intelligence. Indeed, after studying cases of eco-industrial parks, the author exhibits the stronger correlation between success and "self-organized" systems. From this, raise the idea that uncovering industrial symbiosis, kernels or precursors could help addressing the right targets. Territorial intelligence may have the tools to spot them and the available competences on a given territory.

Integration of these many dimensions in scientific projects is less common. The French *Agence Nationale de la Recherche* sponsors a multidisciplinary project since 2008 (Comethe, 2008) but the most frequent situation addresses only part of these dimensions. This is typically the case of the research we have started by reciprocally stimulating industrial ecology and territorial sciences. We envision that it is not only a mandatory crossing but also that it is going to be a fruitful operation for both domains.

2.3 Industrial ecology and territory

Initially, the word "territory" means two things: a legal and administrative reality, as in « national and regional development », or it refers to the concept of « territoriality », which has been very used in the social sciences for twenty years. Environment, experiences, representations and social-politico-organizations compose a system whose parts are interdependent (Gumuchian, 2001). This shows that the "territory" is a complex system. As much as natural reality and social reality, the territory is not easy to break up. At the same time, nowadays, "territory" is the new buzzword called on to provide solutions for socio-economic development, sustainability or a coherent image of the places they encompass. The concept is extremely popular: everything is a "territory", and concepts that reflect other realities tend to slip imperceptibly into that holdall (Moine, 2007). The popularity of the word also shows that the "territory" embodies a quotidian reality as much as an aspiration for the actors of the modern society.

Taking this into account, developing new approaches and tools to fathom and manage the complexity of the "territory" is a major issue. From this point of view industrial ecology could be of great assistance as it helps to revisit the concept of "territory" from a systemic point of view, with the objective of producing an operational definition that could be used to put the territory back into the context of sustainable development. In fact geographical and territorial systems are not very different from natural ecosystems; links can easily be made between the particular functioning of natural ecosystems and the interactions between firms, actors, territory portion, geographical area etc.... taking place within territories. Considering territories as complex but coherent specific case of ecosystems in interaction with other natural and/or artificial ecosystems, industrial ecology provides new guidelines to break into the territories complexity and to help them to evolve towards sustainability by seeking global balance between territories and the biosphere.

In return, such innovative approaches would enhance industrial ecology intelligence since it still lacks the methods and knowledge coming from the sciences for which territories and its components is a main item of studies (such as social science, spatial planning, territorial intelligence etc...). Today, most of projects of industrial ecology are developed at a territorial scale. Thus a major issue is the understanding of the interactions between the industrial ecology's paradigm and the reality of the territories functioning because they are not always cohesive.

For instance an important part of the emerging field of industrial ecology is the development of industrial symbiosis. Symbiosis means co-existence between diverse organisms in which each may benefit from the other. In the context of industrial ecology, the term is applied to the industrial co-operation between a number of companies and municipalities when they exploit each other's residual or by-products or when they operate mutually. Some examples of industrial symbiosis already exist around the world. It engages traditionally separate firm and/or communities in a collective approach to gain competitive advantage involving physical exchange of materials, energy, water, and/or by-products. In most projects of industrial ecology potential cost-effective eco-industrial synergies are often found between firms and/or communities, but they become less often a reality despite the economic rationality. This shows that more complex phenomenon such as confidence between economical actors, culture aspects, political strategies... are at work. Taking this into account, we are trying to build bridges between industrial ecology and social sciences, since it is a crucial issue to improve industrial ecology methods and tools.

3 FOCUS ON FEW METHODS AND TOOLS FOR INDUSTRIAL ECOLOGY

3.1 Territorial metabolism

Metabolism is a term inherited from the study of living organisms. It is an accounting of what they ingest and reject in order to grow, exist and reproduce. The concept of metabolism can be applied to any system that exhibits some of these functionalities. Metabolism reports materials in mass unity (e.g. ton) and energy in joule (or in mass equivalent of fuel oil). The mass conservation principle is respected such that input, output and internal stocks are balanced. Territorial metabolism is nothing much than this principle applied to a territory. The expressions industrial metabolism, economic activities metabolism and regional metabolism are also encountered depending on the focus of the study. Even though such systems do not reproduce similarly to natural organism, the use of metabolism has proven to make sense. Indeed, territorial metabolism is a useful tool for public decision maker. It is essential to understand the physical flows that constitute the basis of the economy of their territory (see the pioneer Belgian work described in the Genesis section). It can reveal potential for new economic activities or confirm or suggest strategic directions. It is remarkable that territorial metabolism, once decisions are taken, is also a tool allowing public institutions to monitor and track progress all along the implementation of their decisions. The ultimate goal is to enhance the quality of the local economy in terms of viability, strength and competiveness whilst improving its environmental performances.

