Industrial Symbiosis and its Alignment with Regional Sustainability

Exploring the Possibilities in Landskrona, Sweden

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Abstract

Recently, industries have changed their efforts of collaboration to encompass transformations not just from an economic view but also for enhancement of environmental and social performance. This collaboration is Industrial Ecology (IE), or its regional application of Industrial Symbiosis (IS). IS can be defined as a long-term, symbiotic relationship between and among companies involving physical exchanges as well as the exchange of human or technical resources. The exchanges serve an effort to improve environmental performances and increase collective competitive advantage. There is often a disconnection between the ideal goal of IS networking and the practice of IS. This is especially apparent in regards to aligning long term outcomes of collaboration and sustainability goals of a region. This study was performed to understand, and strengthen, the alignment of IS networks and regional sustainability.

This work uses an action research approach centered on the Landskrona IS network established in Sweden in May 2002. It entails a review of the field of sustainability and of IS, which was used to develop a Sustainability Framework order to formalize criteria used for evaluating the alignment of the Landskrona IS network with regional sustainability. These criteria, referred to as strategies, are proposed because they have the potential to lead companies in achieving long-term improvements that close both production loops and consumption loops, as well as try to decrease the overall level of material throughput.

Analysis of the Landskrona IS network showed that a large number of incentives and motivations for the companies to pursue sustainability strategies exists. Overall, the economic and environmental pursuits of the IS network seem in line with network and regional sustainability goals. The key aspects missing are mainly social and environmental aspects which require large changes to core business practices. Conclusions are drawn and recommendations are made as to how networks can bridge the gaps to sustainability and how research coordinators can facilitate in the creation of conditions for a self-sustaining network committed to sustainable approaches.

Key words: Industrial ecology, Industrial symbiosis, sustainability, network, strategy, region

Executive Summary

As industry has greatly been behind the development of societies, this sector plays a key role proceeding along a sustainable pathway. Recently, industries have changed their efforts of collaboration to encompass transformations not just from an economic view but also for enhancement of environmental and social performance. This collaboration is Industrial Ecology (IE), or its regional application of Industrial Symbiosis (IS). IS can be defined as a long-term, symbiotic relationship between and among companies involving physical exchanges as well as the exchange of human or technical resources in an effort to improve environmental performance and increase collective competitive advantage. These networks have the potential to put less stress on regional, national, and/or global resources and reduce wastes and emissions. As such, IS networks are often used as an example of efforts by industries and/or regions to develop more sustainable practices. However, it has been observed through background studies that there is often a disconnection between the ideal goal of IS networking and the practice of IS. This is especially apparent when aligning long-term outcomes of IS collaborations and sustainability goals of a region. This study was performed to understand and strengthen the connection between IS and regional sustainability by considering the key question:

- How can an IS network be better aligned with the long-term goal of sustainability, both for the network and for the region as a whole?

In order to address this question in more detail, it was divided into three sub-questions:

1. How well are IS networks currently aligned with sustainability pathways?
2. What needs to be done to bridge the gaps between the regional vision of sustainability and the practical situation?
3. How can network participants be supported in helping to evolve towards a sustainable network and region?

This work uses an action research approach centered on the Landskrona IS network established in Sweden in May 2002. The first cycle of research involved a literature review of sustainable development from global, national, regional, and local perspectives. Information was gathered on IE and IS to understand the development of the field and current practical applications. In addition, literature was reviewed regarding organizational dynamics, cluster theory, and appropriate tools and approaches for pursuing more sustainable pathways. The second cycle was a qualitative study on how to incorporate these findings in the Landskrona IS example. Qualitative data was gathered through company and regional document reviews and semi-structured interviews. A second phase of interviews and group meetings was initiated to get participant feedback on the initial analysis proposed by the author.

A review of the field of sustainability and of IS was used to develop a Sustainability Framework in order to formalize criteria used for evaluating the alignment of the Landskrona IS network with regional sustainability (shown in Figure 1). This framework considers six economic, social, and environmental goals that should be addressed in the planning for and execution of an IS network. There are eight associated strategies in the framework that can be used to pursue satisfying the criteria. These strategies most directly influence two goals, but there are synergies and overlaps in the pursuit of all strategies and goals. The strategies have the potential to lead companies in achieving long-term improvements that close both production loops and consumption loops, as well as decrease the overall level of material throughput.
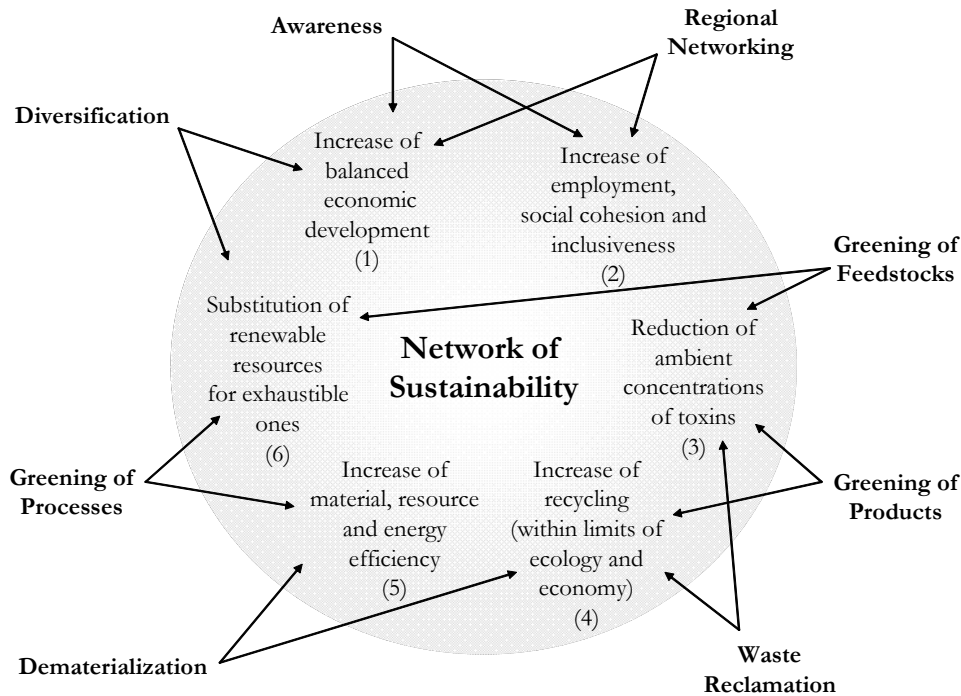
Figure content:

Awareness

Regional Networking

Diversification

Increase of balanced economic development (1)

Increase of employment, social cohesion and inclusiveness (2)

Greening of Feedstocks

Substitution of renewable resources for exhaustible ones (6)

Network of Sustainability

Reduction of ambient concentrations of toxins (3)

Greening of Processes

Increase of material, resource and energy efficiency (5)

Increase of recycling (within limits of ecology and economy) (4)

Greening of Products

Dematerialization

Waste Reclamation

Figure 1. Sustainability Framework for IS Networks: long-term goals and strategies

The Landskrona IS network is still in the development phase. Connections developed so far include the exchange of waste heat, glass waste, water, ethanol, and agricultural waste for renewable energy, waste to energy, and storage capacity. There is collaboration on the managerial developments and transfer of knowledge. Employee exchanges, transportation connections, and solvent recovery collaborations are still being investigated. There has been an increase in social contacts and cohesion, a broadening of mentality for network participation, and saving of financial and environmental resources. An applied research laboratory is being established in Landskrona and will run the coordination of the IS network in the near future.

Along with connections acted upon or planned for, a large number of incentives and motivations for the companies to pursue sustainability strategies exists. The network shows progress in pursuing balanced economic development, increased social cohesion and employment within the network, and high awareness of local issues. Companies are engaging in the reduction of environmental releases, the greening of products and processes, and the increase of recycling and material, resource, and energy efficiency. Overall, the economic and environmental pursuits of the IS network seem in line with network and regional sustainability goals. The key aspects missing are mainly social, e.g. the increase of social cohesion and education levels on a regional basis. Environmental goals and strategies not yet addressed include the greening of feedstocks and switch to more renewable resources as well as the pursuit of dematerialization strategies.

There are three main actions that can be taken to bridge the gaps to sustainability. (i) Use the newly created applied research laboratory to strengthen the support of Landskrona IS network participants. (ii) Coordinate the work of the IS network, the research center, and actors from the greater region (in the case of Landskrona, both Skåne and Öresund Regions) more closely. (iii), Develop a coherent, long term vision and associated action plans for the network. The latter is perhaps the biggest bridge to the identified gaps in sustainability.

Throughout the network development, it is found necessary to support participants both technically and organizationally. Coordinators can significantly contribute by facilitating the creation of conditions for a self-sustaining network committed to sustainable approaches. They can further support network participants by encouraging the creation of a group vision and action plans that incorporate the strategies from the Sustainability Framework as well as regional goals and objectives. Also, experts in strategic management can lead the network and other regional participants through transitional changes and help to formulate a coherent, comprehensive vision and action plans for transitioning through the phases of change.

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1 Introduction

Since the birth of the Industrial Age in the 1750s, society has been faced with the double-edged sword of industrial progress. The almost countless benefits to society can be seen in all fields—from mass-production of life-saving medications to the provision of electricity and heat for nations. However, with these advances and large-scale applications of knowledge and production, society has also created environmental degradation. The chemicals and pollutants that we, the human race, put in our air, water, and soil have been linked with reproductive decline in amphibian species, increased cancer rates in humans, and disappearance of numerous other species, and other impacts. We have spread persistent bioaccumulative chemicals such as DDT (dichlorodiphynyltrichloroethane) as far as the Arctic circle, created a hole in the ozone layer with substances like CFCs (chlorofluorocarbon compounds), and polluted our rivers until they caught on fire[1]. We have also greatly damaged pristine environments in our extraction of fossil fuels and other natural resources used in production. If society continues along this same pathway, a high quality of life for people, and possibly for millions of species with whom we coexist, can not be sustained. These negative side effects of industrialization should serve as motivation for societies, at every level, to develop in a more preventive, sustainable manner. As industry has greatly been behind the development of societies, this sector plays a key role in helping that development proceed along a sustainable pathway.

One change in the traditional business of industry has been the development of collaboration not just from an economic push but also for enhancement of environmental and social performance. One type of collaboration that has been gaining more attention is called Industrial Ecology (IE). In IE, organizations operate with a systems-oriented perspective and seek for ways to increase business success by e.g. exchanging wastes as inputs or sharing resource infrastructure, distribution systems, and managerial activities. This can contribute to a more sustainable development path by putting less stress on regional, national, or global resources and reducing wastes and emissions. In academic literature, it has been hailed as the "science of sustainability" (Ehrenfeld, 2004). As O'Rourke et al. state, it "aims to contribute to sustainable development through two operational objectives: closing material cycles, and realizing a fundamental paradigm shift in the thinking concerning industry-ecology relations" (O'Rourke et al. 1996 in den Hond 2000). A branch of IE that has gained recognition is Industrial Symbiosis (IS). IS is a more localized application of IE where companies have a symbiotic relationship in their interactions. This is focused on more inter-dependent relationships between industries, and is usually a complex network of exchanges on a more localized level. These inter-dependent relationships are seen as closely related to natural system functions and efforts to remain in balance with them. Long-term relationships are established and supporting social networks are developed to make the network more cohesive. Companies can work within a cluster, or network, to promote long-term success both of their company and of the region within which they work.

IS networks provide opportunities for making gains in environmental, social, and economic areas for all involved. As such, these networks have gained a lot of attention as a solution for some environmental problems surrounding industry activities. IS networks are often used as an example of efforts by industries or regions to develop more sustainable practices. But do they really? Is a more sustainable path an inevitable outcome of IS practice, or is it only in theory that IS can help society move towards sustainability? It has been observed through

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[1] On June 22, 1969 Cleaveland, Ohio (USA) an oil slick on the Cuyahogo River caught on fire. This event became a rallying point for environmentalists fighting for protection of water sources (CWRU, n.d.).

background studies that there is often a disconnection between the ideal goals of IS networking and the practice of IS. Often, it turns out that IS connections are very beneficial in the short term. For example, if a company can sell their wastes, this may provide an incentive for the company not to be as efficient with their use of raw materials. This leads to prolonging the company's inefficient use of natural resources. In the same way, a company may significantly decrease their expenses using IS connections to such a level that allows them to increase their production levels. This is essentially a rebound effect, where there is more material throughput in the end. These perverse incentives and rebound effects can often be overlooked when examining IS networks. Therefore, in the end, it is possible to support a system that is not contributing to the sustainability of a region. In fact, a system could be sustained which actually prolongs the practices of resource exploitation and material throughput. More needs to be done if a network or region's goal is an overall higher sustainability level.

With a fundamental paradigm shift, there should be a comprehensive view of how the network interacts with society and the natural environment, so that not just production loops are closed, but also production-consumption loops[2]. This means that there will be concern for increasing the environmental profile of not just processes or feedstocks, but products as well. Social aspects, such as education initiatives or secure and balanced employment, would also become an integral part of the network improvement process. Economic benefits and stability would be sought not just for the individual companies, but for the network and the region as a whole. These conditions are just part of what is necessary to begin pursuing a more sustainable approach.

This potential problem can be addressed by researching the dynamics of IS networks and evaluating how truly aligned they are with sustainable development. Once these dynamics are understood, and it is seen what incentives exist in a network, it can be easier to guide an IS network to take a path more aligned with the sustainability plans of that network's region or nation. This study takes an in depth look at the link between IS and regional sustainability.

1.1 Objectives and Research Questions

The objective of this research is to evaluate the potential for IS networks to evolve towards regional sustainability efforts based on the example of the existing IS network in Landskrona, Sweden that was established in 2002. Thus, it is an attempt to understand, and strengthen, the connection between IS and regional sustainability by considering the key question:

- How can an IS network be better aligned with the long-term goal of sustainability, both for the network and for the region as a whole?

In order to address this question in more detail, it can be divided into three sub-questions:

1. How well are IS networks currently aligned with sustainability pathways?

2. What needs to be done to bridge the gaps between the regional vision of sustainability and the practical situation?

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[2] The term "production loop" denotes the material and/or energy cycle(s) for creating products or services. All inputs and outputs of the production phase are included in this loop. The term "consumption loop" denotes the use and end-of-life phases of products and/or services. Production-consumption loops indicate the integration of these loops in an effort to reduce the overall material and/or energy throughput.

3. How can network participants be supported in helping to evolve towards a sustainable network and region?

1.2 Methodology

This thesis was designed to address the complex issue of the link between Industrial Symbiosis and regional sustainability by analyzing an Industrial Symbiosis network in Landskrona, Sweden. As this network is still being developed, there was an opportunity to initiate change within the network during the research process. Therefore, an action research approach was used. Action research can be defined in many ways: one simple definition of the focus of action research, given by Stephen Kemmis and Robin McTaggart, is "…trying out ideas in practice as a means of improvement and as a means of increasing knowledge…" (Kemmis and McTaggart, 1982 in McNiff et al., 1996). Using an action research approach allowed the researcher to concurrently assess an understanding of what can help make an IS network "thrive" and of how successful different recommendations can be when trying to better align IS networks with regional sustainability. This type of study can help contribute to the practical knowledge of the field of Industrial Ecology.

An action research methodology was deemed most appropriate because its aim is not just for the researcher to understand organizational phenomenon but also to engage in the field of study in order to analyze the changes that can be made. It encourages collaboration and dialogue and helps the research result be more relevant for the field of study and professionals within that field. This was considered as valuable for the field of Industrial Ecology because it is a relatively new field and there are not many cases around the world where networks were analyzed during the early stages of planning and implementation. In action research, also called participatory action research (Whyte, 1991), the researcher pursues both theoretical and practical knowledge by placing herself within the context of the study, instead of outside it as a passive observer. When doing research to understand organizational dynamics, such as those in IS networks, it is advantageous to gain the "insider" perspective that action research allows. Critical knowledge is acquired through this research method which might otherwise not be through more "observer" based methods. Action research can better reflect the dynamic nature of an organization or network and so was seen as an appropriate choice for the research of Landskrona's IS network.

