

# Planning and Unfolding Eco-Industrial Parks: Reflections on Synergy

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## 0. Abstract

Industrial Ecology (IE) in industrial estates has a geographic, resource, and/or industry sector focus. In such geographic and/or industry sector settings IE is often labelled as Industrial Symbiosis (IS), for instance by linking utilities and waste/by-product exchange, the organization of a resource chain such as in the case of biomass, or of linkages around a key-organization.

The role of industrial symbiosis is analyzed in the planned industrial symbiosis activities in the Rotterdam Harbor and Industry complex and the application process of renewable energy in the Östergötland region in Sweden.

The objective of this paper is to discuss a synthesis between the planned activities in Rotterdam and to unfold current industrial symbiosis activities in the Östergötland. Such knowledge can help further developing the application process of industrial symbiosis in Eco-Industrial Parks in China.

## 1. Introduction

The re-emergence of the Industrial Ecology (IE) concept [1] covers more than two decades currently. The most illustrative IE example world-wide is the Kalundborg industrial site, an organically developed and still developing application that, once recognized and acknowledged by some local plant managers, was actively promoted by those local plant managers under the label of Industrial Symbiosis (IS). Kalundborg became the illustration for many IS-initiatives world-wide. However, the – in practice – long incubation time [2] was often unknown or neglected in IS activities world-wide and led to questions whether the complexity of the IS development concept can be effectively dealt with in practical applications. [3] Time is a very important variable in that process. [4] It is a slow development in Northern industrial countries (where the decision-making processes include many different actors [5]), showing different characteristics. However, new examples and initiatives are there: the described developments in the Östergötland region in Sweden in this article is an illustration for that.

In this paper, after reflecting different dimensions of embeddedness in organizing Eco-Industrial Parks, some illustrations in the Rotterdam and Östergötland regions are provided in sessions 3 and 4, followed by conclusions and questions for discussion in session 5.

## 2. Eco-Industrial parks and Embeddedness

Human activities do not occur in a vacuum; they are embedded and shaped by the context in which they occur. Economic relations between individuals or firms are embedded in actual social networks and do not exist in an abstract idealised market. [6] In this analysis, attention is paid to cognitive, structural and cultural dimensions of embeddedness.

Cognitive embeddedness refers to the ways in which common mental models or shared visions among actors impact their economic activities. [7] This is about the manner in which individuals and organisations collect and use information, and the cognitive maps they employ in making sense of their environment. [8] What we know about the *Bounded rationality* assumption of a rational actor model, however, is that individuals and organisations have limited capacities for information processing and decision-making and that individuals have different strategies for problem solving.

With respect to *structural* embeddedness, rules and regulation has led to a complex maze of effects that can be counter-productive for industrial ecology, such as in the case that “the waste of one company may be a resource for another” [1] can be blocked by the ban of the transport of waste from one company to another.

However, the regional Dutch industrial association Deltalinqs, the Rotterdam Port Authority, the Rotterdam Municipality and the regional EPA have been linked in various organisational frameworks for stimulating economy and better environmental performance during several decades. The position of the different stakeholders in the region has a history in dealing with one another. [4]

In its mindset, industry has always seen environmental investments as efficiency improvements with an expected return on investment of two to three years. [9] After environmental policy was integrated into general policy, an expected return on investment of six years became commonplace. With the liberalisation of public energy facilities – electricity and natural gas [10] – in the Netherlands around the turn of the century, it is the other way around. The privatised energy companies expect a lower rate of return on their investments than industry, but not the traditional rate of return over a period of thirty years when they were public energy companies.<sup>1</sup> This generated a different time frame between industry and energy companies that often hindered industrial ecology initiatives in the Rijnmond area.

