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Eco-industrial park initiatives in the USA and the Netherlands: first lessons

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Abstract

Since the introduction of the industrial ecology concept by Frosch and Gallopoulos in 1989, and the apparent success of the Kalundborg Industrial Symbiosis project, attention to planned eco-industrial park (EIP) development projects has grown all over the world. This article includes data from six of these EIP development projects. Three of the projects discussed are located in the Netherlands and three in the US. This article compares the differences in project approach and results on a national level. The approach suggested is derived from the available EIP development literature.

Initial research indicates that the Dutch EIP projects are more successful than their US counterparts. This difference in success can be, mostly, attributed to the fact that the US projects are initiated by local and regional governments that see the project as a way to improve the local/regional economy with access to substantial government funds. Because of this heavy government involvement, US companies are, in general, not interested in the project. The more successful Dutch projects, on the other hand, are mostly initiated by the companies themselves with financial and advisory support from the local and regional government.

Keywords: Industrial ecology; Industrial ecosystem; Eco-industrial park; Eco-industrial development; Life cycle management; Industrial metabolism

1. Introduction

With the introduction of industrial ecology in 1989, industrial development was placed in a new perspective. This new perspective states that industrial complexes should be designed to resemble the natural ecosystem as closely as possible. Industrial development should resemble the natural ecosystem because in such a system, energy and resources are used optimally and wastes are absent.

In recent years, attention for eco-industrial park (EIP) development projects has grown enormously among national and regional governments and industries in many countries. It is believed that a well planned, functioning EIP has the potential to both benefit the economy and substantially relieve environmental pressure in and near the location of its development [1–3].

This mutual benefit to the economy and environment mentioned above is clearly stated in the EIP definition used by the US EPA: "An EIP is a community of manufacturing and service businesses seeking enhanced environmental and economic performance by collaborating in the management of environmental and reuse issues. By working together, the community of businesses seeks a collective benefit that is greater than the sum of the individual benefits each company would realize if it optimised its individual performance only" [4].

In this article, we compare three US EIP initiatives with three similar initiatives in the Netherlands and we analyse whether their development reflects the development process as it is sketched in EIP and industrial ecology literature. We will also try to determine whether the win–win situations, as "promised" in the literature, come into existence in the studied EIP developments [5].

EIP development is mainly based on the industrial ecology concept. Frosch and Gallopoulos first discussed the concept of industrial ecology. In their article

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"Strategies for Manufacturing" [6], they defined an industrial ecosystem as a system in which: "the consumption of energy and materials is optimised, waste generation is minimized and the effluents of one process ... serve as the raw material for another process" [6].

At about the same time the concept of industrial ecology was "invented" other concepts were introduced, like life cycle management (LCM), also known in the Dutch literature as integrated chain management. These concepts are comparable to the industrial ecology concept since they also strive to structurally relieve the environmental pressure by promoting the closing of material cycles and by taking the environmental responsibility beyond the boundaries of individual companies. In other words, these concepts support the presupposition that environmental measures taken in co-operation with multiple companies have greater environmental benefits than measures taken in an individual company.

The definition of integrated chain management used in our research is the definition made by the Task Force of Integrated Chain Management of the Dutch Environment Ministry. "Integrated Chain Management is the management of material flows, in chains caused by social activities, with respect to the environmental space boundaries" [7].

The management of the material flows mentioned in the definition should comply with the following three objectives:

1. Reduce the use of non-renewable resources (fossil fuels) and stimulate the use of sustainable energy as much as possible.
2. Keep the balance in the process of use and production of renewable resources. This means making sure that one does not use more of a particular resource in a year than the amount of the resource produced that same year.
3. Keep renewable and non-renewable resources as long as possible in the material cycles, unless this is not environmentally desirable [7].

The above objectives for the management of material flows or cycles should be kept in mind when one is planning an EIP, because the industrial ecology concept also includes the concept of material flows and cycles.

The main difference between the integrated chain management and industrial ecology concepts can be found in their spatial orientation. The integrated chain management concept is defined by the chain, surrounded by a network of relationships of companies located downstream or upstream of the same chain. Companies belonging to such a chain often are not located in the same region or country.