An action research study is designed in a cyclical nature: the researcher formulates a plan of study, gathers data, analyzes information and experiences, and then introduces a new plan of action based on analytical conclusions. This cycle repeats, as shown in Figure 1-1, as results from one level of analysis are incorporated in revised approaches.
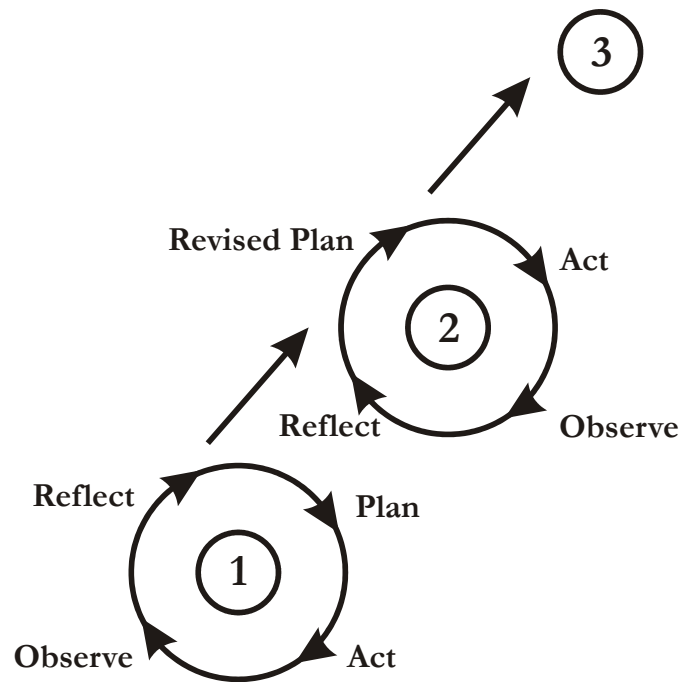
Figure 1-1 The spiral of action research cycle (Zuber-Skerritt, 2001 in Altrichter et al., 2002)

This method can be considered most appropriate for research aimed at understanding organization studies. It allows for an ability to respond to the dynamic nature of an IS network such as that of Landskrona because the researcher can adapt the direction of theory formation to reflect the changing organizational situations and relations involved in the IS network.

The first part of the research for this thesis was performed as a desktop study. Literature was reviewed for two of the main aspects of this thesis: regional sustainable development and industrial ecology. Under the topic of regional sustainable development, there were four sub-levels of research:

1. *Global*: The first step of looking at sustainability issues was to gain a general view of the underlying principles of sustainability from a more global perspective. Information was reviewed from sources such as global organization reports, international conventions literature, and internet sites representing more global perspectives on the issue. This information provided a basis for further refining of the concept of sustainability and sustainable development.
2. *European Union*: It was necessary to evaluate a high level view of the general vision of sustainable development and how regional plans could fit into this picture. Information was gathered on sustainability and development from sources such as EC reports, EU development program internet sites, and reports and online presentations prepared for the EU by independent agencies.
3. *Sweden*: Each country in the EU has unique political, economic, social, and environmental factors. Because this thesis will be applicable for the Swedish case, it was important to evaluate the specific Swedish view and plans for regional sustainable development. Swedish government reports and website information were evaluated and used to formulate the background theory of this thesis. Case studies of regions in Sweden involved in sustainable development projects were also reviewed.

4. *Landskrona*: Although sustainable development concepts can be quite broad, its application on a regional level is usually quite specific to the conditions in that region. Therefore, Landskrona was researched to understand the history and evolution of economic, socio-political, and environmental situations in this context. Knowledge was sought in order to understand the framework in which the Industrial Symbiosis network was functioning. Reports (e.g. regional planning documents) and information (e.g. demographics) was gathered mostly from government and industry websites.

Under the topic of industrial ecology, there were four main sub-levels of research:

1. *Industrial Ecology*: Academic literature review and preliminary assessment were performed regarding the development, ideals, and practice of industrial ecology and industrial symbiosis. Case studies of IS networks (or eco-industrial parks) were reviewed from academic literature, independent organization reports, and internet sources. A site visit (including a presentation, question session, and facility tours) to one of the most developed IS networks was also included in the research process in order to gather primary data about IS practices. The information gathered about the field of industrial symbiosis, both as it is meant to be developed and its current applications, was analyzed to determine the connection between IS networks and long-term sustainability goals.
2. *Organizational Dynamics Theory*: To understand the dynamics of the interactions of components of a network system, a literature review was conducted on organizational learning, organizational interactions, and responses to pressure for corporate responsibility. This collected information built the knowledge base of the analysis of the organizations acting within IS networks.
3. *Cluster Theory*: Industrial Ecology is not the only form of interorganizational collaboration that supports regional success. Information about clusters and other inter-organizational interactions (such as value chain, product chain, and industry branch collaborations) was gathered from journal articles, books, and interviews. This information was reviewed and analysed in order to take advantage of lessons learned in these methods.
4. *Tools and Approaches*: In order to assess the alignment between IS networks and regional sustainability, it was necessary to understand what tools and approaches could or should be used by IS practitioners to progress closer to sustainability ideals. These tools and approaches that could be used by practitioners of IS to improve the environmental performances of their companies and regions are e.g. design-for-environment, environmental management system, life cycle analysis, cleaner production, alternative fuel development, and service business model. These were researched and evaluated using information gathered from academic courses, interviews, industrial site visits, and academic literature reviews.

Together, these parts of the desktop study form the first cycle of the action research approach to the thesis. From the analysis of this information, conclusions and recommendations regarding the direction of IS networks were made that were incorporated into the second cycle. The second cycle of research involved performing a qualitative study on how best to incorporate these findings in the Landskrona case study. A qualitative, or interpretive, method enables a researcher to focus on what is important to the individuals within the system of study. Priority is given to their perspectives and interpretations of the dynamics of the system instead of preconceived notions of the researcher (Bryman, 1989). When interacting with participants of the Landskrona IS network, semi-structured interviews were used. This keeps the focus on the research questions at hand, but allows for flexibility in exploring potential

insights that come up during the interview. Due to time constraints, unstructured was not used because it requires the time to address not only researchers question topics, but also those questions that the interviewee proposes. It is more of a discussion that can stretch in length without assuring that the researcher's required topics are covered. The first phase of interviews with network participants was performed to analyze the current status of the network and expected future progress. Information and feedback was also gathered from researchers involved in the coordination and management of the project. A Sustainability Framework was developed in order to formalize the criteria used for evaluating the alignment of the Landskrona IS network with regional sustainability. A second phase of interviews and group meetings was initiated to get participant feedback on the initial analysis and recommendations proposed by the author.

1.3 Scope and Limitations

This study examines the connection between IS practice and the pursuit of regional sustainability. The field of IS is still evolving, and thus its relationships and definitions are evolving as well. For the purposes of this study, IS can be defined as a long-term, symbiotic relationship between and among firms involving physical exchanges as well as the exchange of human or technical resources in an effort to improve environmental performance and increase collective competitive advantage. There is an ongoing debate in academic circles over the appropriateness of using nature as a metaphor or analogy. This study is not an attempt to resolve this issue. The author accepts that nature as metaphor or analogy is meant as an inspiration and it is understood that not all parts of the model of nature fit exactly with the model of industry. Nevertheless, this does not diminish the strength of the argument that society must learn how to better integrate itself with the natural environment and natural cycles if we wish to be able to preserve it.

Defining regional sustainability can be a much more complex matter. Sustainability is itself a very charged word, denoting quite different levels of complexity for each person or organization employing the term. In this study, sustainability is meant to encompass economic, social, and environmental aspects. Environment refers to ecology or an ecological setting, and is always used in this context. It is beyond the scope of this study to determine the local natural capacity of regions in Sweden or elsewhere. When discussing environmental issues, preservation of biological diversity is not specifically addressed. It is intended that the reduction of pressure on habitat and species (through satisfaction of the environmental criteria outlined in the subsequent sections) will help reduce the threat to biological diversity at the source. A more comprehensive understanding of the term sustainability and its regional context is discussed in Section 2. In general, sustainability is seen not as an end product of efforts, but as a continuously moving goal towards which to strive. Even so, criteria can be used to judge whether there are proper incentives and motivations in place for companies or networks to pursue more sustainable pathways. The set of criteria developed in this thesis is meant as this kind of litmus test for the Landskrona IS network. The term sustainable development can be defined as development efforts or actions taken to progress along the pathway to sustainability.

The main focus of this thesis is on the case of the Landskrona IS network, initiated in May 2002 and located in southern Sweden. This network was studied because it presented an opportunity to gain a comprehensive view of IS networks in the early stages of development. Often, the largest opportunity to direct a network on a desired course is in the early stages of planning and development. Therefore, it was seen as a good opportunity to work with Landskrona companies in order to evaluate where they are along the pathway to sustainability and what changes could still be implemented to establish the right conditions in the network

relationships. Other IS networks are used to illustrate points, however an in depth analysis of these networks is outside the scope of this study.

A comprehensive study was performed in 2003 by Jan-Erik Starlander which analyzed organizational factors that influence the outcome of IS networking. The research tested conclusions derived from theory about influencing factors using the Landskrona IS network as a practical context (Starlander, 2003). Therefore, the scope of this thesis will not include the factors leading up to and securing participation in IS networks. Instead, the research will examine the dynamics that occur once companies are engaged in the network and committed to continuous improvement.

The geographical boundary of this study is based around Landskrona, Sweden. Relevant discussions and information regarding the greater region dynamics are used in the study. A large limitation to this portion of the research is that regional plans are still in the process of development. Assessment of the alignment with regional plans for sustainability therefore is limited to what authorities have developed so far and information that could be gathered from interviews. The lack of Swedish speaking ability of the author also limited the ability to understand the literature that was available on this, and other, topics of the study. As Landskrona is a part of two regions, the political one Skåne and geographical one Öresund, it is in a unique situation. Some conclusions and recommendations are therefore unique for the Landskrona IS network. There are, however, some general findings that can be applicable for other networks and regions around the world. These are discussed throughout the study.

The dynamics of the IS network in Landskrona, and its association with regional plans, are investigated from an organizational and institutional perspective. Market or organizational incentives for companies to change and progress towards more sustainable actions are explored. Policy or economic instruments used by government or other public bodies are not investigated in this study. It is recognized that these can be important when looking at the overall influences on companies and networks. They have the potential to greatly enhance steering efforts. However, due to the need for practical limits in the scope of this study, these will not be addressed.

As mentioned before, the Landskrona IS network is still in the early stages of establishment. All areas of potential connection have not been fully identified, explored or planned for. These types of developments and changes in the network take many months, and usually years, to accomplish. When assessing how aligned the network is with regional sustainability, it was necessary to make assumptions based on what incentives and motivations exist for pursuing strategies towards sustainability. Given the short time frame of this research study, the author was unable to collect data on whether, given time, the network participants would in practice follow through on fulfilling the criteria of sustainability.

1.4 Outline of Thesis

The structure of this report is organized in six chapters. The first chapter introduces the research objectives and questions, the methodology, scope, and limitations of the thesis. The second chapter explores the topic of sustainability. Sustainability is defined and discussed from a global, regional, and organizational perspective. In the third chapter, IE and IS are introduced, defined, and investigated. A framework for assessing a network's alignment with sustainability is discussed and strategies for pursuing these criteria are outlined. The fourth chapter introduces Landskrona and the Landskrona IS network. Network collaborations are discussed in detail as well as management approaches for ongoing efforts at collaboration. Analysis of the Landskrona IS network, from both a network and regional perspective, is

presented in the fifth chapter. The final chapter presents conclusions and recommendations for the Landskrona IS networks and other networks in the world.

2 Sustainability

With the development of technologies that enabled the burning of fossil fuels, society began the process of manipulating the world's natural capital in its quest for "progress" through energy and resource exploitation. The large benefits gained by these activities were not without a price, however. As Cantlon and Koenig (1999) state, "they also expanded both the scope and scale of existing ecological risks and introduced entirely new classes of ecological impacts." Many impacts are now recognized and mitigations are underway, but the comprehensive effects of human development to natural processes and ecosystems are still not entirely addressed or understood (Cantlon and Koenig, 1999). In an effort to put back into balance societal advancement and preservation of natural and social systems, there has been a move towards what is called "sustainable development" or the pursuit of "sustainability." This section will discuss the different levels and approaches to sustainability in the context of industry.

2.1 Defining Sustainability

A widely accepted definition for sustainability was developed by the World Commission on Environment and Development (WCED). In the Brundtland Report, *Our Common Future*, sustainable development is defined as development which "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Most proponents of sustainable development stress the importance of the integration of economic, social, and environmental concerns. Members from the European Union Sustainable Cities initiative state, "sustainable development is about the relationships between economic activity, the use of natural resources and our quality of life" (European Sustainable Cities, 2004). Traditionally, and presently, economic considerations are the prominent drive of businesses and nations. For the industrial sector, the challenge is to better integrate ecological sustainability in economic development, to the limits that financial survival allow. The European Commission (EC) envisions that three areas of sustainable development relating to economic, social and environmental aspects that concern the private sector are:

- Balanced and equitable economic development

- High levels of employment, social cohesion and inclusiveness

- A high level of environmental protection and responsible use of natural resources (EC, 2003).

Within the third area of environmental sustainability, more specific structures can be found in the Brundtland Report. In a summary of the chapter "Towards Sustainable Development" of the report, Huber (1998) outlines the most important "rules" for the use of resources. These are:

- Ambient concentrations of pollutants in environmental media and living creatures must not exceed their absorption and regeneration capacity.
- The consumption rate of renewable matter and energy must not exceed their given rate of reproduction. The consumption rate of exhaustible resources is to be minimized by
  a. substituting renewable resources for exhaustible ones,
  b. increasing material and energy efficiency, and
  c. recycling to the extent that is ecologically reasonable and economically justifiable.

- The development and introduction of ecologically benign, clean resources, technologies, and new products is to be intensified (Huber, 1998).

The application of these goals requires not just integration of economic, social, and environmental issues, but also of the levels on which sustainability is pursued. There must be efforts made on all levels of society, from global to individual, and these efforts must be integrated to be able to make any steps forward. In order for nations or international communities to reverse trends of degradation, there must be people doing the work e.g. to monitor systems. In turn, individuals and companies must have the support of their communities and nations when they e.g. try to implement new, cleaner techniques and approaches. Although all levels of implementation are important, the regional level has come to play an increasingly important role in acting as a focal point for this coordination. The regional level is broad enough to accommodate global and national strategies in planning processes while still being local enough for effectively organizing people into action. Also, economic considerations still drive decision making, and it is becoming clearer that regional activities control a large part of economic success, even in the face of globalization.

2.2 Sustainability and Globalization

The term globalization, or economic globalization, refers to a phenomenon of "increasing integration of economies around the world, particularly through trade and financial flows" (IMF, 2002). Globalization can also signify the flow of resources such as people, materials, technology, and knowledge across international borders. The costs (both in time and money) of international transactions have been reduced enough to stir debates over whether the future will be a picture of a borderless space of people interacting. There has been an increase of transactions involving not just intangible assets such as information, but also physical assets which require increasing use of transportation avenues. Whether the world will be truly borderless is to be seen, however there are already observable impacts, both positive and negative, from the increase in interaction.

A noticeable aspect of globalization has been the increase in speed for transfers of goods and knowledge. This increase has been twofold, first in the distance that people are now able to travel or transport their goods and second in the quantity or frequency with which they do so. The ability to make transfers quickly around the globe has led to the unfortunate under-pricing of resources. Improved technology and global competition can hide the true total costs of the resources being consumed. This has resulted in providing consumer products on continually growing markets for ever shrinking prices. Sometimes, this is beneficial for decreasing transaction costs for things such as communication. For example, "the cost of a three-minute telephone call from New York to London in current prices dropped from about $250 in 1930 to a few cents today" and the number of voice paths across the Atlantic increased by a factor of twenty (from 100,000 to 2 million) in just over twenty years (Bhagwati, 2004). But there are also many examples of globalization trends where negative impacts are not addressed or mitigated. Along with this, some critics argue that there has been an increase in consumption, long distance trade and international economic competition (Curtis, 2003). These increases have the potential to hinder environmental improvements as more products are reaching larger markets. An example can be taken from the international banana trade, part of the horticulture trade which accounts for 5% of global commodity trade. The preference of developed-country markets for a year round supply of one species of uniform bananas has meant large environmental impacts for producing countries. The need to provide large scale, low cost exports puts pressure on improving yields through increased use of fertilizers, pesticides, and fungicides. With large areas of one species, there is dependency on chemicals which contaminate large areas of soil, groundwater, and nearby

surface water. In Costa Rica, the pressure from expanding international banana markets has doubled deforestation area in just seven years (NMU, 2003). It would also seem that industries operating in this global economy would no longer be bound by their physical locations, and therefore social and environmental ties to a place could be weakened. However, this does not have to be the case. The increases in international economic competition can act to bring regional success back into the forefront.

In one sense, the shift towards globalization actually supports strengthening regional sustainable development efforts. Often, one views globalization as a breaking down of borders, or as economic trade that knows no boundaries. However, there is evidence that while increasing global marketing, industries have also been increasing their tendencies to form clusters. In a way, globalization has acted as a force for creating small pockets of industries that are able to compete on global markets by acting together. Conservative estimates are that about 30% of the workforce in developed countries such as the US (Porter, 2001), Italy, and Holland is accounted for by globally-oriented local industrial districts (or clusters) (Scott and Storper, 2003). In order to deal with the market pressures of globalization, industries are coming together to support regional focuses of competitive advantage or return to economies of scale. This suggests that national economies will be more and more tied to regional sustainable development efforts (Scott and Storper, 2003).