Although, it is found that the effects of informal social networks on entrepreneurial behaviour and on innovation strategies of large companies are found to be great, [7] less

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<sup>1</sup> Some experts state that in the decision-making process for the unification of the European Union market, for which obstacles to the optimal operation of the free market had to be taken away, it was forgotten that from an economic perspective the free market does not always provide the best solution. Sometimes a monopoly works better, for instance in the case of the electricity supply. This is because with natural monopolies, the owner needs to have long-term investment perspectives.

attention is paid to cultural embeddedness. The cultural context is rooted in historical developments and addresses the influence of collective norms and values in guiding economic behaviour, such as the shaping of preferences, and the influence of ideologies in shaping future visions. There is a tendency to externalize normative issues, or to take normative positions for granted, both in our scientific activities and in our subject matter. However, it is also argued that three organisational culture characteristics – trust, open communication, and joint problem solving – are key elements for network embeddedness. [11] That was also analysed in the industrial symbiosis research in the Rotterdam Harbour and Industry Complex. [12]

### 3. Waste heat application in the Rotterdam Harbour and Industry complex

One of the projects in a special Industrial Symbiosis programme (Industrial Eco System – INES programme) was the use of waste heat and CO<sub>2</sub> by other companies. At the end of the INES programme, the industrial association and an energy distributor jointly discussed how to utilise approximately 2200 MW of heat that was emitted into the air. A pipeline system to connect suppliers and buyers in the industrial region was a first option for further study. It was calculated that such a pipeline system would cost €112,700,000 and would require government funding for the new infrastructure needed for energy distribution in the industrial region. This waste heat project was further elaborated in the follow-up INES Mainport project. [4]

After it was determined that the establishment of a pipeline infrastructure for the whole area was economically not feasible, smaller scale projects were initiated in the INES Mainport project. The *Utilisation of Industrial Rest Warmth* project involved eight partner projects in the Botlek and Pernis industry clusters. The estimated total investment was €83.6 million. The Dutch National Project Office for CO<sub>2</sub> reduction plans was requested to provide a 30% subsidy in March 1998. A 27% subsidy was reserved in November 1998. A partnership of seven Deltalinqs companies tested the technical, operational and economic feasibility of the eight partners' projects during 1999. They decided to reject four projects, three for economic reasons, one on grounds of discontinuity of supply (see Table 1):

**Table 1 Waste heat supply sub-projects and the reasons for their rejection**

Waste heat supply project from	Reason for rejection
Air Products to Shell Chemistry	Economic: pay-back time is longer than 30 years
AVR to Dapemo	Discontinuity in steam demand of Dapemo
Lyondell to Climax	Economic: not feasible
Esso to ORC	Economic: not feasible

The four projects represented 63% of the estimated investments for the total of eight projects. This meant that also 63% of the subsidy was rejected. One of the two largest remaining projects was dropped because of the closure of the Kemira Agro plant in Pernis (part of Rotterdam).

At the beginning, despite the enormous waste heat surplus, nearly all managers of large plants had reasons to prefer their own facilities for economic (the costs of the required infrastructure) or strategic (the perceived loss of independence) reasons. That is why during

the period 1997 – 2001, the waste heat supply project had to be downsized from a holistic regional approach to a number of small cluster projects. After this approach appeared to be economically unsuccessful, a feasibility study for warmth delivery through a private “Heat Company” was performed. [13] One of the drivers of the continuing effort to implement this theme was pressure from the Water Management Authority, who made it clear that they would no longer accept emission of heat into the surface water.

At the end of the INES Mainport programme and in co-operation with ROM-Rijnmond Energy projects several new partners (housing co-operations, energy suppliers) entered the “playing field.” They formulated the condition that de-coupling of the waste industrial heat of Shell Pernis refinery (and later of Esso/Exxon and BP refineries) to the Rotterdam city district heating system should be economically viable and that the responsibility for the coupling between industry and city should be organised clearly. In 2002, the Rotterdam municipality 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 (part of Rotterdam) and a safety net construction when the application of waste heat should fail. When all conditions for realisation were finally met in 2004 (including liberalisation of the Dutch energy market, and reductions of CO<sub>2</sub> demanded by the national government as part of the Kyoto-protocol agreement), the de-coupling of the 6 MW of Shell’s rest industrial heat to the city’s district heating system would make the temporary equipment redundant; 3,000 houses would benefit in the Hoogvliet residential area (nearby the Shell refinery) in 2007. However, Shell withdraw from the project in 2007 and new arrangements had to be explored. After a delay of some years, new initiatives are taken to start the district heating system in 2012. The heat supply system is still intended to 100 MW for the application to 50,000 houses and the greenhouse sector. [14] In addition, future activities are planned to connect 500,000 dwellings and companies in the Southern part of the province of Zuid-Holland in 2020. [15]

