UNIVERSITE CATHOLIQUE DE LOUVAIN

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IS INDUSTRIAL ECOLOGY A PROMISING PATH TOWARDS SUSTAINABLE DEVELOPMENT OF A DEVELOPING COUNTRY?

THE CASE OF INDIA

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PREFACE

I would like to thanks some distant mentors, those who opened the door to a different way of thinking, the authors of the book "*80 hommes pour changer le Monde"*; Sylvain Darnyl & Mathieu Le Roux. Indeed, it is this very book that introduced me to the idea of Industrial Ecology through authors such as Suren Erkman.

I also have to thank from the bottom of my heart my supervisors, Pr Christophe Lejeune for his guidance and Pr Daniel Tyteca for his constant support and valuable suggestions.

Another important person who helped me by organizing my thoughts, canalizing my energy and helping me change my points of view, Jean-Yves Tilquin.

Last but certainly not least, I have to give credit and my heartfelt gratitude to the persons around me who helped, motivated and supported me during my times of doubt, discouragement or anger, Véronique Collinet, Violette Cassiers, Syed Athar Karim, Adrien de Longvilliers; …

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1 INTRODUCTION

The objective of the following thesis is to wrap my studies around one central subject. The motivation for choosing the subject of Industrial Ecology is linked with my personal history closely related to the Industrial sector. Furthermore, and after an exchange programme in India, I saw, first-hand the potential of this subcontinent as far as the industry was concerned, as well as the increasing impact such a development would have on the environment.

Industrial Ecology takes in notions of industrial development, logistic, environmental management; India has been chosen due to my International Business option and is the place in which I had the honour to spend four months of my life as a Mercator student in the Indian Institute of Management.

Besides, in our day and age, one cannot deny both the importance of environmental focus and the growing influence of developing economies. Mine is to try and link these two subjects in one overseeing notion which scope covers many aspects of the biosphere.

This thesis will be organised in two main parts, the first is a literature review that is aimed at grasping the essence of the subjects of Industrial Ecology, Sustainability and the Indian economy. The second part is a case study of an industrial complex organised around an environmental, social and economic focus.

The literature review will therefore first tackle the subject of Industrial Ecology, with an overview to set the foundations of the different notions, within a firm, between firms with Industrial Symbiosis and larger with an Industrial Metabolism. Next we will move on a review of the historical development of the notion. The usual steps that are necessary to attain a network of exchanges and the linkages that are possible within said networks will be exposed.

The literature review was done by going through the work of the main authors in the field and following their cross references in order to have the largest overview of the subject and where it stands today. Doing so allowed me to be introduced by the mainstream authors as well as their detractors. Then and based on the different school of thoughts, I structured my work based on the requirements of my study.

Then, an overview of the notion of Sustainability will be tackled in order to understand exactly its notion nowadays, linked with developing economies and more specifically related to the industry keeping in mind that in our way of living, these notions have to be complementary.

Finally, an overview of India as a country will be undertaken in order to understand its position today relative to its history and cover its economy and the challenges arising. Then, an important aspect of the country will be assessed, its tax system, in order to explain that the authorities have a limited budget relative to their Gross Domestic Product.

For the case study, a particular project has been selected in Tamil Nadu, a State in the South of India. This initiative responded to a market reality in its strive to survive and came up with an "*out-of-the-box"* solution, combining traditionally separate constraints and benefited from a serious competitive advantage due to this original approach.

In order to draw an exploratory case study on that particular system, a deep research was required to find documents regarding their process. The cross utilisation of these documents gives an overview of the symbiosis with different angles and therefore, a further view of the inner working. However, the data found is almost only qualitative.

That network is now used as an example in India and is therefore a good proxy to assess the feasibility of Industrial Ecology initiative in the country.

FIRST PART:

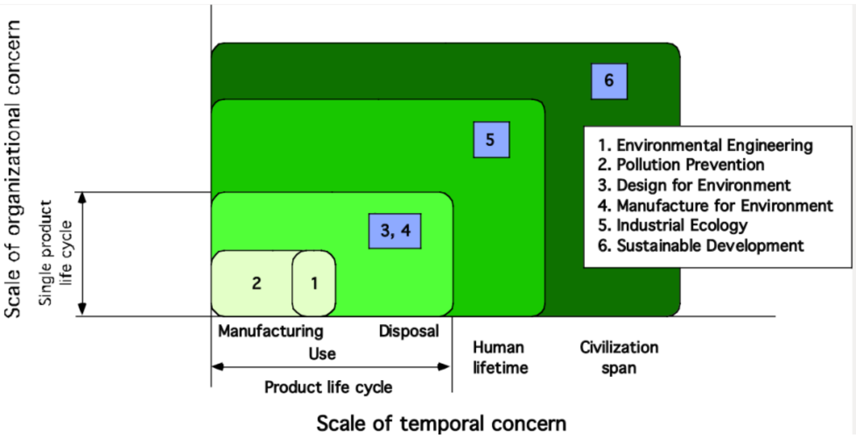
LITERATURE REVIEW

2 GENERALITIES

Industrial ecology, for those who never heard of the concept, appears like an *oxymoron* in the sense that one used to view the industrial sector as separate from the biosphere and later on having a negative impact on the latter but certainly not working hand in hand (Erkman, 1997). Indeed, for half a century the industrial world relied on the end-of-pipe approach in which there are environmental concerns but merely trying to minimize the impact on the "outside" (Erkman, 1997). Industrial Ecology emerges when that end-of-pipe solution proves insufficient and takes the step between the environment and the industrial sector considering the latter as a peculiar type of ecosystem, i.e. "*a particular distribution of materials, energy, and information flows*" (Erkman, 1997).

In order to fully grasp the concepts that will be used throughout this entire thesis, it is important to take a step back and see how they all work with each other. Indeed, Industrial Ecology is merely a tool to achieve sustainability but includes several business practices.

FIGURE 1 : FROM MANUFACTURING TO SUSTAINABILITY



ENVIRONMENTAL AND TEMPORAL DOMAINS OF THE APPROACHES FOR REDUCING ENVIRONMENTAL IMPACT (COULTER ET AL. 1995)

As we can see, according to the aforementioned authors, the several business practices that make Industrial Ecology (i.e. the practices enclosed in the illustration) have a more limited timespan than Industrial Ecology which, in turn, is shorter than a sustainable development. Erkman and Ramaswamy even put it in the following way: Industrial Ecology is the concept of sustainable development made operational economically speaking (Erkman & Ramaswamy 2003).

In 1989, Robert A. Frosch and Nicholas E. Gallopoulos start their article "*Strategies for Manufacturing*" by the following line: "Waste *from an industrial process can serve as the raw materials for another, thereby reducing the impact of industry on the environment"*. They continue further naming the process as an *industrial ecosystem* that could be used to improve the efficiency of the industrial system, reducing wastes and energy consumption (Frosch & Gallopoulos 1989). They go on by comparing such a system with a biological ecosystem.

According to the fore mentioned, if developed and developing economies could embrace such a transformation, the result will lead to a greater sustainability. In the case we are interested in, they consider that developing nations should "*leapfrog older, less ecologically sound technologies and adopt new methods more compatible with the ecosystem approach*".

3 INDUSTRIAL ECOLOGY

3.1 OVERVIEW

Industrial Ecology is a collective practice (Chertow 2000) to achieve a competitive advantage regarding physical resources (Chertow, 2000), sustainability and involves recycling procedures favourable to a lesser ecological impact (Boons 2008). Erkman suggests another more practical definition:

> "*The idea* [of Industrial Ecology*] is first to understand how the industrial system works, how it is regulated, and its interaction with the biosphere; then, on the basis of what we know about the ecosystem, to determine how it could be restructured to make it compatible with the way natural ecosystems function"* (Erkman, 1997).

On the other hand, Lowe considers that Industrial Ecology is much broader than that and allows stakeholder to have a global view of the system they are a part of and can adapt and integrate their system or process to the natural system. In indeed includes the extension of product life and strategically turn from products to services (Lowe 1997).

Industrial ecology as a field of study uses a holistic view in order to explore and improve the use of natural resources (van Berkel et al. 1997) and bears the purpose of transforming straight production processes into a cyclical system resulting in the use of one's waste as another one's resource (Frosch & Gallopoulos, 1989). It involves two or more industrial companies, closely located, sharing energy, materials or information (Chertow, 2000). As an example, it may be sharing a joint infrastructure, management of common utilities, services or waste reuse (Ashton 2009). As a field, it requires to consider the industrial system in concert with its surroundings (Chertow, 2000).

Industrial ecology and industrial symbiosis are used together in the literature without much distinction. In order to clarify that point, we need to keep in mind that Industrial

Ecology is the science and industrial symbiosis the practical use of that science, such as physics and mechanics.

A useful digest of the field of Industrial Ecology has been created by Jelinsky et all 1992:

- Proactive, Industrial Ecology is initiated by the agents in the interests of their own activity as well as their surroundings in which they are involved.
- Designed in the process chain, it requires every product, process and manufacturing decision makers to consider Industrial Ecology as equally important as product quality or manufacturing.
- Flexibility, as time goes by and the number of collaborations increases new opportunities as well as new threats can arise from studies (scientific or environmental) and new technologies. An agent must be able to cope and adapt to those changes.
- Encompassing, Industrial Ecology is not restrained locally; it overflows across the industrial sector and national as well as cultural barriers.

There is a comparison that can be made with the natural ecosystem and can be found in the literature (Ashton 2009; Brand & De Bruijn 1999; Graedel 1996). Indeed, there is a natural web of connections as metabolic linkages between any given organisms at different trophic levels in the food chain (Graedel 1996). Even though that view is deemed too simplistic by Ashton (2009), its value is still useful to understand the development of a regional Industrial Ecology system. This is the origin of the word symbiosis (Chertow, 2000).

Graedel (1996) compares the definition of Biological Ecology and the Industrial Ecology:

TABLE 1: BIOLOGICAL ORGANISM VS INDUSTRIAL ACTIVITY

Biological Organism	Industrial Activity
Capable of independent activity	Plants (through their employees) take care of several activities on their own behalf.
Uses energy and materials resources	Use materials and energy for transformation purposes
Nutrition and excretion	Energy input and material refuses

	emissions
Reproductive capacity	Not dependent on the factory itself but external factors
Response to external stimuli	Prices, resource scarcity, etc... are stimuli taken into account
Growth from one cell through stages	Growth but without following the ordered stages of the biological organisms
Finite lifetime	Indeed

PARALLEL BETWEEN INDUSTRIAL FACTORY AND BIOLOGICAL ORGANISM (Graedel 1996)

Boons and Baas, consider that there are coordination issues at hand in the implementation of Industrial Ecology and study the following types at hand (Baas & Boons 2004):

1. *Product life cycle/material life cycle*: value chain cooperation
2. *Geographical area*: regional collaboration
3. *Sectorial*: similar companies gathered together
4. *Miscellaneous*

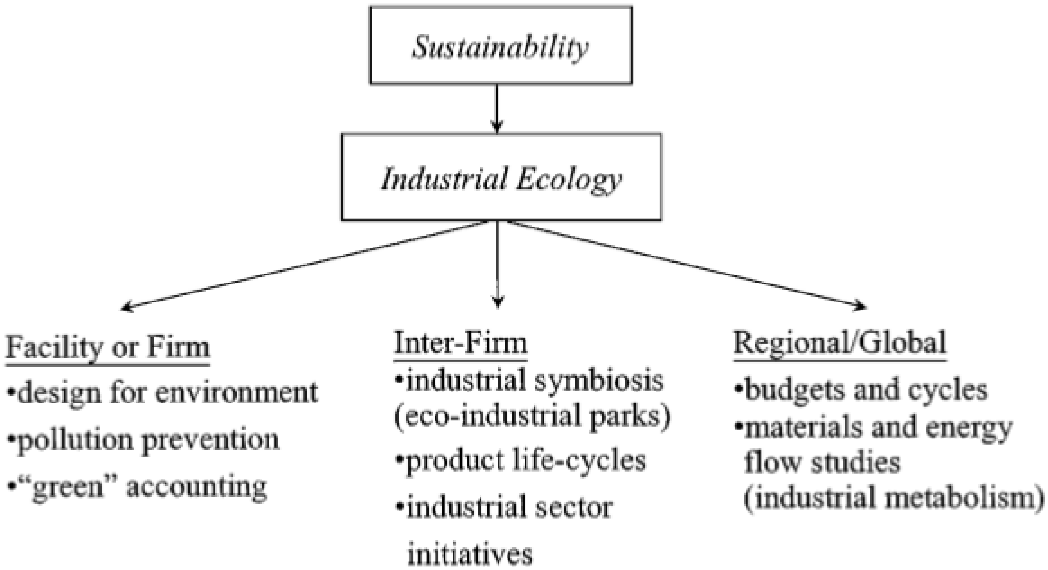
Boons, Baas and Erkman consider that items 3 and 4 are not suited for the development of Industrial Ecology given the fact that there would not be a sufficient coordination possible (Baas & Boons 2004; Erkman 1997).

A great example of Industrial Ecology, present in a great majority of the related literature is Kalundborg in Denmark (Brand & De Bruijn 1999; Erkman 1997) that started voluntarily between the agents responding to a scarcity of water and resources. The cooperation quickly evolved involving the authorities and the inhabitants of the region.

Erkman (1997), Frosch and Gallopoulos (1989) as well as Lowe (1997) consider that Industrial Ecology develops in two separate directions. The first is the constitution of Eco-Industrial parks[1] and on the other hand, dematerialisation-decarbonisation and the service industry. Both approaches complement each other and focus on resource efficiency improvement and pollution reduction, keeping the trade-off between costs and benefits[2] in mind (Lowe, 1997).