2.3 Regional Sustainability

There has of course arisen a debate over what exactly "sustainability" means in a more concrete application, for example on a regional level. What does it mean for industries and businesses trying to act in a sustainable way within their communities? This more local focus is necessary to shift from abstract thinking to the act of implementation. The Brundtland Report definition is quite broad and can seem abstract when trying to formulate a feasible vision for sustainable development. Agenda 21, a comprehensive agenda initiated by the United Nations, was developed in an effort to emphasize the importance of acting not just on a global level, but at all levels, including nationally, regionally, and locally to achieve sustainability goals. Chapter 28 of Agenda 21 discusses the importance of involving local players in sustainable development. As Wallner (1999) says, "it is the citizens, traders, local institutions and other actors that have to collaborate to evolve and implement a concept for their future. Hence, it will only be possible to implement the basic ideas of sustainable development successfully by means of a concerted bottom-up approach" (Wallner, 1999). Through working with this document and other initiatives on a more regional or local level, people can begin to formulate an appropriate vision of sustainable development that is specific for their needs.

First, it must be understood what is meant by a "region." A region can be defined as "any area of subnational extent that is functionally organized around some internal central pole" (Scott and Storper, 2003). This means that a region is not necessarily the area defined by political boundaries, but instead it is defined by its features (both cultural and natural). Regions have unique characteristics that play a role in supporting all three pillars of sustainability: economic, environmental, and social. As put forth by the field of geographical economics, regions can be cornerstones of a country's development process. Their uniqueness and variety in character and constitution are the basis of so-called "geographical foundations of economic growth" (Scott and Storper, 2003). Integrating with the local context of regions is what supports development efforts in a sustaining way. The issue of bringing theory to action on a regional level is not just based on policy; it is also important from a more economic perspective. Development success or progress in countries can be linked with not only macroeconomic trends, but also to the cities and regions within that country.

One example of an area in Sweden that has seen success on a regional level is Gnosjö, in northern Sweden. When Swedes talk about networking or regional development, they refer to the 'spirit of Gnosjö'. Although the town is faced with natural barriers such as no access to raw materials, unreliable communications, and lack of nearness to other centers of activity, it has managed to support thriving industry and employment. For instance, there are 250 small companies in this town of just 10,000 people. Only 2% of the population is unemployed, compared with a level of around 13% for the rest of Sweden (Rock, 1995). Their success is linked with a local drive in entrepreneurship and an increased value-added dimension to their activities. Along with this, it has been noted that there is an extremely strong sense of community. Businesses are kept small, locally owned, and diverse, discouraging economic control by one dominant player. Another main reason for their success is the tight network in the town. As one community member says, "We all know each other and co-operate very well, If we need something we are not making ourselves, we know where we can go and get it" (Rock, 1995). Swedes in other regions have said that they are impressed with the high level of openness and communication between businesses and people in Gnosjö. There is also a learning network program in Gnosjö in connection to their Industrial Development Center. The aim of this learning programme is to "spread the networking culture of the Gnosjö region…to improve the culture of learning and competence development in the region" (SINTESI and Di Bono, 2003).

The works of Michael Porter expound on the concept of regional cooperation and development. One aspect of his work touches on the often overlooked influence that location can have on supporting the long-term success of a region's businesses. Porter (1998, 2000, 2001) develops this idea of the importance of a regional or local focus in his writings about clusters. Clusters are groups of interconnected companies and/or institutions that come together in a specific geographical area to increase collective competitive success (Porter, 1998, 2000, 2001). In economies that are increasingly globalized, a trend has emerged where companies use local strengths, knowledge, and relationships to secure a stronghold in business. Porter's research shows that although companies may compete on a global level, and needs such as resources, capital, or technology can be met inexpensively in global markets, location is still of critical importance. As Porter states, "what happens inside companies is important, but clusters reveal that the immediate business environment outside companies plays a vital role as well" (Porter, 1998).

Operating within a cluster can give industries some competitive advantages that they otherwise would not be able to acquire. When working as part of whole, companies can pool together to get better economies of scale when ordering inputs and they can potentially lower transaction costs associated with accessing information, technology, or even employees (Porter, 1998). The social ties and trust built up between people in companies working closely together can aid in faster and more efficient information transfer. Even for companies working on the global or national level, these personal relationships among people in a community can mean the difference between smooth information flow versus a constant struggle to stay abreast of quickly changing technologies or regulations. Companies in the same location working together can also share recruitment and/or training costs and allow employees to have a higher feeling of security for their employment situation (Porter, 1998). New employees know that they are not relocating to a one-company town and can feel more confident that if something goes wrong with their current company, they will be able to find work they enjoy without uprooting their families. There is more flexibility both for the companies and for the employees, and in general the business community of the region is strengthened.

Porter's writings on clusters focus mainly on companies interacting in regards to their core business functions. It is seen as an alternative or addition to value or supply chain management. Businesses work together to strengthen the whole of their product/process line and each part gains from that strength. This concept can be expanded for the purposes of other types of company networks. Already there are clusters that incorporate organizations outside of industry, such as research institutes, government bodies, or trade associations. Companies that collaborate and network on non-core business aspects, such as environmental resources or byproducts, can enjoy the same benefits. As Porter (2000) states, "clusters represent a new way of thinking about national, state, and local economies, and they necessitate new roles for companies, for various levels of government, and for other institutions in enhancing competitiveness" (Porter, 2000). This represents a new angle for collocated companies to pursue in order to increase their competitiveness. Companies that might not be related by main product can still benefit from collaboration using the principles of clustering. Companies involved in clusters because they are linked by location can begin to use the strengths of their locality. There are often overlooked links, similarities, and overlaps between firms in the areas of technology, skills, information, marketing, customer needs, training services, health and safety programs, and environmental protection plans, to name a few. Companies see that business aspects once thought of as externalities, or non-mission activities, can together have a large impact on a company's competitive edge. By forming networks in an area with people striving to deal with the same issues, companies can reduce the amount of individual resources devoted to these activities while benefiting from the collective action and resulting supportive network. Clusters can also lead to more local competition between firms. This is a good thing: active local rivalry supports the shift in competition from cost to differentiation, and from imitation to innovation (Porter, 2000). A strong local market and demand puts pressure on companies for continuous improvement and innovation. This eventually strengthens a region's sustainability by creating a robust, diverse company base for the region's economy.

2.4 Organizational Sustainability

To support the creation of a sustainable region, nation, or world, we have to address activities on all levels of society. Corporations control a large part of the flow of resources around the globe. How well they use these resources and for what purposes are of critical concern. Their actions are linked to internal dynamics as well as influences from their surrounding communities, nations, and interactions on global markets. Organizations can be considered the "building blocks of the modern economy" (Dunphy et al., 2003). We must therefore consider the importance of the dynamics within individual organizations in order to secure the foundations of the economy.

The top concern of organizations throughout history has typically been financial survival. If a company could manage to sustain profits, sometimes by whatever means necessary, it was considered successful. Its ability to "sustain" itself was based on economic endurance. Over time, organizations have slowly been held accountable for their actions. Employee health and safety became issues that threatened non-complying companies with serious financial repercussions. The emergence of environmental legislation meant that organizations had to spend time and money to make sure they were reducing their impacts. Now, an organization cannot simply ignore the interconnectedness of environmental and social aspects with their economic performance. Companies must face the challenge of incorporating ecological and social sustainability in economic development. Many have begun to incorporate these three aspects in what is called a business's "triple bottom line." Triple bottom line is a term that plays on the phrase "the bottom line." This phrase was used to mean the most important thing, the ultimate point of interest. For a business, the last line on the financial statement

showed the net result of all the financial figures of the company. By looking at the bottom line, one could quickly asses the financial position of the company, and this was thought to be the most important. In contrast, the triple bottom line has three aspects that are acknowledged as all having considerable importance: economy, society, and environment. The recognition of the interconnection and equal significance of these three aspects is a company's first movement on the road to long-term success.

An organization's move towards sustainability is not always a clear or smooth one. It can be said that they pass through stages, or phases, of thought and action in regards to sustainability. These are quite diverse and each company has unique characteristics and styles that would factor into their progress. However, a simplified model of the progress to sustainability can be made in order to compare the progress between individual companies and between groups of companies in different communities. One model put forth by Dunphy, Griffiths, and Benn (2003) has six phases:

1. **Rejection**: A company rejects the idea that there is anything wrong with the method of exploitation. The firm exists to maximize profits and shows no concern for protecting resources such as employees, the community, or ecology. They actively oppose attempts to constrain company activities.

2. **Non-responsiveness**: A company is more ignorant and unaware of than actively opposing corporate ethics. There is a mode of "business as usual" and environmental impacts are accepted as the consequence of doing that business. Efforts are made to create and maintain a compliant workforce.

3. **Compliance**: There is a focus on meeting minimum standards and avoiding environmental abuses in order to avoid sanctions, litigations, or community actions. Firms are reactive to legal requirements and community demands. A company strives to be a 'decent employer and corporate citizen' by having a safe and healthy workplace. In recent years, there has been increased use of voluntary compliance (proactive collaboration with regulatory agencies) by some leading companies.

4. **Efficiency**: A company becomes aware that there are advantages to being proactive. There is a focus on reducing costs, increasing efficiency, and increasing quality (often through investing in employee training). The company also begins to take stock of its wastes. The company realizes that additional expenses now from these improvement and sustainability measures can eventually have significant payoffs later on.

5. **Strategic proactivity**: A firm moves further along the spectrum of sustainability and integrates the idea of sustainability into the business strategy. The firm sees the potential competitive advantage in making the company an employer of choice making "innovative, quality products that are environmentally safe and healthy." The commitment to sustainability lies in the desire to maximize long-term profitability for the company.

6. **The sustaining corporation**: A firm now has fully internalized the "ideology of working for a sustainable world." A company takes proactive steps to go beyond tradition business activities to promoting ecological sustainability values and practices. The company is involved in promoting sustainability not just within its business but within its community and society as a whole (Dunphy et al., 2003).

As mentioned, these phases are simplified. Organizations can skip phases in their progress or decline along the path of sustainability, and they can be in different phases at the same time in respect to social versus ecological issues. However, this model is valuable because it provides a way to assess the relative approach to sustainability of a company in an understandable way.

Organizations are responding to new demands to assume responsibility from sources such as the Dow Jones Sustainability Index, the Global Reporting Initiative, and other numerous forms of social and environmental accountability fora. Some steps taken include a movement towards whole system thinking, where all of the activities of a company are evaluated in a holistic way. Processes are not just looked at piece-meal, but they are evaluated in the context of e.g. how they inter-relate, how product life-cycle is incorporated, as well as how this is achieved within their specific location and community situation. The company is analyzed as a whole system. Part of creating a learning organization is to continuously refresh this system thinking. Peter Senge tells the story of a US automaker discovering why a Japanese automaker was able to achieve "extraordinary precision and reliability at lower cost." The Japanese car was disassembled and found to have the same type of bolt used three times on the engine block, each for different types of components. The American car had three different types of bolts, requiring three wrenches and three inventories of bolts, adding to the time and cost of assembly. This was because there were three teams designing the American car, each responsible for their component only. The Japanese had one designer responsible for the entire engine mounting (Senge, 1990). Separated, the American teams were unable to see that they were part of a larger system. So although their designs functioned correctly, they could have been even better had they taken an opportunity to step back and look at the whole system and its interactions.

This can be taken further to look at the organization within the whole system of the community. A more recent example of the resources that can be saved by looking at the system as a whole can be found in Puerto Rico. Industrial ecology scientists working on the island found that as a whole, Puerto Rico imports about 400 tons/week of recycled glass for glass manufacturing, while each week about 1000 tons of recyclable glass are discarded. About 500 tons/day of used boxboard for cardboard manufacturing are imported, and about 800 tons/day of recyclable boxboard are discarded (Brattebo, 2004). This shows that the companies involved in these trades are clearly not aware of each others' activities, and are missing out on ways to collaborate to benefit themselves, their colleagues, and their communities. An organization must be aware of the industrial system within which it functions. It is not an isolated company trying to stay ahead of other isolated companies. Instead, companies are bound together by interconnected actions, each one having subtle influences on the next, which in turn are influenced by other forces of policy, markets, and so on. The ability to acknowledge these interrelationships and learn from them can increase competitive advantage for companies. This means that companies will go beyond "greening" their own operations by working with other organizations. They can help smaller organizations accomplish sustainability goals. They can also work with other organizations to create symbiotic cycles of industrial ecology. In this way, a cycle of sustainability is created. The understanding and acting on responsibility flows from a broad world view, to regional, to the individual organizations, and then cycles back up as organizations extend their sustainability and learning efforts from internal work, to networks, to regional, national and finally international progress.

3 Industrial Responsibility

As one of the key drivers of economic activity, the industry sector has a large responsibility to pursue more sustainable approaches to their business pursuits. The field of industrial ecology (IE) has emerged as a way for industries, organizations, and the community as a whole to collectively pursue more responsible, sustainable practices. The practice of IE helps balance ecological concerns with the economic and social concerns already in the mindset of companies. Global companies can work within a cluster, or network, to promote long-term success both of their company and of the region within which they work. IE practices could provide opportunities for making gains in environmental, social, and economic areas for all involved.

3.1 Industrial Ecology

The field of industrial ecology was born in an attempt to develop industrial practices that were more socially and environmentally responsible. Van Leeuwan, et al. (2003) explains the field of industrial ecology in the larger framework of societal drivers for increasing the environmental component of responsibility in industries (van Leewen et al., 2003). These ideas are brought together in Figure 3-1 below.
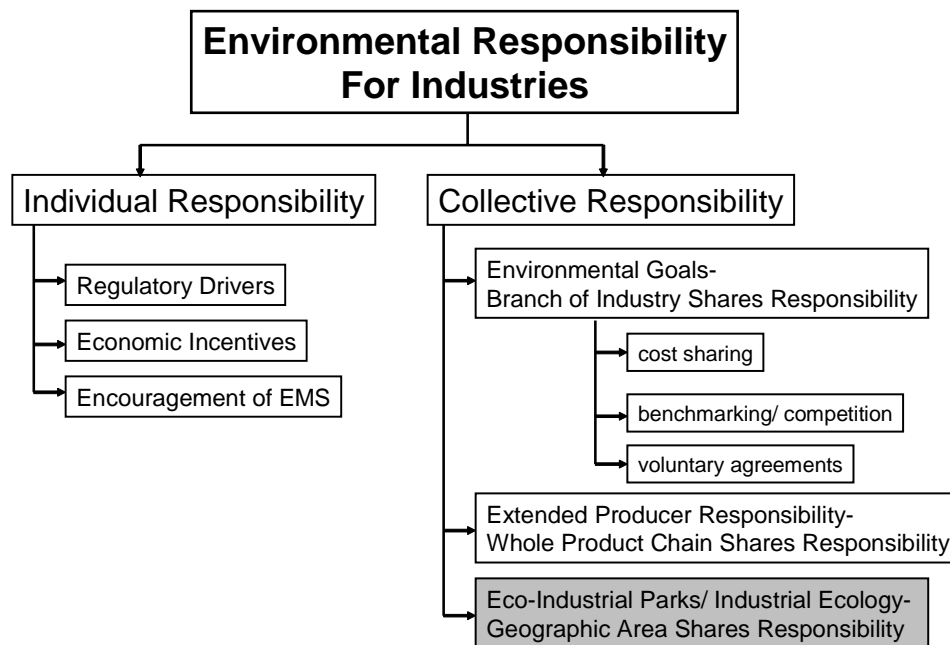
Figure 3-1 Environmental Responsibility for Industries (adapted from van Leeuwan, et al., 2003)

As shown in the diagram, there is a push for both individual and collective responsibility from industry. Individual firms are encouraged or, in some cases, forced to improve their environmental performance with tools such as government regulation, economic incentives, and environmental management systems (EMS). There are also schemes for sharing environmental responsibility among many industrial actors. This involves sharing responsibility in three main forms[3]: by branch of industry, product or value chain, and

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[3] Baas and Boons (1997) actually define these three divisions as system boundaries of an industrial ecology.

geographic area[4] (Van Leeuwen, 2003). The third form, shown in grey, will be the focus of this analysis however it should be kept in mind that industrial ecology networks can, and possibly should, have aspects of all three collective schemes.

The field of industrial ecology has grown over the years and many forms of interaction and interpretation have developed. The field and interactions have also acquired many labels and sub-divisions, such as industrial symbiosis, industrial metabolism, eco-industrial parks, eco-factories, etc. As this field is still developing, the structure of the industrial ecology relationships is still evolving.

