

INDUSTRIAL ECOLOGY AT THE REGIONAL LEVEL

The Building of Sustainable Industrial Estates

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ELLIS BRAND - THEO DE BRUIJN

CSTM University of Twente
PO BOX 217, 7500 AE Enschede, the Netherlands
tel +31-53 489 3203 / fax +31-53 489 4850
e-mail: e.m.l.brand@cstm.utwente.nl / t.j.n.m.debruijn@cstm.utwente.nl

1. Introduction

Environmental policy used to be aiming at individual companies mostly. The targets of this policy were quite modest. During the nineties we see a shift in policy strategies, focusing for example on companies that are part of a value chain or are located in the same region. The introduction of the concept sustainable development also meant that environmental policy was heavily intensified. Targets can imply a reduction of emissions, waste or material use by 90% or even more.

Sustainability has been an important perspective for environmental policy ever since the publication of the report *Our common future* of the World Commission on Environment and Development (Commission Brundtland, 1987). In this report it is being argued that sustainable development in fact is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and the institutional change should be in harmony with each other in order to provide for human needs, now and in the future. *Our common future* however is not a blueprint for the future. Ever since 1987 there has been a constant discussion on the exact definition and impact of the concept of sustainability. Although there is as yet no end to this discussion, it has become clear that equality between present generations and equal opportunities for future generations is at the very core of sustainable development. Although achieving and preserving a balance between economical growth and environmental burden stands central, sustainability also has social dimensions like human rights, women's liberalization and democracy.

Sustainable development is a global concern. A lot of the changes required will start however at the local and regional level. The process of defining regional sustainable development can help in creating commitment and involvement of relevant actors. The industry sector will play an important role in the route towards sustainable development.

The focus of this paper is on (policy-)options by which industrial development at the regional level can be stimulated towards *sustainable* industrial development. In this paper we will therefore identify concrete options for industry to contribute to the local/regional sustainable development and policy options for governments to stimulate industry to do so.

The paper is based on several (research-)projects we have carried out over the last years, such as an international workshop on "sustainability and regional waste management"; a survey and 30 in-depth interviews with key-actors (companies, industrial organizations, consultancy agencies, Chambers of Commerce, policy-makers, civil servants), a regional workshop and the analysis of other local and regional initiatives.

The paper is set up as follows. In section 2 we discuss the role of industry in reaching for sustainable development. There we identify four levels at which industry can be stimulated towards sustainable development. One of these levels is the regional level. Section 3 focuses on the concept of industrial ecology which can be applied at this level. The basis of the concept is discussed as well as some examples. In section 4 options are identified for stimulating estates towards industrial ecology. Section 5 discusses policy actions needed for this. In order to get these actions implemented you need a policy framework. The start of such a framework is

discussed in section 6. The paper is concluded in section 7 with a critical analysis of the possible impact of industrial ecology within industrial estates.

2. Industry and sustainable development

Transforming industry towards sustainability is not the only solution but it certainly is an important part of the answer to the ecological crisis. An important question therefore is how we are going to achieve a sustainable production system. Global problems such as climate change, decrease of bio-diversity, population growth and poverty present new challenges to industry. Projects aiming at pollution prevention and/or environmental management have urged many companies to take action (De Bruijn, Coenen and Lulofs, 1996). Over the last few years this has led to considerable investments in order to reduce waste streams and energy use.

Sustainable development will however require more than these kind of measures. Roome (1997) distinguishes several differences between 'normal' environmental management in companies and sustainable development:

- Sustainable development means a long-term vision that exceeds generations;
- Sustainable development means the integration of economic activity and the industrial production system into the social system;
- Sustainable development in decision-making within companies means the equivalency of notions of equity, justice and environmental concerns to the economic dimension.

He also points at the fact that sustainable development requires changes in the institutional design of society that go beyond the level of individual companies. Sustainability therefore is not a short-term target for individual companies. Individual businesses however need to look in the long term towards new types of activity, development and growth. This, in turn, requires them to look at their own ethics, their objectives and their own forms of organization, corporate culture and communication (Welford, 1996). Sustainable development should result in radical changes in the end. In the short term an important issue is how to move beyond the step-by-step improvements of eco-efficiency.