Integrated chain management has been applied in the Netherlands, for example in organizing take back systems on the national scale, for many product groups [8] and in promoting redesign of products, for example by rethinking the materials applied [9,10], thus expanding pollution prevention activities of businesses beyond the borders of their own site.

Industrial ecosystems (such as they are promoted by the industrial ecology concept) on the other hand have a more regional character. In the concept of an industrial ecosystem, the regional network of companies is the decisive element opposite to the chain in the integrated chain management concept. The closer companies are located together in the network the more cost- and environmentally efficient the exchange relations are.

Because of this difference in orientation the "natural" connection between companies is stronger in the Integrated Chain Management concept. In an industrial ecosystem the companies are not connected to each other through the life cycle of resources through a (product) chain. Companies in the industrial ecosystem or EIP generally need to be linked to each other through specifically engineered exchanges that allow significant savings in the use of resources [11].

Although the EIP concept seems to be "invented" only recently, the implementation of the concept already existed for some time in Kalundborg, Denmark. Table 1 gives an overview of the established exchanges in the Kalundborg EIP.

The Kalundborg EIP, however, was not designed as an EIP but gradually evolved over a number of decades when the participants discovered that the establishment of energy and waste exchanges resulted in economic benefits for all parties involved (see Refs. [13–15] for a detailed history). The total economic benefit of the exchanges pictured in Table 1 is estimated to be between US$ 12 and 15 million per year. The environmental benefits achieved through the exchanges were not instrumental to their establishment but were merely seen as an accidental bonus.

Table 1
Material and energy flows between companies in Kalundborg

To	From		
	Statoil	Novo Nordisk	Asnaes
Statoil	–	–	Steam
Kemira	Sulphur	–	–
Novo Nordisk	–	–	Steam
Gyro	Gas	–	Gypsum
Sanest	Gas, cooling and waste water	–	–
Farms	–	Sludge	–
Fish Farm	–	–	Heat
District heating	–	–	Heat
Cement and road industry	–	–	Fly ash

Source: de Walle [12].

This type of exchange of material flows between firms is not entirely new. Especially in the chemical industry, economic complexes have existed for a long time. The difference with these is that these industrial complexes exist within relatively homogeneous classes of industries linked through their flows of products and by-products, whereas in examples of EIPs like Kalundborg, new *unexpected connections* between *heterogeneous classes of industries* or even outside industrial production can occur, just because they are located close to each other.

The concepts of integrated chain management and EIPs have in common their focus on inter-firm co-operation, allowing additional challenges but also additional risks compared with intra-firm forms of improvement of the firm's environmental performance, like pollution prevention. Oldenburg and Geiser discussed similarities and differences of the pollution prevention and industrial ecology approaches. Similarities are mainly being found on the level of goals, techniques and assessment methods and challenges of economic benefits, some important differences as a consequence of inter-firm co-operation under industrial ecology are that expected economic gains may have to be shared; co-operation may add additional expenses and may generate new risks [16].

From the above, the rising interest in industrial ecology and EIP development seems to be justified as the concept promises to be a huge step forward in the establishment of a sustainable society. But how does one facilitate the development of a planned EIP over a relatively short period (compared to Kalundborg) of five to 10 years? Which parties should be involved? How does one connect unrelated companies or facilitate the exchange of energy, water and waste? How does one deal with the disadvantages (benefit sharing, new risks)?

2. A successful approach to EIP development

Research on EIP literature provided an initial answer to the question of how one could facilitate a successful ''planned'' EIP development. The symbiotic relationships in Kalundborg emerged over a period of two decades, evolving from a number of bilateral relationships. This means that the challenge for eco-industrial development projects seeking to approach the elegance of Kalundborg is how to encourage collaboration. The literature, therefore, often sees the formation of a business network, based on improving both environmental and business performance, as an essential first step in the creation of an eco-industrial complex (see e.g. [4,17–26]).

