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Cleaner Production and Industrial Ecology: A Dire Need for 21st Century Manufacturing

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Abstract: The chapter discusses the dissemination of the concepts of cleaner production and industrial ecology as an operationalization within the framework of *sustainability systems* in the industrial practice. Experiences in cleaner production and industrial ecology projects show that an open, reflective and on-going dialogue must be designed to develop trust, transparency and confidence to ensure real involvement of diverse stakeholders in charting the future of their organizations and regions as part of the transition to sustainable societies. The integration of ecological, economic, social and cultural dimensions of corporate activities become a dire need for a sound use of scarce resources in the 21st century.

11.1 Introduction

Cleaner production and industrial ecology are known concepts worldwide, however, their dissemination is not an easy process. The concepts of *cleaner production* can be described as "the continuous application of an integrated, preventive environmental strategy to both processes and products to reduce risks to humans and the environment [1]". *Industrial ecology* is described as "an integrated system, in which the consumption of energy and materials is optimized and the effluents of one process serve as the raw material(s) or energy for another process [2]".

As a process of dissemination of new concepts, the cleaner production paradigm was introduced to industrial leaders as a prevention-oriented paradigm for achieving cleaner industry and more sustainable communities; this was viewed as an important way to supplant or supplement the old paradigm of pollution control. In the cleaner production paradigm, the conceptual approach was to catalyse the transition from *waste management policies and approaches at the end-of-the-pipe,* to *"environment included"* in *industrial innovation policies for waste prevention* and *waste minimization* at the sources of the problems [3]. Industrial routines are embedded in unsustainable practices that are difficult to change. The complexity and uncertainties of new concepts are often approached with ignorance and misperception. Nevertheless the integration of economic, environmental and social dimensions in industrial activities is increasingly perceived as a necessary condition for a sustainable society.

This chapter discusses the dissemination of the concepts of cleaner production and industrial ecology as an operationalisation within the framework of *sustainability systems* in the industrial practice. At first in Section 11.1.1, some reflection is given to climate change as new environmental policy incentive in the context of global trends and their local adaptation processes. In Section 11.2 the dissemination of new preventive concepts is reflected upon at the macro, meso and micro levels in societies. The practical experiences with the dissemination of cleaner production and industrial ecology concepts are connected to the theoretical notions of embeddedness in Section 11.3. For insight in the challenges of the introduction of industrial ecology concepts, the results of industrial ecology programs in the Rotterdam harbor and industry complex are described in Section 11.4. This section is followed by an analysis of the lessons learned on the introduction and dissemination of the concepts of cleaner production and industrial ecology as interaction between theory and practice in Section 11.5. Finally, conclusions and recommendations for a dire need for manufacturing sustainability systems are formulated in Section 11.6.

Climate Change as Environmental Policy Incentive

Climate change worries many persons in the world, because direct effects are also seen all over the world: from the melting ice in Greenland to the vanished snow at the top of the Kilimanjaro in Tanzania [4]. Nevertheless, the responsibility at the environmental policy level is still diffuse. Both at the public and private policy levels much depends on the sense of emergency [4] of responsible managers in combination with the emerging elaboration of social responsibility.

In the past decade, global trends in environment related issues within multi-national corporations have incorporated different dimensions in the concepts of environmental management (ecology), cleaner production (ecology, economy), industrial ecology (ecology, economy) and corporate social responsibility (ecology, economy, social aspects).

The trends in production facilities have been:

- Outsourcing of (mass) production by the northern corporations: to China, Vietnam.
- Near-sourcing of production: USA to Mexico; Western Europe to Central Europe.
- Emerging national mass production facilities: such as in China, India, Vietnam.

These trends involve that working with preventive concepts needs to estimate the context of their embeddedness in the society and the involvement of relevant partners.

At a global environmental policy level implementation processes are related to agreements and strategies such as:

- Johannesburg Declaration on Sustainable Development [5].
- United Nations Millennium Declaration [7].
- UNIDO’s Corporate Strategy with focus on Environmentally Sound Technologies and CP market mechanisms [8].
- UNEP’s incorporation of Human Development through the Market [8].

It has also to be taken into account that the world population urbanization trend is expected to grow to 60% of the world population living in urban areas in 2040 (developing countries are expected to grow to an urbanization grade of 50% in 2020) [10].

Worldwide the urban problems are concentrated upon: water management, energy, air pollution, and mobility. A recent publication [11] concludes the fact that the following activities and product groups cause 70% to 80% of the total environmental impacts in society:

- Mobility: automobile and air transport.
- Food: meat and dairy, followed by other types of food; and
- The home, and related energy use: buildings, and heating-, cooling-, and other energy using appliances.

In the meantime, tourism, including many aspects of the above mentioned activities, has become the biggest economic sector in the world [4].

The environmental impacts of urban problems can be covered by cleaner production system approaches. Experiences with the dynamic aspects

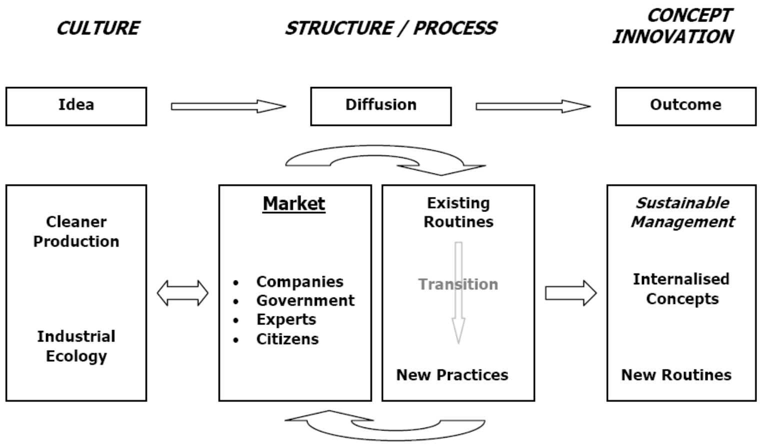

Figure 11.1. The arena of transition processes of new concepts

of the introduction and dissemination of cleaner production and industrial ecology reflect several theoretical notions that are worthwhile to consider in discussing future trends (n*othing is more practical than a good theory*) [11].

11.2 Different Levels of the Dissemination of Preventive Concepts

All considerations about the introduction of (new) concepts such as cleaner production and industrial ecology face an institutionalized arena with routines on environmental performance that challenge *changes in routines* in the competition to achieve better market positions. As the preventive approach is presented as a better business practice, the cleaner production concept provides *prevention as vision* as a label, the *cleaner production assessment* in an organization as instrument for problem analysis, the *cleaner production options* and the integral approach of *continuous improvement* as solutions, and the *cleaner production demonstration projects* as part of a *cleaner production dissemination infrastructure* as the applications of successes.