As said earlier, Industrial Ecology is a tool that may be used to achieve sustainability and comprises different aspects of logistic and business strategies:

FIGURE 2: ASPECTS OF INDUSTRIAL ECOLOGY



INDUSTRIAL ECOLOGY REQUIRES A SET OF PRACTICES FROM THE FACILITIES OF A FIRM TO THE REGION IN WHICH IT IS LOCATED (CHERTOW 2000)

We will use this structure to understand better the concept. Of course, these innovations often evolve at the same moment; for instance product innovation often involves process innovation for the chain of production, new process innovation can lead to new products, new supply chain to products redesigned,…(Pogutz & Tyteca 2002)

[1] also named Island of Sustainability by Erkman

[2] Technical, environmental and economical

We can differentiate three objects of innovation (Pogutz & Tyteca 2002) :

- *Process innovation:* "new technological solutions which modify the characteristics of production systems and are aimed at plant operations"
- *Product innovation :* "changes in products/services made by the company which range from product improvement to product redesign up to radical changes in the product concept"
- *System innovation:* "which identify new organizational solutions at the supply chain level, in the contacts with competing companies and subjects outside the competitive system such as consumers, institutions, environmental groups etc." (Pogutz & Tyteca 2002)

TABLE 2: OBJECTS OF INNOVATION

Type of innovation	*Process innovation*	*Product innovation*	*System innovation*
Competitive advantage obtained by the company	Cost leadership	Differentiation	Both
Intensity of the environmental benefit following the innovation	+	++	+++
Theories and managerial approach to the issue of sustainable development	End of pipe technologies Cleaner technologies	Design for environment	Zero waste management Industrial Ecology

TYPE OF INNOVATION, ADVANTAGE, ENVIRONMENTAL BENEFITS AND THEORIES (POGUTZ & TYTECA 2002)

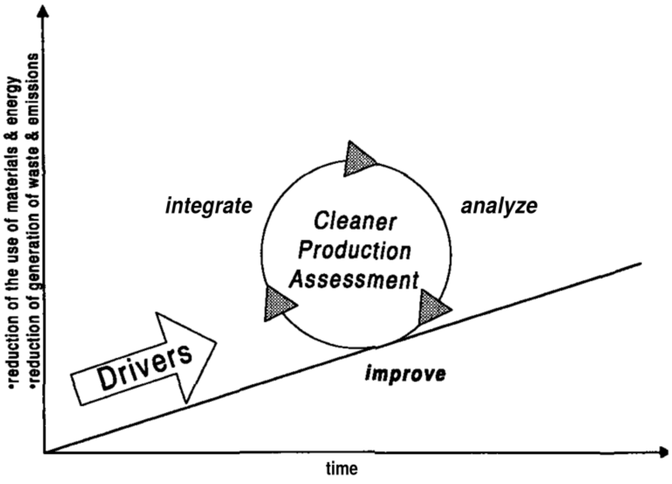
3.1.1 Within the facility of a firm

According to van Berkel, 1997, the usual answer of industries to the growing concerns of environmental degradation are to on the one hand, ignore the issue, diluting it, controlling or treating it and on the other hand, prevention of pollution as well as waste generation. These answers are considered as: "*end-of-pipes*" approaches. The former hand is, simply put, transferring the pollutant from on medium to another. Furthermore, building filters or tools to reduce the emission of pollutants is not economical and doesn't imply any savings (except in cleaning or fines for instance) (Erkman & Ramaswamy 2003). The latter is the foundation of what is known as Cleaner Production. Industrial Ecology is a separate field; however, Cleaner Production is a useful instrument for achieving sustainability and may lead to the former through the development of new tools not yet covered by Cleaner Production (van Berkel et al. 1997)

Cleaner Production has advantages for the firm, the community and the environment in the sense that it protects the latter and induces economic savings for the formers. (van Berkel et al. 1997). It can be defined as the "*continuous integrated environmental improvement of industrial processes and products to prevent the pollution of air, water, and land; to reduce waste at the source; and to minimize the risks to the human population and the environment"* (van Berkel et al. 1997). In a nutshell, for products and processes it means saving energy, reducing the emission of toxic material and wastes throughout the entire life cycle (van Berkel et al. 1997).

Cleaner production is not a set of procedures that any willing company is free to implement. It is rather a "*problem solving strategy"* (van Berkel et al. 1997). In order to put it in motion in a company, one is suggested to start a ``Cleaner Production assessment" process.

FIGURE 3 : CLEANER PRODUCTION ASSESSMENT



CLEANER PRODUCTION ASSESSMENT AS A "VEHICLE" FOR ONGOING ENVIRONMENTAL IMPROVEMENTS (BERKEL ET AL,. 1997)

There are three main dimensions in Cleaner Production (van Berkel et al. 1997):

1. Pollution Prevention
2. Toxic Use Reduction
3. Design for Environment

It is not the purpose of this work to develop those dimensions but as mentioned earlier, Cleaner Production and its notions are a stepping stone for the implementation of Industrial Ecology. Van Berkel et all (1997) however note that the current practice of *environmental improvements* are not yet enough and that a company needs to move forward to *environmental innovations* to have a lesser impact on the environment and eventually a balance between their activities and the ecosystem, such as what Industrial Ecology strives to achieve. Indeed, for Industrial Ecology, there is a change in the purpose from merely waste minimisation of an agent to the minimisation of the emissions of the system as a whole in which the overall reduction is greater than the sum of savings made by the separate agents if alone (Chertow, 2000).

Finally, a finding of the INES[3] project, in Holland, found essential, before joining an Industrial Ecology network, to have Cleaner Production measures implemented within the

[3] INdustrial ExoSystem program

firm (Brand & De Bruijn 1999). Those approaches have their limits (Pollution Prevention and Cleaner Production) because the vast majority of industrial processes generate refuses or by-products (Erkman, 1997). With that logic in mind, using those approaches in the medium - long term is useful to step further into Industrial Ecology, "*Waste prevention must precede waste exchange*" (Brand & De Bruijn 1999).

There is one big and important difference to take into account between Industrial Ecology, Cleaner Production and Pollution Prevention; the purpose of the latter is to minimize wastes as much as technologically possible but, on the other hand, a producer in an Industrial Ecology network could be inclined to even increase a certain waste if another partner in the collaboration has a need for that particular product (Erkman, 1997). Gibbs and Deutz (2007) besides Lowe (1997) add that, beside design for environment, eco-efficiency and Pollution Prevention another concept to be used is green accounting. Furthermore, Lowe adds product policies such as life-cycle assessment and product life extension.

3.1.2 Inter-organisations: Industrial Symbiosis

Industrial symbiosis is a model under the field of Industrial Ecology which arose as *"a body of exchange structures to progress to a more eco-efficient industrial system, by establishing a collaborative web of materials and energy exchanges among different organizational units*" (Doménech & Davies 2011). It allows those "*traditionally separate entities*" (Chertow, 2000) to bring about a competitive advantage from their exchange of physical resources, energy and refuses (Chertow, 2000). It requires the establishment of life cycle analysis and industrial sector initiatives (Gibbs & Deutz 2007). Furthermore, in this field, the common energy - material web of exchanges between Industrial Ecology actors is broadened to include information and, on the one hand, consumers, neighbouring communities and local resources available (van Berkel et al. 1997). It forces companies and agents to quit their individualistic approaches towards a greater cooperation (Brand & De Bruijn 1999). The main area of differentiation from Industrial Ecology is the fact that an Industrial Symbiosis network takes place in a dedicated eco-industrial park while on the other hand Industrial Ecology can also arise between agents not too distant from one another (Chertow, 2000). Indeed, Industrial Ecology is a field of study (Chertow, 2000) while Industrial Symbiosis is a practical instance of the science (Gibbs & Deutz 2007).

Both Industrial Ecology and Industrial Symbiosis may generate substantial gains as well as economically speaking as environmentally compared to individual and isolated initiatives (Erkman & Ramaswamy 2003).

Their central concepts include:

- mass conservation
- energy conservation
- technological improvements

3.1.2.1 ECO-INDUSTRIAL PARK

As explained here above, an Industrial Symbiosis network can takes place in an eco-industrial park. The idea of those parks is still in its genesis, therefore there are obstacles to fully grasp the context (Chertow, 2000). However, according to the latter, two definitions stand:

For the PCSD an eco-industrial park is:

> "*a community of businesses that cooperate with each other and with the local community to efficiently share resources (information, materials, water, energy, infrastructure and natural habitat), leading to economic gains, gains in environmental quality, and equitable enhancement of human resources for the business and the local community*" (President's Council On Sustainable Development 1996)

For the EPA field book:

> "*An eco-industrial park is a community of manufacturing and service businesses seeking enhanced environmental and economic performances through collaboration in managing 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 benefits each*

company would realize if it optimized its individual performance only" (Lowe 1997)

The last author goes further and argues that an eco-industrial park is more than:

"

1. *A single by-product exchange pattern or network of exchanges*
2. *A recycling business cluster (resource recovery or recycling companies)*
3. *A collection of environmental technology companies*
4. *An industrial park designed around a single environmental theme (i.e. a solar energy driven park)*
5. *A park with environmentally friendly infrastructure or construction*
6. *A mixed-use development (industrial, commercial, and residential)"*

Lowe recognizes four strategies (Lowe, 1997):

1. Centralized waste management utility in charge of wastes of no value
2. Design and construction focused on resources efficiency, sustainable energy, non-toxic material use, and ease of reconfiguration
3. Centralized on-site information gathering service linking the companies in a single management system
4. The central management organization eases the exchange of information and select core activities requiring a central focus

In a nutshell, the notion of park is not meant in a confined area but as a network of enterprises putting together their efforts and sharing resources, utilities or services but involving a "*systematic recovery process of resource"* (Erkman & Ramaswamy 2003)

3.1.3 Regional - Global: Industrial Metabolism

Industrial Metabolism is a globalist view of the flows of materials and energy throughout the industrial system from their extraction up till their reintegration in the biogeochemical cycles. Its study is performed mainly through analytical and descriptive approaches (the materials-balance principle) (Erkman, 1997).

In order to do such a study, one needs to consider all the relationships in the industrial sector, such as the raw materials producing factories and the other factories using those raw materials with the distribution systems used to transport and sell the products (Erkman, 1997). All in all, the Industrial Metabolism is a sum of all the means of manufacturing and consumption networks including the amount of raw materials, energy used and the wastes produced (Erkman, 1997). The output would be a physical representation of the economy (Erkman, 1997). Such an analysis is made through the analytical and descriptive approach called *Material Flow Analysis* which is derived from the principle of conservation of mass (Erkman & Ramaswamy 2003)

The second aspect of Industrial Ecology is dematerialisation-decarbonisation and the service industry. It is the "*development of concepts and strategies for the optimization of the flows of materials within the economy, which is largely based, (...) on technological evolutions. This implies an increase in resources productivity, or dematerialization, which is not a trivial concept*" (Erkman, 1997). Its purpose is a reduction in the global consumption of materials and energy (Erkman, 1997).

Industrial Ecology goes a step further, as a reminder, studying the impact of such Industrial Metabolism on the environment.

3.2 Lessons from the past - Central planning or market mechanism

Two authors, Pierre Desrochers and Frank Boons oppose their views regarding Industrial Ecology and whether or not market mechanisms are enough for the implementation of such practices. Pierre Desrochers (2000) argues that in the past, there have been many instances of resources sharing and recycling without any needs for governmental policies or incentives. However, Boons (2008) argues that those instances are to be put back in their original context of *inter-firm recovery* and not *Industrial Ecology* which requires a reduction in the impact of the industries on the environment. According to the latter indeed, studying the past helps understanding the complexity of promoting Industrial Ecology in the present.

Desrochers develops throughout his work that the widespread view that traditional economic development is only characterized by a linear process of extraction and waste is not entirely true and backs his claims on historical evidences in which closed loops were prevalent (Desrochers & Simmonds 2000). According to him, the main driver for such loops was mostly based on the potential savings that one company could capitalize on rather than out of any environmental awareness. He argues that nowadays, there are incentives for the creation of closed loops imposed by the market mechanisms such as the facts that

1. Waste value is greater for a third agent than the producer
2. Because of the processing stage the residuals comes from, it does not require as much costs as compared to producing the resource from raw materials
3. Wastes are produced closer than the production of raw materials therefore lowering the transportation costs.

In order to prove those points, Desrochers uses a panel of historical examples from around the world from the earlier stages of Humanity to the 19th century, such as the German economy before the First World War and the context of resources scarcity that ensued (Desrochers & Simmonds 2000). However, Boons argues that it was far from a free market, with the creation of central city waste recovering units and that pursuing commercial gain alone does not go hand to hand with welfare or a lesser environmental impact (Boons, 2008). Besides, this is not the only example related to the War that Desrochers uses. For instance, during the after war period, recycling activities were disregarded after the sudden scarcity of resources disappeared and that the authorities had a lesser incentive to create policies in this regard. However, nowadays with the increasing resources scarcity that our economies faces and the increasing environmental concerns, it creates new incentives such as those in play during those periods (Boons, 2008).

It is not the purpose of this work to decide whether or not market mechanism are a better driver for Industrial Ecology than governmental actions but it seems interesting to take those arguments into account regarding the historical facts about resources sharing and recycling.

Desrochers considers that central planning or governmental policies create more pitfalls than benefits for potential members of an industrial symbiosis network (Desrochers & Simmonds 2000) and argues that point with the facts that it supposes that firms in the market economy have a greater incentive to dispose and treat wastes rather than trying to eliminate them and that employees either or both lack incentives and information gathering abilities, as compared to the central planning comity, on loop-closing possibilities (Desrochers & Simmonds 2000). He goes further by saying that agents more closely located to the production centre have a greater understanding and knowledge about their activities (Desrochers & Simmonds 2000). On the other hand, Boons argues that in several examples used by Desrochers, there are evidences of a certain involvement of governmental agencies and that the context was not simply between market and governmental activities but was also influenced by culture and social norms, much more inclined to implement waste reduction policies (Boons, 2008).

Ellis Brand and Theo de Bruijn (1999) offer a good summary and conclusion of the two authors above. They argue that first and foremost the possible partners of an Industrial Ecology network need to be convinced of the economic well-being of the venture. Authorities cannot have the upper hand in the negotiations regarding exchanges for the simple reason that they do not have a sufficient insight. However, they can indeed offer stimuli for the process and start the rounds of negotiations between agents and later identify the future leaders and ensure that the legal framework will not act as an obstacle.

Another interesting point regarding the past is developed by Erkman (1997) who tries to explain that, in the past, most of the activities were closed looped but the emergence of specialized units of production separated the once integrated processes. One example seems particularly interesting regarding that point: in the past, most farms were of mixed production with farming on the one hand and breeding on the other. The by-products of farming were used to feed the livestock and the excrements of the latter used to amend the soils. However, modern farms are more and more specialized either in farming or in breeding and the wastes produced are indeed transported from one instance to another but according to Erkman (1997) the supply surpasses the demand and therefore excess production is now considered as wastes that need disposal.