The literature study also revealed that the successful development of an EIP would require the active participation from a number of stakeholders:

- public sector stakeholders from local, regional and national government agencies;
- representatives of local companies and potential future tenants in the EIP;
- leaders in the industrial and financial community;
- local chamber of commerce;
- labour representatives;
- educational institutions;
- practitioners with the full complement of capabilities needed in the project: architecture, engineering, ecology, environmental management, and education and training; and
- community and environmental organizations.

When the participation of the stakeholders in the project is assured, the first step in the actual EIP development process is gathering of information. Information is, in fact, essential to the EIP development process. The information gathered ultimately determines the nature and number of pollution prevention projects that make up the EIP development. The necessary information can be gathered through a (mailed) survey and/or personal interviews with future EIP members and participants.

The areas that should be addressed in the survey and/ or interviews include:

- Basic company information;
- Products and markets;
- Employee information;
- Raw materials;
- Waste streams;
- Energy;
- Environment;
- Manufacturing networks;
- Future plans.

However, besides the added value and potential benefits associated with the industrial ecology and EIP concept, literature also revealed that many problems need to be overcome before an EIP development is successful. The literature states that the main problem in the development of an EIP will be the establishment of the essential ''symbiotic'' exchange relationships between the companies participating in the project.

In the establishment of such exchange relationships, a company may run into five different types of barriers:

- Technical (an exchange is technically unfeasible);
- Economic (an exchange might be economically unsound or economically risky from a company perspective);
- Informational (the right people do not have the needed information at the right time);

- Organizational (the intended exchange might not fit in the current corporate organizational structure); and
- Regulatory/legal (caused by the jungle of environmental laws and regulations).

3. Research methods

After studying the available EIP literature and generating the first factors essential to successful EIP development, the next steps in the EIP comparison project were undertaken.

In the selection of US and Dutch EIP development initiatives, two out of the three Dutch EIP projects ultimately selected were chosen simply because they are the oldest, most developed projects, and therefore, function as an example to all other EIP development projects in the Netherlands. These projects are the INdustrial EcoSystem project (INES) and the Rietvelden/Vutter (RiVu) sustainable revitalization project. The third project, the Moerdijk EIP project was chosen as a representative for all other Dutch EIP initiatives that are in earlier stages of development [27–29].

The three American EIP projects selected were randomly chosen from a group of four projects, which were assigned the status of a demonstration project by the Presidents Council of Sustainable Development (PCSD) in 1994. The three US projects that were selected are: Fairfield (Baltimore), the Brownsville Regional Industrial Symbiosis Project in the Brownsville region and the Cape Charles Sustainable Technologies Industrial Park (STIP) in the town of Cape Charles [30–34].

In the collection of information on the six selected EIP projects, relevant information was gathered through a study of project plans, newspaper articles and on-site interviews with key personnel involved in their development.

4. Results of the case studies

Table 2 presents the most important general features of the six EIP cases studied. The data reveal that four out of the six projects are Brownfield redevelopment programs. This means that an existing industrial park is redeveloped into an EIP. The Cape Charles STIP is the only Greenfield development reviewed. The Brownsville Regional Industrial Symbiosis project is neither of the above, because it is a so-called virtual EIP (VEIP) development. This means that the companies participating in the project are not necessarily located in a single industrial park, but are likely to be located throughout the whole Brownsville region.

Each of the six selected EIP cases, presented in Table 2, is in a different stage of development. The INES and Cape Charles STIP projects are by far the most developed of the six EIP projects studied in this research. In both the INES and Cape Charles cases, the initial planning stages have been completed and both projects are now about to enter into their realization phase. The realization of the first building in the Cape Charles STIP has already started and is about to be completed. In the case of the INES project, the realization of the industrial waste heat exchange infrastructure is to be completed by the year 2000.

The Moerdijk EIP project, on the other hand, is by far the least developed project researched in this study, since the project was only initiated in the beginning of 1998. The Moerdijk EIP project is still in an early phase of project development and a definite project organization structure has yet to be designed. The three other EIP projects studied for this research, RiVu, Brownsville and Fairfield, are all in a stage of development between those of the INES/Cape Charles and Moerdijk projects.