The *arena* of transition processes of new concepts is visualized in the following model shown in Figure 11.1 [3].

It is assumed that a representative of one of the four societal categories in the market of concept transition processes figure will explore a new concept such as cleaner production and industrial ecology knowledge dissemination. Committed to the new concept, the introducing actor(s) will approach organizations to explore it. After the introduction, acknowledgement and acceptance of the concept, learning (explicit or implicit) and change processes connected to the new concept affect expertise at the individual and organizational levels. In this thesis, the concepts of cleaner production, industrial ecology and sustainability are connected to the micro, meso and macro levels. The different levels are used in relation to system boundaries such as single organizations, organizations located in regions or as members of an industrial sector, and society. There are also levels within an organization that affect the dissemination of a new concept. For instance, for the introduction of cleaner production, the focus is on single organizations; outside actors can introduce the concept and the translation by internal actors might affect the routines. The introduction of industrial ecology goes beyond single organizations, which means that actors outside the companies will influence the overall processes in a dependent manner in relation to the individual company managers.

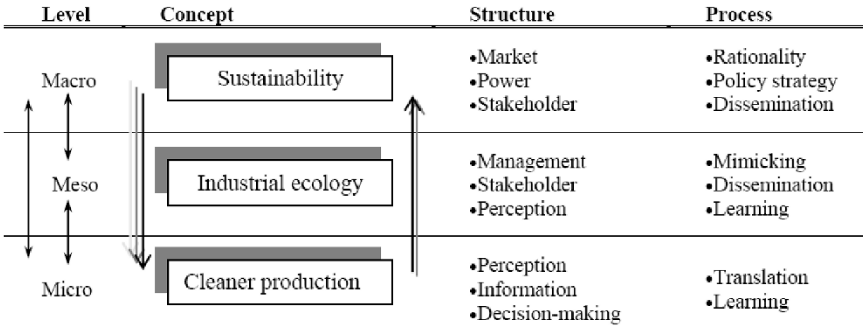

Figure 11.2. The multi-level concept innovation model

The different levels of preventive concepts involve the issue of system boundary. Although one might analyze cleaner production at the micro level of companies and industrial ecology at the meso level of industrial estates, [3] a systems approach of the concept of cleaner production involves the interconnection to industrial ecology and sustainability can be labeled by c*leaner production systems* or s*ustainable consumption and production systems* (see Figure 11.2).

The capacity and capability to break through existing routines is part of an eventual organizational change. Learning processes related to the new cleaner production concept face the techno-structure based on an engineering perspective at the micro level that dominates its translation. The learning processes for industrial ecology face a (plant) management perspective that is limited to the system boundary of their organisation. At first glance, the translation of the new concept is mainly based on mimicking. Both mimicking and dissemination include learning processes. Mimicking involves above all the reception or passive translation of knowledge, while dissemination includes a process of knowledge transfer. At the macro level policy strategy development, both at the private and public organizational levels, is subjected to the influence of translation processes of stakeholders.

Normative concepts – such as the *prevention is better than cure* approach of cleaner production projects – assume implicitly the involvement of all members of the organization in identifying and implementing both non-technical and technical improvements. The following individual and organizational learning processes are experienced according to different dimensions such as:

- Individual learning by members of an organization to look after and cope with incremental (first order) and radical (second order) changes in their organizations [13].
- Different levels at the individual and organizational learning level with single-loop, double-loop, and triple-loop learning processes [14].
- Different types of learning effects: *Learning by doing*, *learning by interaction*, *learning by using*, and *learning by learning* [15].
- Different ways of learning: Strategic or tactical learning [16].

11.3 Practical Experiences and Types of Embeddedness

Several conclusions can be drawn from the shift from environmental technology towards cleaner production [3]. Industrial environmental protection started on a pollution control basis with control technologies. The 1970s can be characterized as a pure technology engineering approach to control pollution. In the 1980s, public policy development included the emergence of integrated environmental policies and new economic and voluntary instruments.

During the cleaner production emergence phase, university experts set up cleaner production research projects, whilst during the growth phase consulting firms mediated the dissemination of results. This process has been repeated in many countries in Europe. UNEP and UNIDO organizations also mimicked the dissemination of the concepts through demonstration projects, instruction manuals and in a later phase dissemination policies with stakeholder involvement. Another aspect of the institutionalization process is professionalization, in the shape of specialized expertise, national, regional and global expertise networks and expert and scientific journals.

In general, during the emergent phase of a new approach, there is space to reflect about further development. However, the status of the *cleaner production assessment method* meant that the label embodied an encoded knowledge approach that became the basis for preventive developments. As a result, it created a trade-mark that was not open to further dialogue. Although the cleaner production assessment was designed with several feedback loops, in practice the assessment developed as a one-loop learning process, ending with a *cleaner production plan* after the feasibility phase. The engineering approach, based on encoded knowledge, largely dominated the characteristics of the cleaner production concept. Furthermore, demonstration projects had to show practical results. All these activities developed in the direction of a mature phase of institutionalization and stronger internationalization. Also, professionalization and specialization are characteristics of a mature phase. However, societal dissemination processes ask for more ingredients in continuous social change processes and this has been hardly the case [3].

The year 1989 can be regarded as a starting point because of the re-emergence on the environmental agenda of industrial ecology in the wake of an article by Frosch and Gallopoulos [2]. The U.S. Academy of Engineering promoted the concept very much. Also a link with the Japanese Ministry of Trade and Industry was established and strengthened in the course of several workshops in the period 1993–1994 [17].

The most famous reference in the field of applied industrial ecology is the *Industrial Symbiosis*[1] project in Kalundborg in Denmark [18]. Every book (including this book), numerous articles and conferences about industrial ecology make repeated reference to the Kalundborg industrial area. The Kalundborg situation has been copied all over the world since the mid-1990s. In discussions of, and references to, the Kalundborg system it is seldom reported that that Industrial Symbiosis program grew organically on a social-economic basis in a small community where plant managers knew and met each other in a local community atmosphere.

In the last 30 years of the community's evolution, a partnership grew between several industrial plants, farmers and the municipality of Kalundborg. This partnership led to huge improvements in the environmental and economic performances of the Kalundborg region [19]. The core partners in Kalundborg are a power station, an oil refinery, a plasterboard factory, an international biotechnological company, farmers and the municipality. These partners voluntarily developed a series of bilateral exchanges such as:

- The refinery provides the plasterboard company with excess gas.
- The power station supplies the city with steam for the district heating system.
- The hot cooling water from the power plant is partly redirected to a fish farm.
- The power plant uses surplus gas from the refinery in place of coal.
- The sludge from the biotechnological company is used as fertilizer in nearby farms.
- A cement company uses the power plant's desulphurized fly ash.
- The refinery's desulphurization operation produces sulphur, which is used as a raw material in the sulphuric acid production plant.
- The surplus yeast from the biotechnological company is used by farmers as pig feed.