3.3 EMERGENCE

There are ways to help and implement Industrial Ecology initiatives on the local level. Even though having the necessary facilities in order to start the cooperation, there is a need for other aspects, social, cultural, etc... (Brand & De Bruijn 1999)

In terms of facilities, one can create or transform industrial estates the following way (KPMG 1998):

- *Sustainable production process*: production process improvement through companies' collaboration, exchange of materials and energy, joint utilities, integrated management of refuses and mobility management.
- *Sustainable estates construction*: careful central planning and administration can help improve the activities of all partners. Optimization of space, energy systems, pairing production processes and joint services.

Transforming existing estates is another step towards a greater sustainability: directly, by the creation of new facilities, optimization of transport and indirectly, by avoiding the creation of a new estate from scratch (Brand & De Bruijn 1999). Indeed, it is difficult to plan in advance without knowing which companies and their respective processes will become partners (Brand & De Bruijn 1999). Brand and de Bruijn offer a way out by proposing to try and locate companies based on the requirements on the regions and offer them to relocate, as well as developing a common thematic that would attract the right kind of agents.

3.3.1 Social aspects

An industrial ecology system is "*embedded*" within the social system around it (Uzzi 1996) in an extend that social relations have a big impact on the decision process (Doménech & Davies 2011). Interactions between the actors is paramount such as discussions to establish exchanges and other co-operative behaviours, it serves as a sense of community building (Gibbs & Deutz 2007). Following such actions, agents will develop an appropriate behaviour and change their own (Gibbs & Deutz 2007).

3.3.1.1 Trust and Cooperation

Given the fact that Industrial Ecology arises from a network of agents, moving towards a closed loop system (Chertow 2007) who have to share information about their processes (Uzzi 1997), trust and cooperation are of the utmost importance. Research has been conducted and a correlation has been uncovered between trust and the social position of the individual in the hierarchical structure (Ashton, 2009). However, according to Uzzi, there is still a lot to be done to understand the underlying mechanism behind trust and cooperation creation (Uzzi 1996).

3.3.2 Steps

3.3.2.1 Emergence

Often, this emergence is linked with a scarce resource putting a high constraint over agents (Doménech & Davies 2011). For that initial step to be achieved, the following conditions are required.

- Changing and stiff regulations
- Uncertainties regarding process and outcome caused by the requirements for the exchanges
- Creation of shared culture and transfer of tacit knowledge (Jones et al. 1997)

However, those conditions are straightforward in terms of cooperation and rarely rely on complex processes or upgrades (Doménech & Davies 2011).

In order for an agent to decide and join in an Industrial Ecology system arrangement, they have to find an access to information, a certain economic attractiveness, a favourable legal framework; it must be technically possible and lastly, have internal motivation (Brand & De Bruijn 1999).

3.3.2.2 Probation

During this step, agents gain contextual experience and knowledge about the system and discover new potential exchanges (Doménech & Davies 2011). The most important aspect is to understand the other agents, but also, their respective needs, skills set and experience (Doménech & Davies 2011).

3.3.2.3 Development and expansion

Next, agents increase the level of their collaboration and start building the new linkages. A virtuous circle is gained, with trust, experience and knowledge between and about the various agents (Doménech & Davies 2011).

Ashton notes that it is important in the long run to have members of the authorities, industries and public around the negotiation tables in order to ensure that each agent finds due in the agreement. It relies on open discourse and has to meet the needs for cost effectiveness as well as quality of life (Ashton 2011)

Authorities can have a great impact on the stimulation of Industrial Ecology and have a few models at their disposal depending on the situation at hand (Oldenburg & Geiser 1997).

First of all, in the case of 'wrong doings' from agents impacting the environment or public safety, the authorities can deploy a *command and control* if they have the suited power and authority. The latter is not always at hand nowadays and therefore, that model might not be possible. Indeed, government might have a greater stimulating role than a coercive one (Brand & De Bruijn 1999).

The other option is for the local authorities to create a *sustainability team* whose goal is to bring information to the estates and to offer help and expertise to the agents (Brand & De Bruijn 1999).

Finally, organizing *workshops* whose goals are to answer inherent questions that potential agents have and building the right team of companies together (Brand & De Bruijn 1999).

3.3.2.4 LOCATION

According to Chertow (2008), different types of symbiosis emerge based on their locations. For instance, by-product exchange will be prevalent in urbanization economies and utility and service sharing will be located mostly in localization economies. Erkman (1997), however, argues that creating “Islands of sustainability” or Industrial parks around specific industrial activities, (such as thermal power plants or steel mills...) can foster exchanges and regional thinking.

3.4 Types of exchanges

Below, will be listed 3 approaches to Industrial Ecology as developed by van Berkel, Willems and Kafleur (1997). Those approaches are not mutually exclusive but used together (van Berkel et al. 1997).

- Material specific
- Product specific
- Regionally focused
    - Service sharing
    - Utility sharing

Beside, based on the definition of Industrial Ecology developed earlier, Industrial Ecology requires two or more agents in order to arise; therefore, one company alone cannot implement those notions by itself. It is indeed possible to use some of the concepts at hand to improve the environmental impact and sustainability of the production but in this respect, it is known as Cleaner Production and not Industrial Ecology (van Berkel et al. 1997).

3.4.1 By-products exchange

It is the exchange from an agent to another of a specific material as an alternative to commercial products or raw materials (Chertow 2007).

There are two types of by-products exchanges depending on the focus of the exchange.

3.4.1.1 Material Specific

The first is Material Specific, defined by (Jelinski et al. 1992), it assesses the flow of materials through the industrial society and as a purpose it spots, appraise and implement improvements opportunities (van Berkel et al. 1997).

Two notions can be used:

- Dematerialisation: "*reduction in the amount of waste generated per unit of industrial service*" (van Berkel et al. 1997) or the reduction of the "*weighted cradle-to-grave materials input per unit of service*" (van Weenen 1995)

- Resource cascading : "*optimal use of the resources, through repeatedly making use of the quality of the resource on its path to ecological equilibrium"* (van Berkel et al. 1997) and is based on four concepts
  - Appropriate fit : using the right quality of resources for the task at hand
  - Augmentation : using the right quality for the utilization time
  - Consecutive relinking : recovering and reusing products from the production chain
  - Balancing resource metabolism : means to adequate the amount and rate of products from entry, circulation and regeneration in the process chain (Sirkin & Tenhouten 1994)

3.4.1.2 PRODUCT SPECIFIC

The second approach is product specific. In a sense, rather than focusing on a particular input of the chain of production, it uses the product as a starting point and assesses how to optimize the materials flow in terms of its impact on the environment (van Berkel et al. 1997).

- There are risks inherent to by-product exchanges as presented by Lowe (1997),
- Depending on one's by-product is less reliable than depending on a raw material
- Shared proprietary information can end up in the hands of the competitors
- Variable quality of by-products stressing equipment and output
- By-product exchange could keep one in using toxic materials

3.4.2 SERVICE SHARING

"*Meeting common needs across firms for auxiliary activities such as fire suppression, transportation, and food provision*" (Chertow 2007). In a nutshell, collaborating between industries in a same area in order to benefit from economies of scale and reduce waste (Chertow 2007).

3.4.3 UTILITY SHARING

"*Pooled use and management of commonly used resources such as energy, water, and wastewater*" (Chertow 2007).

Chertow (2000) notes that utility sharing may not be considered as Industrial Ecology; however, it meets the definition of a 'Collective approach to competitive advantage' for physical resources. On the other hand, Brand and Bruijn (1999) argue that the INES project in the Rijnmond area, whose purpose was to test the success of Kalundborg, unveiled the fact that utility sharing acts like an incentive to join a network by virtue of the fact that it offers a great amount of savings for companies. Furthermore, they add the fact that it can stimulate cooperation, creating the trust and options evaluation in the network.

4 SUSTAINABILITY

4.1 GENERALITIES

Before deep diving into this subject, it is crucial to define one key concept related to Industrial Ecology, the concept of sustainability. As we have mentioned in an earlier topic of this work, Industrial Ecology can be a step towards sustainability. Indeed, according to Allenby, Industrial Ecology is nothing less than the 'science of sustainability' (Allenby 1999). Furthermore, Ashton considers that a concentration of companies, coordinating their activities and resources, achieve benefits for the society in economic and environmental fields (Ashton 2009). There is a lot of research done on the subject; below, I will try to review some authors in order to create a thorough definition, with a particular focus on Ehrenfeld (2000) whose research about sustainability takes into account the mainstream view and brings them further.

The most agreed upon definition of sustainable development, or sustainability (as defined during the Rio Summit in 1992), is any form of progress or development that “*meets the needs of the present without compromising the ability of future generations to meet their own needs*”. However, the assumption behind this definition is that the concept *development* comes from the neoclassic economic theory which assumes that welfare is linked with economic output and if the market functions correctly, there is continuous growth.

Also, in this context, scarcity is defined as “*limited availability of substitutes at competitive prices without regard to the physical or material reality of factors derived from the natural world*” (Ehrenfeld 2000).

Ashton, however, summarizes “sustainability” as the following: “*Within a given geographic context, sustainability implies the maintenance of healthy natural ecosystem functions, desirable economic opportunities, and good quality of life for human inhabitants*” (Ashton 2009). Ehrenfeld argues that sustainability is not merely a technological characteristic of a global system but rather depends on the system's nature framework; for him, sustainability is “*a future vision from which we can design and then construct our present way of living*” (Ehrenfeld 2000). Finally, Ehrenfeld collates different definition for the following: "*Sustainability is a possible way of living or being in which individuals, firms, governments, and other institutions act responsibly in taking care of the future as if it belonged to them today, in equitably sharing the ecological resources on which the survival of human and other species depends, and in assuring that all who live today and in the future will be able to satisfy their needs and human aspirations*" (Ehrenfeld 2000).

Alongside such logic, Ashton (2011) argues that the process that would allow to reach such a dynamic depends on the understanding of the context at a local scale as well as the public needs and expectations, may them be implicit or not (Ashton 2011). In order to do that she suggests open discourse and participation from the public to ensure the fact that agreements between the industry and the authorities meet the needs of both the industry and the local communities as far as cost effective resource management and quality of life are concerned (Ashton 2011).

Even though sustainability is a concern at a global scale, Brand and de Bruijn (1999) argue that the changes required must arise both locally and regionally.

4.2 SUSTAINABILITY AND THE INDUSTRY

Nowadays there is a growing environmental concern that motivates taking the necessary action in order to achieve sustainable development (Brand & De Bruijn 1999). The European Union is moving towards that goal and considers that "*achievement of a higher level of environmental protection is a precondition of (sustainable) long-term economic development*" which is based on four key principles (Gouldson & Murphy 1996):

- Successful combination of environment and economic well being
- Crucial role of technology in this notion
- Environmental measures being integrated externally
- Alternate innovating policy measures.

To that extent, Industrial Ecology is considered attractive given the fact that it is system based and can be assimilated in the fields of science, technology and environment (Brand & De Bruijn 1999). Erkman (1997) considers that Industrial Ecology is one of the several paths that could provide an economically sound solution. Frosch and Gallopoulos (1989) consider that if both developed and developing nations chose to embrace change towards

Industrial Ecology it will be possible to reach a more sustainable economy regarding raw material scarcity and the increased impacts of wastes and pollution.

4.3 Sustainability and developing countries

Sustainable development is based on three dimensions: natural environment, social and economic (United Nations 2013). Developed economies already have a greater level of development as far as the social and economic dimensions are concerned (which allows them to concentrate on the ecology) (Couret 2008) but developing economies still have to give both their priority (Couret 2008). As a matter of illustration, the Millennium Development Goals focused on the human and economic development but new challenges are also arising in the fashion of environmental protection (United Nations 2013). However, anything that happens in one part of the globe as far as the natural environment is concerned has a global impact (Couret 2008).

A major challenge is due to the fact that unsustainable consumption and production methods of the developed world is being imitated by emerging economies (United Nations 2013). The United Nations Conference on Sustainable Development drafted a guide to improve the present and future well-being of populations while attaining sustainable development (United Nations 2013). The United Nations recognise the need for technological innovations to reach such a goal (United Nations 2013).

On the other hand, it must be highlighted that some developing nations have put into motion initiatives more advanced than developed nations (United Nations 2013). Ecuador and Bolivia have legalised the "*Right of Nature*" act in their constitution (United Nations 2013).

The department of Economic and Social Affairs also acknowledges that the three dimensions can work together to achieve a greater role. As an example, giving access to clean cooking fuels and electricity can be achieved at a relatively modest investment cost and help the three dimensions of sustainable development (United Nations 2013). However, it indeed requires to increase public spending (United Nations 2013).

5 INDIA

India is classified as a developing economy with a lower middle income (by GNI per capita, 2011 figures) (United Nations 2013). According to the World's Bank, a lower middle income country has a GNI per capita amounting to 45% of the World per capita GNI (The World Bank 2013).

India's official population amounts to 1 billion 241 million inhabitants (2011 figures) with a population density of 418 people per square kilometres, however, its urban population represents 31% of the country. The purchasing power parity (PPP) per capita amounts to $ 3,640 with a 4.9% growth (6.3 in the case of GDP growth) (The World Bank 2013). In contrast, The Euro Area has 332 million inhabitants with a population density of 131 people per square kilometre with 76% living in cities. Their PPP per capita amounts to $ 35,250 with a growth rate of 1.2% (1.5 in the case of GDP growth) (The World Bank 2013).

5.1 HISTORICAL EVOLUTION OF THE INDIAN ECONOMY

Between 3500 BC to 1800 BC India was ruled by the Indus Valley civilisation whose economy depended on trade eased by transportation evolutions (Consulate General of India 2013). The citizens were involved in the primary sector as well as metal production and transformation (weaponry or tools), pottery and precious metals. By 300 BC the Maurya empire united most of the Indian region and provided unity as well as security which allowed an increase in production as well as trade (Consulate General of India 2013). This period was also prone for roads and infrastructure development throughout the subcontinent. For 1500 years Indian classical civilisation was set and generated wealth at a great amount, ranking the country as the largest economy of the time (Consulate General of India 2013).

Between 1526 and 1858 AD the Mughal controlled the country and offered “unprecedented prosperity” (Consulate General of India 2013) and based on estimations its treasury was higher than that of Great Britain.

Beginning of the 18th century, the Mughal empire lost its major control and soon before the English occupation, the Marathas controlled much of Central India (Consulate General of India 2013).