In academic circles, the concept of industrial ecology is usually traced back to the works of Nicholas Gallopoulos and Robert Frosch, with the publication of their report "Strategies for Manufacturing" in 1989. This article built upon the analogy of natural ecosystems and industrial systems. The main idea is that an industrial system is a part of its natural surroundings, and must act in accordance. According to Frosch and Gallopoulos, the basic features of industrial ecology systems should be:

- Energy requirements should be minimized, as well as should waste generation and the consumption of scarce resources.
- Industrial wastes and discarded products should be used as input to industrial processes '...in a way analogous to the cycling of nutrients by various organisms in an ecological foodweb'.
- The systems should be diverse and resilient in order to absorb and recover from unexpected shocks (Frosch and Gallopoulos, 1989 in Boons, 1997).

With these features, industries would practice cleaner production, waste and by-product exchanges, and long-term planning by the network.

Ayres introduced the term "industrial metabolism" to explain this relationship on a more material basis. Ayres proposes that one can consider the similarities of the "metabolic functions" of both the economic and ecological systems: both have ingestion (intake of raw materials), digestion (processing, separation of valuables from waste), reproduction and growth (production or growth of firm), and excretion (waste disposal). This can be seen in Figure 3-2 which shows part of the ecosystem cycle where the excretion of Firm I is transferred to the ingestion stage of Firm II (Ayres, 2004).

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[4] Although industries are often co-located, there exist variations of Eco-Industrial Parks or Industrial Ecology Networks (or other versions of this concept) that are not strictly co-located.
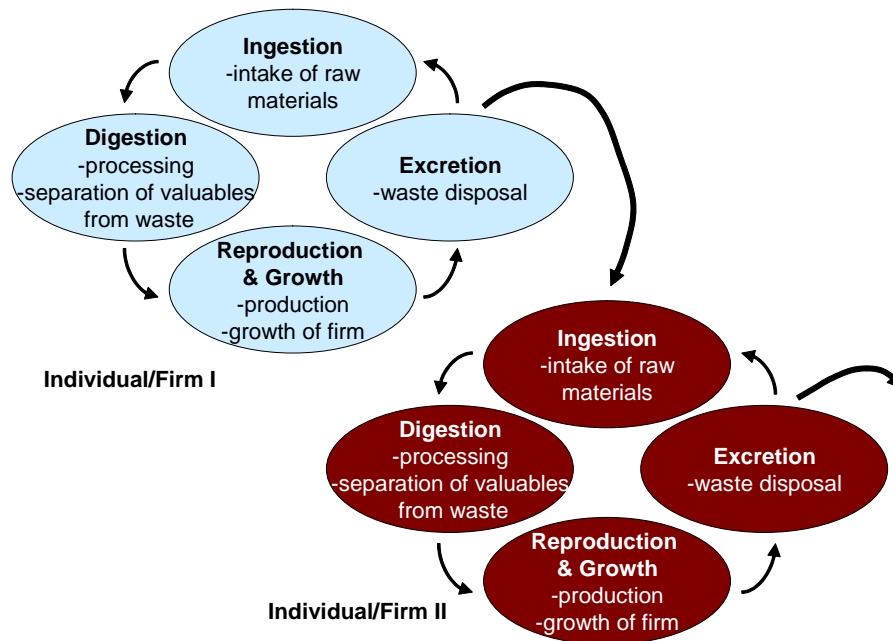
Figure 3-2. Metabolic Functions of Industrial and Natural Ecosystems: One Part of the Cycle (adapted from Ayres, 2004)

In more recent years, Graedel and Allenby (1995) describe industrial ecology as a systems-oriented vision of manufacturing that involves the "design of industrial processes and products from the dual perspectives of product competitiveness and environmental interactions." They define a systems view as being aware of factors such as resources, energy, and capital for the total materials cycle, from cradle to grave (Graedel, 1995). This systems view encompasses all aspects of industrial responsibility, whether companies are acting alone, or as part of collective schemes shown in Figure 3-1.

3.2 Industrial Symbiosis (IS)

According to Chertow (2000), industrial ecology's goal of optimizing energy and material flows, and closing system loops, can occur at the facility, inter-firm, and at regional or global levels. At the facility level, activities may include design for the environment, cleaner production, pollution prevention, etc. At the inter-firm level, there are exchange and interaction options among several organizations. This level can be called Industrial Symbiosis (IS), where "traditionally separate entities [engage] in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products." IS can also involve the exchange of human or technical resources such as organizational infrastructure, experience, and know-how. The symbiotic relationship between and among firms is meant to "exchange materials, energy or information in a mutually beneficial manner" (Chertow, 2000). IS is often be confused with waste exchange programmes, however there is a clear difference. As members of the National Industrial Symbiosis Programme (NISP) explain, waste exchange programmes "focus on 'one time' 'spot' exchanges of solid wastes" and contact or contracts between parties is not always necessary. On the other hand, IS programmes are more complex, with more extensive exchanges between parties and a goal of "long-term, continuous partnerships based on direct communication" (NISP, 2002). In practice, IS networks, programmes, or systems are often referred to as Eco-Industrial Parks (EIP). Although these terms are used interchangeably, EIPs usually represent areas or districts where IS networks operate.

There are many types of IS networks, and many ways to categorize them. The different classifications circulating in academic circles can be simplified for the purposes of this review into three groups: networks defined by 1) development process, 2) scope of interaction, and 3) type of organizations. This is shown graphically below in Figure 3-3. This figure is a compilation and interpretation of IS descriptions found in the works of e.g. Chertow 2000, NISP 2002, Wallner 1999, Baas and Boons 2004, Graedel and Allenby 1995.
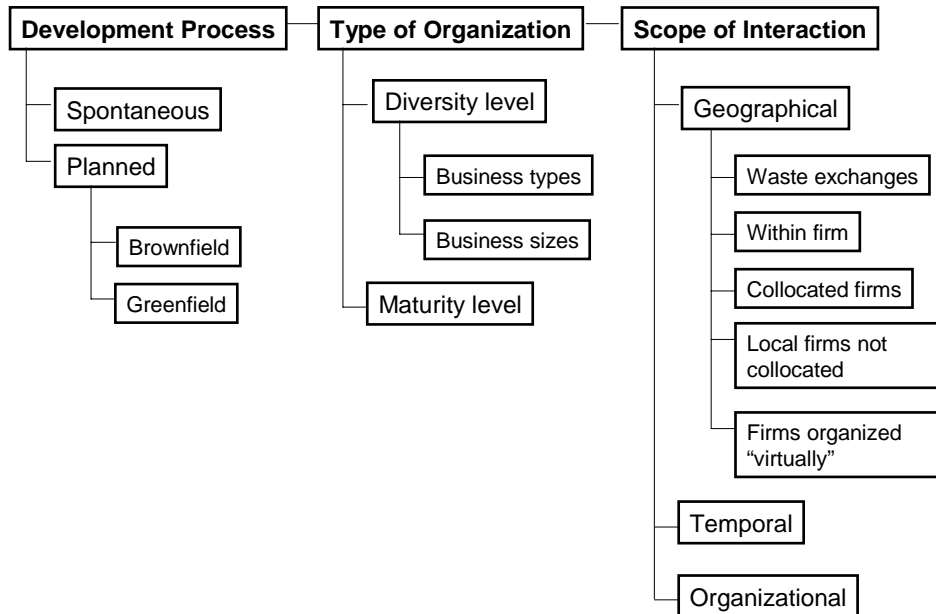
Figure 3-3 Classification of IS Network Interactions

The distinction by development process refers to whether a network spontaneously evolved or it was planned. In spontaneous networks, connections are usually made out of economic motivations for the companies involved. There can often be no conscious realization of a special pattern because companies are acting in their own best interests and aren't aware of all the other links developing in the community. An example of this is the network in Kalundborg. As one Kalundborg representative noted, economic benefits were seen as the primary driver of connections while environmental benefits were discovered later as added bonuses. Exchanges were arranged between or among individual companies with no awareness of fitting into an industrial symbiosis 'framework'. Agreements were spontaneous and initiated independently. After parties realized that there was a pattern in the region, the Kalundborg site was labeled as an industrial symbiosis network (Christensen, May 28, 2004). Planned networks can either be considered 'brownfield' or 'greenfield' sites. In brownfield networks, there is a methodical search for potential connections between industries that already exist in an area. Connections are usually encouraged and facilitated with the broader view of how all the industries can become interlinked. Examples of this type of planned network are found in the UK in the regions of Humberside, West Midlands, and Mersey Banks. The Business Council for Sustainable Development- United Kingdom (BCSD-UK), in academic partnership with the International Institute for Industrial Environmental Economics (IIIEE), has coordinated and facilitated the establishment of these planned IS programmes. Coordinators worked with existing industries by performing preliminary studies, hosting awareness raising workshops, collecting and analyzing data, and leading in the identification

and implementation of synergies (M. Mirata, 2004). Another example of a planned IS network can be found in Landskrona (to be discussed further in this thesis). Greenfield networks involve planning the network from scratch. Industries or companies are recruited to an area because they are identified as fitting connection requirements. An example of this is the Cape Charles Sustainable Technology Park in Virginia, US. This park was built to encourage sustainable use of resources and is now recruiting industries who can meet criteria designed to promote high environmental standards (Manter, n.d.). The difference between planned versus spontaneous networks can be an important one when discussing the long-term vision of a network and the desire to make connections happen on a shorter time-scale.

The types of organizations can be classified by the diversity level of actors (diversity of business types and sizes) (Wallner, 1999) and the maturity level of actors (loosely organized interaction or formal, sustainable industrial district) (Baas and Boons, 2004). Maturity level describes many ways of looking at a network. It can be the phase of progress companies have made in moving towards sustainability (as described in Section 2.4). Maturity level can also describe the relative progress achieved by the group of companies together, meaning how advanced the IS network is in e.g. types of connections made, level of learning, and/or amount of social, environmental, and economic improvements that have been achieved so far.

The group defined by scope of interaction incorporates categories of geographical scope (one facility or among many collocated firms) (Chertow, 2000), temporal scope (activity by demand or permanently active exchanges) (Wallner, 1999), or organizational scope (exchange of minor by-products or sharing of core-business resources). Chertow (2000) identifies five types of material exchanges that have varying degrees of geographical range:

1. through waste exchanges
2. within a facility, firm, or organization
3. among collocated firms
4. among local firms not collocated
5. among firms organized "virtually" across a broader region

Those types that can be considered IS involve two or more firms acting in an extended relationship, and so correspond to types 3-5 of this classification (Chertow, 2000).

As the field of IS is still evolving, the classifications are meant more as a general guideline. There are overlaps between these classifications and some projects may not clearly fit into any of these categories. It is still useful to begin to outline the types of networks though, as it lets researchers see where the greatest potential for steering effects may lie. For example, researchers, or change agents, concerned with guiding an IS network towards having a greater potential for regional sustainability may consider their roles in planned IS networks. In these planned networks, there may be great room for positively influencing and accelerating the outcome of efforts at collaboration.

3.3 Sustainability Framework of IS Network

The pursuit of sustainability in IS practice will be directed by the specific conditions of the network. Not only is the type of network a factor in what can be achieved, but also the location characteristics are important. Even if two types of network are the same, their paths to sustainability can be quite different due to differences in e.g. culture, environmental awareness, education level or legislation. Nevertheless, a general sustainability framework can be created that can be applicable for all networks as an ideal vision.

There is often greater emphasis put on the environmental dimension of a sustainable IS network. Economic and, more recently, social aspects of business have been developed and now there is an effort to bring environmental aspects to the same level. One model was set forth by Korhonen (2001) and explains the underlying environmental principles of an ideal network.

In theory, an industrial system that mimics the natural ecosystem sets out on a path of sustainability. Table 3-1 shows the parallels between the natural and industrial systems.

Table 3-1 Ecosystem principles in industrial ecosystems (Korhonen, 2001b).

ECOSYSTEM	INDUSTRIAL SYSTEM
Roundput	*Roundput*
Recycling of matter Cascading of energy	Recycling of matter Cascading of energy
Diversity	*Diversity*
Biodiversity Diversity in species, organisms Diversity in interdependency and co-operation Diversity in information	Diversity in actors, in interdependency and co-operation Diversity in industrial input, output
Locality	*Locality*
Utlising local resources Respecting the local natural limiting factors Local interdependency, co-operation	Utilising local resources, wastes Respecting the local natural limiting factors Co-operation between local actors
Gradual change	*Gradual change*
Evolution using solar energy Evolution through reproduction Cyclical time, seasonal time Slow time rates in the development of system diversity	Using waste material and energy, renewable resources Gradual development of the system diversity

The analogy is demonstrated through four themes, or parts of a natural system: roundput[5], diversity, locality[6], and gradual change. The generic industrial ecology system is meant to promote closed loop cycles, respect for the local natural carrying capacity (limiting factors), and use of renewable resources. With these four themes in mind, a model of the "ideal" industrial system is presented in Figure 3-4 (Korhonen, 2001b).

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[5] 'Roundput' was developed by Korhonen as a term meant to be the opposite of the concept of 'throughput', which usually indicates a linear flow of material in a system.

[6] Korhonen later noted that the principle of locality should be adjusted for regional considerations. An example given was for certain biomass-rich regions where the export of local renewable fuels could reduce fossil fuel use in other regions (Korhonen, 2004).

solar energy

roundput | **Ecosystem - environmental win** | diversity

roundput | diversity

Industrial recycling (roundput) system - economic win

use of renewables by respecting the renewal rate

outputs that nature tolerates and re-uses

locality | gradual change

locality | gradual change

waste heat (infrared radiation to space)
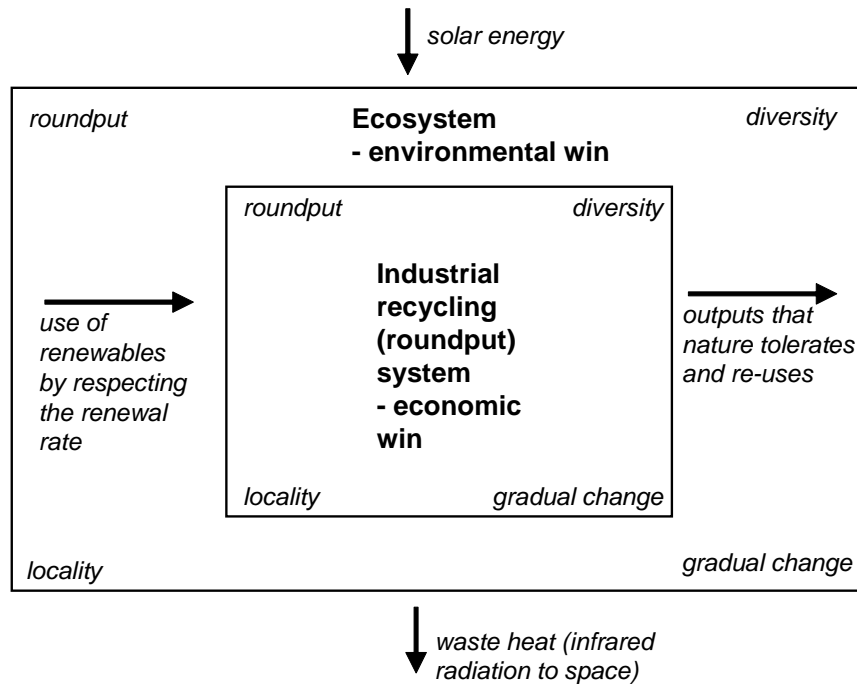
Figure 3-4 Vision of a perfect industrial ecosystem (Korhonen, 2001b).

In this ideal model, both the industrial and natural systems would operate with the same principles (as explained in Table 3-1). The industrial system would be a sub-system of the natural one, and inputs and outputs would be transferred with respect to the capacity limitations of the natural system. The natural ecosystem would benefit from long-term reduced pressure and exploitation, and the industrial system would benefit through economic gains such as "reduction of raw material and energy costs, costs resulting from environmental legislation, waste management costs," etc. This ideal system would also satisfy the requirements for progressing towards regional sustainability. Nevertheless, as Korhonen notes, it is clear that there will never be a perfect, or ideal, industrial ecosystem. This model is meant to show that learning from the ecosystem is the direction that should be followed when "striving toward sustainable development" (Korhonen, 2001b). It should be understood that nature is meant as a model, or a metaphor, towards which to strive. Natural systems are extremely complex and it would be naïve to assert that we could correctly mimic all its interactions. As many researchers say, much can be gained by "learning from nature by selectively applying nature's smart solutions, evolutionary strategies and ecological principles" (Isenmann, 2003). The idea is to understand that industrial systems are interlinked with natural ecosystems and IE is an attempt to determine how an industrial system can be restructured to work in concert with the natural one.