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1 The Industrial Symbiosis label was introduced by the spouse of a plant manager in Kalundborg in Autumn 1989 (According to Jørgen Christensen in New Haven, 8 January 2004).

In practice the concept of eco-industrial parks evolved from waste exchange between companies towards integrated regional ecosystems. The implementation of industrial ecosystems was considered on existing (*brown fields*) and new (*green fields*) industrial areas. An industrial ecosystem must be designed in relationship with the characteristics of the local and regional *ecosystem* but its development must also match the resources and needs of the local and regional *economy*. According to Lowe [19], these dual meanings reinforced the need for working in an inquiry mode: learning from the experiences of other communities developing industrial ecosystems is important.

A compressed air pilot study in an industrial symbiosis project in the Rotterdam harbor and industry complex (INES project) [3] presented instructive challenges. A feasibility study showed that the usage of compressed air was lower than expected (7,000 Nm^3/hr instead of the presumed 12,000–15,000 Nm^3/hr). The results meant that the economy of scale needed for cost reduction was insufficient. Compounding the problem of diminished economies of scale, the supplier was very busy with the installation of a larger system for the delivery of compressed air to the largest refinery in the region. As a result, they gave less priority to the INES compressed air sub-project. In addition, not all of the potential users were enthusiastic about the INES sub-project, although they did not reject participation completely. Another compressed air supplier, however, learned about this project. This company was able to start a new project by building the trust required for the exchange of knowledge with four other firms and by reducing the scale of the investment needed for the installation. The supplier invested in the installation and the pipelines, and now runs the process, maintains the system and is responsible for a continuous supply. This central installation for four companies has been in operation since January 2000.

Preliminary results show savings of 20% in both costs and energy, and a reduction of CO_2 emissions (as a result of the reduction in energy use) of 4,150 metric tons each year. In 2002 another three plants and in 2003 seven plants more, joined that system. This construction provided new business opportunities for the utility provider. They designed a new utility infrastructure for compressed air and nitrogen for 10 companies in the Delfzijl industrial park in the north of the Netherlands (aluminum, chemical and metal-working companies) that opened under the management of the utility provider in 2004 [21].

It can be concluded that the industrial ecology concept is increasingly becoming widely accepted. Also, institutionalization – as with the initiation of a scientific Journal on Industrial Ecology in 1997 and the start of the International Society on Industrial Ecology in 2001 – draws attention to the issue of industrial ecology. The complex system of eco-industrial parks involving different companies and actors (including their different activities and targets) that is required for the existence of industrial ecology in a region is an important, but time-consuming variable. In the Netherlands, several local authorities were encouraged to set up successful eco-industrial parks through a deliberate policy-making process; the consulting firms involved developed various planning methods with several functions. However, the vision of sustainability was scarcely explicitly defined, the categories *symbiosis* and *utility sharing* were not sufficiently considered, the companies were not sufficiently involved in the development process, and the steering instruments could only enforce options with a limited environmental benefit [3].

Considering the practical experiences of the introduction and dissemination of cleaner production and industrial ecology from a systemic perspective, the concepts are addressing material and energy streams as they result from human activities. These activities do not occur in a vacuum, they are embedded, *i.e.*, they are shaped by the context in which they occur. The following five dimensions can be described [21]:

11.3.1 Cognitive Embeddedness

The manner in which individuals and organizations collect and use information, the cognitive maps they employ in making sense of their environment, the mental disposition of individuals. Themes that can be derived from this are:

Bounded rationality: following economic approaches, we often assume individuals and organizations to behave according to a rational actor model. A more realistic view is that action is that rationality is bounded, in the sense that individuals and organizations have limited capacities for information processing and decision-making. It has consequences for our ability to deal with complex, multi-value problems such as sustainable development. In the cleaner production and industrial ecology concepts, boundaries of departments, hierarchical decision-making, and between companies have to be faced.

Systems thinking: individuals have different strategies for problem solving. Some of these are more suited to systemic problems than others. It is difficult and often neglected to what extent such strategies can be identified in participants in cleaner production and industrial ecology initiatives.

Characteristics of change agents: cleaner production and industrial ecology deal with social change processes. Individuals that act as change agents within or between organizations have special backgrounds and capabilities [23]. The knowledge about the ways in which these characteristics emerge, and how they can be successfully employed within cleaner production and industrial ecology networks, is still limited.

11.3.2 Cultural Embeddedness

This dimension addresses the influence of collective norms and values in guiding economic behavior, such as the shaping of preferences, and the influence of ideologies in shaping future visions. A tendency to externalize normative issues, or to take normative positions for granted, both in our scientific activities and in the subject matter s often experienced. Referring to the latter, some interesting topics are:

Collective cognitive maps: social groups (industrial sectors, regions, national societies, product chains) tend to develop a collective view on the world and ways in which problem should be addressed (both cleaner production as well as industrial ecology itself are such a map). This narrows the search for innovations and solutions for social and ecological problems with respect to the development of maps, and how do they restrain or enhance the development of cleaner production and industrial ecology. Although the concept of industrial ecology was new in the area, the traditional waste exchange results in the INES project 1994–1997 were disappointing in the view of the researchers [3].

Industrial systems fulfil and help define consumer preferences. These preferences are to a great extent culturally determined. How preferences have developed over time, and in what ways has industry influenced them to increase material consumption, is another issue for further research in the 21st century.

Defining what is *legitimate*; the definition of what is acceptable industrial behavior is a social construction, as is the definition of what constitutes acceptable government intervention in industrial activities. This helps to explain why legitimate behavior differs from country to country. Consequently, it is difficult to copy successful practices of cleaner production and industrial ecology from one country (or even region) to another.

Defining what sustainable, cultural embeddedness is directly implies that sustainability cannot be defined objectively. The major consequence of this is that it needs to be defined in local contexts. What are processes to do so, and what mechanisms make existing definitions difficult to change?

11.3.3 Structural Embeddedness

Structural embeddedness emphasizes the way in which relationships between actors influence their actions. This dimension is the one which has gotten most attention as organizational contribution to the field of cleaner production and industrial ecology. Industrial networks have been analysed [24], and co-ordination mechanisms have been discussed [25]. However, linking these structural features to other dimensions of embeddedness remains a relatively unexplored territory.