Table 3 gives the estimated realization costs for each of the six EIP projects studied. The realization cost estimates given in Table 3 are taken from financial figures presented in various official project publications. An estimate for the Moerdijk project is not given in Table 3 due to the early development stage of the project. For the same reason, the realization cost estimate given for the RiVu case only comprises the finances needed for project planning and not those needed for actual project realization (building the EIP). The RiVu sustainable revitalization project organization is still working on the EIP project mix. Further the Brownsville figure only comprises the development cost of the

Table 2
Important situational features of the selected EIP projects

Case study	INES	RiVu	Moerdijk	Fairfield	Brownsville regional IS	Cape Charles STIP
Location	Rotterdam	Den Bosch	Moerdijk	Baltimore	Brownsville	Cape Charles
Initiated	1994	1996	1998	1994	1994	1994
Type of EIP	Brownfield	Brownfield	Brownfield	Brownfield	Virtual EIP	Greenfield
Established	–	1950s and 1960s	1967/1968	±1920	–	–
Size (ha)	>3000	290	2600	508	Brownsville region	232
Companies	±80	±200	±200	±60	34	Unknown

Table 3
Estimates of project realization costs and economic and environmental benefits

Project	Realization costs	Economic benefit	Environmental benefit
INES	>US$ 100 million	>US$ 16 million/year	157.6 MW_{th} energy 152.2 M Nm^3 gas/year 272.5 ktons CO_2 225.7 tons NO_x, 158 MW waste heat, and additional reduced resource use
RiVu	US$ 100,000 (planning)	Unknown	Unknown
Moerdijk	Unknown	Unknown	Unknown
Fairfield	±US$ 62 Million (original project plans)	A minimum of 2500 jobs in the next 10 years	Unknown
Brownsville	US$ 250,000 (computer program development)	Unknown	Unknown
Cape Charles	±US$ 7.5 million	395 direct jobs	Unknown

computer program that is capable of identifying possible waste exchange between companies in the Brownsville region.

Besides an estimate on the realization costs, Table 3 also gives an estimate of the economic and environmental benefits of each project insofar such estimates were incorporated in the various plans and publications studied.

In order to compare the six cases to each other, and with the ''ideal'' development process established through the literature study, the cases were studied in terms of the six aspects mentioned below:

1. History and location of EIP;
2. Stakeholder involvement and project organization structure;
3. Planned EIP development (development vision);
4. Economic and environmental impact of the project;
5. Results (established EIP development up till now, what has been realized?);
6. Factors essential to project success and/or failure.

Further, in order to select the most successful of the six EIP cases studied each case was quantified for each of the six aspects. Points ranging from 1 to 6 were given for each aspect on which the projects were compared. The best project scored 6 points, the second best 5, third best 4, etc. So overall, a project could obtain a maximum score of 36 points. The results of this quantification are given in Table 4.

A low scoring for an aspect does not necessarily mean that the project failed on this aspect. A low scoring may, in fact, mean that the project was highly successful on that particular aspect, but that the same aspect had been addressed even more successfully in the other projects.

The quantified order presented in Table 4 is by no means definite since every project discussed is in a different stage of development and has its own specific weak and strong points. The presented sequence is based on the perceived development potential and current project development of the various projects studied. It is likely that when one compares the projects again after completion, the sequence may have changed dramatically.

5. Comparing US and Dutch EIP project results

The comparison between literature/theory and the Dutch and US ''planned'' EIP projects can be summarized in two tables. Table 5 compares the most important process and physical factors in the EIP

Table 4
The six EIP case studies quantified based on developed criteria

Project	Participation	Organization	Vision	Economy environment	Result	Success or failure	Total score
INES	6	6	5	6	4	5.5	32.5
Cape Charles	5	3	2	5	5	3.5	23.5
Moerdijk	3	4	6	1.5	–	5.5	20
RiVu	4	5	3.5	1.5	–	3.5	17.5
Brownsville	2	2	1	4	6	2	17
Fairfield	1	1	3.5	3	–	1	9.5

–, quantification not possible due to the fact that the project plans have not reached the realization phase.