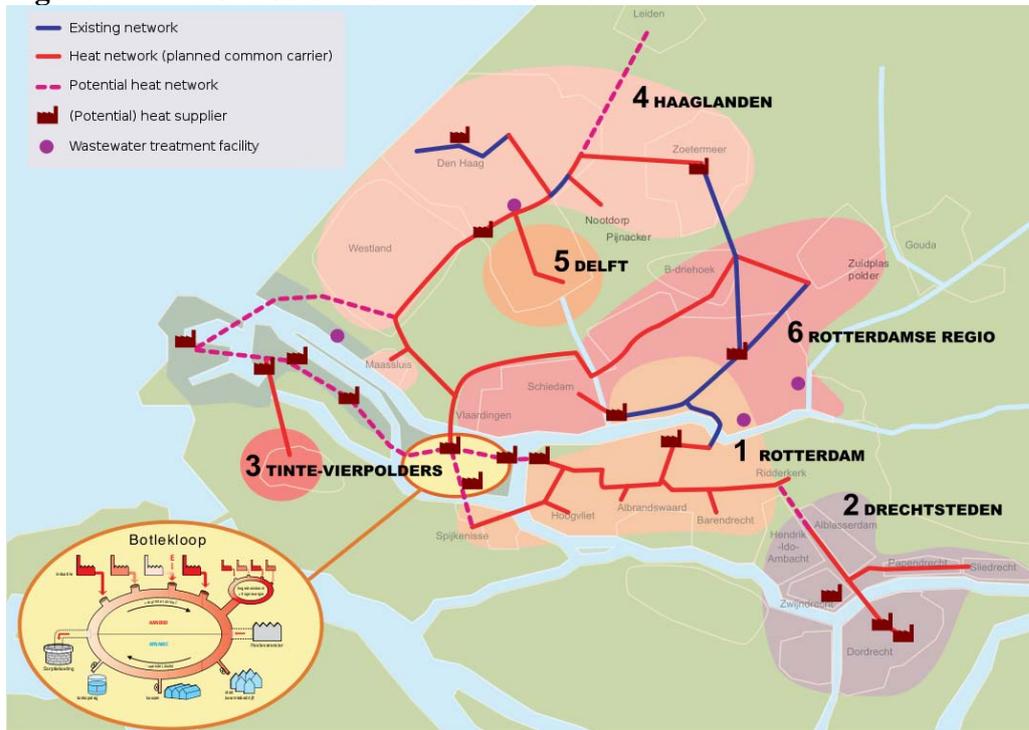
Also CO<sub>2</sub> is part of the project; a new private company OCAP has the responsibility and owns the infrastructure for the delivery of CO<sub>2</sub> emissions from the Shell plant in Pernis (Rotterdam) to 500 greenhouse companies at the North of Rotterdam. The CO<sub>2</sub> (and waste heat) delivery started in July 2005. The greenhouse companies reduced 170,000 tonnes CO<sub>2</sub> emissions through saving 95 million m<sup>3</sup> natural gas<sup>2</sup> in 2007. The designed future waste heat infrastructure is shown in Figure 1 at the next page (the red lines are the new pipelines as common carrier; the blue lines are already existing).<sup>3</sup>

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<sup>2</sup> Natural gas is burned in greenhouses for heating and the input of CO<sub>2</sub>

<sup>3</sup> The picture of the Botlek Loop at the left under part of figure 2 illustrates the waste heat exchange between companies, houses, greenhouses and an underground storage centre for cold and heat supply.

**Figure 1 R3 Waste Heat Infrastructure**



Despite several up-and-downs in decision-making processes for application, the potential of the project is still the basis for further activities.