11.3.4 Political Embeddedness

Political embeddedness is acknowledging the fact that processes of power influence economic actions. This includes the role of the state in the economic process. The role of power is hardly discussed systematically. This maybe has to do with the fact that it is one of the more difficult concepts of sociology in terms of empirical analysis. Nevertheless, actors are not equally able to influence each other's actions and system outcomes, and this has to be taken into account. In relation to the industry-government relationship the *new institutionalism* paradigm formulated by Jordan and O'Riordan [26] is interesting. They cluster various definitions of *institution* as a conglomerate of types of policy networks, standard operating procedures and barriers to rational decision-making, structures of political power and legitimacy, national policy styles, international regimes, and pre-determined social commitments. This means that many stakeholders influence developments in this conglomerate of positions and approaches on the basis of their power (the ability to get what one wants, usually at the expense of the interests of others [27] and/or status.

State promotion of cleaner production and industrial ecology: Although research indicates the importance of spontaneity and emergence in successful examples of cleaner production and industrial ecology, many governmental actors have sought to promote cleaner production and industrial ecology. For the dissemination of new concepts, this means first that standard operating procedures and other routines [28] have important consequences for decision-making processes regarding cleaner production and industrial ecology – by regulating the access of participants and the patterns of negotiation and consultation. Regulation can entail affecting the participants' allocation of attention, their standards of evaluation, priorities and perceptions, identities, and resources. Secondly, in this process, the individual's motivations and perceptions are determined by their own preferences, but also by the importance of the role given to them by the company ("…where you stand depends upon where you sit…" [29]). Thirdly, standard operating procedures can become reifications into specific ideologies or worldviews within entire departments.

Market power: Relationships between firms are asymmetrical. This has effects in terms of their abilities to start or raise barriers to changes in product chains. In eco-industrial parks it is often observed that certain companies such as electricity works, refineries, chemical and food processing companies are in the core of industrial symbiosis activities.

Exit, voice and loyalty: Industrial actors often have an economic/rational management approach [30] to operational organizations. Their approach determines the economic conditions for environmental projects and outcomes. Their function is described within the system boundary of their organization. Their position (responsibility for decision-making), scope (compliance and mandate), perspective (value of the project or concept), commitment and the authority that the actors draw from this, influence the outcomes and the intensity of changes at the aggregated level of industrial ecology. Contrarily to cleaner production demonstration projects, were employees of different organizational were involved, participants in industrial symbiosis are limited per company. When the environmental awareness that many people have cannot be deployed in the work environment, an external compensation will be sought, for instance through membership of an environmental advocacy organization [31].

11.3.5 Spatial and Temporal Embeddedness

Spatial and temporal embeddedness cover the way in which geographical proximity and time influence economic action. The dimensions of space and time are implicit in many accounts of industrial ecology in peculiar, yet it is believed that they deserve explicit treatment. Physical proximity has been identified as crucial in, for instance, complex forms of learning and the building of trust. Porter [24] points to four issues on the strategic agenda for a breakthrough of cluster management: the choice of location, local commitment, the upgrading of a cluster, and working collectively. Time is important as the evolution of industrial systems typically involves long time periods [31].

11.4 Industrial Ecology Programs in the Rotterdam Harbor Area

In this section, the perspective of sustainability embeddedness issues will be applied to the Rotterdam Harbor and Industry Complex. The Rotterdam Harbor and Industry Complex (HIC) has been an environmental sanitation area in the period 1968–1998. The regional Environmental Protection Agency and Water Authority regulate all companies in the area. Many, but not all,[2] companies are involved in different covenants,[3] concerning environmental performance targets, such as covenants on the reduction of hydro-carbons, the chloro-fluorocarbon reduction program, the implementation of environmental management systems, and the four-year environ-mental management plan of a company. The INES project in the Rotterdam harbor industrial area started with the participation of 69 industrial firms in 1994 [25]. The project was initiated by an industrial association Deltalinqs, active in the joint interests of industrial companies in the Europoort/ Botlek harbor area near Rotterdam.

Originally, the Deltalinqs approach to environ-mental problems was very defensive. Later, a more constructive attitude was developed through the stimulation of environmental management in companies. The development from environmental management systems to sustainability projects can be characterized in four phases in the period 1989–2007.

11.4.1 Phase I: The Development of Environmental Management Systems

Following the national trend of self-regulation, Deltalinqs in 1989 started to develop an approach to promote environmental management systems in 70 member companies. During the period 1991–1994 it stimulated the companies' own respon-sibility through separate meeting groups for six branches of industry. Facilitated by a consultant, companies exchanged information and experiences on the implementation of environmental manage-ment systems. In a co-ordinating group, experi-ences were exchanged among these groups. This structure was evaluated positively by the parti-cipating environmental co-ordinators of the firms. Deltalinqs started to search for funds, which led to the start of the Industrial Ecosystem program (INES project) in 1994.

11.4.2 Phase II: INES Project (1994-1997)

Based on assessments of the resources, products and waste streams of companies 15 industrial ecology projects were defined and pre-feasibility studies were performed. Although the projects had a limited scope in terms of the product chain links and preventive approaches, sharing of utilities was found to be a first possibility for developing alliances within the region. After a complex decision-making process within the INES-project team (consisting of the two university researchers, the Deltalinqs project leader, a consultant, and a company representative) three projects were selected for further development. They were seen as good prospects for development within the INES-framework due to their economic potential, environmental relevance, and company partici-pation potential. The projects were:

- *Joint systems for compressed air:* The use of compressed air systems constituted a significant (7% to 15%) part of electricity use of companies. The companies participating in the pilot project were an air supplier, an organic chemical company, an inorganic chemical company, an aluminum-processing company and a cement company. It was assumed that the companies in the pilot project could achieve the following results in the economic and environmental spheres: the price of compressed air can be lowered by approximately 30% and energy consumption could be reduced by approximately 20%.

[2] An USA multinational corporation perceives the covenant as a risk for unexpected liabilities; they prefer to participate in separate projects of the covenant that are within the management policy of their organization

[3] Voluntary agreements between the government and industry

When the real use of compressed air was measured, it was found that it was much lower than expected (7,000 Nm^3/hr instead of the anticipated 12,000 to 15,000 Nm^3/hr) [33]. Another finding was that the total energy consumption could be reduced in two ways. Firstly, by lowering pressure, preventing or reducing leaks, and by a re-design of the existing pipeline system, companies could save approximately 20%. Secondly, by installing a central supply through a ring pipeline system, companies could save approximately another 20%.