Table 5
The importance of various process and physical factors found in the literature and the Dutch and US case studies compared

	Theory	NL	US
Process factor			
EIP as an environmental project	+++	+++	+
EIP as an economic project	+++	+++	+++
Involvement of local/regional government	++	++	+++
Involvement of national government	++	+	+++
Involvement of local entrepreneurs' association	–	+++	–
Involvement of local industry	+++	+++	+
Community involvement (residential)	+++	–	+++
Anchor tenant	+++	+	++
Local champion	+++	+	+
Physical factor			
Exchange infrastructure for wastes and by-products	+++	++	++
Energy cascading and cogeneration	+++	+++	+
Water infrastructure	+++	++	+
Telecommunications infrastructure (site-wide)	+++	+	++
Utility sharing	+++	+++	++

development process discovered through the study of EIP literature and selected cases.

Table 6 presents information pertaining to the main stakeholder groups and their roles in the development process in each of the six selected projects. Table 6 is intended to give one a more detailed insight into the differences between the Dutch project approach on the one hand the US project approach on the other hand. Table 6 therefore pictures some of the differences between the process factors in the US and Dutch cases pictured in Table 5 in a more detailed manner.

The comparison between the six cases revealed, besides the differences between the individual cases, some interesting differences between the Dutch and American cases in general.

5.1. Objectives

An important difference between the Dutch and American cases can be found in the project objectives. The first and most important objective in the American projects seems to be the creation of family wage jobs for the local population. The economic factor in the American projects reviewed is generally valued as more important than the environmental factor.

However, an exception to the above can be found in the Cape Charles STIP development. Although the

Table 6
The stakeholders and their role in the EIP development process

Stakeholders	INES	RiVu	Moerdijk	Fairfield	Brownsville regional IS	Cape Charles STIP
Government						
Local	F	I,P,F	M,A	I,M,P,F	I,M,P,F	I,M,P,F
Regional	F	I,P,F	I,P,F	F	F	I,P,F
National	F,C	C	C	F,C	F,C	F,C
Chamber of commerce	–	I,P	–	–	–	–
Companies	A,F	A,F	A,F	[F]	[F]	[F]
Entrepreneurs' association	I,M,P	I,M,P	I,P	–	–	–
Educational institutions	C	–	–	C	A,C	A,C
Consultant agencies	C	C	–	–	A,C	–
NGOs						
Labour	–	–	–	C	–	A,C
Environmental	–	–	–	–	–	A,C
Local residents	–	–	–	A,C	–	A,C

I, project initiator/commissioner; M, project manager; P, member of the planning group; A, active participant in project development (not financial); F, provides/provided funds to the project; C, consultant to the project; –, is not a stakeholder in the project concerned; [ ], the stakeholder was supposed to take up the role but has not done so yet.

economic factor was the most important factor in initiating the project, the environmental factor is treated equal to the economic factor. Economic growth is only desired when this does not adversely affect the natural amenities of Northampton County, Virginia.

In the Dutch cases however the projects are, in general, initiated for both economic and environmental reasons. All the Dutch projects were initiated in hopes of improving business economics and the environmental performance, of participating companies, at the same time. In Dutch cases reviewed, the environmental and economic aspects of the project seem to be equally important.

5.2. Initiator

In the Netherlands, the local entrepreneurs'/employers' association is often, on behalf of its member companies, the initiator of the project. The local entrepreneurs'/employers' association, in turn, closely coordinates its actions with local and regional government. The important role of the entrepreneurs'/employers' association in the overall project organization also insures the active participation of its member industries (see also Table 6). The individual companies that are represented in the local entrepreneurs'/employers' association usually contribute their vision and ideas on the project through the various project groups established by the overall EIP project organization.

The local and/or regional government on the other hand initiates the US cases, in order to improve the local/regional economy. Local industry remains, in general, more passive throughout the course of the project compared to their Dutch counterpart. Maybe this difference can be explained by the fact that Dutch industry often has more experience with government-industry project participation [35]. US companies also seem to have more distrust towards the motives and actions of the government.