5.1.1 British Occupation

From 1757, The British East India Company expanded its political power in India and created a double impact on the economy. On the first hand, an inflow of wealth due to the purchase of goods, spices and raw materials but on the other hand, foreign trade was at a full stop (Consulate General of India 2013). Most of the revenues generated from India was used to wage war and not to develop the lands, furthermore, in the span of less than a century, India changed from being a net exporter of processed goods to being an importer of manufactured goods as well as exporter of raw materials (Consulate General of India 2013).

According to the British Economist Angus Maddison, the Indian economy declined to a great extent, from securing a 27% of the World's income in 1700 AD to 3% in 1950 (Consulate General of India 2013).

5.1.2 Post-independence

India recovered its independence in 1947 and started rebuilding its economy through centralised planning with the USSR Five Year Plans tool that was implemented in 1952 (Consulate General of India 2013). Most of the infrastructure development investments were made in the primary sector, the largest at the time but also in modern industries and institutes. The growth did not catch as fast as the authorities hoped (Consulate General of India 2013).

Later on, between 1980 and 1990, the growth rate improved coming from 3.1% to 5.5% explained by a high investment. The sources of the investment changed from private savings to borrowed funds in the late 1980s. A payment crisis arose in the 1990s resulting in a decrease in available loans, solved by a promise for further liberalisation by the authorities (Consulate General of India 2013).

From 1991, India began its economic liberalisation process and as the third largest economy in the world, attracted one of the largest amount of FDI (Consulate General of

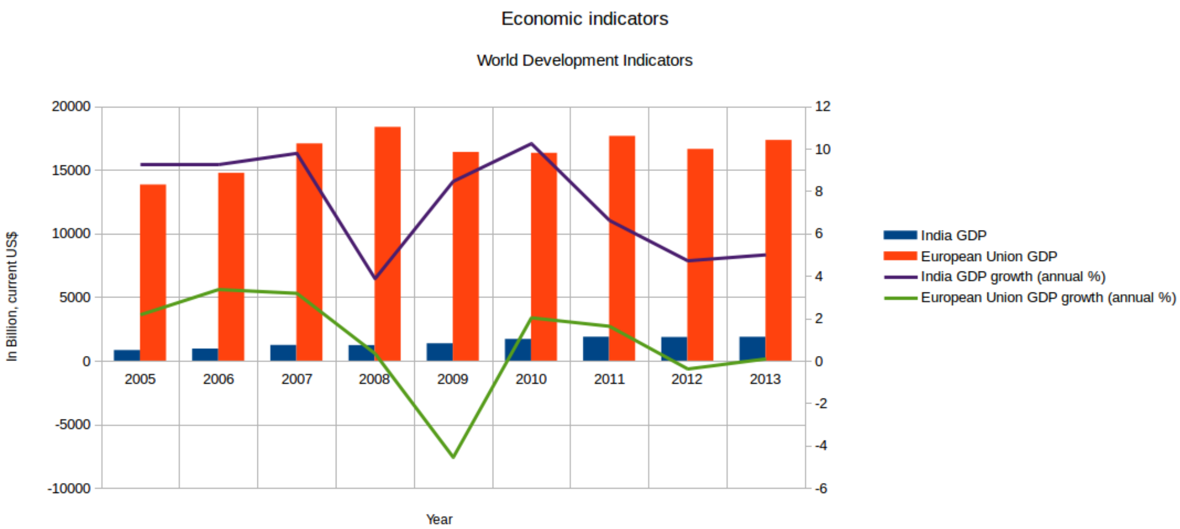
India 2013). In recent years, India improved its knowledge base and became a reference in manufacturing, striving to become the second largest economy in manufacturing by 2017 following the National Manufacturing Policy (Consulate General of India 2013).

5.2 Country Indicators

This section will be built around a comparison between the European Union and India the underlying reason is that of contrast. India's size represents about three quarters of the European Union (4,324,782 square kilometres for the European Union (CIA World Factbook 2014), 3,287,263 square kilometres for India (CIA Factbook 2014)) but they are very different in other aspects.

5.2.1 Economic Indicators

FIGURE 4 : GDP COMPARISON



GDP DATA COMPARISON BETWEEN EU AND INDIA (The World Bank 2013)

As presented in the table, The GDP of India is much lower than the European Union's (1/16th in 2005) but has a significantly higher growth rate. In 2013 the gap is reducing between the areas and the European Union's GDP is then "only" 9 times higher.

The GDP share per sector is as follow:

TABLE 3 : ECONOMIC SECTORS

Sectors	Percentage Share in GDP	
	1950-51	2011-12
Primary sector	59	16.1
Secondary sector	13	24.9
Tertiary sector	28	59

PERCENTAGE SHARE OF THE ECONOMIC SECTORS IN INDIA (Consulate General of India 2013)

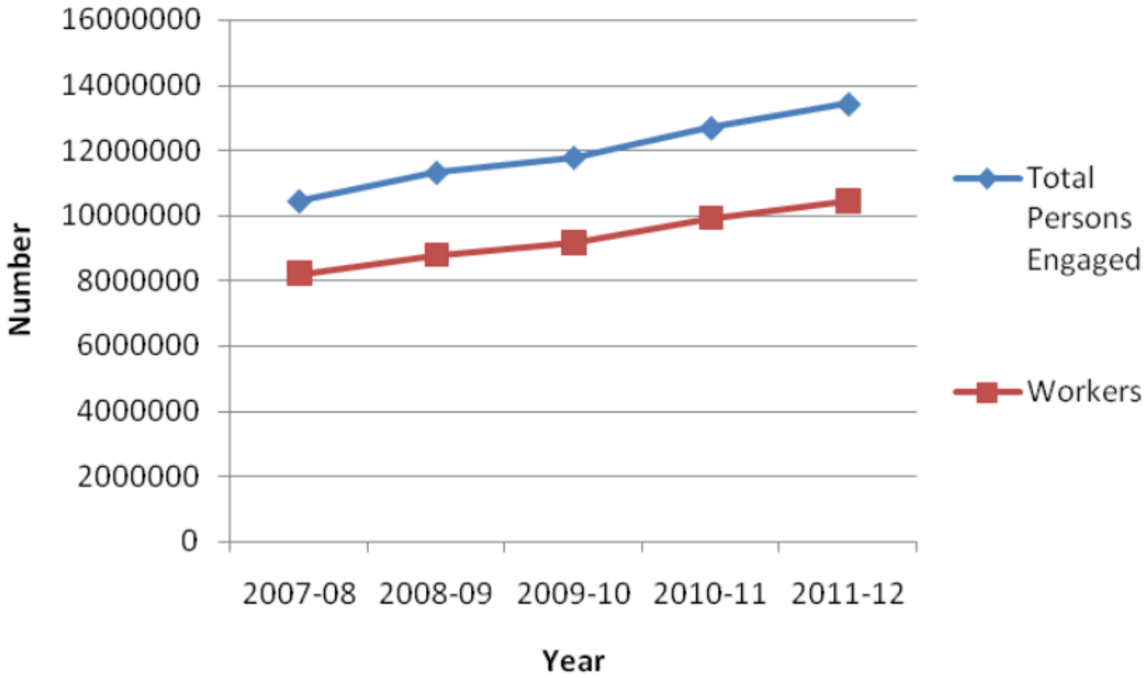
On the other hand, the European Union has a 1.8% GDP composition in the agricultural sector, 25.2% in the industrial sector and therefore 72.8% in the services sector (CIA World Factbook 2014), which is relatively constant with a notable but smaller decrease in the industrial and agricultural sector in favour of the services sector (CIA World Factbook 2014).

5.2.2 WORK FORCE

According to the World Development Index (2013) India has a nuanced score as far as employment is concerned. On the one hand they have an unemployment rate of 3.5% and a labour force participation rate of 56% but on the other hand vulnerable employment[4] rate is as high as 81%. On the brighter side, India is moving towards a higher education standard (Ministry of Statistics and Programme Implementation 2014) by mandating an obligatory primary education. As a result, the literacy rate for the 15 - 24 years old is 81% and growing (The World Bank 2013).

[4] unpaid family workers and own-account workers as a percentage of total employment

FIGURE 5 : EMPLOYEMENT



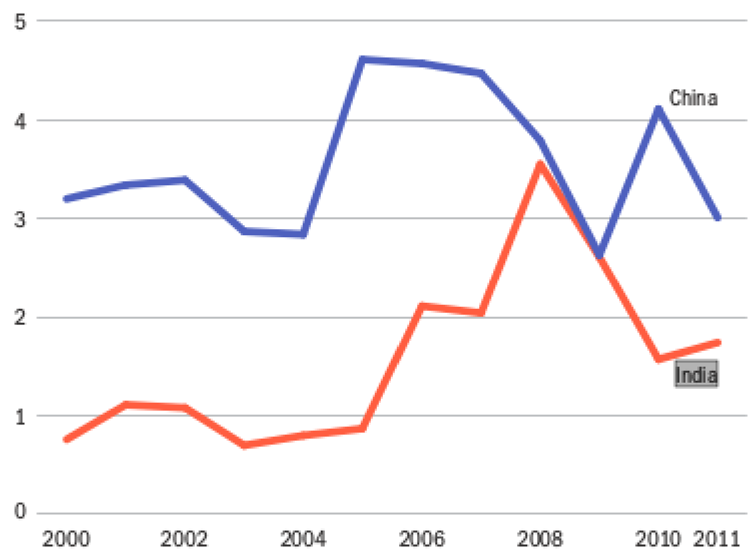
NUMBER OF WORKERS AND TOTAL PERSON EMPLOYED IN INDIA (Ministry of Statistics and Programme Implementation 2014)

There is a steady growth in both aggregates but it is worth mentioning that lately there are a higher growth in Total Persons Engaged, due to the increase of auxiliary employees or managerial staff (Ministry of Statistics and Programme Implementation 2014)

5.2.3 INDUSTRIAL DEVELOPMENT

According to the World Bank, India and China are the two best growing economies within the developing countries (The World Bank 2013) and attracts a high FDI inflow. India went for an import substitution policy putting barriers for foreign investors and promoting domestic companies (The World Bank 2013). FDI started liberalizing in the 1990's and decreased between 2008 and 2010 before growing back up afterwards (The World Bank 2013). In 2011 FDI represented $ 32 billion 190 million (The World Bank 2013).

FIGURE 6 : FDI



FDI EVOLUTION IN INDIA AND CHINA (THE WORLD BANK 2013)

The industrial environment of India is statistically analysed by the Ministry of Statistics and Programme implementation of the Government of India. They publish an annual survey of industries which is the principal source of information available on the subject.

The coverage of this analysis is any factory defined as:

> "'Any premises' including the precincts thereof:
>
> 1. Wherein ten or more workers are working or were working on any day of the preceding twelve months, and in any part of which a manufacturing process is being carried on with the aid of power or is ordinarily so carried on, or,
>
> 2. Wherein twenty or more workers are working or were working on any day of the preceding twelve months, and in any part of which a manufacturing process is being carried on without the aid of power or is ordinarily so carried on, but does not include a mine subject to the operation of the Mines Act, 1952, or a railway running shed.
>
> The 'manufacturing process' referred to above has been defined [vide Section 2(k)] in the Factories
>
> Act, 1948 as:

'Any process'

1. making, altering, ornamenting, finishing, packing, oiling, washing, cleaning, breaking up, demolishing or otherwise treating or adapting any article or substance with a view to its use, sale, transport, delivery or disposal; or,

2. Pumping oil, water or sewage; or,

3. Generating, transforming or transmitting power; or,

4. Composing types for printing by letter press, lithography, photogravure or other similar process or book binding; or,

5. Constructing, reconstructing, repairing, refitting, finishing or breaking up ships or vessels; or,

6. preserving or storing any article in cold storage." (Ministry of Statistics and Programme Implementation 2014)

5.2.3.1 PRINCIPAL AGGREGATES

The summary of the findings of the Annual Survey of India regarding the Industrial Sector can be presented in the following table. The results are compared with last year's findings (2010 - 11):

TABLE 4: INDUSTRY AGGREGATES

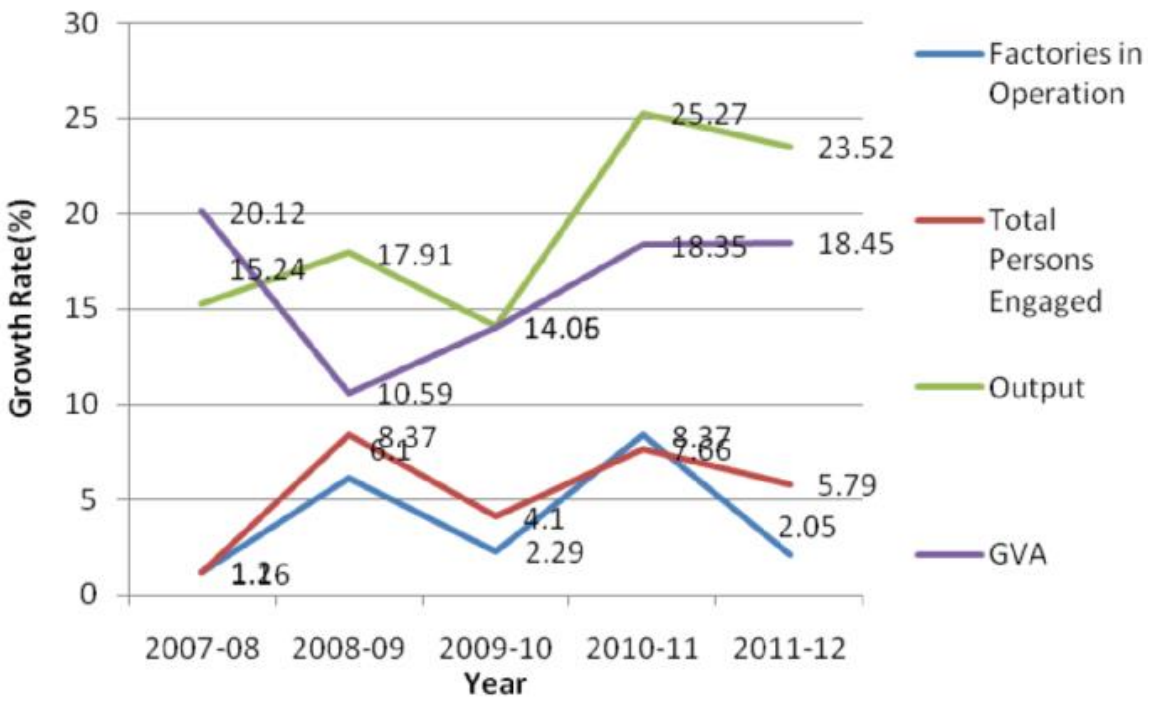
	Local value	Value in €[5]	Growth rate
Operating factories	175,710		2.05
Stock of Fixed Capital	₹19,495,508 M	€250,520 M	21.32
Invested Capital	₹ 28,400,951 M	€ 365,956 M	18.65
Employment	13,429,956		5.79
Emoluments to employees	₹ 2,147,334 M	€ 27,593 M	17.15
Inputs	₹ 47,986,655 M	€ 616,636 M	23.52
Worth of produced goods and services	₹ 57,760,325 M	€ 742,228 M	23.52
Net value added by organised manufacturing sector	₹ 8,367,029 M	€ 107,517 M	18.75

SUMMARY OF THE PRINCIPAL INDUSTRY AGGREGATES (MINISTRY OF STATISTICS AND PROGRAMME IMPLEMENTATION 2014)

[5] Calculated using an exchange rate of 1€ for 77 Rupees

Another way of looking at the industrial “environment” of India is having a look at the growth rate across the sectors.