- *Waste water circulation*: The reduction of diffuse sources had high priority for the Water Authority, and was consequently of interest to companies. The project increased the awareness that water management improvement can facilitate a remarkable reduction in water emissions and the use of clean water. The use of the so-called pinch technology[4] showed how it is possible to use a certain water quality at the highest level of need of the company's production process or an industrial ecology cluster of companies. By doing this, re-use of several wastewater streams could result in a 10% reduction of total water use.
- *Bio-sludge reduction system*: The total, annual amount of waste bio-sludge produced by 12 companies was about 57,000 tons, including a 3% dry component of 1,900 tons. The actual logistics and treatment costs were approximately €1,200 per ton of dry component. Due to the implementation of primary waste minimization within the companies, a bio-sludge reduction of between 10% and 20% was expected, which could result in annual savings worth between €250,000 and €500,000.

In this phase, these projects did not result in immediate innovations; the projects mirrored political demands and were to a great extent end-of-pipe oriented. However, they created awareness for efficiency improvements at the company level (waste water cascading, compressed air). In the latter case, this actually decreased the necessary economies of scale for a collaborative system. In at least one case, an identified sub-project was commercialized. This concerned the flaring of natural gas that occurred as a by-product of oil drilling in the Rotterdam harbor. Through the INES project, a contract for utilizing this natural gas was made with a company within one week.

11.4.3 Phase III: INES-Mainport Project (1999-2002)

In 1998, the results from the INES program were evaluated by the Board of Deltalinqs, which took time given their meeting only twice every year [33]. Nevertheless, Deltalinqs used this period to acquire new funding, and thus the insights from the first INES program and the learning process that arose from it, led to a second INES program, called the INES Mainport project 1999–2002.

The INES Main port project was a four-year program focused on initiating and supporting industrial ecology initiatives, coordinated again by Deltalinqs. The INES Main port project took the feasibility studies of the INES 1994–1997 program and focused on the following themes: water, CO_2/energy, utility sharing, rest products/waste management, soil, and logistics. At the same time, a more strategic process was initiated. The project initiated a strategic decision-making platform, in which the following societal actors were involved: Deltalinqs – supervising the projects; representatives from major companies in the area; the Dutch National Industry Association; the Dutch National Ministries of Economic Affairs (EZ), and Environment & Spatial Planning (VROM); Province of Zuid-Holland; Municipal Port Authority; Regional Environmental Agency (DCMR); Regional Water Management Agency (RWS/directory Zuid-Holland); Provincial Environmental Association (MFZH); and the Erasmus University.

4 The functional specification of the wastewater was researched for re-use at the highest level in production processes.

11.4.4 Phase IV: Inclusion in the Sustainable Rijnmond Program

Starting on 1 January 2003, the industrial ecology programs were included under the label of *Sustainable Enterprises in the Rotterdam Harbor and Industry Complex* (HIC) on the ROM-Rijnmond program.[5] The project (which is to run until 2010) aims to strengthen the Rotterdam harbor and industrial area as international gateway and to improve the living quality of the residential areas by integrating the environment in the physical planning of the Rijnmond region. This project, which includes a strategic discussion platform made up of relevant stakeholders, was intended to be part of the driving mechanisms towards a sustainable region. In 2003, it presented its 45 page vision document, [35] based on the concept of transitions, a then emerging theme in the national environmental policy agenda. The vision was summarized in the following statement:

> *"A world striving towards lowering carbon-intensity of the economy provides an attractive perspective for industrial centres that are able to process carbon related streams in a highly efficient, clean, and sustainable way. Rotterdam harbor is ideally suited to be such a centre. It has the ambition to be in 2020 the preferred location in Europe for the haulage and processing of carbon-related fuels and raw materials. It can only make this ambition a reality by being a trendsetter in economically feasible reductions of CO_2 emissions related to these activities, and by acting as a field of experimentation for innovations on themes such as clean fossil fuels, clean energy carriers such as hydrogen, syngas, heat, electricity and biomass as a gateway to a carbon-extensive future."*

The program runs for the period 2003-2010 and is led up by a small ROM Rijnmond staff bureau of a strategic platform that involves representatives of the Ministries of Economics and Environment, the province of Zuid-Holland, the Development Board of Rotterdam, the Port Authority, the industry association Deltalinqs, a plant manager, the Sustainable Mobility Program manager, representatives of the Universities of Delft and Rotterdam, and the representative of an environmental advocacy organization. Thanks to the historical development within several programs the strategic platform could build on the built-up trust between the members of the different organizations and the conditions for successful projects that earlier failed.

A long-term vision *To C or not to* C [35] was developed and established in 2003. The conclusion was that Rotterdam port activities were heavily based on fossil carbon energy sources such as oil and gas. Because of both climate change, dependency on fossil energy sources in political and ecological sensitive regions, as well as the development of new technologies for less or non-fossil carbon based energy supply, the vision is that the Rotterdam Energy Port should anticipate these developments by stimulating innovation, the development of new markets and a transition path towards a sustainable region on the basis of renewable energy, mobility and physical planning. The strategic platform functions as stimulator and *sustainability conscience* of all involved stakeholders in these Rotterdam Energy Port developments. The members of the strategic platform also share the reflective learning processes from projects within and around their own organizations as a basis for the construction of the *ecological concept learning and innovation* transition model of Figure 11.3.

Within this context a large project of the application of the rest heat (in total 2,200 MW in the area) was kept under study, under the condition that coupling the rest industrial heat of Shell Pernis (and later of Esso/Exxon and BP) to the Rotterdam city district heating system should be economically viable and that the responsibility for the coupling between industry and city should be organized clearly. In 2002, the Rotterdam municipality

[5] The ROM-Rijnmond programme (Physical Planning and Environment in the Rijnmond area) is based on a policy covenant signed by all the government bodies and industry in the Rijnmond area on 9 December 1993.

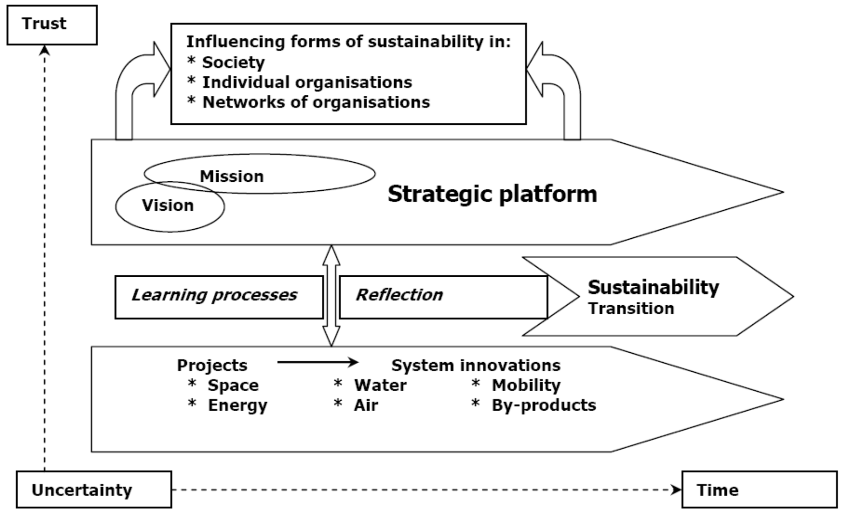

Figure 11.3. Reflective learning in the transition from projects to sustainability system innovations

decided to provide a guarantee for the extra funds that had to be invested in a heating system with temporary equipment in a new residential area nearby the Shell industrial site in Pernis. When all conditions for realization were finally met in 2004 (including liberalization of the Dutch energy market, and reductions of CO_2 demanded by the national government), the coupling of the 6 MW of Shell's rest industrial heat with the city's district heating system would make the temporary equipment redundant; 3,000 houses started to benefit in the Hoogvliet residential area in 2007. The heat supply system will be extended to 100 MW for the application to 50,000 houses[6] [36]. The feasibility study *Grand Design Project* [37] has analyzed that 900 MW can be applied for the heating of 500,000 houses in 2020.