#### 4. State-of-the-art of Industrial Symbiosis in Östergötland

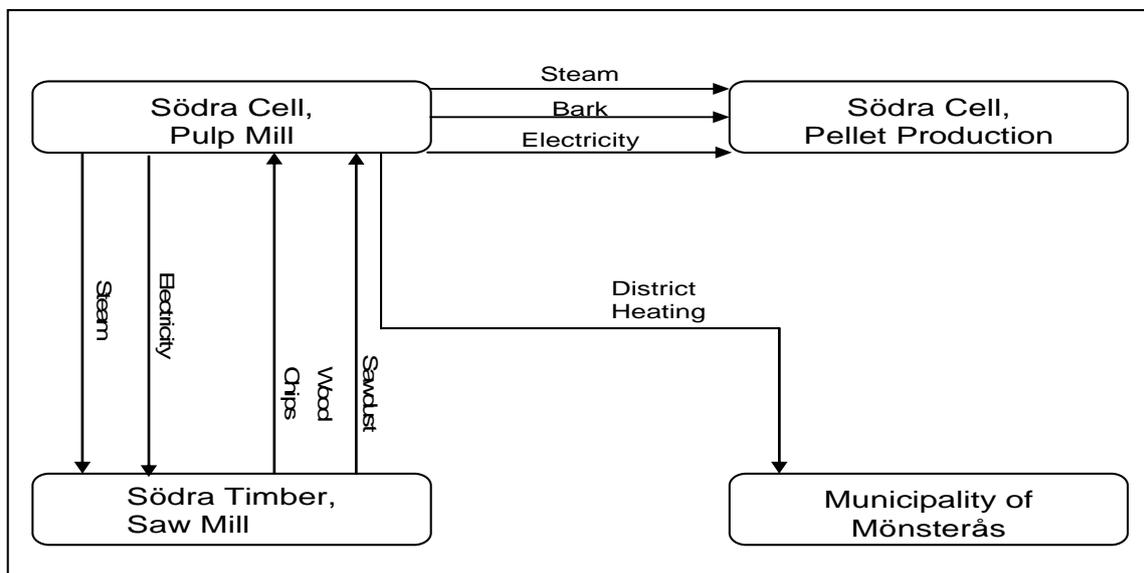
The care for nature has a long history in Sweden, such as the more than a century old slogan “The nature is everyone’s” illustrates. The related forestry industry’s tradition of integrated diversification for efficient resource use fits in that mode. Uncovering and mimicking existing symbioses seems to fit better in the Swedish business concept than intended developments to eco-industrial parks. During the recent decade, several such initiatives can be detected in Sweden. Nevertheless, production-oriented forest policies were dominant since early 20<sup>th</sup> century; a fundamental changed when timber production and maintenance of biodiversity became of objectives of equal dignity in Sweden’s forestry policy in 1993 [16].

Cascade flow management has been practiced in some cases in the Swedish forest industry for a long time. However, in the 1960s and 1970s many companies became too much diversified despite creating more value [17]. In the 1990s, the argument for changing the strategy of many larger corporations to focus on more limited number of forest products seems to be influenced by globalization trends and the need for decreasing bureaucracy and higher coordination costs [17]. Despite this, the integrated diversification for efficient resource use is still involved in several companies.

The forest industry is one of the most important industries in Sweden. The sector employs 11 – 12% of the industrial labour force and generates approximately 12% of the GDP. The forest industry forms strong clusters of different companies that fit each other. An inventory [18] found 15 By-Product Exchange (BPX) networks; none of them were deliberately planned or labelled as Industrial Symbiosis. Integration of pulp and paper is more energy efficient – 65% of the pulp is used in such system of integrated production. As long as the forestry is sustainable, the forest industry production is based on renewable raw materials. Besides that 14% of the pulp production comes from recycled fibre, and is the industry an important user of woody biomass. The forest industry is involved in bio-fuel production (by-production); the expanding bio-fuel market leads to both business opportunities and competition.

An inventory of the existing exchanges of material and energy in the Swedish forest industry illustrates that IS in the form of by-product exchange networks exist in the forest industry sector as more than a third of the investigated companies have some kind of material or energy exchange with adjacent entities. [19] Chertow is stating that uncovering existing symbioses has led to more sustainable industrial development than attempts to design and build eco-industrial parks incorporating physical exchanges. [20] The Swedish forest industry shows ultimate illustrations of integrated IS in business practices as in the Mönsterås network in Figure 2 [18]:

**Figure 2 Mönsterås network**



In several Swedish regions an intermediary organization for co-operation between different societal actors are designed such as the intermediary organization Processum in Örnsköldsvik and CleanTech/Östergötland in the Östergötland region. Processum organizes cluster collaboration between companies within the processing industry, Örnsköldsvik municipality and universities and colleges. [21] This form of co-operation within Processum

with clear goals and allocated resources offers huge opportunities for making use of the strong development potential in the industry. The level of knowledge of process chemistry, process engineering and process control in the companies in Örnköldsvik is advanced. Processum functions as a driving force for the promotion of new development opportunities, mainly alongside the core activities of the member companies. Although, IS is not mentioned, the nature of activities are similar.