The main issue however is how to get started. How can companies effectively be stimulated to start up the transformational processes? We distinguish four levels at which industrial sustainability can be stimulated. The first level is that of *individual companies*. Despite all the efforts put into pollution prevention and environmental management during the last few years, undoubtedly a lot of improvements are still possible at this level. To get individual companies going is therefore very valuable. For some changes however individual companies are too small. Especially in the case of fundamental technological changes individual companies often lack the resources to do the research needed and to invest. Stimulating *branches of industry*, the second level we distinguish, sometimes can help solving this problem. The problems individual companies within a branch suffer, are often alike. Solving the problems and involving the branch organization serves two purposes. Firstly the larger scale will enable more (fundamental) changes since the costs of these can be spread over a large amount of companies. Secondly the branch organization can be used to get access to companies.

Sustainable development will not only require step-by-step changes within companies. Structural changes in the economy (and eventually in society at large) will also be needed (see for instance Clark and Georg, 1995; Huber, 1995). This will result in changes in the production system and will eventually lead to other ways of producing and consuming. As a first step we therefore need to stimulate cooperation between companies in addition to changes in individual companies within branches of industry. This cooperation can take place within a certain *product chain* (third level). At the regional level *industrial estates* (fourth level) can be the focus of change processes.

We have identified policy-options for each of these levels. In this paper we will concentrate ourselves on the fourth level, industrial estates. The basis, opportunities and problems of sustainable development within industrial estates are dealt with below.

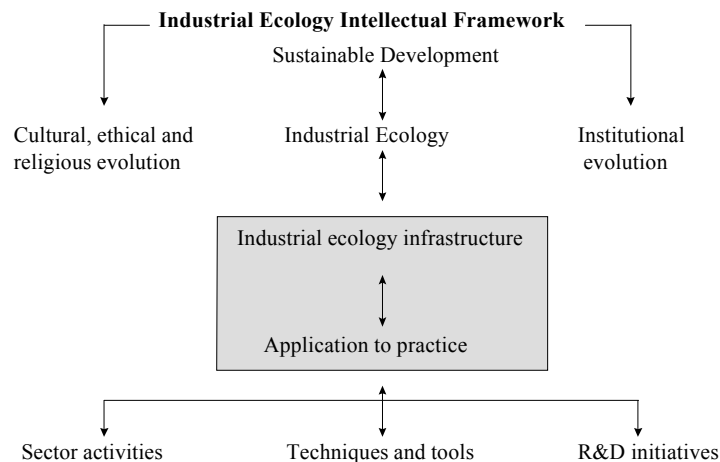
3. The concept of industrial ecology

Industrial ecology is a relatively new concept in the discussions on waste management and sustainable development. The idea of industrial ecology is based upon an analogy with natural ecological systems. In nature an ecological system operates through a web of connections in which organisms live and consume each other's waste. In an industrial ecology, unit processes and industries are interacting systems rather than isolated components. This view provides the basis for thinking about ways to connect different waste-producing processes, plants or industries into an operating web that minimizes the total amount of industrial material that goes to disposal sinks or is lost in intermediate processes. The focus changes from merely minimizing waste from a particular process or facility, to minimizing waste produced by the larger system as a whole (Allenby and Richards, 1994, p. 3).

Industrial ecology has attracted a lot of attention in the last few years. Nevertheless there is as yet no consensus on the exact meaning and value added of the concept. Is industrial ecology an instrument, a method, an approach, a research subject or a subject (De Kruijf and Weterings, 1997, p. 74). An important issue seems to be the level of change: does industrial ecology aim for radical change, trying to minimize waste production by redesigning the production process or does industrial ecology aim for a more incremental change to maximize recycling uses by looking at alternative uses of the waste (De Kruijf and Weterings, p. 73).