In addition to the planned projects it is experienced that other initiatives are taken. The knowledge of the feasibility study of the compressed air project (see Section 11.4.2) stimulated another company to start compressed air delivery in a joint pipeline system. The air supplier started with the delivery of compressed air to four companies in 2000. Preliminary results showed savings of 20% in both costs and energy, and a reduction of CO_2 emissions (as a result of the reduction in energy use) of 4,150 metric tons each year. In 2002 another three plants, in 2003 seven plants more, and in 2005 three joined that system. [3]. This construction provided new business opportunities for the utility provider.

They designed a new utility infrastructure for compressed air and nitrogen for 10 companies in the Delfzijl industrial park in the north of the Netherlands (aluminum, chemical and metal-working companies) that opened under the management of the utility provider in 2004 [37].

On the basis of sensitivity for the concepts two young professionals at the Rotterdam Port Authority started a private initiative. Their exploration of industrial ecology possibilities resulted in the most well-known industrial symbiosis project in the Rotterdam harbor area. They started the production of fresh king-size shrimps in the *Happy Shrimp Farm* [39], constructed on the basis of rest heat and CO_2 delivery in February 2007.

[6] This is the part of the Hoogvliet/Rotterdam South river border delivery.

11.5 Lessons Learned on the Introduction and Dissemination of Cleaner Production and Industrial Ecology

The cleaner production and industrial ecology concepts are faced with business economics routines of the general *rule of thumb* approach that environmental investments should show a pay back of the investment within a maximum of three years. Although the concepts are being promoted as the *common good* for the economy and ecology of organizations and describe the relationship between the costs of environmental protection and the efficiency of the production process as a *win-win* concept, this usually triggers an *environment* perspective instead of the intended *innovation* perspective.

At the level of single-loop learning, incremental steps such as good housekeeping and regional efficiency improvements have gained credibility as part of these new concepts. In order for radical breakthroughs to sustainability to occur, the approach needs to be different. Continuous learning processes play an important role in this approach, see Table 11.1.

Various experiences demonstrate clearly that the *cleaner production concepts need a broader approach in order to be accepted*: cleaner production involved a radical new perspective, but progress within organizations and their surroundings only took place in small, incremental steps. From this it is clear that various levels of management and the crucial professional educational backgrounds in organizations have different "personal and social clocks" as regards the recognition, acknowledgement and acceptance of new approaches.

At the level of the subject boundary the question can be raised as to whether cleaner production is limited to a system's perspective. As an analogy, the example of a car can be used: one can study the development of cleaner cars, but this does not say much about the sustainability of transportation systems in general. This does not mean that cleaner production concepts are irrelevant, but in a sustainability hierarchy, a holistic approach such as a *cleaner production system* is needed. On the one hand, one can debate whether this is a radical technological process change or a product change; at least it is a breakthrough concerning material substitution, a change that may play a longer term catalytic role. On the other hand, one can debate whether there are ups and downs in continuous improvement. That is to say that continuous improvement is not a straight-line evolutionary process and that sometimes companies seem to move backwards.

The industrial ecology concept is becoming increasingly becoming widely accepted. It is obvious that the Kalundborg Industrial Symbiosis experience is used as the main example worldwide. In the Kalundborg industrial area, [18] company managers developed bilateral links for the shared use of waste and energy; these agreements evolved over several decades. They performed this intentionally in an open economic system of modification and survival. One can say, without labeling this with the metaphor of an industrial ecosystem, that they mimicked elements of the ecosystem. Once environmental problems had been thrust upon the political agenda, it was realized at

Table 11.1. Cleaner production application as result of the type of cleaner production learning processes and their elaboration in organizational change

		Organizational change	
		Incremental change	Radical change
Learning process	One-loop learning process	Cleaner production assessment in demonstration project	Cleaner production innovation
Learning process	Continuous learning process	Cleaner production assessment implementation and continuous improvement	Cleaner production re-designing

Table 11.2. Industrial ecology application as result of the type of industrial ecology learning processes and their elaboration in organizational change

Learning process	Organizational change: Incremental change	Organizational change: Radical change
One-loop intervention: single lesson given from outside	Industrial ecology assessment in demonstration projects	Industrial ecology innovation
Continuous intervention: learning within a region, as a routine	Industrial ecology implementation	Industrial ecology re-design

one point that all the different links can be labeled an industrial symbiosis, for which Kalundborg is now world famous. However, the human activity system cannot fully mimic an eco-system, because one has to take into account the fact that the various actors in the system have targets and intentions that may not be known to each other. Those targets and intentions can be conflicting and without any knowledge of this, the foundations of an industrial ecology system can be weak from the start. If industrial ecology is viewed as a process, this is the first phase to elaborate. The further dimensions of this type of change can also be applied in the industrial ecology concept, as portrayed in Table 11.2.

In relation to industrial ecology, a similar development can be observed. Despite the fact that industrial ecology is perceived as a normal business practice (waste exchange and energy sharing), the industrial ecology assessments in demonstration projects generated mainly first order changes of knowledge about the concept.

However, the implementation of that knowledge in practice is time-consuming and difficult, and only a few incremental first order changes are usually made. Often the concept is found to be attractive but its operationalization is strongly path-dependent on the originator of the plan. Also, until now, the industrial ecology concept has had a strong engineering focus. The social conditions and organization of the concept have scarcely been explored.

The lack of awareness about and the utilisation of the concepts of change management within both cleaner production and industrial ecology assessments lead most of the assessments to be limited technical approaches that usually do not include the social and psychological dimensions of organisational change. Existing experience and implicit knowledge are almost never utilised in the process of exploration and development of the new cleaner production and industrial ecology pathways. The question is whether industrial ecology on a longer time frame will be an essential part of the sustainability system. The number of companies, their diversity in size and type, and the intensity of their interactions are major variables in the system. Here the links between individual companies and the links between companies and society are to be tested according to the criteria of sustainability. This system demands a holistic approach based on new world views. The production process is an element at the level of individual companies (at the micro level) but the output of by-products is also the function of the *servant of the network* [40] at the meso level (Table 11.3).