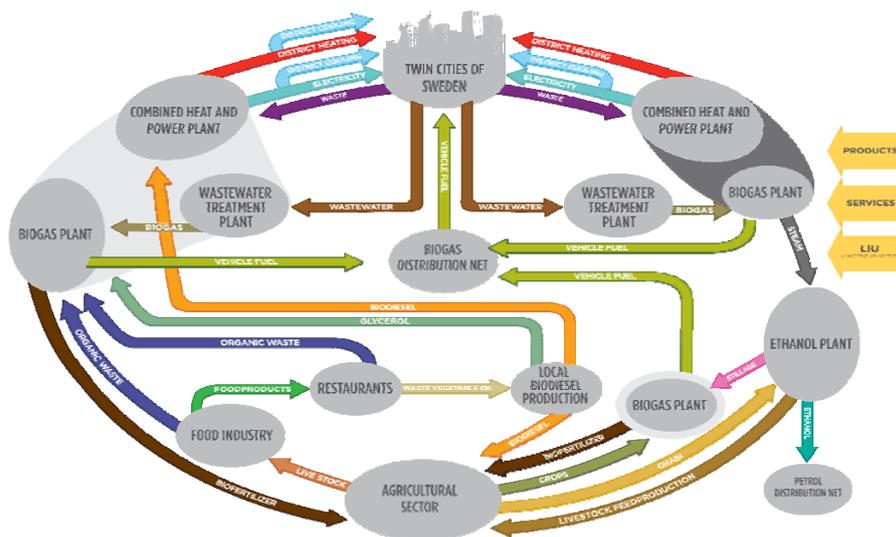
A similar development can be seen in the Östergötland region by the start of the CleanTech/Östergötland - an organisation with as members the municipalities of Linköping and Norrköping and 80 industrial organizations - in 2008. The IS concept is "marketed" as an umbrella for environmentally driven regional development in Östergötland and is defined as *business practice: .."Characteristic for industrial ecology is to turn environmental problems into business opportunities by applying wide system boundaries, using resources efficiently and co-operate through resource sharing" .. [22]*

Several IS activities were already developed such as the 1.7 kilometer pipeline for the utilization of nutrient rich waste water from the slaughterhouse in the biogas production facility. CleanTech/Östergötland will stimulate such activities as business cases. Along that line, district heating companies such as Tekniska Verken in Linköping and E-On in Norrköping are stimulating IS as driver of regional sustainability innovation. The bio-gas production as affiliated or linked facilities of the district heating companies are providing bio-gas for all public bus transport and taxis in both cities. In addition to the 5% average bio-fuel use in Sweden, the 5% bio-gas use in Östergötland means that approximately 10% of the mobility in Östergötland is based on bio-fuel in 2009.

It is remarkable and encouraging that the developed policies and activities in Östergötland have already resulted in more than 20% CO<sub>2</sub> reduction compared with emissions in the region in 1990. The district heating system and increased bio fuel applications seems to be the basic elements in the emergence of a "silent" transition to a "100% renewable energy" region. Renewable energy is often taken for granted as a sustainable energy label. Sun, water, wave, wind, and geo-thermal energy is in focus for renewable energy. However, the incineration of household and non-toxic industrial waste is also called renewable energy. In essence, it is a re-use of the energy of waste materials that can have been produced on fossil fuel basis. That will not say that incineration under the label of "Waste to Energy" cannot be part of the renewable energy system. It is an important issue when regions focus on or claim to be a renewable energy region. However, the discussion about this topic is not included in this article.