In a recent book, Allenby explores the concept further with a specific focus on the policy implications of Industrial Ecology (Allenby, 1999). Allenby develops a framework, the so-called Industrial Ecology Intellectual Framework (Allenby, 1999: 12). The framework describes the relationship between industrial ecology and sustainable development. Sustainable Development is the highest level and represents the general goal, society is aiming for. It is not possible to define sustainable development but it does give a direction for preferable actions. Industrial ecology is needed to develop these concrete actions. What makes industrial ecology an attractive approach is that it is system based and able of analyzing complex relationships in a globalizing world and it is integrative, including science, technology and environment. Industrial ecology, in the framework, is then a multidisciplinary *study* of industrial systems and economic activities, and their links to fundamental natural systems. While sustainable development is highly normative, I.E. should provide the objective basis for decisionmaking. Allenby recognizes that besides I.E. you will need changes in culture and institutions in order to reach sustainable development. The third level in the framework represents the policy side of I.E. Allenby calls this the industrial ecology infrastructure. The infrastructure in place should enable the implementation of industrial ecology. This includes developing and implementing legal and economic incentive systems as well as tools and information resources. Finally, in practice different firms, consumers, etc. implement industrial ecology. Examples are designing for the environment and green accounting systems.

Figure 1: The Industrial Ecology Intellectual Framework (source: Allenby, 1999: 12)



How industrial ecology works out in practice (the grey part of the figure) is described in the cases in this paper. Over the last few years a number of projects aiming at industrial estates already has been initiated. A recent inventory mentions over forty projects, in the Netherlands as well as in other countries (Dekker, 1997). Before we describe our attempts to specify the concept for a province in the Netherlands, we'll first describe some examples to illustrate the use of the concept in various settings.

The most well known example of a regional industrial ecology approach can be found in *Kalundborg*, a small town that lies along the coast in Denmark. Here a complex web of waste and energy exchanges has developed among the city, a power plant, a refinery, a fish farm, a biotechnical plant and a wallboard maker. The exchange works as follows: the power company pipes residual steam to the refinery and, in exchange, receives refinery gas (which used to be flared as waste). The power plant burns the refinery gas to generate electricity and steam. It also sends excess steam to a fish farm, the city and a biotechnical plant that makes pharmaceuticals. Sludge from the fish farm and pharmaceutical processes becomes fertilizers for nearby farms. Further, a cement company uses fly ash from the power plant, while gypsum produced by the power plant's desulphurisation process goes to a company that produces gypsum wallboard. During a workshop in Kalundborg we had the opportunity to discuss the cooperation with representatives of the companies and municipality involved in the process in Kalundborg (workshop, May 1996). Especially interesting was to hear their view on the development of industrial ecology and the role of the partners involved. In Kalundborg the exchange of waste products started 30 year ago because the companies involved saw an economic benefit. The cooperation between the companies started voluntarily. During the process a very close and open relationship developed between the industry and the public authorities. The participants in the industrial ecology in Kalundborg believe that a cooperation like theirs can only develop if good relationships exist between the companies and the authorities. According to them 'creating industrial ecology is more a question of psychology than technology'. The possible partners need to be convinced of the economic advantages. The authorities can not regulate the process because often the options for exchanging waste in the region will not be visible to them. There is a role for them in stimulating initiatives by providing information; initiating a discussion with industry to convince them of the economic advantages; identifying the persons who can be the leaders in the process; and to ensure that there are no laws that constrain the application of industrial ecology.

To test the success of Kalundborg, the *INES project* was initiated in the Rijnmond area, an industrial area near Rotterdam (Holland). The project was set up in 1993 by an association in which 80 companies of the Rijnmond area are member. Erasmus university in Rotterdam was assigned to coordinate the project. The goal of INES was to prevent or to reduce the waste and emissions from industrial activities in an efficient and effective way, so that the environmental damage is reduced and the management of the production process is improved. The project consisted of three steps: (1) the creation of company com-

mitment to the concept of industrial ecology (by organizing meetings, training programs), (2) the analyses of the material flows in the area, and (3) the selection of projects and the formation of project teams involving the companies, experts and the university.