The interconnectedness of cleaner production and industrial ecology to sustainable regional development can be linked to regional education and innovation institutes. Also, new employment for the region and informational, social and cultural contributions complete the holistic worldview at the macro level (Table 11.4).

In this triple bottom line approach, government agencies and relations between companies and regulating agencies must also be changed. The integration of environmental management within companies means more self-regulatory responsibility for the companies and as a result, important changes have to take place in the relations between industry and regulatory agencies. Regional learning that involves multi-loop learning processes within and among organizations is

Table 11.3. The type of concept and the involvement of actors and the main characteristics of focus and perspective in business management

Concept / Issue	End-of-pipe technology	Cleaner production	Industrial ecology	Sustainability
Actors	Environmental co-ordinators; Environmental technology specialists	Environmental managers; Plant managers	Eco-industrial park management; Plant managers; Physical planners	CEO; Division Managers; Plant managers
Focus	Pollution control	Pollution prevention	Pollution prevention, Recycling and Utility sharing	Production for needs in balance with socio-economical and eco-system
Perspective	Waste	Production process, Products, Services	Production process, product chain and energy carriers	Re-engineering and innovation of production, products and energy carriers

Table 11.4. The three concepts challenge for sustainability: from weak to strong

Three Concepts Challenge	From WEAK to STRONG	
Cleaner production	*One hit* intervention in EMS	Integration in decision-making
Industrial ecology	Waste exchange	Material flow, logistic & social industrial park management
Sustainable development	Lip service to policy integration; Faint social awareness and little media coverage	*Triple bottom line* performance of all relevant stakeholders

essential. Until now this more integrated approach has scarcely been used in an optimal way anywhere in the world.

11.6 Conclusions and Recommendations

There are many different perceptions of the impact of cleaner production. A simple one is: "The picking of low hanging fruit in new areas and organizations" ("..although it is not as easy a process as is often suggested..") [41]. A more complex one is: "A time consuming process in more advanced phases like business re-engineering or re-structuring" [3].

Because so many actors and organizations are involved, the development of industrial ecosystems is site-specific. An important distinction can be made between existing and new industrial areas. The design of an industrial ecosystem must take into account the characteristics of the local and regional *ecosystem* but its development must also match the resources and needs of the local and regional *economy*. These dual requirements reinforce the need for working in an inquiry mode [19]. In combination with learning processes involving the experiences of other communities, developing industrial ecosystems in an interactive dialogue with stakeholders is a practical route towards the implementation of sustainability projects in a long-term perspective.

In the life-cycle of dealing with environmental issues, we are for answering the question whether environmental management is needed as an independent concept, beginning to understand that negative impacts on our surroundings are indicators of the inefficiency of industry, due to wastage of materials and energy. So, how can we influence other choices in production, products, services, and logistics in such a way that negative impacts are reduced? In this perspective, can we imagine that the emergence of an advanced clean industry is noticeable? The answers to these questions have evolved to the concepts of *sustainable enterprises* [42] and *corporate social responsibility* [43], [44], and s*ustainable regions and communitie*s [45]. The long-term sustainable development of regions ask for new institutional arrangements and the facilitation of initiatives such as organizational research, information, conferences, think tanks, vocational training providers, specialized training and general education [46].

It is recommended that in order to make more effective progress with cleaner production and industrial ecology in the future, the following should be done:

1. All cleaner production efforts, in the case of application in the design, start-up and growth life-cycle phase need to be made with a comprehensive organizational support and involvement and should also include the stakeholders throughout the life-cycle of the products and services that the organization provides to society.
2. Multi-loop learning processes should be used both within single companies and between clusters of companies. This should also increasingly involve the wider citizen population in sustainable regional development planning and implementation.
3. Cleaner production and industrial ecology concepts and approaches should be integrated vertically and horizontally from the policy and strategic levels down to the detailed operational levels of both individual companies and clusters of companies.
4. The implementation of industrial ecology should be integrated within the regional economy, ecology, technology, culture, and sustainability plans of the region.
5. Trust, transparency and confidence must be developed through an open, reflective and on-going dialogue designed to ensure real involvement of diverse stakeholders in charting the future of their organizations and regions as part of the transition to sustainable societies.
6. On the basis of cleaner production and industrial ecology and conditions of trust, transparency and confidence, the concepts of sustainable enterprises and communities can integrate all social, economic, environmental and cultural dimensions.

In stimulating and facilitating the above recommendations several partnerships create added value:

At the macro level, international policies and agreements, such the United Nations Millennium Declaration, Clean Development Mechanisms, Global Environmental Forum, Environmental Sound Technologies, and Human Development through Markets, must be integrated in an economic, ecological and social regional framework.

At the meso level, municipalities, industry associations, and education institutes/knowledge centers can join in integrated public private partnerships to generate and facilitate sustainability programs. The local situation provides the context whether it be government-driven, such as is the case in several Asian countries for eco-industrial park development, or voluntary partnership-driven. Also regional approaches for cleaner production in partnerships in developing countries can have a broad scope [47].

At the micro level, various disciplinary approaches such as industrial (eco) design, environmental management accounting and sustainable banking must be integrated.

Overall, the emerging education initiatives for initial Master’s courses on sustainability subjects must be strongly stimulated. Where UNESCO initiated the UN Decade on Sustainability in Higher Education 2005–2014, [48] the concepts of cleaner production, industrial ecology and sustainability can be educated within a cleaner production systems approach.

All together, the ecological, economic, social and cultural dimensions of nations and corporate activities are best combined in the label *nations and corporations taking their responsibility for working towards social, economic, environmental and cultural sustainability*.

References

[1] Baas L, Hofman H, Huisingh D, Huisingh J, Koppert P, Neumann F. Protection of the North Sea: Time for clean production. Erasmus Centre for Environmental Studies 11, Rotterdam 1990.

[2] Frosch RA, Gallopoulos NE. Strategies for manufacturing. In: Managing planet earth. Scientific American Special Issue, September 1989; 144–152.

[3] Baas L. Cleaner production and industrial ecology; dynamic aspects of the introduction and dissemination of new concepts in industrial practice. Eburon, Delft, 2005

[4] Creating Solutions for Industry, Environment & Development. UNEP, 9th International Conference on Sustainable Consumption and Production. Arusha, Tanzania 2006; 10–12 December.