These ecological themes form a basis for the flows within an IS network. A profile of a sustainable IS network can be further developed by using the themes as a foundation for what makes a network. A sustainability framework was developed to show the interaction between the long-term goals of sustainability (described as areas or rules in Section 2) and the strategies to achieve those goals (based on the work of Shi et al., 2001). This is shown below in Figure 3-5. There are five strategies developed by Shi et al. (2001) that correspond to environmental goals of sustainability:

1. dematerialization of products (replacing resources by services and techniques, such as information techniques, nano-techniques, molecular manufacturing, and so on);

2. greening of products (alternatives of forbidden products, bio-degradable products, recyclable products, and other environmentally benign products);

3. greening of processes (energy integration, mass integration, the green catalysis system, the non-solvent reaction system, the mild reaction system, and so on);

4. greening of feedstocks (alternating or reducing toxics use, replacing minerals by biomass); and,

5. resourcelization of wastes (waste reclamation techniques) (Shi, et al. 2001).

The three remaining strategies—diversification, awareness, and regional networking—correspond to economic and social goals. These strategies are shown in Figure 3-5 with arrows indicating where the most direct influence on sustainability goals can be gained. However, as will be stressed throughout this thesis, when working in a system it is necessary to keep in mind how parts of the system are or could be interconnected. There will be synergies and overlaps among strategies. The actions of companies can create feedback loops which help the progress of achieving more goals than just the two main ones. The strategies are interlinked and therefore could have influence over achieving many of the sustainability goals. These strategies, along with relevant tools, will be discussed further in the next section.
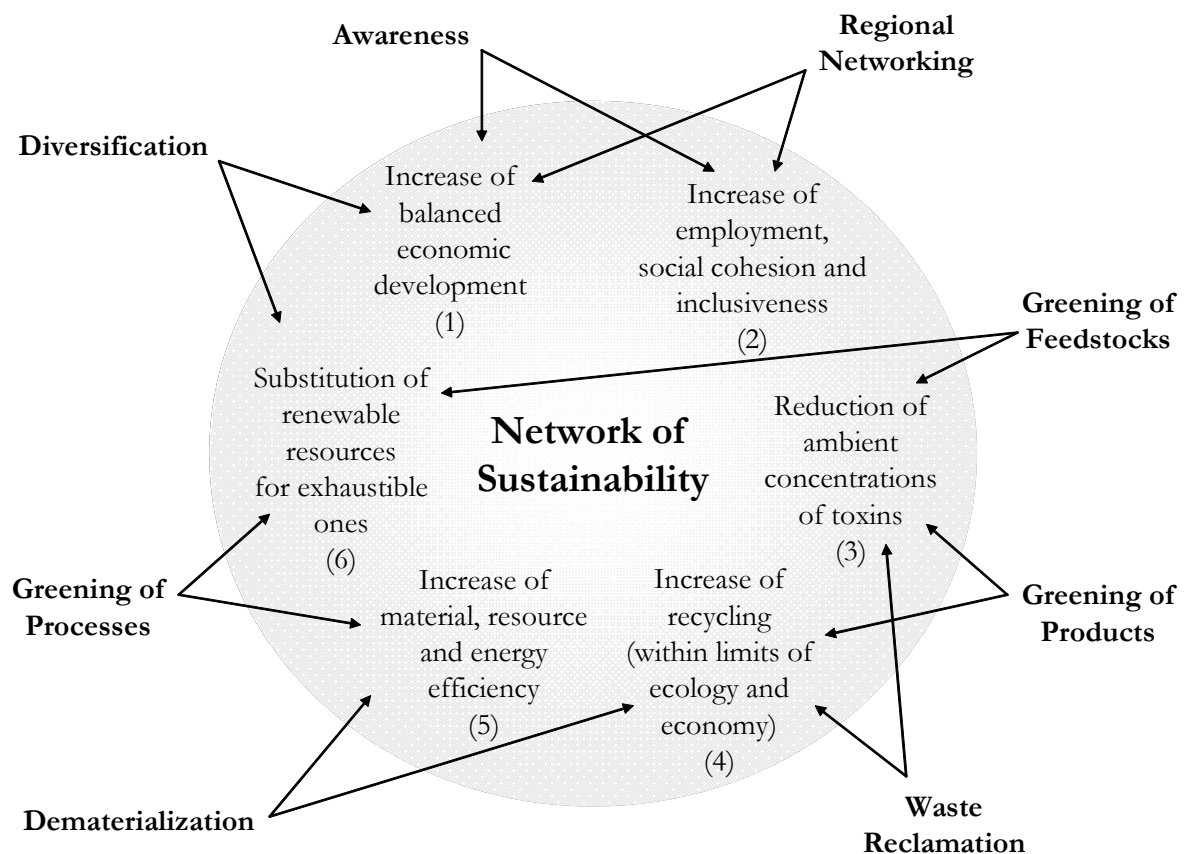

Figure 3-5 Sustainability Framework for IS Networks: long-term goals and strategies

3.4 Strategies for Sustainable Networks

The positive steps of companies engaging in IS should not be underemphasized. Each type of IS network shows improvement over the "traditional" industry model. Companies have persevered in collaborating in IS despite many large organizational, technical, and informational challenges. There have been great achievements in reducing environmental impacts and aspects. Wastes have been reduced and in most cases, there are initial reductions in resource use. However, these successes should not be assumed to completely satisfy efforts for regional sustainability.

Heeres et al. (2004) state that in theory, an IS network has the potential to "both benefit the economy and substantially relieve environmental pressure in and near the location of its development" (Heeres et al., 2004). It does this by fostering collaborations that focus on not just waste exchanges, but also on stressing integrated, minimal use of resources. Boons and Baas (1997) also argue that IS practice should be an "integrated approach towards the environmental effects of industrial processes, rather than aiming at the reduction of the effects of separate industrial processes" (Boons and Baas, 1997). In other words, the main focus of IS should not be an end of pipe exchange of 'problems' turned into 'opportunities'. The following eight strategies can be used to ensure that an IS network addresses concerns of sustainability along the entire life-cycle of operations, affecting both the production and consumption loops. This section will discuss these key strategies for pursuing regional sustainability through network establishment. Examples of well-known IS networks will be used to discuss the current alignment between IS and sustainability.

3.4.1 Diversification

Diversification can have many connotations and levels when used in the context of IS networks and regional sustainability. In its most simplified form, diversification means the creation of variety for a system. This can prove to be an essential element for long-term survival of that system, whether it is the region acting as a system, or businesses within the region in the system of an IS network. For a region, having diversification in businesses is important for the ability of the region to respond to economic slumps. When regions have a diverse array of businesses or industries within them, there may be some industries that are more resilient to changing markets. They can form a solid base for a region until other companies have a chance to recover from a recession or other economic hardship. In this way, a region is less likely to enter a downward cycle of industrial failure. Another advantage to diversification of a region is the ability to attract a broader range of actors to that location. Diversity in the type of businesses and people can increase the new ideas and entrepreneurship in an area. Different strengths of people and industries can be combined in new ways to boost innovativeness and creativity so that new markets, products, or services can be provided. This can increase the ability of a region to pursue a more balanced economic development (goal 1 in the sustainability framework).

A diversification of businesses acting in an IS network sees the same advantages as the region. When there are a variety of actors of different size, structure, and industrial sector, a network can evolve and respond to external pressures more easily. For example, if markets in a certain sector are shrinking, businesses in another sector may be able to provide their network partners with new insights or support in how to recover. Smaller companies may provide larger companies with opportunities to try out pilot scale tests of new materials recovery methods. With a diversity of actors, there is a large potential for companies to share access to resources without being in direct competition with each other. Each actor can find its own niche in the market place and be able to collaborate and share information with less threat. Diversification can also apply to the types of connections that are established between

companies. The type of connections can be anything from using one company's metal scraps as another's raw material, to sharing the management of health, safety, and environmental training programs. Connections can be on a flexible level, such as the purchase of byproducts that can be dropped off at the receiver's facility when enough volume is gathered. They can also be more permanent, such as the construction of pipelines among facilities that transports waste heat (in the form of hot water) for district heating. Each connection made in the IS network will require planning, business agreements (either formal with contracts or informal with verbal discussions), and some form of risk before it can be realized as a success. Some industrial outputs will require more complex designs and agreements, and might therefore have a higher risk value. With a more diverse set of choices and actors involved, risk can be distributed more easily. This supports the concept of diversity as described by Korhonen (2001b) in Section 3.3.

3.4.2 Awareness

One of the representatives from the Kalundborg IS network in Denmark stated that "industrial symbiosis is seen in Kalundborg as a management and communication phenomenon" (Christensen, 2004). For them, communication and mindset are seen as more important than technology. The importance of these themes holds true for most networks. No connections can be promoted unless people are aware that an opportunity exists. The first step is for local companies to simply communicate openly and frequently among themselves. Open communication and sharing of information can lead to the next step of building trust among network participants. Trust acts as the foundation for exploring new ideas and business ventures. With strong trust, connections may go ahead even though there are longer payback periods than companies are used to. Once a basic trust is established, people can begin to see that a long-term relationship can help all parties. More patience can be given to examining all the angles of how connections can be made.

It is also important for participants to be aware not just of how local companies interconnect, but also of how they affect and are affected by their communities. A high level of awareness of impacts from working in a region can begin the process of directing those impacts to become more positive. Again, it is difficult to change a system for the better if participants are unaware of the need to change and develop. Increasing education is vital to helping this process of improvement. Education in this sense means that participants increase their knowledge and skills through a learning process. Learning can take place at the individual, organization, network, or community level. Participants can learn from others' mistakes without having to spend the time and money to make them themselves. Equally, successful attempts can be mapped out for organizations by those who have been there before. Both internal and external experts can host network-wide education sessions. When people are educated on what possibilities exist, it is easier to brainstorm ideas and creative solutions to troublesome issues. Individuals and organizations also gain a larger base of tools with which to work. Communication and information dissemination can be a critical factor for the success of an IS network. In a study comparing networks in the US and the Netherlands, researchers found that the top two factors for success were active participation by participants and the presence of an entrepreneurs'/employers' association. The association was important because it acts as "an effective platform to educate and inform companies of the potential benefits" and "functions as a much needed communication platform between the companies" (Heeres, 2004). The top ranking IS network (out of 6 studied) had both an entrepreneur's association and an educational institute involved in the project.

Awareness raising, communication, and information sharing is also necessary with potential critics (e.g. NGOs or environmental groups) of industries as well as allies from the

community. If community members are aware of what industries are trying to do, they can be more supportive and create a receptive atmosphere for change. The same can be said for involving consumers in industry efforts. Consumers play a large role in placing demands on industry activities. If they are more aware of what goes into making their desired products or services, and the potential benefits of IS endeavours, they can use their market power to reward these more sustainable practices. Elevated communication and education add to a positive feedback loop, where increasing trust and awareness can lead to more possibilities and positive experiences and vice versa. Taken as a whole, a higher level of awareness of local issues is essential for dealing with larger economic, social, and environmental issues in a region (thereby influencing almost all of the sustainability framework goals).

3.4.3 Regional Networking

Cortright (2001) concludes in his summary of Annalee Saxenian's work that companies' degree of openness and willingness to collaborate can be essential for collective survival of a region's industries. Saxenian compared the success of California's Silicon Valley firms with the failure of Boston's Route 128. Some of the few significant factors for the success of Silicon Valley firms proved to be their informal internal practices, their openness to new ideas, their ability to collaborate, and their strong networks (Saxenian 1994 in Cortright, 2001). Networking of local businesses is the first step to create a more resilient local presence. It is important enough to emphasize regional networking as a strategy of an IS network. Locality is one of the attributes of an ideal industrial system, as put forth in Korhonen's model (2001b), as well as of an ideal network. It involves the use of local resources and co-operation between local actors as described in Section 3.3 and demonstrated with the example of Gnosjö (see Section 2.3). The Gnosjö region is successful in part because businesses have a high stake in local issues. Businesses are locally owned and community members buy and sell resources from each other. The product or service sold to external markets is value-added, which implies that the highest price obtained for that product/service is kept by a Gnosjö company and not by a separate retailer. This more local focus keeps the cycle of wealth within the region and prevents a large throughput not just of energy and materials, but also of wealth. When raw materials are purchased from outside the region or when sales profits are directed to distant headquarters, economic benefits can flow out of the region. Alternatively, as shown with the Gnosjö example, trading products and services within a region leads to companies supporting each other and strengthens the region's economy.

3.4.4 Greening of Feedstocks

The greening of feedstocks is the reduction of use of toxics and exhaustible resources. When following this path, companies begin to substitute their fossil-based fuels and toxic raw materials for more environmentally benign resources. This relates to the principle of gradual change, where a system gradually shifts to using resources that are able to tolerate the level of depletion. This is a necessary change when looking at the whole picture of sustainability. To achieve goals 3 and 6 of the framework, a vision for long-term reduction of non-renewable resource use and toxics should be in place for an IS network as a whole and for the individual companies.

In practice, IS networks have had mixed success when aiming for the greening of feedstocks. Instead of searching for substitutes for toxic inputs, companies begin to search for connections with other companies who can make use of these toxics that come out at the end of the pipe. There has been more progress with changing fuels. It is becoming more common in Europe and Nordic countries to have district heating systems for industrial districts, towns and cities. In Sweden, district heating is about 40% of the market share for heat

(Constantinescu, 2003). It is provided to a large extent by renewable fuels (usually woody biomass) and industrial waste heat (Statistics Sweden, 2002). An example of an IS network where a regional power plant is using a combined heat and power system and using renewable resources is in Jyväskylä city in Finland. The city power plant uses local waste materials as fuel, mostly from the forestry industry. They have reduced the use of fossil-based external fuels (coal and oil) by approximately 40%. There is large potential to expand the replacement of fossil fuel use in the region due to the type of technology (fluidized bed burning) used in the power plant (Korhonen, 2001a). This type of action supports the desired shift in industrial contributions to reducing fossil-fuel use for heating purposes.

Unfortunately, this is not common practice for IS networks. A district heating loop usually accounts for only a small part of the fossil-fuel use in the region. Without the long-term goal of greening of feedstocks, there is a potential that the use of fossil fuel use can become more entrenched in society. This can be illustrated with an example of one of the most well-known, and probably most advanced, IS networks: Kalundborg, Denmark. This network evolved over two decades and is touted as the ideal model. Involved are six processing companies, one waste handling company and the Municipality of Kalundborg. There is also a Symbiosis Institute that provides information, support, and facilitates mentoring for other IS networks. At its core, there is a coal fired power plant and an oil refinery. This type of network has made great strides in helping the region reduce its environmental impacts. As mentioned, at its core are companies dependent on oil and coal. In the beginning of the Kalundborg network, the power company set up a district heating loop and replaced 3,500 oil furnaces from the community, reducing about 20,000 tonnes per year in fuel oil consumption (Kalundborg Centre for Industrial Symbiosis, n.d.). About twelve years ago, the power plant began substituting some of the coal fuel with surplus refinery gas (Indigo Development, 2003). However it seems that further innovation in switching to renewable or cleaner fuels has not happened since that time. This suggests that this IS network has the potential to prolong the use of these fossil fuels by creating a system that maintains the success of these businesses. Furthermore, Kalundborg's oil refinery has doubled its capacity over the last several years (Chertow, 2000).

Of course, this is not a simple black and white picture of switching from oil to wood. It is common for IS networks around the world to have a power plant or refinery as an anchor business. For example, most of the companies in the INES (Industrial EcoSystem) Project in Rotterdam are crude-oil refineries and chemical industries (Boons and Baas, 1997). It is understood that at least in the near future, there will most likely be a continued demand for fossil fuel for meeting the current energy needs of society. In order to reduce this fossil fuel use, the entire industry or company would have to shift and all the dynamics in the network would change. Although this could be a long-term goal for a region, a realistic view is that, in the meantime, it is better to have these industries involved in IS networks than not at all. In this light, from a regional or even global perspective it may be preferable to supply our fossil fuel needs from companies involved in networks such as the one in Kalundborg. Nevertheless, this enduring use of fossil fuels ultimately is not in harmony with regional sustainability goals of minimizing the consumption rate of exhaustible resources and developing the use of ecologically benign, clean resources.

3.4.5 Greening of Processes

IS networks are often cited as helping reduce resource use because the cumulative use of resources becomes less than if actors were supplying their needs without the awareness of potential network-focused alternatives. For example, Company A can reuse the water from Company B for their needs instead of from a local lake. This is good practice, but it does not

necessarily guarantee that there will be long-term reduction of resource use. Actions must be taken both on the network level as well as on the individual level. Even if a feedstock to a company is changed to be more 'green', the way it is used can negate a lot of the environmental benefits. The greening of processes involves changing organizations' operating and product systems so that the processes put the least strain on environmental resources. This means that a company focuses on how it is using resources in its operations and tries to improve this. This could be done by changing process techniques to use more environmentally benign materials or inputs, or by redesigning processes to either eliminate or reduce the need for certain inputs. Economic benefits can also be gained for the companies by reducing the cost of inputs through eliminating inefficiencies. The intent of this path is the long-term reduction of resource depletion on an individual level that can be combined with network level actions. In an ideal version, companies would seek to exchange materials and resources on the network level only after they have done all they could at the individual level to reduce their inputs and outputs. When companies green their individual processes, this can lead to satisfying goals 5 and 6 of the sustainability framework.