The most important findings of INES were: (1) the sharing of utilities is very attractive for the companies because it is beneficial in environmental and economic terms; (2) the involvement of an independent facilitating organization (such as the university team within INES) can stimulate the cooperation between the companies especially to create the necessary trust and to judge the options of an alliance; (3) before starting an industrial ecology project it is essential to implement cleaner production assessments within the companies: first waste prevention before waste exchange.

On Thursday May 9, 1996, the *Province of Milan* and the Greening of Industry Network organized a workshop 'Regional Sustainability: From Pilot Projects to an Environmental Culture'. Seventy participants representing the regional and local authorities, the industry, distributors, the public and the Greening of Industry Network gathered to discuss the current waste problems existing in the province of Milan and to explore possible solutions and strategies. Central in the discussions was the idea to develop an industrial ecology plan for the region of Milan. At the workshop several examples were presented including their success and fail factors. The key to success in these cases were: (1) the involvement and education of the public; (2) the open communication and close cooperation between companies and authorities and (3) the linking of economic and environmental objectives. In the discussions we had during and before the workshop it became clear however that Milan lacked these success factors at that moment. The workshop however might be the start for a process in which options for industrial ecology in the Milan region are further explored by setting up a system for analyzing the material flows in the region. On the basis of this system industrial ecology projects could be identified. Simultaneously, the province of Milan could initiate roundtable discussions on waste management (including cleaner production, industrial ecology) in the region involving all stakeholders to start developing a carrying network.

4. Stimulating industrial estates

In a recent research project we have used the experiences in the examples described above to explore the possibilities for industrial ecology within a province of the Netherlands, named Overijssel. Traditionally industry has been an important source of job creation within Overijssel. Nowadays the level of unemployment however exceeds the national level. Creation of jobs by means of economic growth is therefore important. At the same time Overijssel is seen as the 'garden' of the Netherlands. Preserving nature and landscape and contributing to national environmental goals is valued highly. This calls for industrial growth while at the same time controlling and reducing environmental effects.

Our research design comprised three different stages. After studying relevant literature we did a survey. Central in this survey were twelve items on which we asked the opinion of the respondent. These items covered different approaches to sustainable development, from a more stimulating to a more coercive approach. We used the outcomes to get insights into the governmental strategy the respondents think is needed and acceptable. The second stage was to interview some of the actors involved. We talked to individual companies, governmental agencies, Chambers of Commerce, employers' associations, consultancy firms, technology centers, environmental groups, etc. The focus in the interviews was on concrete options for industrial ecology and the role of the actor involved. The third stage consisted of two workshops in which the preliminary findings were presented and discussed in order to get some feedback.

Stimulation of sustainability at the level of industrial estates was one of the scenarios we worked out. Other levels involved stimulating individual companies, stimulating value chains and stimulating certain sectors of industry. Sustainability exceeds the level of individual companies. Optimization at the individual level in the end leads to sub-optimal results and tends to focus mainly on the production process. With the broadening of focus to higher levels other options come into play, like for instance joint energy facilities or improvements of (the use of) products. In this paper however we concentrate ourselves on the

level of industrial estates, which was seen by our respondents as the most promising one.

When looking at stimulation of industrial estates one has to differentiate between revitalize existing estates and the sustainable composition of new ones. The latter of course offers other options for cooperation between companies than the first one. The options for governments to stimulate differ accordingly. In the figure below this is illustrated.

STIMULATION OF SUSTAINABLE INDUSTRIAL ESTATES

◆ **REVITALISATION OF EXISTING ESTATES:**

- Facilitation of the management of waste streams
- Stimulation of the building of energy and water cascades
- Efficient use of space
- Stimulation of the creation of joint facilities
- Mobility management

◆ **SUSTAINABLE COMPOSITION OF NEW ESTATES:**

- Stimulation of alternative energy sources
- Stimulation of a second system of waterworks
- Acquisition strategy
- Efficient use of space
- Alternative transport systems