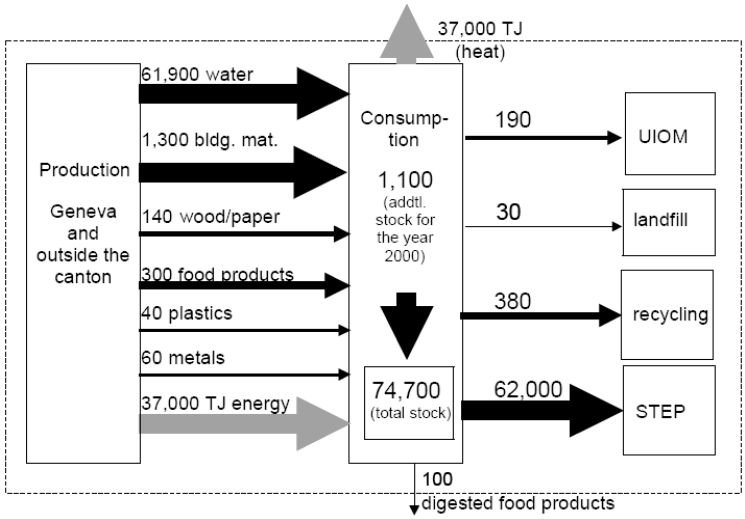

Figure 2 Representation of the metabolism of the Canton of Geneva (GEDEC, 2005)

For instance, territorial metabolism successfully served the Genevan State in the context of its Law on public action for sustainable development, voted in 2001. Industrial ecology was stated in one of the article of this text, as a mean to accompany the Agenda 21 of the canton of Geneva. A preliminary phase was to make a diagnosis of the resources consumed by the canton. They include not only industrial or commerce activities but also daily life of inhabitants. The seven most significant resources going through the canton were selected (see Figure 2). The metabolism revealed that water (62 millions of tons) was largely the biggest resource consumed in the canton. Building construction materials (1.3 millions of tons) and food goods (300 000 tons) followed. All of them were first consumed by inhabitants. The resource flows were also transformed into their ton-equivalent

CO2 to explore contribution to greenhouse effect. Energy, first consumed by inhabitants, was the main contributor (2.8 millions of tons-equivalent CO2 of which a third was due to energy production and the rest resulted from its use). Second was food (with about 600 000 tons-equivalent CO2) whose contribution laid in its production. Finally the respective importance of the economic sectors was observed and showed that household was the greatest resources consumer in the canton, followed by tertiary sector. These data and more information are available in (GEDEC, 2005). Based on the findings recommendations were drawn and submitted to the Genevan State to help making decisions regarding priority domains and pertinent actions (for instance this situation is likely to require individual and punctual actions to reach household).

3.2 PRESTEO: a Program to Research Synergies on a TerritOry

The identification of industrial symbiosis and synergies demands resolute attention to the flows of materials and energy through local and regional economies. It also supposes a constant circulation of information on the consumed and rejected flows by each entity. For those reasons, the collection and the processing of these data require a methodological and technical support. An input-output matching appears to be an useful tool in eco-industrial development. That is the purpose of PRESTEO.

PRESTEO software helps to collect and exploit data from the industrial metabolism of the different economic entities within a territorial system. In fact, stakeholders of a territory enter their input-output table in the software. Those information are stored in databases and matched, such that users of PRESTEO can conduct studies to find relevant synergies of substitution (an output becomes one other's input) and/or synergies of mutualization (two entities with the same input or the same output cooperate in order to optimize their supply or waste processing). Beyond a simple data-processing tool, PRESTEO includes several methodological tools: a data collection method, a formalization method of flows and components and a processing method to filter the results obtained. This tool is initially developed in French and then translated to other languages (its first version is available in English). It is almost without any equivalent in the world, and perhaps the only one accessible on the market. It is the result of 5 years of research begun at the "Université de Technologie de Troyes" and then continued by the company "Systèmes Durables".

PRESTEO has already been used with success in Switzerland by the state of Geneva and in France by The Club of Industrial Ecology of Troyes. Currently PRESTEO is used by the firms association Ecopal in Dunkerque and by the *Communauté d'agglomération de Marne-et-Gondoire* (77, France) to assist them in improving or reshaping two working areas. The use of PRESTEO in Geneva came in the second phase of their Agenda 21, as a complement to the first territorial metabolism. Indeed, territorial metabolism has shown limits to suggest concrete synergetic actions to parties. This is where a methodology and tool such as PRESTEO come in the picture to improve the action on the territory. In the context, a sample of about twenty enterprises representative of the economic activities of the canton was created. A particular focus was put on construction area given the territorial metabolism findings. PRESTEO was not fully operational at that time, so only the methodology and algorithms were applied "on paper". For instance, they allowed identify potential sources and a receiver for a recycling platform of construction materials. This was a wish of the government and administration. First results were so interesting that the canton of Geneva bought PRESTEO as soon as the software was available and started to fill in the collected data. Since then it has kept adding new enterprises to the database and seeking new synergies to explore with economic actors.

These experiences have produced important feedbacks on the actual limits of the projects of industrial ecology as they are conducted today and of the software PRESTEO. The principal conclusion is that social aspects are not enough taken into account in all these approaches. For instance, PRESTEO has no link to economic information about the territories, nor to the available job competencies. The integration of knowledge and methods coming from social sciences appears to be a critical issue to improve industrial ecology intelligence. This is the purpose of the researches we are conducting today.