FIGURE 7 : SECTORIAL GROWTH RATE



ANNUAL GROWTH RATES OVER PREVIOUS YEARS IN INDIA (Ministry of Statistics and Programme Implementation 2014)

As one can see, the growth rates in India are high which indicates a dynamic sector in expansion. However, one should highlight the fact that the Gross Value Added and Output are growing at a higher rate than the Factories in Operation and Total Persons Engaged (Ministry of Statistics and Programme Implementation 2014). This would indicate an increase of productivity per worker due to increased capital or technology.

The major employers in the Industry are Food Products (12.13%), Textiles (10.86%), Basic Metals (8.11%), Other Non-Metallic Mineral Products (6.98%) and Wearing Apparel (6.87%) but in terms of Gross Value Added, Basic Metal, Chemicals and Chemical Products and Pharmaceutical Preparation are on top (Ministry of Statistics and Programme Implementation 2014).

5.3 TAX SYSTEM

As said earlier, in order to achieve a sustainable development, a nation will have to increase public spending. This is hindered in India because their tax revenues are low and represent about 10.5% of GDP in contrast with an average of 20% in more developed economies (The World Bank 2013). With a majority of VAT, India is introducing new goods and services imposition but remains penalised by the low collection rates in terms of VAT and income tax (The World Bank 2013) due to the size of the informal sector as said earlier.

Palaniappan Chidambaram, Finance Minister of India reported that a mere 2.86% of citizens pay their income taxes (Ghosh 2013). It amounts to 36 million people, in contrast with the USA where 45% individuals contribute to the income tax system (Rao 2000).

Palash Ghosh (2013) identifies two underlying reasons for such a low rate:

- Many do not qualify to the taxes because of their income level[6]
- India has a massive shadow economy and in remote places acting as a deterrent to the required logistic of tax collection

The second point involves both rural companies and citizens but big companies duly registered are basically captive by the tax authorities and therefore pay their corporate taxes (Rao 2000). Similarly, the dividends they give out to their shareholders are automatically duly declared (Rao 2000).

Most of the filed individual income tax statements are sent by larger companies to the authorities regarding their employees (Rao 2000).

However, there is a growing concern about tax evasion due to the fact that many can easily hide their real income (in Singapore or Switzerland) (Rao 2000). The authorities will be trying to alleviate that issue and widen the tax base by citing their expenditures (Ghosh 2013). However, there is a concern about the corruption and the inefficiency of the system (Ghosh 2013).

[6] No income tax below an annual revenue of ₹ 200,000 ; between the former and ₹500,000 a 10% tax is levied ; 20% up to ₹1 million and 30% above that (Ghosh 2013)

6 CONCLUSION

Sustainability is a global concern for sharing resources in the present as well as the future for the benefit of all species, without impeding the economy. It is as important on a global scale but requires changes made locally, in regions or even smaller nodes. Sustainable development is a spread goal amongst nations and the key to success is for each nation to take the necessary actions.

Environmental measures should therefore be integrated externally and an evolution of technology is paramount to combine environmental protection and economic wellbeing. In developed economies with established industries, achieving a sustainable way of production is costly due to the infrastructure changes required.

On the other hand, in developing economies, adopting best practices in the establishment of production units can represent a competitive advantage and a head start compared to existing units.

India is a large country populated with 1.4 billion inhabitants and whose economy is growing at a fast pace. The country is experiencing a strong industrialisation and attracting an increasing amount of Foreign Direct Investment. Invested capital, employment and output are undergoing a constant growth rate with the environmental impact that goes along with such an evolution.

A developing economy is facing increasingly important issues. Its economic development as well as environmental protection and oftentimes, the strategy taken by the authorities is to focus on the economic development at first in order to increase revenues and later on spending it on ecological solutions.

Industrial ecology has not only to do with the industrial or manufacturing sector but also goes far further. It studies the flow of all resources in a broad sense through an identified system whose size may vary from a group of factories to a region or a country. Its ultimate purpose is an optimisation of the use of resources in both production and consumption.

The Industrial ecology's primary goal is to reorganise the industrial system (including all aspects of the human activity) in order to make it sustainable and compatible with the biosphere. There are four main elements in its strategy, namely (1) optimising the use of resources (2) closing material loops and minimizing emissions (3) dematerializing activities and (4) reducing and eliminating the dependence on non-renewable source of energy.

Optimizing the use of resources (material and energy) has already been in focus for a few decades with Pollution Prevention or Cleaner Production techniques but there is room to go further. One example is that of the industrial food chain, increasing resources utilisation, which can take place in an Eco-Industrial Park, not reduced to a single location, hence the concept of an eco-industrial network.

Closing material loops require compounds that deconstruct any product into smaller materials. In the industrial system that recycling activity is still far from perfect and only a fraction is returned to the system, the rest being lost and dealt with as such. These wastes are produced during the manufacturing process for the smaller part and for the bigger part when a product is not considered to be valuable anymore and in products designed to be dispersed during their use. It therefore requires addressing the product in its entire life cycle.

The dematerialisation of activities is another way to minimise the total flow of energy and material used, providing equivalent level of services. Technological improvement is one way of achieving dematerialisation; however, it can occur that by reducing material input the overall robustness may be reduced hence a shorter lifespan. One of another way to achieve such a saving is service and / or utility sharing in closely collocated companies.

Energy is indeed a key factor in the restructuration of the industrial system and efforts are required to increase energy efficiency. Fossil fuels are the roots of ecological problems because of their dissipative effect. A change is required to either make the use of fossil fuels less harmful or to move towards a more sustainable form of energy.

On top of that and to wrap the different notions up, Industrial Ecology can be seen as a way to combine two usually separate strategies as seen previously, economic development and ecological measures. Developing economies could therefore put focus on both at the same time.

SECOND PART:

CASE STUDY

7 PROBLEMATIC AND RESEARCH QUESTION

In the previous section we have covered intensely the topic of industrial ecology in India as a proxy for developing economies. It would therefore be pertinent to analyse an existing case in the country.

More precisely, the purpose of this analysis is to highlight *How* the project emerged and *What* is happening in the system. A further question would be to uncover the benefits that are arising thanks to the process. Benefits will be regarding the economics, the people as well as the environment.

The *Case* that will be studied in this paper is the initiative taken by Seshasayee Paper and Boards Limited (SPB) in Tamil Nadu, near the river Cauvery. Faced with a raw material problem, the factory first reinvented its technology to incorporate waste from the sugar industry in their process. Later on, they decided to launch a diversification and created a sugar factory as well as uniting the sugar cane producers in the region.

The purpose of our analysis is therefore to uncover and understand the reasons that motivated the creation of an Industrial Ecology initiative in that factory and draw a timeline of the evolution of the project.

Then, based on their logistic we will produce a map of the system from entry to exit and with the different exchanges within the functioning units. Based on such a representation of the system it will then be possible to grasp the overall system

Finally the several impacts the system now has over its environment (economics, people and natural) will be analysed to highlight the positive effects such an initiative may have. This will allow us to tackle the sustainability of the project as compared to the situation before or as it would be without such system.

8 METHODOLOGY

The method that will be used in this section is that of a single, exploratory, case study. The reasons underlying that choice has to do with the facts that even though there are Industrial Ecology projects in India, they are very different in nature, scope and background. However, one of them stands out due to its reach and complexity.

A caste study is:

> *An empirical inquiry about contemporary phenomenon (e.g., a "case") set within its real*-world context especially *when the boundaries between phenomenon and context are not clearly evident* (Yin 2009)

In other words, a case study research requires the context to be examined as well as other complex conditions in order to fully understand the case. It answers a descriptive or explanatory question (Shavelson & Towne 2002)

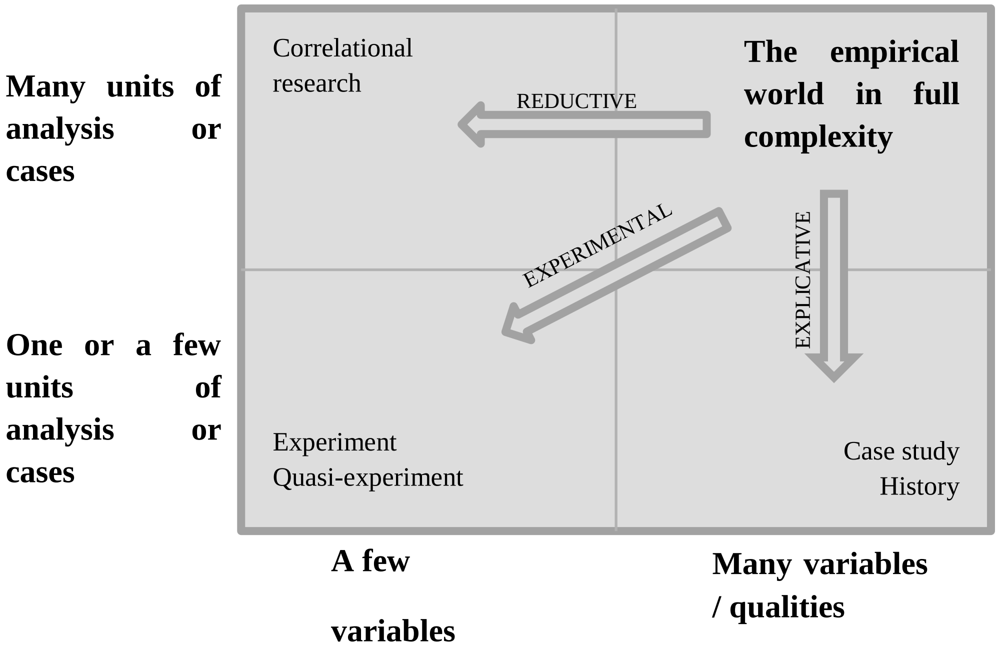
These questions are 'How' and 'Why' as mentioned in the first section. They deal with operational links occurring during a large time rather than incidents. Furthermore the extent of control exercised by the researcher is much lesser in a Case Study as compared with a quantitative study using surveys and similar tools (Yin 1984)

The tasks required to produce a case study research include the design of the case, the collection of data, its analysis and reporting the results (Yin 2003).

Designing a case is the first step of a study. It helps organising the case study but can evolve throughout the evolution of the research. Data collection is the second step undertaken. Good case studies have multiple sort of evidence used compared to other methods of research. It can include both qualitative and quantitative data. Data analysis is then performed and starts with a careful reorganisation of data in pattern matching, explanation building or time series analysis. Finally, the analysis must be reported and explained. (Yin 2003)

A case study is more adapted in our case as we are looking at a situation with many different variables, and because it is useful in fields such as environmental studies and business studies (Yin 2009). It is a single case story due to the fact that we will be studying a single case compared to several examples. Furthermore it will take the form of a descriptive exploratory case study.

FIGURE 8 : FOCUS OF EMPIRICAL RESEARCH



THREE STRATEGIES TO FOCUS EMPIRICAL RESEARCH BY REDUCING THE UNITS OF ANALYSIS (CASES), THE NUMBER OF VARIABLES (QUALITIES) OR BOTH. (Johansson 2003)

The object of a case should be a complex functioning unit, analysed in its natural context with a variety of methods and be contemporary (Yin 2003). Concerning this case the characteristics are indeed verified, it is indeed a distinctive example of production (Yin 2003) that results from a long development and is still contemporary. Furthermore, this case has intrinsic interests. It has been selected for being information rich, revelatory as well as unique in the World. It is similar to the Kalundborg example of applied Industrial Ecology with the slight difference that in Kalundborg, companies got together to share their wastes, while in our case, one company created a network to secure its raw material input.

Due to that characteristic, a case study is better suited for our focus. Indeed, there is no existing framework adequate to analyse the effect and emergence of an Industrial Ecology example.

A central characteristic of case study research is that different methods are used in order to illuminate the case from different angles (Stake 1995). This is paramount with our intent. Industrial Ecology is by essence a complex issue. It has impacts on several other aspects of the biosphere usually considered as separate. A fresh perspective is indeed needed (Rowley 2002).

In a nutshell, a case study analysis assesses critically the steps undertaken by an organisation to reach their objectives and uncovers the structure of their approach in order to achieve their goals.

The data used in a case study research is not only limited to a single source. Of course, having multiple sources of evidence is very beneficial in drawing a valid case study (Yin 2003). There are usually six common sources of evidences (Yin 2003):

- Direct observations
- Interviews
- Archival records
- Documents
- Participant-observation
- Physical artefacts

In this work we are bound to using three of these six sources. Archival records, Documents and physical artefacts. Indeed, direct observations and interviews were not possible due to lack of answers from the companies involved in the process.

The methodology that will be followed here is therefore the review of multiple case studies as well as triangulation, the use of multiple sources of evidences to corroborate a fact within the case studies reviewed (Yin 2009)

It will mainly be the use of previously made researches or case studies, based on both qualitative and quantitative researches. Integrating all of those works together will produce a broader view of the case study in its environment. These case studies were made by a large range of authors, from students in the form of theses to part of books made by university professors specialised in Industrial Ecology as well as other authors. Beside, papers and newspaper article, incidence study and reports will be used.