For many businesses competitive advantage is the focus of success. This is not necessarily linked to an efficient use of resources (Boons and Baas, 1997) and very seldom linked to effective use of resources. Therefore, there exists no obvious incentive for companies to evolve towards eco-efficiency, either on their own or within an IS network. In fact, there might even be less incentive for companies in IS networks to improve their eco-efficiency since they may now find alternative markets for materials previously "wasted." With a new revenue source, there is no drive for reducing the excess use of resources. Figures from Paul Hawken for the United States suggest that for every 45 kilos of product manufactured, 1451 kilos of waste have been created (Cohen-Rosenthal, 2004). Industry can do better than this ratio. Eco-efficiency and dematerialization is actually stronger in other industry networks, such as integrated chain management. Within these networks, there are often take-back programs, product redesign (including changing of materials used), and other pollution prevention activities (Heeres et al., 2004).

For those IS networks that achieve a higher level of eco-efficiency, there still remains the ever looming rebound effect. When efficiency increases, there will most likely be an increase in consumption or production levels. For example, when fuel efficiency is increased, production costs and prices can go down. This stimulates increased demand to the point that fuel consumption may actually increase (Korhonen, 2004). In other words, industries that gain efficiency may have an incentive to produce twice as much for the same amount of input, instead of cutting their production in half. The case of Kalundborg, where the oil refinery doubled its capacity, could perhaps demonstrate this "perverse incentive."

There are many tools that can be used to help companies green their processes. Some of these include using an environmental management system (EMS), total environmental quality management (TEQM), and Cleaner Production (CP) audits. Developing and using an EMS helps a company view their business from a systems perspective. They begin to systematically identify their largest environmental aspects and impacts and can create plans to mitigate these. An EMS allows a company to more easily track its progress towards continual improvement. EMS can be combined with a quality management system for a total environmental quality management system, where all business systems and improvements are integrated. This may involve life cycle analysis, environmental auditing, waste management, emergency planning and prevention (Cote, 1995). Another very effective tool is using CP techniques. In CP, the root cause of waste or inefficiency is examined. Instead of finding a way to treat wastes, one focuses on the process that created it in the first place. Questions are asked such as:

- Why is the product produced in the first place? Is there a better type of product that would satisfy the same need?
- Why is the product produced in this way? Is there a better way to design the whole process?
- Could the use of energy and materials be more effective and efficient (Siljebratt, 2004)?

This leads to recommendations for changes in process systems or a rethinking of the whole operation in order to mitigate environmental impacts and economic losses.

Implementing these changes in practice has been difficult. An example can be seen in the INES (Industrial EcoSystem) Project in the Rotterdam harbour area. There were two studies (pre-feasibility and feasibility) performed before the implementation phase, and a workshop which resulted in companies declaring their commitment to environmental management, cleaner production, integral chain management, industrial ecosystem, and sustainable development. The foundations for a sustainable IS network seemed solid, but problems fulfilling this vision arose even before implementation. Baas (1998) notes that "in many cases a lack of support for continuous cleaner production improvements at higher decision-making levels in the companies was shown." He also observed that many of the companies in the INES project in practice were still in a "reactive and receptive phase." So, although the goal of internal reduction of resource use was professed from the beginning, there was no concerted effort to do internal audits before or after entering an IS network (L. Baas, 1998).

One network still in development that has tried to encourage CP is the Burnside Industrial Park in Nova Scotia, Canada. This park contains about 1300 businesses, most of which are considered small to medium (SME) enterprises. In 1992, a project was started to convert the industrial park into an eco-industrial park (an IS network). In 1995, initial participant surveys indicated a strong commitment to the environment. Some were willing to change business practices: 36% have considered substitute materials and 45% have considered alternative processes to reduce waste (Cote, 1995). These seem to be well-intentioned businesses, however it is unclear how many actually followed through with business changes. The issue of companies following through with commitments for action can be addressed within the network by making a strategic plan with the companies that includes long and short term actions. Companies can then be guided in transitioning from their present state to the fulfilment of their plans. The role of planning and transition management as a tool for guiding networks will be discussed further in Section 3.5.

3.4.6 Greening of Products

The next step in ensuring that an IS network is aligned with regional sustainability is reducing impacts from the <u>entire</u> production loop. There must be continual evolution towards respect for the natural ecosystem in all parts of a region. This can help attain high levels of environmental protection. When aiming for an IS network aligned with regional sustainability, it is suggested that actors would benefit from making the mitigation of ecological effects in the design of products a priority, instead of finding new pathways for existing waste streams (Boons and Baas, 1997). From a societal, or regional, perspective, it is important to look at the entire life-cycle of a product or process because impacts do not stop once a product leaves the boundaries of industry. The greening of products involves changing the product to reduce toxins and use-phase resource consumption while increasing reuse- and recycle-ability for end

of life management. When this is sought, companies can come closer to the ideals of goals 3 and 4[7] in the sustainability framework.

Life Cycle Assessment (LCA) is a tool that can be used to determine the environmental impacts of a product along its entire lifetime. Companies may not be fully aware of where their products have the greatest impacts on the environment until they perform an LCA. This can be a great tool for helping a company determine what needs to be changed in order to make their production efforts more sustainable for society as a whole. When design changes are made that can improve the environmental profile of a product or process, this is called Design for the Environment (DFE). DFE is a concept for designing a process or product with the goal of less environmental impact over its lifetime. DFE "requires that environmental objectives and constraints be driven into process and product design and materials and technology choices (Allenby, 1994 in Lowe, Warren, and Moran, 1997). It is a systemic view of industry, in which the social and environmental implications of industry choices are meant to be weighed alongside economic decisions.

DFE can be applied within an industrial symbiosis setting at different levels of design and scales of time. Three main divisions can be defined as: incremental improvement in design of a product or process, radical redesign of that product or process, and integrated approach to redesigning the system within which the product or process currently functions (or satisfying the "function" of a product or process possibly in an entirely different way). Lowe, Warren, and Moran (1997) use the example of automotive travel to illustrate these three levels. On the first level, small changes are made to a car to reduce its air emissions and increase its gasoline mileage. On the second level, an entirely new car is created that radically improves efficiency in ways not previously thought possible. At the third level, the transportation system is assessed from a holistic point of view and changes are made involving e.g. telecommunications, urban planning, and work design in order to move people in the region in the most efficient and least polluting way possible (perhaps putting more people on trains instead of in cars). These levels can be seen as the amount of integration and/or the maturity level of an IS network.

Currently, the focus of IS networks in practice is to consider the "material loop" closed when production wastes are taken care of. Companies do not seem to consider the fact that for many products, the largest social and environmental impacts occur during the operations and end-of-life part of a product's life-cycle. In the IS networks in existence, companies do not seem to be engaging in efforts to change their core business products in order to reflect this trend. The design of products to have reduced total material consumption, ease of reuse or recycling, or long-term lives is simply not outlined as a priority. Cohen-Rosenthal (2004) points out that a study for the US National Academy of Engineering found that about "80 percent of products are discarded after a single use, and many of the rest are not as durable as they should be." Paul Hawken further estimates that "over 90% of the original materials used in the production of, or contained within, the goods made in the US become waste within six weeks of sale" (Cohen-Rosenthal, 2004). It is apparent that any efforts from firms involved

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[7] There is a danger defining "increased recycling" as a goal of a sustainable network or region instead of as a tool or strategy. Some companies could misinterpret this by assuming that sustainability efforts lead to or stop at recycling. Instead, one must keep in mind that although 'increased recycling' is a goal, it should always be pursued after all efforts have been made to design and execute the production process as sustainably as possible. Consequently 'increased recycling' can be regarded of lower hierarchy than for example increase of material efficiency. Despite individual companies' efforts, there may still remain a portion of material or energy that is necessarily defined as waste. In this case, defining "increased recycling" as a goal can help ensure that companies will be motivated to actively pursue innovative or creative ways for recycling their outputs instead of relying on traditional alternatives that may not be so environmentally preferable, such as landfilling or incineration.

in IS have only been implemented at the first level of DFE. The systems view of the third level has not yet been achieved and it is doubtful whether this is even in the mindset of any IS participants. For long-term success, a gradual evolution from the lowest level of improvement to the highest level of systemic change is necessary. Industries must think about changing their decision to continue with business as usual if they want to participate in a collective business arrangement such as IS.

3.4.7 Dematerialization

Dematerialization is generally considered a minimization of the total flow of material and energy while still providing the same level of goods or services. There are two types of dematerialization: relative and absolute. Relative dematerialization can be described as increased resource productivity, where the amount of material can remain the same while the level of service increases. Absolute dematerialization is a reduction in the overall level of material and energy use while still maintaining or increasing the level of service provided (Erkman, 2003). In IS networks that wish to be truly sustainable and reach goals 4 and 5 (increase of recycling and increase of material, resource and energy efficiency), dematerialization is a step that can help industries make systemic changes.

Often, the 'business as usual' attitude can pose a large threat to regional sustainability efforts because only small changes are made when systemic changes are needed. In the case of IS, the systemic change needed is the view of what is part of the industrial system. Presently, the consumption portion of society is left out of this view even though it is closely linked with production. Dematerialization can help reduce the production-consumption loop. A new business model that also diminishes the production-consumption loop is the service system, or service economy[8]. This is a concept where a company sells the service of a product instead of the product itself. Profits are decoupled from volume of product or material sales. The traditional relationship between the buyer and seller is changed to reflect more diverse approaches, such as leasing, pooling, sharing and take-back schemes (White, Stoughton, Feng, 1999). Products are designed to be more durable, modular, multifunctional, and with components more easily reused, recycled, or remanufactured. Researchers at the Tellus Institute say, "the service and information based economy may be a means to divorce economic growth from growth in material and energy throughput and environmental degradation" (White, Stoughton, Feng, 1999).

For those industries engaged in IS, it means not only closing the materials loop, but also diminishing the size of the producer-consumer loop without sacrificing company profits. Part of the unsustainability of regions can be linked to unsustainable consumption patterns. Consumers and producers become caught in a cycle of consumption: producers push products onto the consumer markets and consumers drive producers to produce even more material goods. Many of the types of industries usually involved in IS have the potential to switch to a service economy model. For example, energy providers (including both power plants and district heating companies) and chemical plants are just two types of companies that have been involved with service economy approaches. More well-known company examples include Xerox (provides copy services instead of machines), Kodak and Fuji (takes back cameras after use), DuPont (provides plastics services), Interface (provides carpet services) and Mobil Oil (sells the supervision of motors and lubricants) (Stahel, 1998 in Erkman, 2003).

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[8] Walter Stahel, director of the Product-Life Institute, has popularized the term "product-life extension" to describe this business model.

This type of change in business model is an important step for IS companies to take in order to diminish the overall regional impacts of their businesses. It can also help improve the regional social responsibility of IS companies; a service economy offers a means of developing skilled jobs (Lowe et al., 1997). Many times, service companies create new business opportunities with related businesses from the local area in order to satisfy all customer needs. Then, not only could companies help each other with waste exchanges, but also with exchanges of business ventures. The service economy model brings those involved closer to supporting the ideas of roundput, gradual change, locality and diversity. The development of alternative business models can foster new, diverse collaborations at the local level, and gradually shift industries to closing all the loops.

Although there are many benefits to this type of change, it is important to keep in mind the rebound effect. As mentioned before when discussing eco-efficiency (see Section 3.4.5) there can be a 'perverse incentive' that must be minimized consciously. There can be unintentional increases in the use of complementary goods. For example, many people thought that with the increase of computers, people would shift from consuming paper reports to receiving the service of information transfer (i.e. reading off the screen). This has not been the case; there has actually been an increase in the consumption of paper as well as energy demand (Tackels, 2003).

However, it is not common for companies in EIPs to change their 'business as usual' model. Researchers acknowledge that there are challenges built into the establishment of regional industrial systems that must be overcome in order for industries to move towards sustainability. Baas and Boons (2004) say that regional industrial systems are often networks of industries or businesses that are not necessarily dependent on one another. Relationships between companies are often "dominated by non-core business activities" (L. W. Baas, Boons, F.A., 2004). This is because the affiliations that are dependent on core business activities are more found in product or value chains, where suppliers and producers interact. In the case of interacting on a non-core business level, there is usually a "separation between the production system and the actors that consume the products" (L. W. Baas, Boons, F.A., 2004). This separation presents an inherent challenge for a regional system to be sustainable, as key drivers of sustainability may be left out of the system. Consumers, who are driving the demand for an industrial process, may continue to provide incentives for a non-sustainable form of production because they are not changing or evolving along with the regional industrial system. Regional actors then become caught between competing interests of the regional networks and other key actors, such as an international mother company or global product chain partners (L. W. Baas, Boons, F.A., 2004). There is no push for re-evaluating the concept of a company's role in the region, or in society, and so their core business is left intact.

3.4.8 Waste Reclamation

After all has been done to avoid the production of wastes and eco-toxins in the first place, throughout the entire cycle of a product or service, there may still be an amount of material or energy that is considered waste by a company. This might not be considered waste by someone else though, and this presents a potential for exchange well known in IS networks. Partnerships are sought where companies can exchange wastes and use them as inputs. This can be in the form of materials, chemicals, water, heat, or even not waste per se but underutilized resources such as storage space. This reuse or recycling of "waste" is common practice in IS networks and helps regions decrease the amount of material and energy drawn from and released into the environment. Examples can be drawn from all over the world,

where partnerships are formed from economic incentives and prove to have large environmental benefits.

The use of waste can be extended to include material already deposited in landfills and specialized end-of-life facilities. Many waste management companies are already engaging in this type of waste reclamation, with techniques such as sorting at material recovery facilities or energy recovery at waste-to-energy plants. Research and development can lead to new techniques of reclaiming wastes from the environment. This could help increase satisfying goals 3 and 4 of the sustainability framework, or increasing recycling and reducing ambient concentrations of toxins.

3.5 Means to Approaching Sustainability

Satisfying all the goals for reaching sustainability can seem a daunting task for companies involved in IS networks. The framework should act as a guideline to judge if IS efforts are progressing in the right direction. It is important to remember that the path to sustainability, as outlined in the previous chapter, cannot be achieved all at once or in a short time. Companies should be aware that there will be steps along the way and transitions that lead to longer term changes. They can more easily align themselves with sustainability by using the approach of transition management.

A transition is a set of changes that eventually leads to a desired long-term outcome. Changes, or social transformations, occur in several different areas, such as technology, behaviour, culture, economy, or institutions. Each change influences and supports the next, and a reinforcing spiral is created to transform society in a fundamental way over a time period of more than one generation (Rotmans et al., 2000). The process of change can be thought of as an evolution of the system because it is somewhat gradual, but there are ways to manage this transformation to ensure that each step along the way contributes to a sustainable end. Transition management is a way to deliberately guide a transformation so that actors are involved and aware of what they are doing and how it will add up to the whole (Rotmans et al., 2000).

There are four different transition phases (shown in Figure 3-6) described by Rotmans et al. (2000):

- **Predevelopment** phase- the status quo does not visibly change.
- **Take-off** phase- the process of change starts because the system begins to shift.
- **Acceleration** phase- visible structural changes take place that influence and reinforce each other. There are collective learning processes, diffusion and embedding processes.
- **Stabilization** phase- the speed of social change decreases and a new dynamic equilibrium is reached (Rotmans et al., 2000).
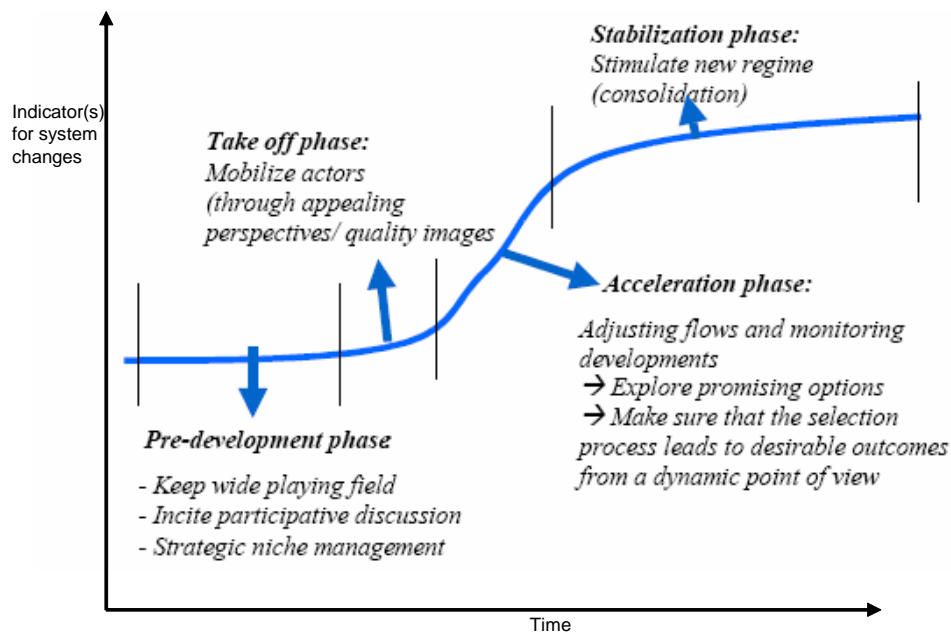
Figure 3-6 Four phases of transition for system changes (Rotmans et al., 2000)

This transition model is appropriate for IS systems because the success of IS networks is based on systemic, structural changes across many domains, such as institutional, behavioral, economic, and technological. Transition is characterized by slow and fast, long and short term changes. For example, in an IS network, this can be the construction of hot water pipes between industries for district heating (fast change) or the change of behavior of company management to understanding the full importance of resource use reduction (slow change). The management of transition in the IS system is a way for actors involved to focus not just on system improvement, but also on innovation. It is a constant re-evaluation of the goals and means of achieving them. This reevaluation keeps options open and supports the learning cycle.

