# Industrial ecology: a new paradigm?

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## *Introduction*

The aim of industrial ecology is to design and re-design industrial systems, by using nature as a metaphor and model. In this way far less non-renewable resources will be used and far less emissions and wastes will be released to the natural environment than up to now. Many approaches to industrial ecology are attempted, varying from those looking upon industrial ecology as a method for waste recycling to those who see industrial ecology as a new paradigm in a wider social perspective . By going into some of the central literature in industrial ecology, it will be examined to what extent the theoretical perspectives, methodology and practical experiences within industrial ecology can be seen as a new paradigm

## *Paradigms*

The physicist and history of scientist Thomas Kuhn's famous book, «The structure of scientific revolutions», was first published in 1962. Kuhn argues that science goes through revolutionary developments, where a revolution leads to a replacement of one paradigm by another. A paradigm is made up of general theoretical assumptions and laws and techniques for their application that the members of a particular scientific community adopt (Chalmers 1978). Within a paradigm the science makes stepwise progress through so called puzzle-solving activity leading to better matches between the theories, models and nature. This view is in contrast to Popper, who is arguing that the science develops through falsification of existing theories and methods, leading to new and better ones (Popper 1968). Kuhn states that after a period within a certain paradigm, *anomalies*, miss-matches between the ruling paradigm and

the ongoing scientific activity, will arise. When one or several serious anomalies threatens the very fundamentals of the ruling paradigm, the scientific development has entered into the crisis and revolution phase, where the old paradigm is fighting against potential new ones until a new (single) paradigm is established. Through this revolutionary process or *paradigm shift*, more and more of the scientific community will convert to the same new paradigm.

The term paradigm is also used outside the strictly scientific world and the progress of scientific development. Paradigms are used in wider social perspective, as a frame of believes, values, norms and standard practices that guide human action within a community. Ehrenfeld (1997) is describing the western dominant social paradigm with its organisational and economic structure containing central elements such as anthroposentrism, free-market, democracy, freedom, and self-realisation.

### *Industrial Ecology*

In the first text book in industrial ecology, Graedel and Allenby (1995) state that industrial ecology takes a system view where the industrial system must not be isolated from surrounding systems. The aim is to optimise the total material cycle from cradle to grave where resources, energy and capital are factors to be optimised. Industrial ecology can be viewed as a set of notions (theoretical/conceptual) and methods (practical/instrumental), which are using the natural eco-systems as a metaphor and model to express how industrial society could be organised and function (Brattebø et. al. 1998). The challenge is, according to Brattebø et. al., to develop methods, models and tools based on ecological principles and in accordance with nature's carrying capacity for *implementation of preferred change.* A new perspective, compared with other fields working with environmental challenges, and the main approach in industrial ecology, is to combine economic- and ecological efficiency on both company- and society level (Brattebø et. al. 1998). According to Lifseth (1997), industrial ecology can be seen as the operational part of sustainable development. An interesting model, illustrating the differences between industrial

ecology and other areas and the development of industrial ecology as the last step before reaching sustainable development, is shown in figure 1 (Bras 1996). The first axis is the time axis, the product's lifetime with its phases planning, manufacturing, use and disposal, human lifetime and the civilisation span. The second axis indicates the scope of the environmental concern, ranging from a single product life cycle, to x products within one manufacturer and towards x manufacturers and the society. The areas in the figure represent environmental performance efforts at different levels:

1. Environmental engineering.
2. Pollution prevention.
3. Environmental conscious design and manufacturing.
4. Industrial ecology.
5. Sustainable development.