5.3. Public participation

The participation level of the local community (residential) and NGO's in the development of the various US cases seems to be very high compared to that in the Dutch cases (see Table 6). In fact, the US project management often stimulates community involvement in project development. People are encouraged to present their vision and ideas on EIP development. This community involvement usually takes place in the form of so-called ''planning and design charettes''.

The above level of community participation is unknown in the Dutch cases discussed. The community is not encouraged to give its opinion and ideas on the EIP that is to be developed. The development process is usually limited to the companies and direct stakeholders involved in the EIP project supplemented by consulting agencies and/or educational institutions.

5.4. Financing

The financial participation of companies in the EIP development process is more developed in the Dutch cases studied. This difference in financial participation might be explained through the fact that American industries are more passive in the development of plans for the intended EIP. This also means that the local/regional government and other parties interested in the project bear the cost of the planning process in the US.

In the Dutch cases reviewed, companies on the one hand, and government and other participants on the other hand, each seems to be responsible for 50% of the planning costs. Companies often contribute their 50% in the cost through the supply of personnel and other equipment. However, the cost needed for the realization of the planned EIP developments, both in the Netherlands and the US, are to be provided by the companies, who stand to gain from the implementation of the planned exchanges (except for the part that is covered by subsidies).

5.5. Local champions

A significant difference between the cases discussed and the literature studied is the absence of anchor tenants and local champions in the cases reviewed. At first sight, there seems to be no difference between the US and Dutch EIP cases here, because both the anchor tenant and local champion are absent in the US and Dutch projects reviewed. However, in the Dutch cases, the roles of anchor tenant and local champion remain vacant simply because there is no need for a company to fulfil such a role. One could even state that, in the Dutch cases reviewed, the local entrepreneurs'/employers' association takes up the role normally assigned to a local champion.

In case of the INES project, the role of local champion and anchor tenant remained purposely unidentified to avoid the idea of favouritism among companies since the majority of participating companies would be suitable for one or both of the tasks. Anchor tenants and local champions also have not been identified in the RiVu and Moerdijk cases. In the Moerdijk case, most companies could fulfil one or both roles while in the RiVu case a company that could fulfil the role of anchor tenant is hard to find. In both the RiVu and Moerdijk cases, a company willing to fulfil these roles has not (yet) come forward, but at the same time is not really missed.

However, in two of the three US cases reviewed the absence of a local champion and anchor tenant in the EIP development is felt. In both Fairfield and the

Brownsville Regional Industrial Symbiosis projects, a company would be welcome that stimulates other companies to participate or that functions as a central node in the exchange network. In Cape Charles, the role of local champion is more or less fulfilled by the Sustainable Technologies Industrial Park Authority (established by the Town of Cape Charles, Northampton County, National Oceanic and Atmospheric Administration and the Virginia Coastal Program).

5.6. Material exchanges

From Table 5 one could also conclude that the establishment of materials and by-product exchanges, energy cascading and water infrastructures in practice, are not the most important features of an (initial) EIP development. Although, from theory one could easily get the impression that the establishment of such "physical" energy, water and material and by-product exchanges are an essential element of the initial EIP development process.

In practice, the initial EIP development of the Dutch cases discussed focused on the establishment of pollution prevention projects with a utility sharing character. A reason for the development of such projects is found in the fact that such projects are perceived as low risk projects with a potentially substantial economic and environmental benefit. When these projects prove to be a success, companies often become more enthusiastic about further EIP development and become more willing to invest in projects with a greater economic risk and benefit.

A perfect example of such a development can be found in the INES project in which an energy and waste heat exchange project was later included. Prospects for the establishment of physical exchange relationships are also promising in the Moerdijk EIP project whereas the prospects for such projects seem to be limited in the RiVu sustainable revitalization project due to the mix of companies located on the terrain. In the RiVu case, the companies located on the terrain simply do not have the needed financial resources or wastes suitable for the establishment of such exchanges.

In at least two of the three US cases reviewed (Fairfield and Brownsville), however, the project was immediately focused on the establishment of physical energy, water and material waste exchanges. In Fairfield, this focus was later adjusted somewhat since a majority of the companies located in Fairfield did not want to participate in such projects. They did not want to participate in such projects because the financial risks and the risk to business continuity were too big. The Brownsville project had only one project focus from the beginning, the exchange of wastes between companies in the Brownsville region, and it is therefore, a somewhat limited EIP project.