To begin, a long-term vision is created by a broad range of actors. This vision can be adjusted along the way as re-evaluation activities will reveal new insights and lessons for actors. Essentially, the vision is a picture of what a successful future would look like. In transition management, interim goals or objectives are then established by main actors. This can be done in many ways. One option that has been growing as a viable tool is backcasting. Backcasting is the development of action paths starting from the future and working backwards to the present situation. Actors plan out the direction they would like to go, and interim objectives serve as influences on the pace and initial scale of a transition (Robert et al., 2002). This is represented graphically in Figure 3-7 below. When aligning IS networks with regional sustainability, the network vision should be planned either in conjunction or in harmony with regional long-term visions. An important aspect of transition is the reinforcing nature of the changes. There is a level of reflection and involvement required by many actors. This can be further developed by supporting the collective learning and embedding processes. Educational initiatives play a large role in this while working with industrial actors.
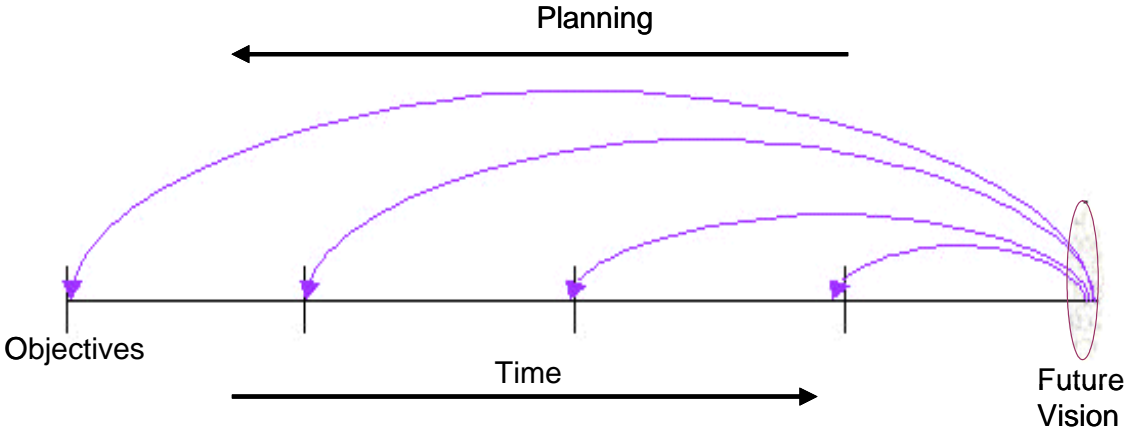
Planning

Objectives

Time

Future
Vision

Figure 3-7 Transition management: backcasting from future vision to interim objectives (J. Rotmans, Kemp, Rene, van Asselt, Marjolein, 2001)

4   Responsibility and Sustainability in Sweden

Sweden is a country in the EU known for consistently being in the forefront of environmental initiatives. The country is considered a leader in supporting efforts at all levels to ensure the protection of the environment within and across the borders of the country. It has also long sought to improve the economic and social viability of its people. Sweden continuously helps sustainable development efforts through government funding and support for research in this area. Industries within Sweden are held to high standards, and have responded by acting responsibly in moving towards a more sustainable country and world. In line with these efforts, organizations have come together to establish an IS network. The first consciously formed IS network in Scandinavia is located in Landskrona, in southern Sweden. This network was formed through efforts to catalyze development of a broad range of connections, and it therefore differs from other types of clusters or networks in Scandinavia. The work in Landskrona helps Sweden and the rest of the world see the benefits of collaborative action among industry, government, and research institutions. It is an example of a cluster of organizations organized around the goal of improving the economic, social, and environmental aspects of their area. Landskrona's successes and areas of future improvement will be discussed in this chapter.

4.1   Landskrona, Sweden

Landskrona is a city located in southern Sweden along the west coast in the region of Skåne and is connected to larger cities by rail and highway. It is home to almost 38,000 people. According to community members, Landskrona has many strengths, including the advantage of having a good harbor for big ships, a good connection to the highway and railway, a good location near major cities like Malmö and Copenhagen, low cost for housing, and plenty of land for development.

The environmental situation in Landskrona has changed a great deal over the past thirty years. It has changed from being considered the "Pittsburgh of Sweden" to an environmentally progressive area. One community member states that companies are now on the right track and have improved their environmental performances by about 75%. Heavy polluters have changed or left the town and there has been a general shift in thinking. This has helped Landskrona be higher on the environmental scale. The environmental department of the municipality has been a great force behind this improvement and they are working towards a sustainable Landskrona.

Landskrona economy has also changed greatly over the last thirty years. Thirty years ago, the main employer in Landskrona was the shipyard. It employed about 4000 people, out of a population of about 30,000. It was the center of industry and of life, with almost everyone having at least one relative or friend who worked there. In the 1980s, the Swedish government stopped subsidizing shipyards. There was a huge blow to Landskrona's economy and spirits when the shipyard left. To try to reverse the downward cycle that started, the municipality established the business development center. Another shipyard was founded, but only to repair and not to build ships and ferries. With the help of the Office for Trade and Business in Landskrona, many more, smaller businesses were developed in Landskrona to fill the gap. As a result, Landskrona was not hit so hard by the recession in the 1990s because they had a bigger economic base that was more stable than just one large company in town. Today, there is another recession but a representative from the Business Development department feels that Landskrona is in a better position to survive. They have started new housing construction projects and there are plots for new companies to buy where the rent

level is not so high. The economic situation can be considered more stable in Landskrona today. Even so, there are aspects that threaten the general economic flow of the region. Many people who work in Landskrona commute in from other places. This includes upper management from local companies. This means that there is less tax base for Landskrona, and less people who feel a personal responsibility to improving the region. People who live in Landskrona often do their shopping and other economic activities elsewhere, leading to an outflow of money from the region.

The situation in Landskrona is still slightly strained, though, and some companies feel that there is even now a struggle to survive. One company representative described Landskrona as "a dying city, but still kicking." This could be turned into a rallying point for Landskrona. As he further described, he has the feeling that knowing of the city's position brings people more together. They are willing to fight for their city, to cheer on the local soccer team, and to aggressively market local sites. Other problems that Landskrona faces are a sinking educational level of the community and a lack of social integration. The Landskrona community has experienced an influx of immigrants over the past few years, and so far there have been difficulties in fully integrating the new people into the job market and social fabric of the community. Social cohesion levels are low and it is unclear what efforts are underway to integrate the community while still preserving cultural diversity.

During the 1980s and early 1990s, there was a CP project in Landskrona organized by the Foundation of TEM (Technology, Environment, and Management) and sponsored by the Swedish National Board for Industrial and Technical Development (NUTEK) and the Swedish Environmental Protection Agency (EPA). This was the first CP project in Europe. The project ran from the fall of 1987 until 1994 and involved three main parts: process change, environmental management systems (EMS), and eco-design. The project started with six small and medium sized companies and expanded by the end to more companies working on about ten different sub-projects. Companies involved included those from the graphics, chemical, and mechanical industrial branches. Five of the companies are now participants in the Landskrona IS network project. The TEM project team worked with representatives from the firms to assess the firm's manufacturing processes and management procedures in order to identify opportunities for waste reduction or prevention. Waste reduction audits were performed for the companies and ideas about how to improve their processes and designs were gathered from conferences and examples from both the EU and the US. Sub-projects were developed in Landskrona, such as hosting conferences and producing a video demonstrating the cleaner production ideas.

This cleaner production project had both environmental and economic benefits. These benefits resulted from changes in both product materials and processes. For example, one company switched from organic solvent-based inks, which emitted VOCs, to water-based inks. Another company switched from petroleum-based oils to biodegradable oils. This eliminated the need for degreasing agents containing trichloroethylene further down the process line. The same firm also changed from using organic solvent-based paints to powder paints, reducing VOC emissions and employee exposure to solvent vapors (Backman, et al., 1989). This kind of cleaner production project was the first application of its kind in Scandinavia. Ideas developed in Landskrona were used as seeds for Dutch and Danish projects, as well as others around the world.

4.2 Regional Development

Within the EU, Sweden is known as one of the countries on the forefront of environmental progress. In line with this reputation, the Swedish government has established 15 national

environmental quality objectives for ecologically sustainable development (see Appendix A for a full list). These are based on three themes: 1) protection of the environment, 2) sustainable supplies, and 3) efficient use of energy and other natural resources (Planning and Environmental Department of Region Skåne, 2001). The objectives are to be reached by 2020 (2050 for the objective of reduced climate impact). These national objectives are to be adopted by regions within Sweden and adapted for the local context.

The political region of Skåne, of which Landskrona is a part, is developing an environmental programme based on these national objectives. There will be regional targets and indicators that contribute to satisfying national goals. The region is concerned about sustainable development and has set up goals to promote "good health and a sound living environment." The region has committed to:

- Evaluate and describe the environmental impacts of projects during the planning and procuring stages and prior to making a decision to continue.
- Stimulate the environmental work of its staff and increase skill levels in matters related to the environment.
- Draw attention to and report on the connections between the environment and people's health.
- Prevent pollution and continually improve environmental work.
- Reduce the use of non-renewable natural resources.
- Endeavour to reduce the use of environmentally harmful materials.
- Set a good example in the choice of environmentally suitable technology taking into account the social and economic conditions.
- Follow current legislation and be well prepared for future demands in the environmental field.
- Openly communicate and regularly follow-up environmental work (Region Skåne, 2001).

In 1999, the Regional Council approved plans for creating a regional development programme, the first for Skåne. Efforts will be made to improve the growth, attractiveness, sustainability, and balance of the region through development of economy, industry and employment, environmental conservation, and quality of life (Planning and Environmental Department of Region Skåne, 2001). For each of the four areas of development, there is an overall objective and action plan. Although sustainability is listed as one of the four, each development objective really comes together to promote the ideals of sustainability, as discussed in this thesis. Table 4-1shows examples of the objectives within each of the four areas of development in the vision of Skåne (Regional Development Programme for Skåne, 2004). The region hopes to base their work on Agenda 21.

Table 4-1 Skåne's Four Areas of Focus for Development and Examples of Objectives (Regional Development Programme for Skåne, 2004)

	AREAS OF FOCUS			
	Growth	**Attractiveness**	**Sustainability**	**Balance**
OBJECTIVES	• Finance R&D in region • Increase employment level • Improve access to education and work • Increase housing	• Protect, preserve and develop nature and cultural values • Establish more R&D centers • Increase quality of public sector	• Reduce release of toxic substances • Ensure quality and pursuit of education • Improve public health • Improve safety • Increase collaboration	• Increase access to public transport and broadband • Promote suitable labour force in all parts of region • Support growth of business sector in eastern Skåne • Reduce segregation • Ensure access to housing

In Landskrona, the municipality has developed an Agenda 21 document aimed at guiding activities in Landskrona. Although this is a positive step, it seems through interviews that this is not a 'living document.' One representative from the municipality department where it was created suggested that it is a document that is not actively used or referred to for operational or planning activities. Plans for developing an environmental programme for Landskrona have been on hold due to lack of funding. Municipality representatives hope that in the fall of 2004, discussions between the municipality and industry of how to accomplish the national aims will begin. Interviews with company representatives suggest, however, that they do not see themselves as having a role in regional development plans.

4.3 Creation of the Öresund Region

Landskrona, and part of Skåne, are located next to the Öresund Sound. There are ongoing efforts to recognize that the populations living and working around the Sound can be considered a region, in more than a political sense. This "new" region is called the Öresund Region. The creation of this region as a political entity as well as a natural area brings theory into practice. As the literature suggests, a region is really an area of unique characteristics organized around an internal central pole. The Öresund Region is such, and now the politics are catching up with the more functional definition of a region. The Öresund Region is home to about 3.5 million people. The region hosts about 20 universities and about 130,000 students (OECD, 2003). The area encompasses the north-east of Denmark and the south-west of Sweden, with the Öresund Sound between them. It is linked by a bridge between the two largest cities, Malmö and Copenhagen. For the past ten years, a committee has worked to better integrate the societies and create a cohesive, successful area that can be considered a "green" region. Their goal is to create a region "where it is easy for its inhabitants to live, study or work as well as create good conditions for business and trade investments and expansion." Efforts are being made to harmonize the policies of this region which incorporates area from two countries. Harmonization will take place in four policy areas: 1) infrastructure and spatial planning; 2) labour market; 3) networking and knowledge diffusion; and 4) taxation (Öresund Committee, 2003a). On the environmental front, the Öresund

Committee is concerned with three main areas of priority: 1) water and wastewater, 2) solid waste and energy, and 3) managerial structure (e.g. management systems, product and process design, corporate responsibility promotion) (Jacobsen, 2004).

The Öresund Region has received funding from Interreg IIIA, part of a European Community Initiative for strengthening economic and social accord in the EU. Interreg IIIA focuses on cross-border cooperations and funds efforts that foster the cross-border educational, scientific and entrepreneurial projects with the long-term goal of strengthening the area's identity as a common region (Öresund Committee, 2003b). The region has also received political support from the EU which considers Öresund a "flagship programme" worthy of demonstration to the rest of the union as an example of a successful, environmentally responsible region. A study of the region was performed by the Organization for Cooperation and Development (OECD) to assess the economic and social success of the new region. According to the OECD, it is crucial for the improvement of the region to establish and strengthen "networks that stimulate innovation and better use of skills and knowledge." A better integration of society around the Öresund Sound could help expand this inter-firm cooperation. They recommend the establishment of an innovation center that could help networks of businesses, especially those small and medium sized businesses that have limited resources. This center would provide specialized services and promote training (OECD, 2003). These recommendations are in agreement with theories such as Michael Porter's, that regions thrive due to the clusters, or networks, within them and it is this type of focus that allows regions to compete in a globalized world.

This realization of the importance of promoting innovation and knowledge transfer is also in agreement with broader goals of the EU. In March of 2000, the Lisbon European Council set a "new strategic goal for the European Union to become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion" ("Council Decision 2001/63/EC of January 2001 on Guidelines for Member States' employment policies for the year 2001," 2001). One part of the strategy to achieve this goal is the encouragement of partnerships and social networks at all levels. Lifelong learning is also stressed as necessary to support the continuing growth of a knowledge-based economy. These two aspects of the strategy can be found in the context of IS network development. The foundation of the IS connections lies in the forming of social contacts, partnerships, and eventually networks and a large part of the continuing success is due to the efforts of sharing and supporting group learning. One difference, though, is that the IS networks do not necessarily strive for developing a knowledge-based economy. There is potential for the work to promote IS networks to be used as one tool in the EU's and in the Öresund Region's overall schemes to improve the economic, social, and environmental conditions of their people. At the moment, it seems that shifting from the present economic paradigm to a more knowledge-based one is not yet actively pursued. Often, people in the planning stage of network projects work to change a "harmful" practice. They do not consider that thought must be given to the economic system itself within which the new development projects or plans are meant to function. So although a change in the right direction is made, the old economic paradigms are left intact. This ultimately limits the amount of progress that can be made on a systemic level. If EU's goal of moving towards a more sustainable, knowledge-based economy is taken to heart, this could lead to benefits for both sides. Regions, which are ultimately charged with implementing this task, will now have a concrete way of increasing the social networks and employment opportunities within their boundaries. IS networks, in turn, will have more support and understanding for their efforts.