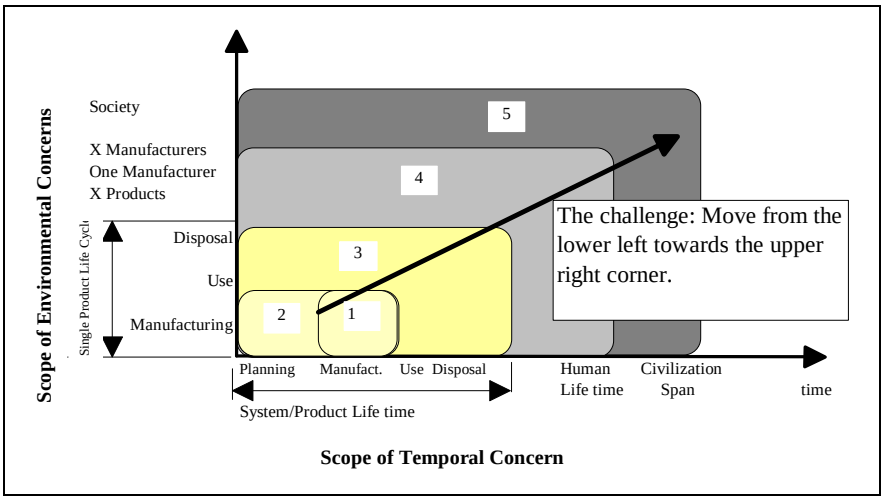


*Figure 1: Classification of environmental performance levels (Bras 1996).*

There are, however, many approaches to industrial ecology and there has been a lot of arguing in the scientific community and industry what industrial ecology really consists of and what it should consist of. Is it a concept, a scientific field, a method, or an analytical framework? For some, it is a new, powerful analytical framework, for

others it is a metaphor that leads to a new vocabulary for talking about and making sense of the world. In the latter sense, industrial ecology is paradigmatic in nature (Ehrenfeld 1997). Sagar and Frosch (1997) point out that industrial ecology is loosely used in literature, varying from the narrow outlook like recycling of waste to the broad outlook of social and environmental change at the global level.

In the forthcoming, the theoretical and methodological basis as well as relevant practical experiences within six important areas in industrial ecology will be presented.

## The paradigmatic perspective

John Ehrenfeld stresses that industrial ecology has a potential to be a new paradigm. He argues that industrial ecology can be an opening to a new way of thinking and acting that offers new insights into designing a world that approaches the ends of sustainable development (Ehrenfeld 1997). According to Ehrenfeld, the concept opens a perspective different from the more established modern economic, capitalistic, democratic ideals on which the western social paradigm rests. Industrial ecology can be a part of a new social paradigm that would include maintenance of the natural world as a fundamental normative goal. In another article, Ehrenfeld (1998) argues that natural ecosystems, the source of the ecological metaphor in industrial ecology, offer the only example available to us of long-lived, robust, resilient living systems. These systems are the only kinds of system which are offering the three C's, *connectedness*, *community and co-operation*, in many ways the exact opposite characteristics of what we find in the industrial community today.

## The System perspective

By taking a system perspective in industrial ecology, the aim is to examine the industrial ecosystems or product chains as holistic systems, consisting of material- and energy flow and involving many actors. The purpose is to prevent sub-optimisation of each process and product within these chains. It is also stressed that industrial product

chains must not be seen isolated from the social community, the natural ecosystems and other industrial product chains (Brattebø et al 1998, Asbjørnsen 1998). Similarly as when investigating natural ecosystems, a system perspective applied to the analysis of complex industrial ecosystems may help to a better understanding of the interactions between the various entities, and their overall interactions with the natural environment. Looking into the practical level, such an analysis can also assist in the efforts to effectively mitigate the environmental impacts of industrial production (Sagar and Frosch 1998). Practical examples of systems engineering and system analysis include environmental life cycle performance within ship industry (Fet 1997) and in application on a metals-industry system (Sagar and Frosch 1997).

Multidisciplinary approach

In contrast to the traditional way of dealing with environmental problems, industrial ecology is strongly emphasising the multidisciplinary approach. In the last couple of years authors like O'Rourke et al (1997) and John Ehrenfeld (1997, 1998) has contributed to a multidisciplinary extension of the field. Ehrenfeld takes a critical and very broad multidisciplinary perspective when claiming that to design a sustainable future, there is a need for other disciplinary frameworks than the positivistic and technocratic, which are dominating many universities like NTNU and MIT. There is a need for duelling paradigms - positivism and the natural science tradition on one hand – and historicism, hermeneutics and other variants all harking back to the phenomenology, on the other (Ehrenfeld 1998). At NTNU's Industrial Ecology Programme, the multidisciplinary approach is emphasised by focusing on the theoretical, methodological and experimental level both in social science as well as in technological issues. It is stressed that multidisciplinary approach to complex problems is an absolute necessity. Without this approach it is not possible to analyse, far less understand, the connection and cause-effect relations in the intersection between technology, industry, market, consumer, governmental institutions and the natural environment (Brattebø et al 1998).