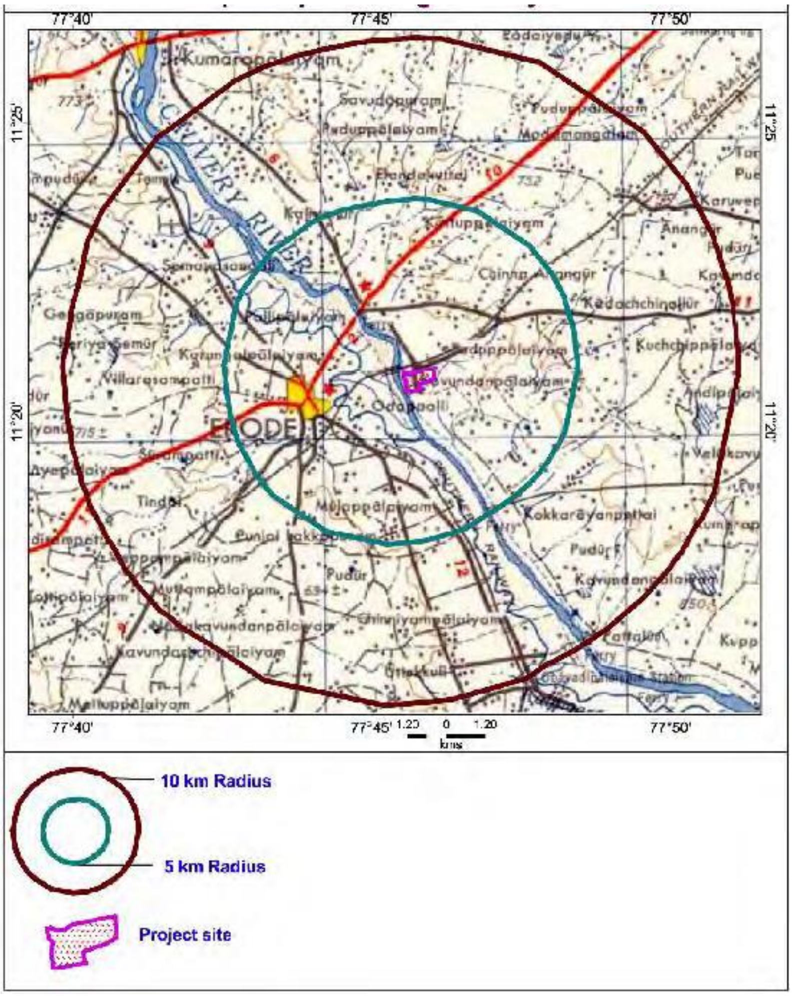
Generalisation will then be possible for India. Indeed, it fulfils characteristics that many other factories have in a developing country such as India. Generalisations are made with an analytical fashion with case studies and are based on reasoning rather than statistics (Johansson 2003). It can be achieved through induction. It is theory generation or conceptualisation based on data from the case (Glaser & Strauss 1967). Some authors indeed use the example of Seshasayee Paper and Boards limited to uncover other, smaller scales, initiatives in India (Erkman & Ramaswamy 2003; Patnaik 2014; Mahajan & Ives 2003).

9 CASE STUDY

9.1 BRIEF PRESENTATION OF THE COMPANY

Seshasayee Paper and Boards Limited is a paper company located in the South of India, in the state of Tamil Nadu, on the banks of the river Cauvery (Erkman & Ramaswamy 2003). They specialise in paper, paper boards, packaging and copier paper (Mahajan & Ives 2003; Dawande et al. 2015). The capacity of the company has been increased from 20,000 TPA[7] in the 60's to 115,000 TPA today (Mahajan & Ives 2003). Most of their production is aimed for export and the company employs about 1600 people (Mahajan & Ives 2003).

FIGURE 9: LOCATION OF THE FACILITIES (SESHASAYEE PAPER AND BOARDS LIMITED 2015)



7 Tonnes Per Annum

The company's vision, mission and values are the following (Patnaik 2014):

Values:

- Ethical practices
- Customer Focus
- Commitment to Society, Safety and Environment
- Professional and Transparent Management
- Empowerment and Accountability
- Adaptability to 'Change'
- Innovation and Creativity
- Emphasis on Human Resources Development, Cost Reduction, Productivity Enhancement and Resource Conservation.

Mission:

To manufacture quality products at competitive cost through technology and teamwork.

Vision:

To excel as a trusted, socially responsible and customer driven organisation providing maximum value to all stakeholders.

9.2 TIMELINE OF THE PROJECT

- 1961: creation of Seshasayee Paper and Boards limited
- 1962: Creation of the first Seshasayee Paper Mill (20,000 TPA)
- 1968: Adding 3rd paper machine (35,000 TPA)
- 1978: 4th paper machine (60,000 TPA)
- 1978: Water effluents treatment
- 1980: Energy crisis
- 1983: Creation of Ponny Sugars limited
- 1990: Creation of the farmers' cooperative company
- 1992: First signature of the joint venture agreement between SPB, Ponni Sugar and the cooperative
- 1996: Environmental clearance to double production
- 2001, 5th machine added (120,000 TPA)
- 2002: Second signature of the tri-partite agreement
- 2012: Third signature of the tri-partite agreement

- 2015: Environmental Clearance request for increasing capacity of paper production, chemical recovery, environmental equipment and power production

9.3 THE EMERGENCE OF AN INDUSTRIAL ECOLOGY INITIATIVE

9.3.1 RAW MATERIAL PROBLEM

Raw material availability has always been a problem for the paper industry in India due to the limited availability of wood, partially due to the continued effort of the authorities to reduce deforestation (Dawande et al. 2015). This motivated the use of bagasse, the fibrous waste remaining after the extraction of juice for sugar production from the sugar cane, as well as a technological development to include it in good quality paper production (Erkman & Ramaswamy 2003).

However, the sugar industry in India already used bagasse as an alternative fuel almost replacing the use of other sources; for the paper mills to benefit from the use of bagasse, they had to pay a sufficient price to the sugar mills for their alternative fuel supply (Dawande et al. 2015). This created many agreements between separate companies for the exchange of bagasse; however, in the beginning of the 1980's and the energy crisis, the sugar industry grew more reluctant in sharing its bagasse, on top of that the availability of wood even worsened making the situation even more constraining for paper mills (Erkman & Ramaswamy 2003).

9.3.2 RESPONSE FROM THE COMPANY

No conventional ways could help with such a situation. They decided to secure their supply of raw materials by vertically integrating and became involved in sugar production founding the company Ponni Sugar Limited (Mahajan & Ives 2003). However, everything had yet to be done given the fact that sugar cane cultivation was not a regional occupation.

9.3.2.1 ISSUES

Launching a new sugar factory faced many regulatory constraints. Indeed, there is a very strict governmental monitoring on sugar canes related activities due to the impacts it has on the lives of people. For examples:

- The growing lands are specified by the government
- A price roof is set
- Movement restrictions
- A tax is due in nature for the Public Distribution System
- Molasses cannot be sold

Beside sugar, sugar canes are used as a raw material for the manufacture of jiggery (an unrefined sweetener). Furthermore, after crystallisation of the juice to produce sugar, the liquor left is called molasses and is used to produce ethyl alcohol and the fibres resulting is bagasse as mentioned earlier (Erkman & Ramaswamy 2003).

The supply of sugarcane for the sugar factory was yet another problem to be addressed. It had to be as close as possible to the sugar plant, which was collocated next to the paper mill. Transporting cane is indeed expensive and since cane was not yet cultivated and agricultural lands are fragmented in India, neighbouring farmers had to be sold the idea of cultivating canes for the company. Another problem was linked with water supply as the lands were too far and high from the river. (Erkman & Ramaswamy 2003)

Other regulations are constraining paper producers as far as wastes are concerned; besides non-condensable gases emissions there are releases of furans, dioxins and chlorinated products (Dawande et al. 2015).

9.3.3 INITIATIVES

In order to address all those issues at once, the company decided to use the effluent water for irrigation of neighbouring fields. It was made possible thanks to the efficient effluent water treatment system of the paper mill and after elaborate testing (Mahajan & Ives 2003). It later on attracted more farmers to join in the partnership. Over time, the treated effluents alone was enough for the irrigation of 600 ha (Erkman & Ramaswamy 2003).

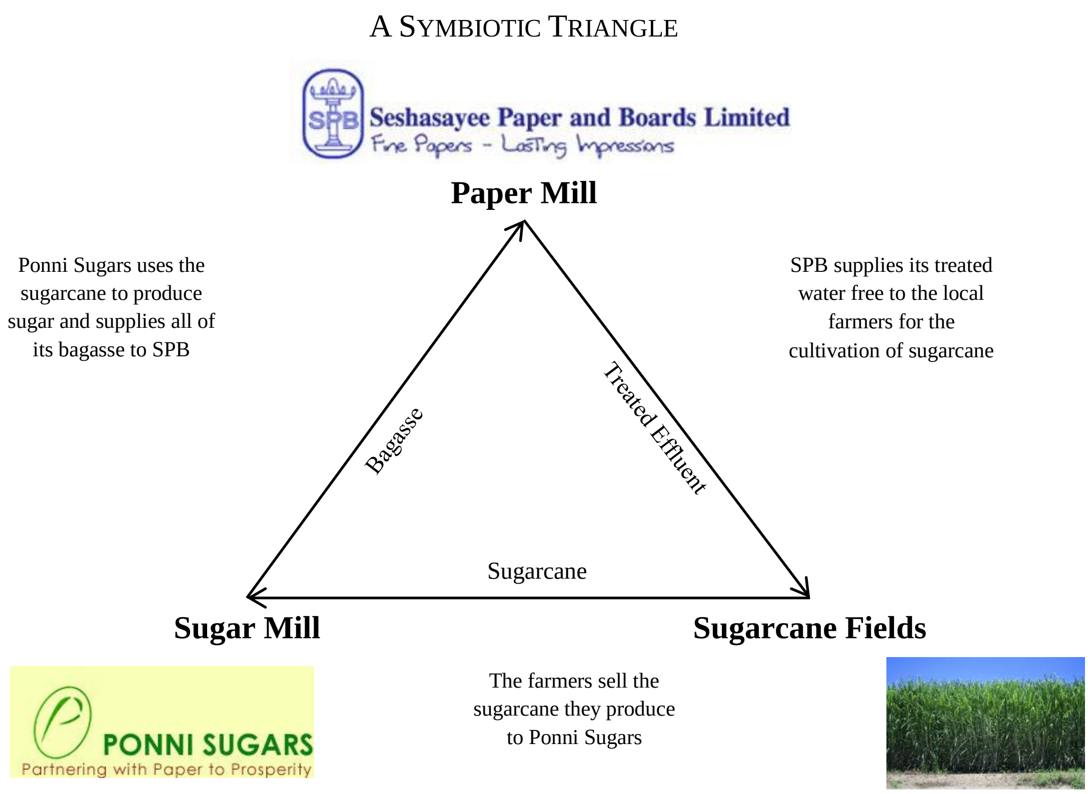
The company helped the farmers organise into cooperative societies intended to set up and manage the water flow through the fields. The company brought forward the necessary investment for setting up the company, supplying the required materials and the permissions required from the authorities on the other hand. The costs and overall overseeing of the operations are shared between Ponni Sugar and SPB. One of the agreement of the venture is the fact that the farmers dedicate 75% of the surface for sugar cane cultivation (Erkman & Ramaswamy 2003).

9.3.3.1 PRODUCTION ORGANISATION

SPB contacted Tamil Nadu Agricultural University in order to study similar projects and deemed the initiative potentially successful which motivated SPB to planning the details (Mahajan & Ives 2003). Another important help came from Mister S. R. Karuppannan, the Salem district collector, who introduced and coordinated the different stakeholders that would be involved in the project. Once a detailed plan was drawn, it was sent for financing. The agreements works between Seshasayee, Ponni sugar and the Farmers' cooperative and is valid for 10 years renewable (Mahajan & Ives 2003).

9.4 AN ECO-INDUSTRIAL PARK AT WORK

FIGURE 10: RELATIONS OF THE SYSTEM



THE SYSTEM CAN BE SUMMARIZED BY A SIMPLE TRIANGLE (Dawande et al. 2015)

9.4.1 STAKEHOLDERS INVOLVED AND THEIR PARTICIPATION

Seshasayee Paper and Boards limited: true initiators of the project, they coordinated the efforts required at first and mobilised the resources and experience to help the other partners. Besides, they supply training for farmers as well as their employees on the use of effluents in agriculture or about the other partners' processes. They are involved with Ponni Sugar in the maintaining of the shared infrastructure.

Ponni Sugar Limited: created by SPB for the sugar production side and now is responsible for the supply of bagasse to SPB as well as wastes used in boilers. Besides, they share the costs of facilities with SPB.

Neighbouring farmers and the Farmers' cooperative company: responsible for the growing of sugar canes and woods for the supply of SPB and Ponni sugar in an agreed upon share of their overall production.

Government authorities: involved since the beginning in the promotion of the system as well as the implementation of the procedures required for the licenses obtaining, and environmental measures supervision.

9.4.2 Environmental Management Programmes

Seshasayee Paper Boards Limited has the following policy concerning the environment (Mahajan & Ives 2003): "

- Manufacture quality papers in a clean, green and safe environment
- Continuously improve its environmental performance by reducing air emission, process effluents and solid wastes
- Maximise the use of eco-friendly materials and methods in the manufacturing processes
- Optimise usage of resources like water, power, fuel and raw materials
- Comply with relevant regulations
- Train and motivate the human resources to be environmentally responsible
- Make this policy known to all interested parties"

The company has been involved in numerous EMP initiatives over the years, within their Industrial Symbiosis system. Their objectives are to minimise pollution and environmental impacts while producing paper. Their initiatives include projects which purposes are (Mahajan & Ives 2003):

- Reforestation of the vicinities of the plants
- Reduction of dust emissions
- Reduction of chlorine use
- Minimisation of energy and water consumption

9.4.2.1 Waste Management

Cleaner production techniques were used in order to minimize pollution loads within the process as compared to end of pipe solution (Patnaik 2014). Another effort was aimed at reducing the emission of three main air pollutants (sulphur dioxide, nitrogen oxide and suspended particular matters) but also required the installation of Electrostatic Precipitators in all power and recovery boilers (Mahajan & Ives 2003). The effluent treatment plant includes a anaerobic lagoon for high BOD liquid effluent as well as a secondary treatment system for the rest of the effluents (Patnaik 2014).

9.4.2.2 Solid and Hazardous Waste Management

Pollution prevention techniques were also put in motion in order to reduce the quantity of pollutants at the source given the fact that because of filtering which produces wastes (Mahajan & Ives 2003). However, the company innovated by using filter cakes in the boards making process (Mahajan & Ives 2003; Patnaik 2014). As we can see in Table 5, other wastes have seen their status increased as raw materials and used internally or by other firms in the vicinity, see Table 5. (Mahajan & Ives 2003; Patnaik 2014).