6. Why have Dutch EIP projects been more successful?

From the six comparison elements between the individual projects mentioned above, it was concluded that the Dutch EIP projects are more successful in their initial development than the US cases. However, this is not a solid conclusion since it was based on the perceived development potential and current project development of the projects reviewed (see also Table 4).

Since all projects are still in early phases of development and none of the projects reviewed has (yet) been implemented, sufficient data to make a definite evaluation of project success are unavailable. However, it was possible to identify some factors that contributed to the current success or problems/failure of the EIP development projects studied. These factors essential to the current success or problems/failure of the project are summarized in Table 7.

Looking at Table 7, one sees that the initial success of the Dutch projects in general can be attributed to two factors, which are connected to each other. Firstly, the active participation of companies to the project is important. A majority of the companies located in the project area are willing to invest time, money and other resources in the development of an EIP. Companies decide by themselves whether they wish to participate in the projects, that are to be developed under "the EIP umbrella". Overall, this means that companies contribute to those projects that stand to significantly improve their own environmental and economic performance.

Secondly, the presence of an entrepreneurs'/employers' association in the industrial park is relevant. This association proves to be an effective platform to educate and inform companies of the potential benefits that can be achieved through the establishment of an EIP. The association also functions as a much needed communication platform between the companies themselves and provides company management and staff with important "social" contacts (see Kalundborg).

Therefore, it should be no surprise that in the Cape Charles project, the most successful of the US projects reviewed, the active participation of local residents in co-operation with that of the local and regional government is an important factor in the success of the project.

Additional factors that contribute to the success of an EIP project can be found in the Moerdijk and INES cases. In case of the Moerdijk EIP project, an additional factor for success could be the fact that there are already some energy, waste and material

Table 7
Factors essential to the success or failure of the six cases reviewed

Project	Factors essential to project success	Factors causing problems or failure
INES	Active participation of companies, environmental management network, Europoort Employers' Association	–
RiVu	Active participation of companies, Entrepreneurs Association RiVu	Few large, financially strong companies, differences of opinion regarding rezoning of the RiVu industrial park
Moerdijk	Active participation of companies, existing exchange relationships, entrepreneurs association	Relatively large distance between companies
Fairfield	–	Baltimore and state politics, lack of company interest, absence of an entrepreneurs association that represents all Fairfield industries/ companies
Brownsville	–	Lack of finances needed to improve the computer program used to identify possible exchange relationships, lack of company interest
Cape Charles	Active participation of local residents, co-operation between town and county	The attraction of industry to Cape Charles, The location terms demanded from candidate companies

exchanges among various chemical companies and between these companies and the local power plant. The environmental and economic benefits of these exchanges could prove to be strong incentives for other companies located on the Moerdijk industrial park to search for exchange possibilities of their own.

The additional success factor in the INES case is provided through the presence of the BIM-Network[1] in the project organization structure. This network was taken from a previous project of the Europoort Employers' Association, concerning the implementation of environmental management systems in member companies, and now functions as an important communications platform among the various companies participating in the INES project.

Although the reasons for project success seem to be fairly uniform, the reasons causing problems or failure in project development seem to be more diverse in nature. The reason most frequently presented in Table 7 however is also the deadliest; lack of company interest for the project. Lack of company interest is deadly to the project because ultimately it is the company that will have to invest and work with the designed and planned exchange infrastructure.

Active company participation in the project is the most important element for success because ultimately companies themselves need to implement the EIP plans made. In both the Fairfield and Brownsville cases, the majority of companies located in the project area did not want to invest in the establishment of the planned/ discovered EIP exchange relationships with other companies located in their vicinity. They did not want to invest in such exchange relationships because they deemed them to be financially risky and because of their distrust towards the (local) government which helped to establish the EIP plans.

The project approach taken by local politicians in the Fairfield case did not help convince industries to participate in the project as well. Baltimore and Maryland state politicians mainly considered the project as a job creation initiative and not as an economic program designed to help the economic and environmental performance of the companies involved. In order to make the project a success, however, this political approach will have to shift more towards active involvement of the participating companies.