Life cycle perspective

When designing or re-structuring products, processes, infrastructures and other industrial activities, it is of major importance that the whole life-cycle is considered. This means that potential environmental impacts from production-, user- and the end phase (recycling etc.) of products and activities are evaluated and attempted to be minimised. Such a work is often done with the method of life cycle assessment (LCA) (Lindfors 1995, SETAC 1992, ISO 1998), one of the major methods within the field of industrial ecology. Many LCA-studies have been carried out around the world, but until now mostly on smaller products such as packaging (Ølund and Eriksson 1999, Ekvall 1998). However, it is possible to use the method, or a simplification of the method, on larger product systems such as buildings or infrastructure. It is also possible to take a life cycle perspective into consideration without carrying out an LCA.

Eco-Efficiency

The concept of eco-efficiency is important as a strategy for evaluating both ecology and economy in projects, activities and whole economies. Mostly eco-efficiency has been used on microscale to connect business profitability to environmental impacts of production processes as part of cleaner production initiatives and recently also connected to products. However, there is also work going on at the macro-level and according to OECD the term "eco-efficiency" as it stands today is insufficient on its own as a basis for policy making. A wider understanding of the links between economic activity and environmental damage, driving forces of change and the psychological and ethical motives of producer and consumer behaviour, is needed. Eco-efficiency is therefore expressed as *the efficiency with which ecological resources are used too meet human needs* (OECD 1998). There are many examples of companies implementing eco-efficiency, for instance (Fussler 1996):

- Xerox offering the service instead of the product of a copy-machine by taking back used machines to change the essential components, before bringing it back to the market.
- 3M, who has an eco-efficiency manager and are producing scouring pads which are made from recycled plastic.

Other examples on eco-efficient products and services can be found at Ecomarket International (http://www.ecomarket.net) and The Gallery of Environmentally Preferable Goods and Services (http://tbe.mit.edu/gallery/)

Eco-parks

The last important area brought in here, and in many ways the example of industrial ecology in practice (Ehrenfeld 1997), is the concept of eco-parks. An eco-park is an industrial ecosystem consisting of many companies (clusters), often located in the same area. The purpose with the parks is to achieve better economical and environmental performances when companies are co-operating on transportation, waste exchange, energy exchange etc. The best known example of an eco-park is Kalundborg (Ehrenfeld and Gertler 1997), where eleven companies, including Statoil and Kemira are exchanging energy, by-products and wastes. Another example is the Burnside Industrial Park, which encompasses an area of 1200 hectares with 1300 businesses and approximately 20.000 people in Nova Scotia in Canada. The park is, differently from Kalundborg, composed of mainly small or micro scale businesses (Cote and Smolenaars 1997). It is worth to notify that both Kalundborg and Burnside were not planned as industrial ecosystems when they emerged a couple of decades ago.

### *Industrial ecology – a new paradigm?*

Before discussing whether industrial ecology is a new paradigm, it should be mentioned a few words on why it seems so important to construct new paradigms. Is this transfer from one paradigm to another a governed development? In that case; who are governing it? Why is there a need for a new platform for doing science or running industry?

In the case of the environmental area, there has obviously arisen a demand for change because of the steadily increasing problems we are facing. The old theories, methods, and solution are clearly insufficient to solve today's and future problems. In Kuhnian sense, threatening anomalies like resource depletion, waste accumulation and increased emissions of nitrogen oxides and carbon dioxide, is not properly addressed in the existing industrial paradigm.

As shown, industrial ecology takes many directions. Is it a concept for designing a new (industrial) society or is it a strategic framework for business working with environmental problems? The definitions are many and often vague. In relation to Kuhn's scientific revolutions and development of new paradigms, this unclear situation is typical for development of new fields, such as industrial ecology is in spite of ten years of development. The question is nevertheless whether industrial ecology will develop into a mature theoretical field with appropriate methods for use in industrial practice, or if it will continue to develop in different directions where it is more or less up to the users to define what the contents should be.