TABLE 5: WASTE GENERATION AND ITS MANAGEMENT

Type of Pollutants	Characteristics	Disposal method	Degree of recycling
Lime sludge	Semi-solids – inorganic in nature – 40% solid contents – mostly calcium carbonate	Reused within the unit to lime kiln and balance quantity to cement industries	100%

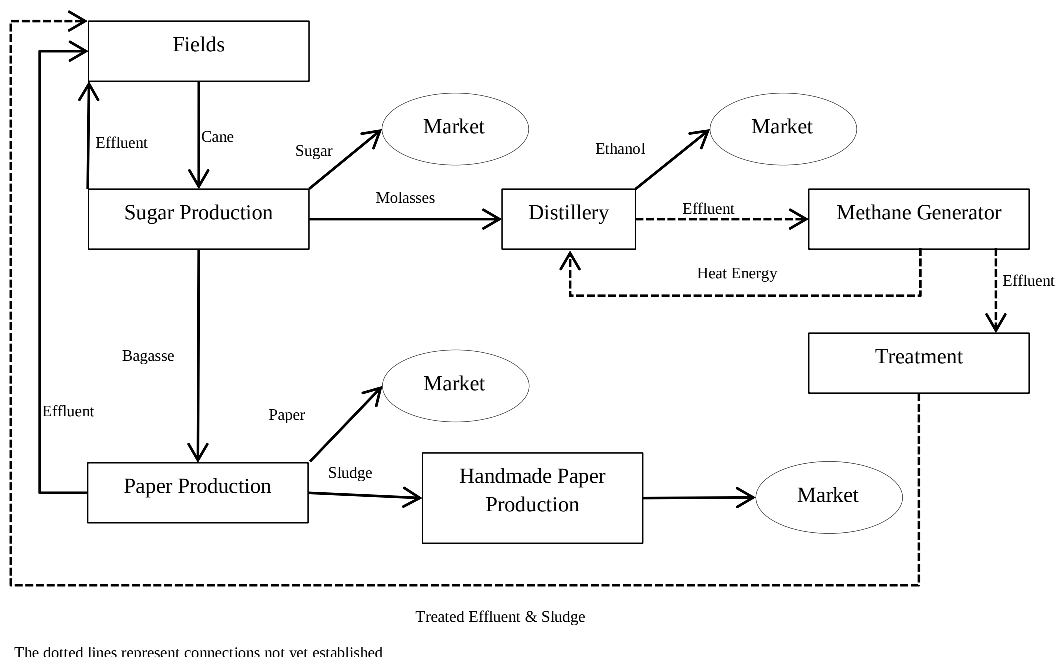
Cinder (fly ash)	Semi-solids – Inorganic in nature – 60% solid contents	Used for the making of hollow bricks / compressed bricks	100%
Filter cake	Semi-solids – 20% solid content of which 60% organic	Board making units	100%
Spent oil	Mineral oil	Used as lubricant in chains and conveyors	100%

(Patnaik 2014; Seshasayee Paper and Boards Limited 2015)

9.4.3 RESOURCES FLOW

SPB's equipment include fiver paper mills, power boilers, turbo-generators as well as an effluent treatment plant and a water treatment unit (Mahajan & Ives 2003).

FIGURE 11: SIMPLE REPRESENTATION OF THE SYSTEM



BESIDE THESE CONNECTIONS THERE IS A CAPTIVE POWER PLANT FEEDING ON SEVERAL AGRICULTURAL WASTES. (Erkman & Ramaswamy 2003)

As illustrated by figure 11, molasses and bagasse, the major wastes from sugar production, are being used respectively in the distillery to produce ethanol and in the paper production plant to produce paper. Wastewater from all units is treated in the captive effluent treatment plant and is later on used as irrigation for the fields (Erkman & Ramaswamy 2003).

There were further plans to set up a distillery that would produce methane and feed it back to the distillery as fuel. There are more wastes not represented in the form of heat, stack emission and solid wastes, also, the company has excellent chemical recovery processes (Erkman & Ramaswamy 2003)

9.5 IMPACTS

9.5.1 ECONOMICS

Due to the shared facilities, any investment the symbiotic system undertakes constitutes a common fixed cost for the members. It includes the bagasse treatment system, the effluent treatment and piping facilities as well as the captive power and heating plant (Dawande et al. 2015). Furthermore, there are linked production costs and production quantities.

Agricultural yield is increased by 10 to 15% in fields receiving the effluents as irrigation as compared to fields in which fresh water is used (Mahajan & Ives 2003), 40% as compared to local average yield (Patnaik 2014). Furthermore, the supply of water is offered free of costs (Patnaik 2014). As a result, the net value of land has increased tremendously (Patnaik 2014). Besides, yearly salary of farmers has also increased 20 times in the course of 30 years (inflation not included) (Patnaik 2014).

Following these initiatives, the region experienced a burst in employment (Patnaik 2014). Furthermore, Seshasayee Paper and Boards has further investment plants to expand their raw material capacity, chemical recovery systems and caption power generation going from 190 thousand TPA to275 (Balaji 2014).

9.5.2 PEOPLE

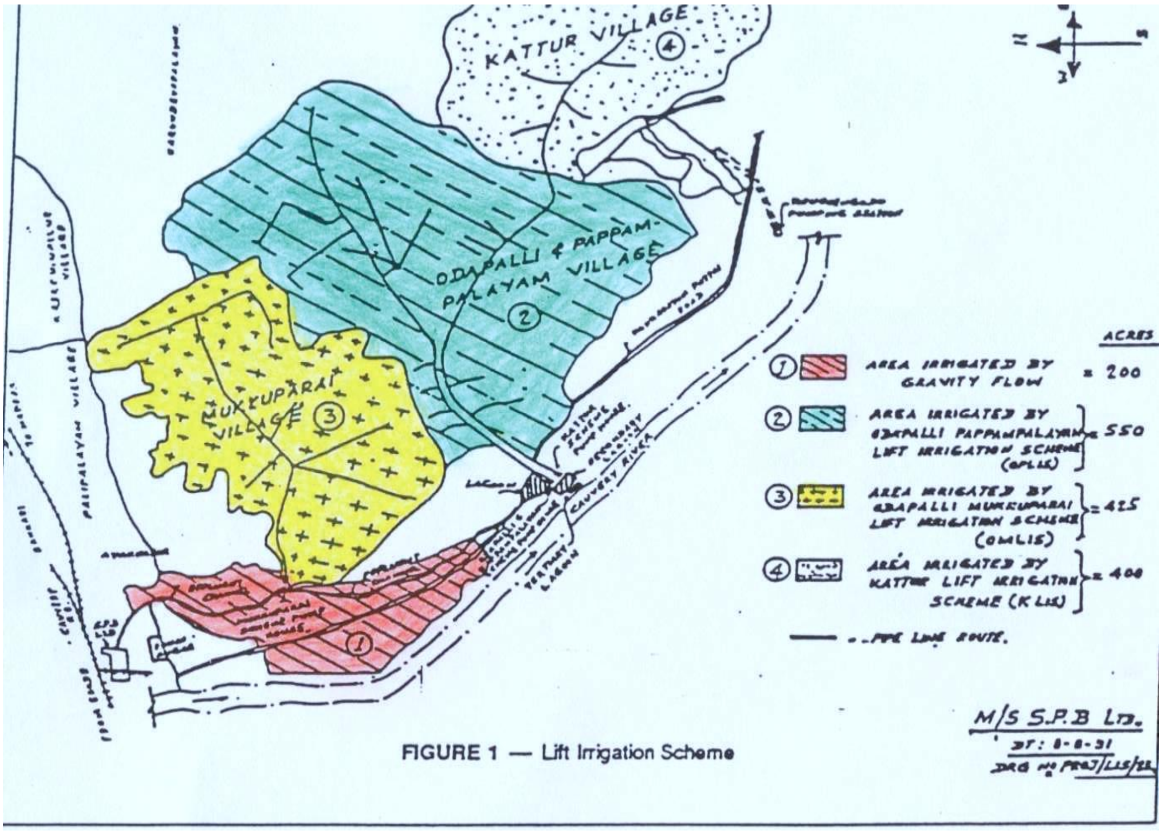
Before the setting up of the cooperation between SPB, Ponni sugar and the farmers, the land was not a good agricultural area (Mahajan & Ives 2003). Afterwards, it benefited from constant water supply which increased the yield and production for farmers, giving them access to a better livelihood (Erkman & Ramaswamy 2003). Ponni sugar furthermore buys part of the production from those producers, in a nutshell, Ponni and Seshasayee offers added value to production and buy that added value back from the farmers (Erkman & Ramaswamy 2003; Mahajan & Ives 2003). On top of that, the fields are in the direct vicinity of the plants, reducing the needs for transportation and therefore increases the farmers' margin (Erkman & Ramaswamy 2003).

SPB and Ponni Sugar are also involved in Community development. They installed facilities to supply drinking water to neighbouring villages, restored religious places, improved transport networks and healthcare centres (Mahajan & Ives 2003).

9.5.3 Natural Environment

The irrigation offered by the plant to its immediate vicinity modified the place from a semi desert to a green belt (Mahajan & Ives 2003) amounting to about 866 ha (Patnaik 2014).

FIGURE 12: IRRIGATION AREA USING SPB'S TREATED WASTE WATER (PATNAIK 2014)



ANOTHER BENEFIT FROM THE METHOD IS THAT IN THE PAST, THE TREATED WATER (TO SOME EXTENT) WAS DIRECTLY DISCHARGED IN THE RIVER (PATNAIK 2014). THERE HAS BEEN AN INCREASE IN SOIL QUALITY DUE TO THE ORGANIC MATTER PRESENT IN THE EFFLUENTS, ORGANIC MATTER THAT WOULD OTHERWISE NOT BE OPTIMAL FOR THE RIVER (MAHAJAN & IVES 2003).THE SOILS ARE NOW ABLE TO HOLD MORE AIR AND WATER (MAHAJAN & IVES 2003). FIGURE 13: CHANGING LANDSCAPE AFTER IMPLEMENTATION OF IRRIGATION SCHEME (PATNAIK 2014)

Furthermore there is a decrease in wood consumption (a scarce resource in India) because the factory uses more renewable resources beside having a reforestation initiative (Mahajan & Ives 2003). Seshasayee Paper and Boards is also asking the farmers to plant eucalyptus trees for their production of paper (Seshasayee Paper and Boards Limited 2015); the company is now supplied by partners' responsible wood production (Seshasayee Paper and Boards Limited 2014). One note is worth being added to that aspect in the regard that Eucalyptus is not an indigenous specie of India but comes from Australia. On the other hand, its fast rate of growth allows to supply paper to industries with diminished pressure on natural forests (Palanna 1996).The use of bagasse is energy efficient and has a much lesser impact on the environment as compared with wood

(Dawande et al. 2015); moreover, the bagasse process uses less chemical inputs and therefore improves water wastes quality (Patnaik 2014). For every 6t of bagasse used, the company spares the use of 3.7t of wood and bamboo (Patnaik 2014)

10 DISCUSSION

10.1 CONCLUSION OF THE CASE STUDY

10.1.1 HOW

Seshasayee Paper and Boards limited is a company that had in its development a focus on its environmental impact, which in turn helped developing the mind-sets required to achieve an Industrial Ecology initiative. Indeed, as said by Brand & de Bruijn (1999), "*Waste prevention must precede waste exchange".*

The company then faced a situation in which usual models were not sufficient in their own. Using alternative fuel sourced from other companies was not profitable, prices of wood, coal or bamboo rocketed, the situation was far from ideal.

They therefore turned to usual responses such as vertical integration but in a very unusual way, integrating another, totally unrelated trade, sugar production in order to consolidate their supply network. In order to make that possible, they requested the help of experts, federated the local community around the plant and started planning another way of production. Other instances of bagasse use in paper production existed in India but the government supported the development of alternative technology and gave a tax incentive to help companies adopting the new production process.

Seshasayee Paper and Boards started developing an Industrial Symbiosis system, "*a body of exchange structures to progress to a more eco-efficient industrial system by establishing a collaborative web of materials and energy exchanges among different organisational units'* (Doménech & Davies 2011). The company and its management team acted as a real coordination team and catalyst for the project to work.

Their project then evolved towards an Industrial Ecology initiative, based on the main difference of geographical distance, on the first hand, the partners are collocated in a same area while on the other it also involves partners on a larger scale.

The emergence of the system was due to a sustainable production process involving exchange of materials and energy, integrated management of wastes and mobility as well as joint utilities but also thank to a sustainable estate construction. Indeed, Seshasayee used its own facility but built the exchange network of water and energy as well as the sugar production plant.

After this emergence, the companies started to develop and expand their networks integrating other wastes in their production chain (such as agricultural based biomass) but also started to develop the local infrastructure.

10.1.2 WHAT

The network involves Seshasayee Paper and Board, Ponni sugar, the agricultural cooperative as well as the local community. In order to put the system in motion, the initiators had to get proper clearance from the authorities, tasks that were taken by SPB due to their experience.

They created a tripartite body of exchanges between a paper mill, sugarcane fields and a sugar mill. The paper mill takes in a sugar mill waste, bagasse and integrates it in its production process; the sugarcane fields (and the fields in general) benefit from treated effluent water coming from both mills, treated with the proper technology and constraint. Indeed, there are no more materials toxic for the fields but some wastes are left in the effluent, wastes that would otherwise be toxic for the river or human consumption but based on their organic origin, they are beneficial for the soil. Finally, the sugar mill takes in the sugarcane from the agricultural cooperative and sends its wastes to the paper mill as well as in the heat production and captive power plant shared between both mills.

Beside, a strong focus is given on reducing overall waste production or emission and is therefore putting in place different systems (end of pipe or other) not only in order to reduce their impact on the biosphere but also in order to increase their value in the system. As a result, the overall impact of the system on the environment is well below legal levels.

10.1.3 RESULTS

The system is embedded into the local social system and creates an interesting decision-making process. The fact that the founders of the network created their partners (through literal creation or federalisation) set the trust required for community building and cooperation behaviours. Furthermore, given the fact that Seshasayee created Ponni Sugar after a careful study of the sugar production trade gave both of them a valid understanding of the other's process. Besides these two, they also cooperated with the local farmers' community by helping in the establishment of a cooperative society but also by offering training in order for the workers to increase their skills regarding the change involved by the use of effluents.