Figure 3 provides an overview of the major IS activities in the Östergötland region (as electronically constructed by the CleanTech/Östergötland organization). The IS activities in Linköping are on the left side and the IS activities in Norrköping are on the right side of Figure 3:

**Figure 3 Industrial Symbiosis in Linköping and Norrköping**



The Handelö Eco-Industrial Park in the Norrköping municipality is interesting: it combines an IS renewable energy cluster, a logistical centre and Natura 2000 conservation<sup>4</sup> areas. [23] The IS renewable energy cluster links the combined heat and power (CHP) plant with a biogas plant, an ethanol plant and another biogas plant. The privately owned Norrköping CHP plant has a fuel mix of 95% renewable resources including household waste, rubber, woodchips and wood waste. The biogas plant owned by the CHP plant produces biogas from sludge of Norrköping’s waste water treatment facility. After fermentation the biogas is upgraded to vehicle fuel which is distributed to the local refuelling stations. 29% Of the output of the CHP plant is delivered as steam to the ethanol plant. The ethanol plant is using wheat, triticale and barley as raw material for making ethanol and protein pellets for livestock feed. The part of the stillage not used for livestock fodder, becomes raw material for the biogas plant.

The business case type IS seems to fit many IS cases in Sweden. Despite developed conceptual models of an eco-industrial park based upon ecologically mimicked relationships, [24] it is not easy to generate the needed links between actors and organizations in intentional projects. This is illustrated by the Landskrona IS project “created” by the Lund University as part of Ph.D. research. [3] The *creation* approach of the IS Landskrona project for networks was based on the following definition: ..“a collection of long-term, symbiotic relationships between and among regional activities involving physical exchanges or materials and energy carriers as well as the exchange of knowledge, human or technical resources, concurrently providing environmental and competitive benefits”.. [25] The involvement of some anchor organizations and key persons in the field provides important drivers for the dissemination of IS activities in a region. It is very important to

<sup>4</sup> Natura 2000 is the name of the EU network of protected nature areas

detect them as “owners” of the project when the project is initiated from the outside. Unfortunately in the Landskrona project, the IS initiative phased out when the research project budget including external IS management was finished in 2006. Although, the Landskrona industrial park was leading in the introduction and dissemination of cleaner production in Europe in the period 1987-1989, [4] the industrial ecology concept did not found such basis.

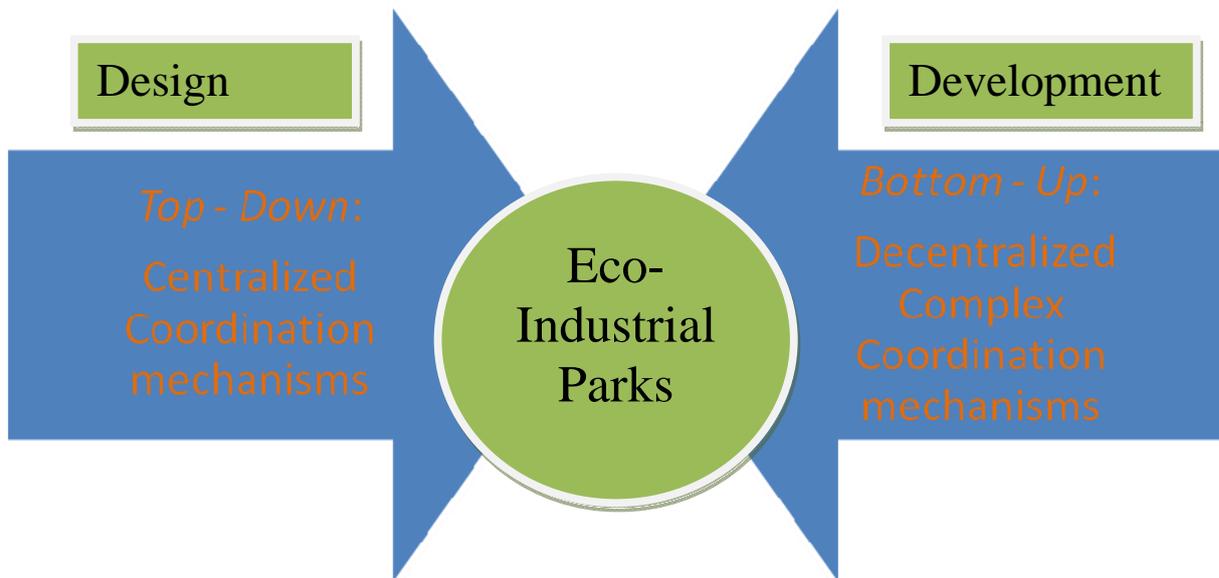
Besides academic uncovering industrial symbiosis activities such as renewable energy and efficient material use [26] also intended approaches are developed in Östergötland. A 4-year Sustainable Norrköping programme will research the IS development of the energy cluster and a logistics centre in the Händelö Eco-Industrial-Park nearby a Natura 2000 conservation area. A visualization centre for popular science communication of industrial symbiosis through visualization of material flows and connections in the Händelö Eco-Industrial-Park is also part of the project. It is argued that the citizen’s willingness, commitment and support for these changes are very important dimensions for further developments; their empowerment, continuing engagement and support are essential to ensure that this region continues on its transition journey.