Revitalization of existing estates serves several purposes. The economic viability can be improved, the physical composition can be re-organized, and environmental facilities can be created. A lot of estates have gone to seed during the years. Revitalization offers the opportunity to give the estate a face-lift and at the same time improve the environmental situation, both directly and indirectly. Examples of *direct environmental improvement* are a joint car wash facility, central waste collector points, improvements in the energy supply, the building of cascades of waste streams, etc. The point of departure may hinder the realization of such facilities. After all you will be dependent of the investment schemes of the companies involved. Another possibility is to create a form of mobility management. Based on a proper inventory of all transport to and from the estate, options for joint transport of employees and of goods can be developed. This may result in for instance car-sharing by employees. It may however also result in alternative forms of transport. An example of *indirect environmental gains* are the decreasing pressures to develop new estates as a result of revitalization of old ones. In our case this was important given the emphasis on protection of the structure of the natural environment .

In the case of the planning and development of new estates there are more options to implement. Facilities that need extensive construction work or investments can be developed in early stages. Examples are divided water works (for drinking water and process water), environmentally friendly transport systems, efficient use of space (for instance subterranean buildings and car parks), sustainable buildings, and advanced energy systems. The main problem here is that the planning of such systems is difficult without a detailed vision of the companies that are going to invest on the estate. Usually however the planning and development anticipates this phase¹. The judgment of the feasibility is therefore very hard. With new estates one can also think of acquiring companies that fit each others profile environmentally speaking. First options is to locate companies that can make use of each others waste streams and surplus energy flows can be put next to each other. Another option is to develop a thematic estate, for instance a “sustainable estate”. On such an estate only pro-active, front-running companies producing special or experimental products are welcome. But of course, governments here mostly have to rely on the coincidental supply. Especially the competencies of provinces are limited in this respect.

5. Policy options to stimulate estates

¹ In the Netherlands there also is the problem of divided competencies. Usually the planning of estates is done by the province, together with the power and water companies, while the actual development is supervised by the municipality.

Despite the lacking legal basis for direct regulation, governments can try to improve the environmental situation both on existing and new industrial estates. The question is how to stimulate the actions that have been described. In principal three basic models can be applied: command-and-control, economic stimulation and the voluntary model. In this order they have less radical and direct consequences for the target group. The degrees of freedom for the target group are for instance in the voluntary model maximal. Governments have to rely on reasoning to persuade the target group.

The choice for one of these models depends on the specific situation. In situations where the consequences of "wrong behavior" of the target group are far-reaching and very serious (for instance when there is a direct threat to the environment or to public health) the government should take its responsibility and deploy command-and-control. Of course governmental agencies need power and knowledge to precisely describe what is right and what is wrong. Lack of power can be a reason to abandon command-and-control. In general governments can be expected to use the most effective model taking into account characteristics of the problem at hand, the desired behavior and the target group. Another argument can be found however in the image the government wants to promote.

The outcomes of our research clearly show that there is a preference for a stimulating role of the province instead of a more coercive one. An important reason for this is the lacking legal basis for a lot of the actions described. Companies also almost never like command-and-control. Intermediary organizations saw a need for cooperation between companies, something that is hard to realize via command-and-control. The province itself wants to establish an image of a partner for industry instead of an opponent. Below is a list of policy options that are seen as most successful:

POLICY OPTIONS

◆ MOTIVATING POLICY OPTIONS:

- Information office
- 'Sustainability Team'
- Workshops
- Joint permit / tradable rights

◆ FACILITATING POLICY OPTIONS:

- Regulation for stimulating non-enforceable investments
- Regulation for stimulating of company removals
- Regulation for stimulating a management/facility system

The gathering and diffusion of information is seen as most valuable. Information should be easy accessible. Almost all respondents had the opinion that a lot of relevant information already exist. Main problem is the accessibility of this information. One of the options is to set up an *information office* for sustainable development industry. At this office all relevant material such as information on successful sustainable estates, possible partners for projects, subsidy options, etc. should be available. Given the fact that all this material is available in one office, companies at a specific estates, their associations, and other initiators (municipalities, consultancy firms, teaching institutes) can have easy access to relevant information.