In this example, we see an industrial ecology initiative in operation that has been running for three decades. In this system, waste is literally turned into wealth for everyone involved, farmers, Ponni Sugar and Seshasayee; meeting a triple aspect: economic development, local community empowerment and environmental protection.

In terms of making a step towards a sustainable development this example is very illustrative.

Indeed, first and foremost, the economic side of the venture is clear and benefitted all parties involved. The farmers benefited from a better quality soil increasing their production, part of their production is entirely bought by their partners having an beneficial impact on their salary and hence quality of life. Such a situation could be compared to what was experienced by Henri Ford in 1914. By improving the situation of their partners, Seshasayee creates attachment to the system but also increases the size of their market (intuitively, as the purchasing power increases, the quantity consumed of paper and sugar increases as well). Last but not least, it gave them a competitive advantage compared to other producers more impacted by market variations and allowed the companies to maximise profit.

Seshasayee and Ponni Sugar benefited from economies of scale given by the utility sharing put in motion, economies from their supply of material including wastes as well as reduced transportation costs.

Secondly, people also benefited from the system. The local community increased, attracted people in the system due to its profitability. Training was offered to the partners increasing their value and the companies shared their development with the local community in other ways such as giving access to drinkable water in remote villages, a rare commodity.

Finally, as far as the environment is concerned, there are different aspects to be covered.

First, it is safe to assume that the overall impact on the environment has decreased due to waste exchange, decrease in raw material dependency and reduced transportation networks. The sum of advantages is intuitively bigger in the system compared to a situation in which all actors work separately. Wastes are reduced, energy is shared and produced out of refuses; the supply of raw materials is more controlled, etc. However, due to the lack of quantitative data at my disposal, there is no evidence to back this claim up.

Beside such a consideration, it is not yet totally sustainable (see reference six for more information), fossil fuels are still used. One way to decrease the use of such raw materials would be to increase the production of sugarcane and therefore bagasse but such a solution does not appear to be possible in the short run.

The company needs to stay competitive and has, like any other, to combine its profitability as well as to minimise its environmental impact and has therefore to use other, less environmentally friendly solutions to be able to respond in a short term to the market fluctuation.

10.2 Critical evaluation of the work provided

The case study produced in this work allows having an overall understanding of a complex system set in a clear context. In order to do so, different case studies were used with different objectives, acting as equally important aspects.

This allows comprehending the big picture of a system as compared to a macro focused research greasing the visible aspects and a micro focus in which intricate parts are exposed in great details.

However, even though the case is extensively used as an example in India and abroad with international organisations such as Teri or ROI having studied it, there is not much information accessible from afar.

Most of the case studies on which this work is based have been done by Indian students or other people who had the opportunity to visit the facilities. In my case, there was no answer from the companies despite my repeated requests.

This lack in first hand data, be it quantitative or qualitative, impaired the possibility to have a deeper intrinsic view of the but nonetheless, this case study gave the opportunity to shed a different light based on existing works.

10.3 Contributions

The main difference between other case studies and the present one is the fact that this one is linked to a theoretical background emerging from a large literature review. In this way, models could be added to the analysis, technical terms and other perspective.

In this way, any other researcher willing to go deeper in its understanding of the subject has an easy access to an extensive amount of research and scientific papers on several aspects of an Industrial Ecology system.

Furthermore, it studies on three different aspects, the aspect of industrial ecology, the sustainable development objective more specifically applied to a developing country and its constraints, shared with other countries facing the same kind of objectives and difficulties.

10.4 Limitations:

Choices had however to be made on the scope of the analysis. A more in depth research could have been made on important technical details, or in the impact such a production system has on human resources involved with the process. Besides, there could have been room for a competition analysis in order to uncover the market benefits such companies can have.

However, it would have complicated the case study and added less pertinent aspects of the network. Besides, as exposed earlier, this case study was hindered by the lack of available data, certainly due to the fact that it involves private companies.

This system is not the only industrial ecology related project in India, but compared to all others, it seemed to be the most accomplished one (based on the book of Erkman and Ramaswamy, 2003) and which scope is much larger. On the other hand, the data availability was even worse whatsoever.

10.5 REMAINING QUESTIONS

There are more aspects that could benefit from further study, for instance:

In this situation, the partners were “lucky” because of the location in which Seshasayee operated, because bagasse was an alternative source of fuel or raw material in the paper process. In this case, one could literally produce raw materials out of wastes. A valid study could be made on other cases in which the linkages are not as straightforward. Many such studies exist in the case of Kalundborg but not many as far as India in concerned.

Something else entirely, a stress test of the system and a change impact study to understand how the inter-linkages create interdependence on the other partners. Intuitively, we could say that a bad yield would negatively impact the sugar as well as the paper factory; any problem in the effluent treatment plant would have a bad impact on the local community and the farmers, etc.

Furthermore, another study could be conducted on the construction of trust and cooperation in the system. Indeed, there were clear potential benefits for all of the partners but it is required to lose some freedom in order to join an interdependent system.

11 FINAL WORD

In the literature review, the concepts of Industrial Ecology, Sustainability and an overview of India as a country have been undertaken. In the Case Study, a particular project has been analysed under different aspects such as the way it emerged, how it is working and the impacts it has on its stakeholders.

Industrial Ecology is a vision that analyses the flow of resources through an industrial system, related or not. Its purpose in indeed to improve the use of natural resources in order to reduce the impact on the environment by increasing the scale of organisational concern as well as temporal concern.

It is a prerequisite step towards Sustainable Development and a step further from Design for Environment or Manufacture for the Environment and ever further than Pollution Prevention and Environmental Engineering. The concept includes however, the latters as well as industrial symbiosis (or eco-industrial parks), product life-cycles and industrial sector initiatives as well as industrial metabolism, as a set of practices. Such a vision requires a large scope innovation in process and product as well as technological improvements.

Sustainable development is a fashionable notion nowadays and it was defined as *"a possible way of living or being in which individuals, firms, governments and other institutions act responsibly in taking care of the future as if it belonged to them today, in equitably sharing the ecological resources on which the survival of human and other species depends, and in assuring that all who live today and in the future will be able to satisfy their needs and human aspirations"* by a figure of the Industrial Ecology concept, Ehrenfeld in 2000.

Furthermore, the industrial sector is experiencing an increasingly strong pressure to evolve in a more environmental friendly process yet in an economically sound manner. The same is true but even more constrained in developing economies given the fact that they need to split their attention between economic development and environmental protection. Industrial Ecology could offer a solution answering both issues.

The prerequisite to emergence of such a network are waste management practices already implemented in a candidate company giving them a clear understanding of their activity in terms of resource and energy flow. Then, linkages must be drawn between entities to exchange resources considered as wastes by one of the partners. Industrial Ecology, as opposed to pollution control measures, can indeed motivate the production of a certain waste if a partner of the network requires it in its process. Linkages can be the either, both or all, exchange of resources, utility sharing, and service sharing.

There is a large deal of debate in the literature concerning the relative usefulness of central planning compared to market mechanism in the emergence of Industrial Ecology. In a nutshell, some argue that today there are economic incentives derived from an Industrial Ecology initiative that could be sufficient for taking part, others claim that in order to have an overview of the flow of resources in the economy, a neutral party is required and argue about the role that could be undertaken by the authorities.

Due to the fact the industrial ecology system is truly embedded with the social system evolving around it, there are more interactions as compared to a more traditional and linear system. These interactions to be successful are based on a high trust and cooperation.

As a focus of this work, India was chosen. The country shares common characteristic with other developing countries, such as its lower middle income, high population density and high GDP growth rate. Industrial development is booming in the country and creates opportunities for its citizens but also for the natural biosphere already constrained by a lack of resources. Furthermore, there is an increased export of industrialised goods to the industrial world, in a sense, displacing environmental concerns abroad. A note is added in order to address the issue of central planning which is hindered in India due to the low rate of tax revenues and collection in the country.

In order to illustrate the literature review on Industrial Ecology and highlight how a network can emerge and what is happening on a daily basis, the case of a market emerged eco-industrial network in the South of India, was chosen due to its practical application of the theory at hand.

In a nutshell, a Paper Mill with environmental awareness responded to a constraint in their supply chain by creating a Sugar Mill company in order to benefit from one of their wastes, bagasse, which could be used in quality paper production after technological improvement of their facilities. Besides, they shared some of their utilities and improved their energy and resource recuperation in order to reduce their waste further or recycle them in an economic fashion. Facilities include a captive power plant, heat circuits using organic wastes, and effluent treatment systems.

In order to start in a new trade, totally unrelated to theirs, they had to request the help of experts and start from scratch. Besides, their supply of sugar canes also needed to be established and in order to achieve this, they federated local farmers under a cooperative company with which an agreement was signed, establishing the share of products to be grown on the fields (Sugar canes and eucalyptus trees) and bought by the companies.

Another waste valued by the organisation is the water they pump from the nearby river and use throughout their process chain. Afterwards, these effluents are treated and optimised for irrigation use, including removing toxic chemicals to be recycled within the firm. The three partners are involved in the development of the irrigation system, its maintaining but as a gracious gesture, they even decided to supply drinking water to nearby villages.

All in all, the system uses fewer natural resources, supplies them with controlled renewable sources and even supply natural resources to neighbouring companies or the local community in a cleaner state than before. However, they are not yet rid of fossil fuels or toxic chemicals but have improved their process to use less of both by changing the methods of transformation or recycling them within the facilities.

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REFERENCES

REFERENCE 1: OVERVIEW OF THE PROPOSED EXPANSION PROJECT 2015(SESHASAYEE PAPER AND BOARDS LIMITED 2015)

Description	**Unit**	**Existing capacity**	**Post project capacity**	**Incremental capacity**	**Proposal**
Paper Machines					
Paper production	tpa	120,000	165,000	45,000	Modernisation/ Up gradation/
Pulp Mill					
Wood Pulp (bleached)	BD tpa	115,500	145,000	29,500	Up gradation/ modernisation
Bagasse pulp (bleached)	BD tpa	35,000	35,000	--	No increase in capacity
O2 generation	Nm³/h	--	400	400	New
PCC plant	tpd	--	100	100	New
Chemical Recovery Plant					
Evaporation plant	Tph of water evaporation	200	250	50	Up gradation/ Augmentation
Recovery Boiler	Tpd of black liquor solids	630	950	320	Augmentation and Addition of one more ESP for handling capacity
Recausticising plant	Tpd of AA	200	200	--	Up gradation
Lime kiln	Tpd of lime	200	200	--	No change
Power plant					
Power boiler(s)	Tph of steam	117	217	100	Addition of one more 100 Tph boiler
Turbo Generators	MW of power	40	55	15	Addition of one 15 MW TG
Water Treatment Plant	M³/day	50,000	50,000	--	Adequate to handle the load RO/DM plant required for boiler will be added
Wastewater Treatment	M3/day	53,000	53,000	--	Up gradation

REFERENCE 2: RAW MATERIAL REQUIREMENT(SESHASAYEE PAPER AND BOARDS LIMITED 2015)

Raw material	Unit	Existing	Post Expansion	Incremental
Bagasse (Depithed)	tpa	57;800	57,800	--
Wood	tpa	227,000	317,000	90,000

REFERENCE 3: FUEL REQUIREMENT (SESHASAYEE PAPER AND BOARDS LIMITED 2015)

Fuel	Unit	Existing	Post Expansion	Incremental
Furnace oil	Kl	6,920	9,170	2,250
Coal	Tpa	188,000	269,000	81,000

REFERENCE 4: WATER REQUIREMENT(SESHASAYEE PAPER AND BOARDS LIMITED 2015)

S. No	Category	Average Daily Requirement (in m3/day)	
		Existing	Post Expansion
1	Paper Machine 1-5	8,800	10,000
2	Bagasse Pulp Mill	2,400	2,400
3	Hard wood pulp mill	7,500	10,300
4	Chemical Recovery Plant	3,000	3,800
5	Power Plant	4,400	5,600
6	Miscellaneous	1,900	1,900
Fresh Water Requirement		**28,000**	**34,000**
Plus: Recycling paper machine back water		**9,000**	**10,500**
Total water requirement		**37,000**	**44,500**

REFERENCE 5: WASTEWATER TREATMENT PLANT (SESHASAYEE PAPER AND BOARDS LIMITED 2015)

1.	Total waste water quantity	29,800 m^3/day
2.	Loss of water in sludge/cooling tower	500 m^3/day
3.	Total treated waste water discharge	29,300 m^3/day
4.	Treated effluent for irrigation	29,300 m^3/day

REFERENCE 6: EVOLUTION OF ENERGY AND MATERIAL INPUT – OUTPUT (SESHASAYEE PAPER AND BOARDS LIMITED 2014)

	Unit	2002-03	2003-04	2004-05	2005-6	2006-07	2007-08	2008-09	2009-10	2010-11
Inputs										
Wood	t	22.000,00	3.050,00	4.030,00	4.163,00	116.525,00	122.366,00	163.205,00	192.291,00	202.388,00
Bagasse	t	1.499,00	1.521,00	1.233,00	1.787,00	75.120,00	65.882,00	63.065,00	60.650,00	52.252,00
Purchased Pulp	t	6.899,00	7.741,00	9.192,00	9.423,00	37.282,00	17.752,00	18.004,00	2.221,00	2.411,00
Waste Paper	t	105,00	111,00	419,00	514,00	1.381,00	450,00	112,00	0,00	0,00
Electrical energy bought	mkWh	98.47	98.34	108.56	38.56	25.22	18.31	21.31	15.89	10.15
electrical energy (own)	mkWh	59.15	60.28	53.54	141.89	153.72	158.74	173.97	188.76	200.78
Coal	t	90.153,00	96.078,00	89.182,00	152.937,00	155.054,00	147.109,00	132.981,00	149.392,00	169.067,00
Lignite	t	22.140,00	19.318,00	12.839,00	--	--	6.106,00	18.148,00	21.530,00	988,00
Furnace Oil	kl	802,00	663,00	574,00	906,00	959,00	1.296,00	3.316,00	10.065,00	8.224,00
Other Bio-Fuels	t	2.166,00	689,00	12.777,00	--	7,00	3.953,00	3.373,00	3,00	0,00
Chemicals										
Output										
Paper	t	113.684,00	117.271,00	118.854,00	122.003,00	123.468,00	124.312,00	119.779,00	117.989,00	120.558,00