A more important perspective here is the distinction between the establishment of a new science or paradigm and the approach where already existing methods and disciplines are used to solve given problems in the ruling paradigm. Where is industrial ecology situated in this picture? By looking into the theoretical approaches, methodology and practical experiences in industrial ecology, it will be examined whether industrial ecology are addressing the threatening anomalies, and thus representing a potential new paradigm.

The theoretical approaches within industrial ecology is in many respects fundamentally different from previous theory dealing with environmental issues, such as the case is in cleaner production and waste management. Ehrenfeld (1997, 1998), a central and maybe the most radical author within the field, is stressing the importance of required fundamental and non-incremental changes. Inspired by the natural ecosystem, he is introducing the notions of community, connectedness and co-operation among actors in the industrial society and in that way offering possible solutions to the environmental anomalies that the ruling paradigm in today's industrial society are not able to handle. The existing paradigm has on the contrary its fundaments on individualism, competition and industrial privatisation. Frosch and Gallopoulos (1989) see industrial ecology as a new way of designing industrial systems, inspired by the organisation of nature, where no waste is accumulated. Differently from waste management and pollution prevention, industrial ecology emphasises the importance of co-ordination and net-work among actors along and between product chains (Boons and Baas 1997). Based on these authors, it is no doubt that theories within industrial ecology are addressing the environmental anomalies and offering changes in such a way that a potential new paradigm can be seen.

Not necessarily because of the emerging field of industrial ecology, several methods for evaluating and improving environmental performance in companies and the society at large, have developed. Life cycle assessment, design for environment, systems engineering and development of the environmental management systems ISO 14000 and EMAS are examples of this trend. These methods and strategies are important in the environmental area and definitively a part of the industrial ecology field. In the development of these methods, the importance of life cycle- and systems perspective is focused in a more extensive way than in previous methods. However, at least until recently, much focus has been put on improving the environmental performance on smaller products such as packaging. This work is of course important, but increased environmental performance for these products will not contribute significantly to the environment. This is, however, more a critique of the insufficient

use of the methods than a critique of the methods themselves. For some of the methods and strategies, the focus is still on the company level and less has been done to develop methods and models to improve the situation outside the factory gate or beyond the single product's value chain . To conclude, there are important changes going on at the methodological level, but until now methods have not been developed and used in such a way that they are addressing the anomalies properly and thus representing a driving force towards a new paradigm.

Some companies have started the work in an industrial ecological direction. One example involving net-work and co-operation between companies, is the Norwegian project involving Tomra Systems, Dyno Industries and Håg. Tomra are collecting used screw caps and sending them to Dyno Industries, who are reprocessing them. In the next stage, Dyno sends the plastic material to Håg, who uses it in production of new chairs. Several similar projects among companies are going on and it seems that running business in a more environmentally friendly way is becoming more and more usual. However, the new thinking around running eco-efficient business, producing more goods and services with less use of resources, is not necessarily improving the environmental situation on a larger social scale. Introducing new cars, which are using far less fuel per driven kilometre, are not doing any good for the environment if this leads to increased production and use of cars. This is a typical example of ignorance of the systems perspective. The environmental performance and eco-efficiency are increasing at the microscale (per car) but not at the macroscale (all cars in the society). Another problem is that it is mostly the big companies that have the interest and resources to work with environmental problems in an industrial ecological way. As the case with the methodological part of industrial ecology, changes can be seen, but the changes are often incremental, and at the present state not at a level that addresses the threatening environmental anomalies properly.

## *Conclusion*

The theoretical level of industrial ecology emphasises the need for extensive structural changes to solve the environmental anomalies that the existing paradigm can not handle . A potential for a new industrial paradigm can be seen. On the other hand, when it comes to methodology and practical experience in industrial ecology, the activities can mostly be characterised as puzzle-solving which is not addressing the anomalies that are threatening the structures of the existing paradigm. This puzzle-solving is, however, to some extent improving the overall environmental situation within the existing industrial paradigm, but not to a sufficient level. An important question is then how the theoretical part of industrial ecology can influence methodology and work in practice, and hence lead to an implementation of the structural changes needed. To release the paradigmatic potential in industrial ecology, the challenge is to turn the individual business from the today's short-term micro-oriented perspective to a long-term macro-oriented perspective, where ecological issues are evaluated at the same level as the economical ones.

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