Another option is that the province itself takes the initiative to bring the information to the estates by a so-called *sustainability team*. Such a team could initiate projects on specific estates on specific aspects of sustainability. They also should be involved in all revitalization projects. The team could offer expertise and help for auditing the situation and trying to think of possible measures. It can also act as an information broker. Research has shown that offering concrete help and expertise (including project management expertise) really helps in improving the environmental performance of companies. With the stimulation of waste minimization good results have been made using this method (see for instance De Bruijn, Coenen and Lulofs, 1996).

The next option is the organization of *workshops*. These workshops can serve two purposes. Firstly, they can facilitate information exchange. Respondents coming from companies all had specific questions that need to be answered, for instance on design for the environment. Secondly the workshops can help building consortia by getting the 'right' people together.

Another option is the issuing of a *joint permit*. Current permits and other legal requirements sometimes prevent collaboration between companies, for instance with the exchange of waste streams. To facilitate collaboration between companies one could think of formulating goals at the level of the estate rather than at the level of individual companies. This could be accompanied by a system of tradable rights in order to get some flexibility on the estate.

The building of more sustainable industrial estates is often very costly. Besides concrete help financial support can enable such estates. Below are some examples of financial regulations on specific aspects. The first example is a *regulation for stimulating non-enforceable investments*. All kinds of new and extra pipe systems have to be build, for instance to facilitate cascades of energy, water and material. Also the infrastructure needs to be revised and sometimes rebuild. The building of joint facilities, such as a joint car wash facility and central waste collector points, also need investments. Often these investments are not legally required. Especially in the case of joint facilities it will be hard to get commitment. Also these specific investments are often not cost-effective. One way to get them nevertheless realized is to have a regulation for stimulating non-enforceable investments.

In some cases it might be useful or even necessary to remove a company in order to enable the building of cost-effective cascades. The building of joint facilities also may require a different lay-out of the estate. Since the removal costs for companies are usually very high, the second example therefore is a *regulation for stimulating of company removals*.

A third option is a *regulation for stimulating a management/facility system*. By means of building cascades companies become dependent on each other. This can give friction. A third party can help in solving this friction or even prevent it. The facility point can also be responsible for the maintenance of joint facilities. This organizational structure can also prevent that the whole system of cascades collapses after the withdrawal of only one company (for instance due to bankruptcy). A last responsibility for the facility point is to take care of continuous improvements. With a certain regularity initiatives can be taken to further optimize the environmental performance.

In the Netherlands the most important actor concerning industrial estates is the municipality, rather than the province. After the stage of physical planning of the estate the municipality is concerned with further developing it. This means that in the efforts for sustainable industrial estates municipalities should play a prominent role. Part of the policy-options on sustainable estates therefore should be focused on evoking and streamlining initiatives of municipalities. These options also can comprehend information exchange, the building of expertise within municipalities, financial stimulation, etc.

6. Towards a policy framework

When discussing industrial ecology the debate is mostly on changing industry and industrial systems irrespective of governments (Oldenburg and Geiser, 1997). In our project we focused mostly upon the options for governments (i.c. the province of Overijssel) to stimulate industrial ecology at the regional level. In this paper we have described some of the actions the province can take on the level of industrial estates. Taken together with the actions proposed for the other levels we analyzed (individual companies - sectors of industry - value chains) it resulted in a large set of nearly 30 actions. To guide the implementation of (some of) the actions we designed a policy framework. Key problem is that the province cannot implement all actions by itself or all at once. The policy framework is designed to guide implementation and to ensure the coordination with other policy fields (for instance economic and employment policy) and actors (other departments of the province itself, Chamber of Commerce, etc.)

The framework holds two aspects: Prioritization of activities and an implementation structure.

In order to make a suggestion for the *prioritization of activities* we used the survey and interviews. This way we explored the preferences of the potential partners both in terms of general policy orientation as in terms of concrete measures and projects. We asked our respondents for instance whether the province should make use of financial stimuli or be more coercive. On a more concrete level we asked for instance if the respondent would favor the use of alternative energy sources, some form of mobility management,

using waste streams of other companies, etc.