In order to make companies actively participate in an EIP project, one will have to convince companies of the economic and environmental improvements that are to be gained in the realization the planned EIP. In order to do this, one could point out the successful developments elsewhere or organize a conference at which one invites representatives of companies currently participating in a successful EIP project.

The reason the Dutch EIP projects seems to be more successful might also be attributed to the fact that their development process seems to follow a, relatively smooth, fixed pattern. The use of this "fixed" pattern can be ascribed to the fact that all Dutch cases discussed are based on the "Kalundborg EIP model" (collocation, waste exchange). The American cases, on the

[1] BIM-Network is a communications platform formed, in the course of the EBB BIM-project, by a cluster of Industries located in the Europoort–Botlek region. The companies represented in this network kept each other informed about their progress and problems in the implementation of pollution prevention and environmental management systems.

other hand, each have their own, more unique, development vision and process.

7. Industrial ecology as extended pollution prevention?

Pollution prevention utility sharing (like combined treatment of waste water or combined cogeneration of heat and power) proved, as shown in Section 5.6, to be easier to implement than material exchanges. From a skeptical point of view, one might state that in practice industrial ecology tends to be a form of *extended* pollution prevention.

Oldenburg and Geiser have suggested bridging the divergent perspectives of pollution prevention and industrial ecology. Pollution prevention might be more effective if the focus included regional networks of firms like advocated in industrial ecology. Industrial ecology should, in their view, also consider recycling and "take back" of products and waste: "indeed industrial ecologists also offer limited consideration of waste treatment and disposal practices. If industrial ecology schemes are to be made compatible with pollution prevention programs, industrial ecology should de-emphasize the current concept of firms made interdependent by linking waste streams and input needs" [16].

In the light of the results of this study, this turns out to be an interesting observation. Additional disadvantages and risks of linking waste outputs to nearby input needs seem to be an important reason for a focus in practice on utility sharing. For utility sharing disadvantages of inter-firm co-operation (expected economic gains may need to be shared, co-operation may add additional expenses and may generate new risks like uncertain supplies) may be less than for material exchanges. Seen from this perspective, extended pollution prevention may very well be an indispensable first step in the direction of establishing industrial networks, where effluents of one process serve as the raw materials for other processes.

One should bear in mind that the company experts needed for identification of material exchange options are the same experts applying pollution prevention and environmental management system activities within the firm (see also Note 1).

8. Concluding remarks: lessons learned

From these points, one can identify those which one should keep in mind when developing an EIP.

First and foremost, one should assure active company/industry participation in the planning stages of the project. Company participation in the project should be assured through the involvement of the local entrepreneurs'/employers' association or through an active recruitment procedure by the project initiator.

Second, the costs of EIP planning should not be solely carried by the government. Companies should also be financially committed to the planning phases. This will also enhance company commitment in the realization phases of the project.

Furthermore, the initial focus of the EIP project should not be on the establishment of physical energy, water, and material waste exchanges but on the establishment of utility sharing projects. The project should initially be focused on such projects because these projects, compared to the physical waste exchange projects, require relatively small economic investments while at the same time they offer a possibility for a reasonable economic and environmental benefit. When such projects are deemed successful, companies will be more eager to explore the possibilities for the establishment of more symbiotic energy, water and waste exchanges.

This research shows that planned EIP development, like "natural" EIP development, is a long-term process. In order to stimulate development, it is important to focus on the establishment of low cost, high benefit utility sharing projects and "simple" exchanges.

Finally, when the project is well established—that is when companies are fully aware of the benefits that are to be gained—the development can move along to the more company-specific and economically challenging projects, although the projects should always render an economic as well as environmental benefits.

Industrial ecology and EIP development are still promising steps towards a more sustainable society. The current "successful" development of the various EIP pilot projects initiated all over the world could come a long way in establishing a new international standard in industry development. The cases function as examples and help motivate other companies to follow their example. An ongoing international comparison of EIP projects could further help stimulate governments and companies to initiate EIP development projects.

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