[5] Mandler JM. Stories, scripts and scenes: aspects of social theory. Lawrence Erlbaum Associates Publishers, Hillsdale NJ, 1984.

[6] World Summit of Sustainable Development. Johannesburg Declaration on Sustainable Development Johannesburg 2004; Sept. 4

[7] UN General Assembly United Nations Millennium Declaration. UN 8th Plenary meeting 55/2. New York 2000; Sept. 8.

[8] UNIDO Cleaner Production Expert Group Meeting. Baden, Austria 2006; October 29–31.

[9] UNEP/Wuppertal Institute Collaborating Centre on Sustainable Consumption and Production, and UNEP. Creating solutions for industry, Environment & Development 9th International Conference on Sustainable Consumption and Production. Background Paper. Arusha, Tanzania 10–12 December, 2006.

[10] UN-Habitat Responding to the challenges of an urbanizing world. Annual report. Nairobi, 2005.

[11] Tukker A, Jansen B. Environmental impacts of products: A detailed review of studies. Journal of Industrial Ecology 2006; 10(3): 159–182.

[12] Billsberry J. There is nothing so practical as a good theory: how can theory help managers become more effective. In: Billsberry J, editor. The effective manager: Perspectives and illustrations. Sage, London, 1996; 1–27.

[13] Bateson G. Steps to an ecology of mind. Ballentine Books, New York, 1972.

[14] Snell R, Chak AMK. The learning organization: Learning and empowerment for whom? Management Learning 1998; 29(3):337–364.

[15] Vickers I, Cordey-Hayes M. cleaner production and organizational learning. Technology Analysis & Strategic Management 1999; 11(1):75–94.

[16] Dodgson M. Organizations learning: a review of some literatures. Organization Studies 1993; 14(3):146–147.

[17] Richards DJ, Fullerton AB (editor). Industrial ecology: U.S.-Japan perspectives. Report on the U.S.-Japan Workshop on Industrial Ecology. March 1–3, 1993, Irvine CA. National Academy of Engineering, Washington D.C, 1994

[18] Gertler N. Industrial ecosystems: Developing sustainable industrial structures. Master's thesis MIT, MA, 1995

[19] Christensen J. Kalundborg Industrial symbiosis in Denmark. Proceedings Industrial Ecology Workshop; Making business more competitive. Ministry of Environment, Toronto 1994.

[20] Lowe EA, Moran SR, Holmes DB (eds.). Fieldbook for the development of eco-industrial parks. Indigo Development, Oakland, 1996

[21] Voermans F. Delfzijl krijgt persluchtnet (Delfzijl starts a compressed air network). Petrochem 2004; June, 6(22).

[22] Baas L, Boons F. Industrial symbiosis in a social science perspective. Discussion proposal for the 3rd Industrial Symbiosis Research Symposium. Birmingham (GB) 2006; 5–6 August.

[23] Vliet F van. De Change Agent en zijn Resources; Een modelmatige benadering van regionale technologische veranderingsprocessen (The change agent and his resources; a model approach of regional technological change processes. Delft, Ph.D. thesis (in Dutch), 1998.

[24] Porter ME. Clusters and the new economics of competition. Harvard Business Review November 1998; December: 77–90.

[25] Boons FAA, Baas LW. The organization of industrial ecology: the importance of co-ordination. Journal of Cleaner Production 1997; 5(1-2):79–86.

[26] Jordan A, O'Riordan T. Institutional adaptation to global environmental change (II): core elements of an `institutional' theory. CSERGE Working Paper GEC 95-21 Norwich/London 1995.
[27] Lukes S. Power: a radical view. Studies in Sociology, London 1974.
[28] Saunders P. They make the rules: Political change and learning. Westview Press, Boulder, 1976.
[29] Allison GT. The essence of decision: Exploring the cuban missile crisis. Harper Collins Publishers, Boston, 1971.
[30] Burrell G, Morgan G. Sociological paradigms and organizational analysis. Ashgate Publishing, Brookfield, 1979.
[31] Baas L. Woorden en Daden; Evaluatierapport INES Mainport Project 1999–2002. (Words and actions; Evaluation report of the Mainport Project 1999-2002). Erasmus Universiteit, Rotterdam, 2002; Dec.
[32] Baas L, Boons F. the introduction and dissemination of the industrial symbiosis projects in the Rotterdam Harbour and industry complex. International Journal on Environmental Technology and Management 2007; 7(1):1–28.
[33] Silvester S. Air-sharing, End report INES project phase 3a. Erasmus Studiecentrum voor Milieukunde, Rotterdam, 1997; 24 January.
[34] Baas L Developing an industrial ecosystem in Rotterdam: Learning by … what? Journal of Industrial Ecology 2001; 4(2):4–6.
[35] ROM-Rijnmond. To C or not to C. Rotterdam 2003.
[36] ROM_Rijnmond. Rijnmondse Routes. Rotterdam 2005.
[37] ROM Rijnmond R3. Grand Design; Warmte voor Zuidvleugel Randstad (Heat for the Southern part of Zuid-Holland). Rotterdam 2006; February.
[38] Voermans F. Delfzijl krijgt persluchtnet (Delfzijl starts a compressed air network). Petrochem 2004; 6(22).
[39] Greiner B, Curtessi G. The happy shrimp farm. Rotterdam 2005; Oct.
[40] Wallner HP. Towards sustainable development of industry: networking, complexity and eco-clusters. Journal of Cleaner Production 1999; 7(1):49–58.
[41] Dieleman H. De arena van schonere productie; mens en organisatie tussen behoud en verandering (The Arena of cleaner production; mankind and organization between conservation and change). Ph.D. thesis Erasmus Universiteit Rotterdam, 1999.
[42] Cramer J. Ondernemen met hoofd en hart; duurzaam ondernemen: praktijkervaringen (Enterpreneurship with head and heart; sustainable enterprises: experiences in practice). Van Gorcum, Assen, 2002.
[43] Cramer J. Learning about corporate social responsibility – The Dutch experience. IOS Press, Amsterdam, 2003.
[44] Werther WB, Chandler D. Strategic corporate responsibility: Stakeholders and global environment. Sage Publications Inc., Thousand Oaks, 2005.
[45] Corbett MN, Corbett J. Designing sustainable communities: Learning from village homes. Island Press, Washington DC/Covelo, 2000.
[46] Hart M. Guide to sustainable community indicators. Hart Environmental Data, North Andover, MA, 1999.
[47] Mbembela PJK. Managing environmentally harmful economic activities in informal settlements: The case of the Dar es Salaam City – Tanzania. IHS Master Thesis Rotterdam, 2006.
[48] UNESCO. The UN decade for education for sustainable development 2005-2014. http://portal.unesco.org/education/en/ev Accessed 12 December, 2005.