Concerning industrial estates this leads to the following recommendations:

I. *The use of a Sustainability Team*

As said before, the spread of knowledge and the offering of concrete help is seen as very promising. Especially since working on issues of sustainability is not a daily routine for business people such a team can put and keep these issues on the agenda. Also the team can help solving specific problems drawing on their experience. An important function of the team will be to initiate developments. A special team with some visibility and credibility and a growing experience is believed to be best equipped for this.

II. *The development of scenarios*

There was a general feeling among respondents that sustainable development should not (only) result in ad-hoc projects. There is a need to develop a long-term perspective via the development of scenarios. These scenarios can also give some idea of continuity of policy to companies, instead of an image of an ever changing, unpredictable government.

Point of departure in the scenarios is the economic prospect of an estate (or a sector of industry). Out of this perspective the chances that sustainable development offers can be viewed upon. This gives the opportunity to strengthen the economic position and the environmental situation at an estate at the same time.

III. *To ally with revitalization projects*

Revitalization of outdated estates will be a major item in the coming years with large budgets devoted to it. This gives some funding options. Allying with these major projects also ensures a good timing of activities.

Even more important than the prioritization is the question on *implementation structure*. The province is just one of the parties involved. Crucial to the success of activities is the close linkage to related activities, for instance the revitalization projects. Also acceptability was seen by the province as the keyword. In this sense the whole project is a perfect example of the strive for shared responsibility as reflected in the fifth EU Environmental Action Program. Crucial is therefore to bring all relevant partners together. The province can start building a consortium that further guides the implementation phase. Partners in the consortium could each adopt one or more actions and function as a pioneer for that action. This way the focus stays on concrete actions and concrete results. In a situation like this, where there is little legal basis to force implementation the success highly depends on commitment and enthusiasm. Getting results is one (effective) way of creating and keeping commitment.

The role for the province within the consortium is special and can be described as 'leader amongst partners'. Their role could be twofold:

- an initiating and stimulating role (driving force);
- a coordinating role between the different actions.

Besides that the province should also formulate the goals to reach for (in their role as public authority). Last but not least they will have to provide some of the funds necessary.

7. **Concluding remarks**

We have seen that industrial ecology can generate new ideas for environmental improvements at industrial estates. But to build an effective industrial ecology at an industrial estate, conditions have to be perfect. Applying the concept of industrial ecology is therefore not easy. There are several barriers that have to be overcome. First of all there are *technical barriers*: There is the possibility that industries in the region do not fit together. Also there are *informational barriers*. These can make it difficult to find new uses for waste, since data available are of poor quality. Often information is lacking that hinders the operation of markets for waste and recycled material: who has what (supply), who could use what (potential market), who could

produce something if somebody else wanted it (potential supply). Furthermore there are *economical barriers*. The incentive to find resources in waste streams depends in part on there being a reliable market for the waste-by product. At present there are also *regulatory barriers*. The current regulatory structure/laws prevents the linking of industries or industrial processes (especially in the US with liability laws this is a problem). Last but not least one can identify *motivational barriers*. The industries and the local government and others involved must be willing to cooperate and to commit themselves to the process. Trust is very important in this respect. Companies are also not very happy to provide information about their production processes and (by)products out of competition reasons.

Apart from these practical barriers there are also fundamental barriers that can be identified. Critics argue that industrial ecology makes the partners in the project too dependent upon each other. By creating connections between the industries in a region, the infrastructure is fixed to some extent and the company is binded to the location for a longer period of time. An inflexible situation is created in which there is a danger that inefficiencies within the companies are not dealt with. One of the answers to the sustainability crisis will be to maximize the capacity for innovations. It is questionable whether industrial ecology contributes to this.

In our view industrial ecology is not so promising as the amount of attention nowadays seems to suggest. A lot of both fundamental and practical barriers exist. Nonetheless industrial ecology can help in some situations, especially in creating innovative links between individual companies. What prevents this from happening are mostly informational barriers. Apart from offering concrete help and financial support the building of 'regional platforms' for industrial ecology seems to be the first priority for governments. By bringing possible partners together at least the options for cooperation can be assessed.

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