4 CONCLUSION

The main principle of industrial ecology is the view that societal and technological systems are bounded within the biosphere, and do not exist outside of it. Ecology is used as a metaphor due to the observation that natural systems reuse materials and have a largely closed loop cycling of nutrients. Industrial ecology approaches problems with the hypothesis that by using similar principles as natural systems, industrial systems can be improved to reduce their impact on the natural environment as well. Through this holistic view, industrial ecology recognizes that solving problems must involve understanding of the connections that exist between these systems; various aspects cannot be viewed in isolation. Based on this framework, industrial ecology looks at

environmental issues with a systems thinking approach. From those points of view, links can easily be found between this innovative approach and territorial intelligence.

Industrial ecology projects require accounting of the flow of materials and energy passing through local and regional economies (also called "territorial metabolism"). The collection and the processing of these data require a methodological and technical support and input-output matching appears to be an useful tool in eco-industrial development. That is the purpose of the software PRESTEO. This software can be use to find potential eco-industrial synergies between firm and or communities on a given territories. Actual experiments tend to show that the keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity. From this point of view, territories seem the perfect scale to develop projects of industrial ecology. Consequently a great understanding of the territorial systems and integrated approach of the territories is critical to enhance industrial ecology's tools and methods. Thus, bridge-building between industrial ecology and other fields such as territorial intelligence and social science is a major stake.

Taking this into account, new researches involving "Systèmes Durables" and the "Université de Toulouse II – Le Mirail" started on April 2008. Their goal is to have a fresh look at the concept of territory from the angle of industrial ecology in order to reach an operational definition that resituates territory inside the biosphere's bounds. The objective is to reinforce the methods used in PRESTEO and the understanding of territorial systems. This will lead to a third version of the software. The cross-over between industrial ecology and social sciences such as spatial planning will also create new knowledge and open innovative perspectives of research in both disciplines.

5 BIBLIOGRAPHY

Adoue C. (2007) *Mettre en œuvre l'écologie industrielle*. Lausanne : Presses polytechniques et universitaires romandes, 2007, 106 pages. ISBN 978-2-88074-710-7.

Ashton W. (2008) Understanding the Organization of Industrial Ecosystems. A Social Network Approach. *Journal of Industrial Ecology*, Vol 12 (1), pp 34-51.

CCIP & al (Chambre de commerce et d'industrie de Paris and Associates) (2008). Bourse des déchets. [**online**]. Available at : <http://www.bourse-des-dechets.fr>. (last visit on April 23, 2008).

Chertow, M. (2000) Industrial Symbiosis: Litterature and Taxonomy. *Annual Review of Energy and the Environment*, vol 25, pp 313-337.

Chertow M. (2007) Uncovering Industrial Symbiosis. *Journal of Industrial Ecology*, Vol 11 (1), pp 11-30.

Comethe (2008) Conception d'outils méthodologiques et d'évaluation pour l'écologie industrielle [**online**]. Available at < www.comethe.org>. (last visit on August 29, 2008).

CTTÉI (Centre de transfert technologique en écologie industrielle) (2008). Bourse des résidus industriels du Québec (BRIQ). [**online**]. Available at <http://www.briq.ca >. (last visit on April 23, 2008).

Diemer, A. and Labrune, S. (2007), « L'écologie industrielle : quand l'écosystème industriel devient un vecteur du développement durable » [**online**]., *Développement durable et territoire*, Varia, online on August 30, 2007. Available at URL : http://developpementdurable.revues.org/document4121.html. (last visit on August 26, 2008).

Duret, B. (2004) *Pratiques internationales d'écologie industrielle : retour d'expérience*. Projet d'étude, 164 pages.

Erkman, S. (1997), "Industrial ecology : an historical view", *Journal of Cleaner Production*, Vol. 5, No 1-2, pp. 1-10.

Frosh, R.A. and Gallopoulos, N.E. (1992), "Towards an industrial ecology", in A.D. Bradshaw, R. Southwood and F. Warner (Eds.) *The treatment and Handling of Wastes*, London: Chapman and Hall for the Royal Society, pp. 269-292.

Gallopoulos, N.E. (2006), "Industrial ecology: an overview", *Journal of Cleaner Production*, Vol. 3, No 1-2, pp. 10-27.

Gautier-Sicari, M.-A. (2006) *Les plates-formes industrielles et le droit de l'environnement : contradictions et avancées juridiques*. PhD Dissertation (Law studies). Nantes: Faculté de droit et des sciences politiques 539 pages.

GEDEC (2005) « Écologie industrielle à Genève: premiers résultats et perspectives », 48 pages.

Gumuchian H. (2001), « Ecole, territoire et développement durable », in *L'Enseignement scolaire en milieu rural et montagnard,* Tome 1, *Espaces ruraux et réussites scolaires,* Besançon : Presses universitaires franc-comtoises, Besançon, pp.43-46

Moine A. (2007), « Le territoire : comment observer un système complexe », Harmattan, Paris, 176 p.

Van Berkel, R., Bossilkov A. and Harris S. (2006) Opportunities and Constraints for Regional Resource Synergies in Minerals Processing Regions. **In** : Green Processing Conference, Newcastle, pp 113-122.