Furthermore, the Linköping district heating company Tekniska Verken and Linköping University agreed upon funding a 10-year Industrial Ecology Research Programme by Tekniska Verken connected to a new chair in Industrial Ecology. [27] The Long term Industrial Ecology Research Programme 2009 – 2019 will contribute to focused research, education, and knowledge dissemination with respect to clean technology, industrial symbiosis, waste to energy, and bio fuel applications on a sound economic basis through the results of Ph.D. research and continuous evaluation of sustainability projects in practice. In the Industrial Ecology Research Programme, *“Industrial symbiosis is seen as a process whereby materials, water, energy and informational flows between and among companies are investigated with the objective of developing and improving co-operative links between/among them”*. [28] Research projects such as the utilization of waste heat, CO<sub>2</sub> and nutrients from the district heating company in greenhouses, bio-fuel synergies and urban mining have started in 2010.

## 5 Analysing IS observations and conclusions

An important issue is the question whether IS has better results when business cases are developing in a more or less organic way or that intended approaches create more optimal frameworks for development. Or, when advantages and disadvantages from both approaches are mixed, what conditions are influencing a synthesis of both approaches?

**Figure 4 Policies for Eco-Industrial Park Development**



Firstly, strong IS links are found in the historical settings between companies in a region such as in the Rotterdam Harbour and Industry Complex [28] and in the spin-off integrated industrial activities in the Swedish forestry. [19] The historical links between companies in the Rotterdam Harbour and Industry Complex became basis for a network of key stakeholders that initiated many new sustainability projects. [4]

Secondly, the issue of trust is a very important variable in general and especially in the Swedish society. The trust level is very high in Sweden, and lead to many links between government, industry and knowledge centres to develop common solutions. In this context the local authority is on the one hand a very strong actor because they are involved in many decision-making processes effecting economic activities. Their important position in the Swedish tax system provides strong economic power incentives for having a role as coordinator of local integration projects. On the other hand in analogy of Selman's "Canons of sustainability" analysis [29], such role is impeded by the weak integration of different divisions in the municipality's organisation.

It is suggested that companies with integration as their business concept can be key actors when developing more integrated networks. Along that line, the district heating systems in Östergötland since the 1950's and increased bio fuel applications in the early 21th century are today's basic elements in IS development. Also, later policies on landfill tax and landfill ban have strengthened the waste incineration system's transformation in a "Waste to Energy" philosophy. The philosophy is going from linear to circular approaches, where waste turns to being "resources" as part of the new way of business case thinking. The China Circular Economy Promotion Law and regional "green economy" policies are providing a similar facilitating framework for IS developments.

Thirdly, continuous academic research and energy supplying companies' initiatives are exploring how to increasingly effectively apply renewable energy. Also regional sustainability programmes such as the CleanTech/Industrial Symbiosis programme in Sweden are stimulating the industrial symbiosis concepts and renewable energy applications. Fortunately, past and ongoing initiatives in Östergötland have resulted in the expanded consciousness that clean technology and industrial symbiosis provides a synergy mode for innovative approaches beyond the adaptive capacity of single organizations.

A synthesis between planned and uncovered IS can intentionally positively influence and generate new IS links within the context of historical links between companies, a social learning network of key stakeholders, a high level of trust between them, and an industrial culture including a strong sustainability innovation focus.

It is interesting to discuss which combination of dimensions and policies fits the IS development in China.

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