4.4 Landskrona IS Network

The IS network in Landskrona was initiated in 2002 by researchers from IIIEE and representatives from Landskrona companies. According to the researchers, the initial goals of the project were to increase the competitive advantage of Landskrona companies by:

- cutting down their waste management, pollution control and environmental management, resource input, and operational costs;
- generating new revenue streams and developing new products;
- creating a better image owing to improved individual and/or potentially regional environmental performance (Mirata, et al., 2003).

To achieve these goals, researchers planned to work with the companies to identify environmental and economic benefits from network collaborations. They would then assist in developing identified potential partnerships and work to help overcome barriers. Eventually, these experiences would be used to help guide similar developments in other parts of Sweden and around the world.

The project was coordinated in overlapping phases, where IIIEE researchers would provide the main impetus and guidance for change and company representatives would be responsible for ensuring implementation of connections and continuation of the spirit and mindset of the project. The first phase was the initial review to gain insight into what factors (technical, political, economic, informational, and organizational) may play an important role in the establishment of the IS network. The second phase was raising awareness. In the beginning of the IS network establishment, the focus will be on raising awareness of company participants as to the benefits and upcoming challenges of participating. As the project progresses, awareness-raising was more specific to different topics of concern for the project members. Breakfast meetings for network members were organized to have a regular exchange of ideas and lessons learned. The third phase was strategic data collection, where data was collected systematically on the needs and capacities of the participating member organizations. Examples are material, energy, and water inputs and outputs, logistics and managerial infrastructure needs and capacities, and know-how or expertise that can be shared or gained. The next phase was data analysis, where potential synergies and/or areas of improvement were identified. The final phase was implementation and support for continuous improvement. National and international reference groups were established in order to provide platforms on which to discuss relevant issues, barriers, and support for continued success. A list of participants to these reference groups can be found in Appendix B. The original time plan for the project can be seen in Figure 4-1 (Mirata, et al., 2003). The timeline of the project under the present funding scheme has been extended until October, 2004 due to continued funding support.
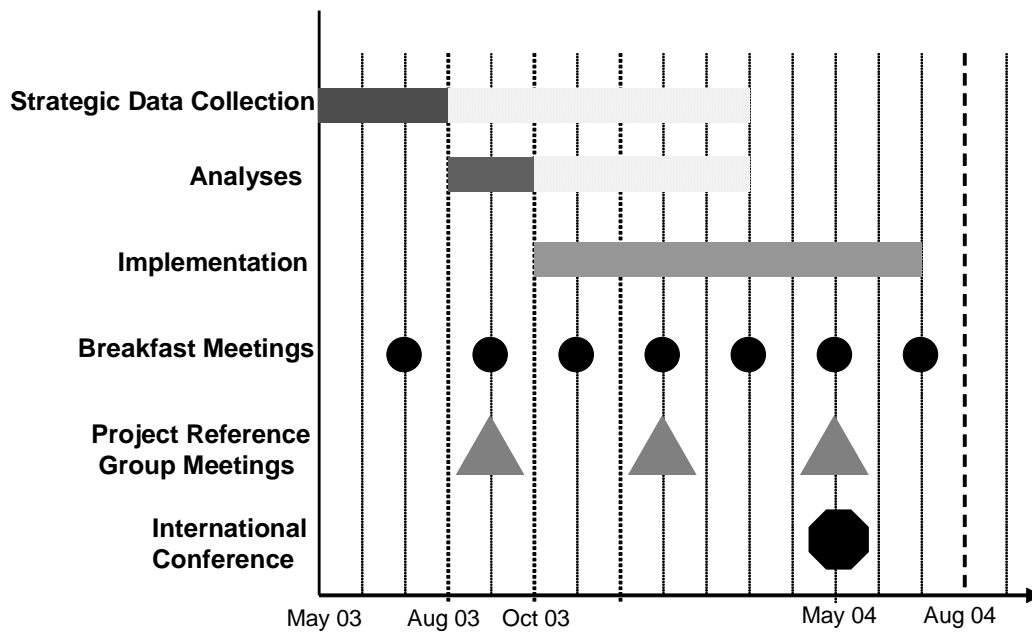
Figure 4-1 Original time plan for the Landskrona IS Network establishment (Mirata et al., 2003).

The project was funded partly through NUTEK and partly through company participation fees. Each company participating made a financial contribution of 5000 SEK. The network can be considered a planned, brownfield IS network of local firms that are not collocated. There is a high level of diversity in the type and number of businesses interacting in the network. There are 21 participating companies spread over ten sectors (see Appendix C). These include: four metal works (plating and recycling), two chemical, two automotive components (brakes and glass), two agricultural products, two packaging, two printing, one cement/construction material transfer station, one lighting equipment, one rail vehicle component, and one waste management company. There are also three public agency departments participating. The companies range in size from four to over 500 employees and represent locally, nationally, and internationally owned businesses. Currently, twelve companies have a certified environmental management system (ISO 14001 certification) and four companies are in the process of pursuing certification. Eleven of these sixteen companies also have certified quality management systems in place (ISO 9001). One additional company has a certified quality management system in place but no environmental management system. In total, 17 out of 21 participating companies have or are actively pursuing an internationally certified management system, either for quality, environment, or both. The four companies that are in the process of pursuing ISO 14001 certification are participating in a project called Step-By-Step.

The Step-by-Step program, run by a consultant, allows companies to work towards certification in a group setting. The certification process is divided into six stages with companies gaining credit after completion of each stage. Participants meet regularly throughout the phases. The phased implementation approach is based on a new British environmental standard for small and medium sized businesses called BS 8555:2003. Companies work through each of the phases shown in Figure 4-2 and meet to discuss their

progress and difficulties. With the mediation of a consultant, they can help each other achieve goals in a more effective, efficient way.
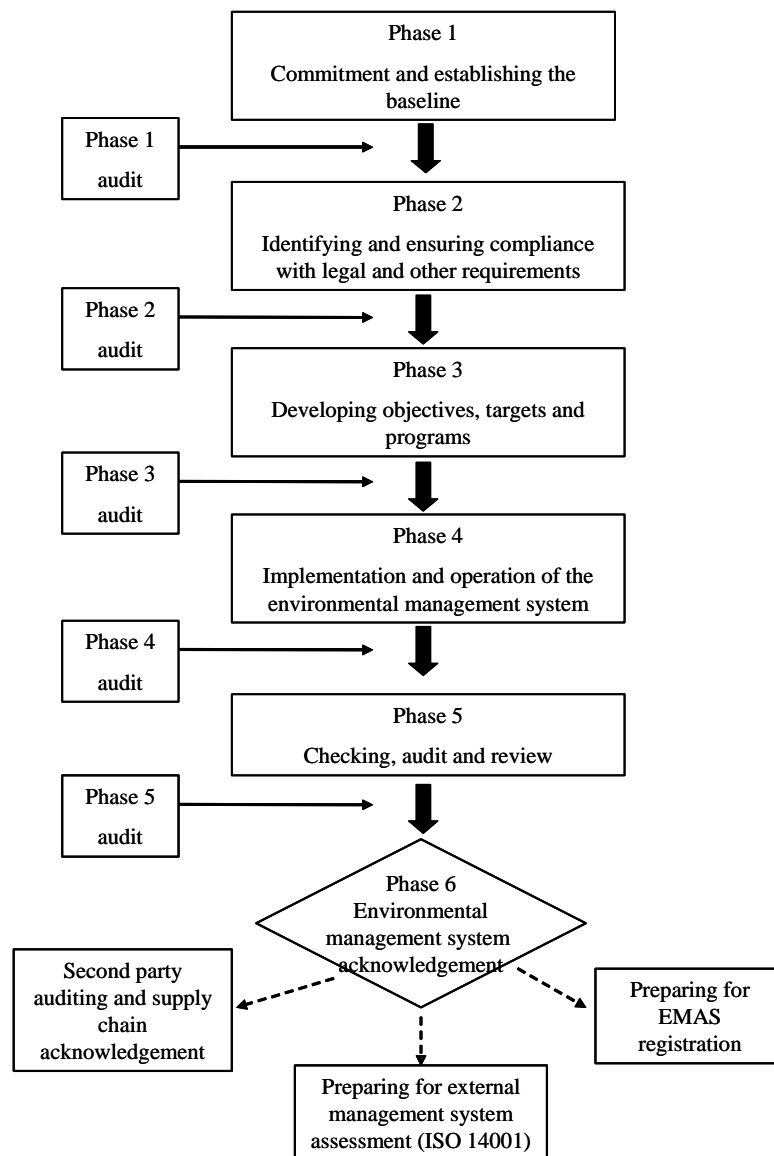
Figure 4-2 Phases of environmental management system implementation according to BS 8555:2003 (Acorn Trust, 2003)

Companies participating in the Landskrona IS network can generally be considered to have a high maturity level in regards to age, market experience, and pursuit of sustainability. The average age of establishment of companies is over 50 years, indicating that these companies are well established in the community. Many have survived harsh economic times during the 1980s when Landskrona lost the shipyard. Not including the municipality departments, more than 70% of the participant companies operate on a global level. Companies stated in interviews that they are comfortable operating in global markets, yet they maintain close ties to Landskrona. This demonstrates their experience in having developed a mature strategy of operation that allows for flexibility in responding to global and local needs. Finally, of 18 companies interviewed in the network (not including non-producing government departments or offices), all companies have matured beyond the first two phases of sustainability (rejection and non-responsiveness) as described in Section 2.4. Of these companies, 50% are in an advanced stage, or phase five of the model strategic proactivity, 40% of the companies are

operating in phase four, or efficiency, and the remaining 10% operate in the stage of compliance. Two companies are moving into phase 6, the sustaining corporation, and are beginning to fully internalize the pursuit of sustainability within its business and society.

The maturity level of the network as a whole can be judged using the same model as for individual organizations (found in Section 2.4). Although the Landskrona IS network is only a few years old, the maturity of the individual companies contributes to a higher maturity level of the network than starting from scratch. Landskrona companies are aware of the need to address environmental issues alongside the usual economic issues planned for in a business. Currently, the network is in a position of establishing a reputation as a collection of responsible companies. In pursuing connections, the companies have started to think more proactively, for example in trying to set up different transportation arrangements. However, the network as a group is not yet at the fourth phase of efficiency, as not many connections have been established and administrative issues (such as the financial details of the network or frequency of meetings) are still being settled. The network can be considered at the end of phase three (compliance) in maturing towards higher sustainability.

4.5 Network Collaborations

As this IS network is quite new, connections are still being evaluated and initiated. There have been some observed changes in Landskrona companies from interacting in the IS network. These have been both physical and mental changes. There have also been interactions in the community not mediated or facilitated by the IS project. These connections are just as important to note as those directly related to the IS project because IS should involve the community as a whole, and not be limited by artificial boundaries set around administrative procedures. The goal of the IS project is to both stimulate and acknowledge these types of interactions so that beneficial patterns can be realized and pursued further. Therefore, all connections and changes involving participating companies can be seen in Figure 4-3.
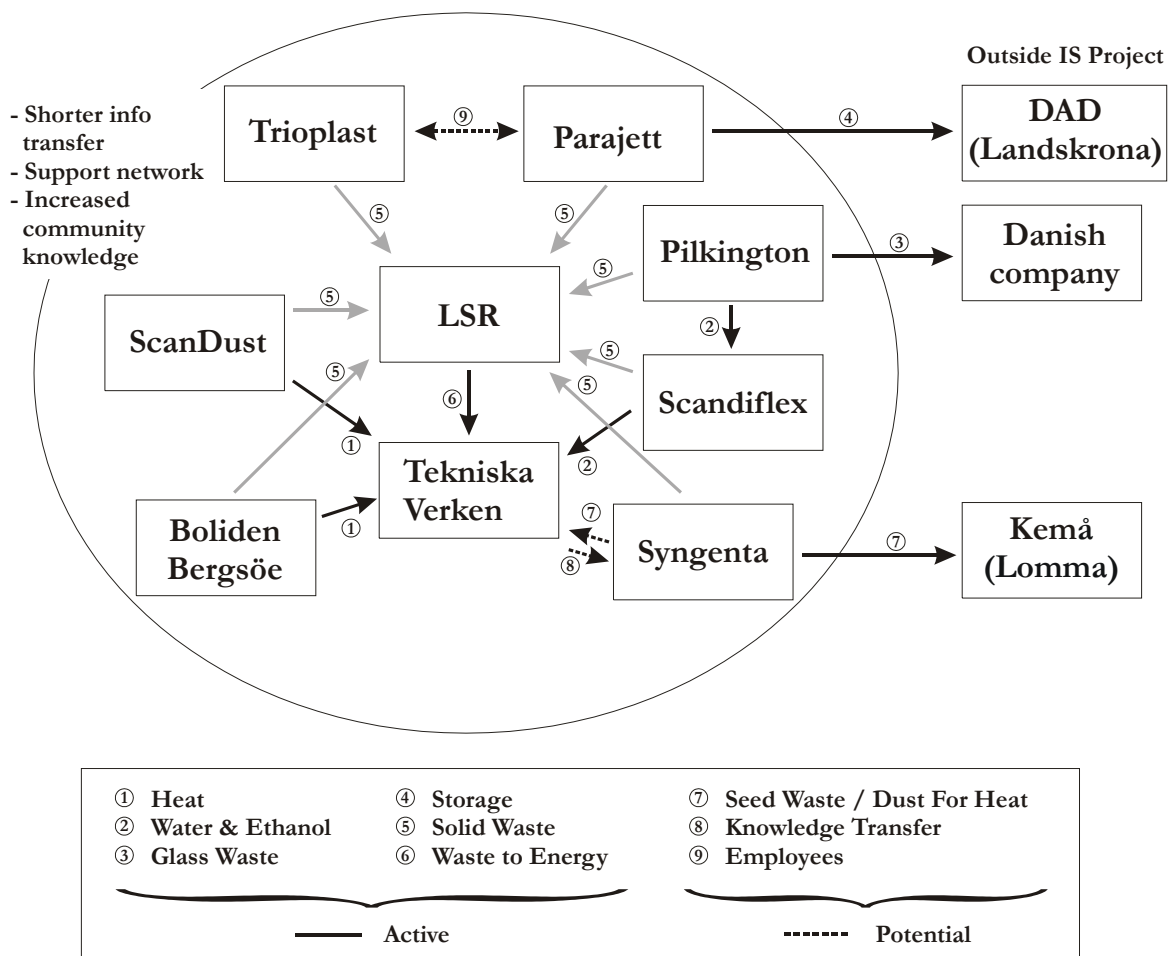
Figure 4-3 Industrial Symbiosis connections in Landskrona network

Communication

Almost all of the participants interviewed expressed that there was an improvement in the communication level among companies. It was noted that open communication between companies is not so common in Sweden, and to develop these relations takes patience and a long time. Participants in the network feel that there has been an improvement and they acknowledge the usefulness of being in contact with one another. Often, companies within the same business sector cooperate on issues such as health and safety or waste problems. In this case, they are appreciating the opportunity to cooperate and learn from companies in other business sectors who they might not have the chance to interact with otherwise. Some

participants state that the atmosphere of communication is better; before, a person might pick up the phone only if there is a problem. This way, people are talking and developing a more stable relationship. There is a shorter time for information transfer and increased community knowledge. One participant stated that he has been able to connect with more local people in a shorter period of time through the IS project than what would otherwise have taken 2-3 years. They are also finding that companies may have useful contacts outside of Landskrona of which the others were not aware.

Mentality

Almost all participants stated that there has been an increase in the open-mindedness of the companies involved. Companies are not simply focused on how to get paid for getting rid of waste materials, but they are looking into collaborations on all levels. They are willing to consider options that perhaps at first do not seem straightforward for economic profit. One example of this change in mentality was seen in a chemical company. This company investigated the exchange of one of its waste solvents with another network company. It turned out that an exchange could not be made at that time. Instead of stopping there, the chemical company worked to figure out how to redesign the process to be able to reuse up to 60% of the waste material. They are currently researching how to reuse a higher percentage and close even more of the loop from their facility.

Waste heat

Two long established connections have been between the Municipality of Landskrona Technical Department and two local companies, a metal recycling company and a battery recycling company. Both connections involve the sale of waste heat from the company to the municipality for the purpose of district heating. The municipality buys the company energy on commercial terms and prices to supply about 25% of the community heat demand, or about 75,000 MWh (15% from the metal recycling company and 10% from the lead-battery recycler). The municipality thinks that these companies cannot deliver more to the district heating loop and ones that are currently not connected do not have enough capacity to make the investment economically worthwhile. Now, about 70% of the buildings in the center of Landskrona are connected to district heating.

Water and Ethanol

A connection has been established between an automotive glass manufacturer, a printing (for packaging) company, and the Municipality of Landskrona Technical Department. This connection involves the recycling of water and reduction of ethanol use for the waste water treatment plant (WWTP). The glass manufacturer pumps their wastewater (used process water from washing activities) to the printing company. About 5-7 cubic meters of water are sent per hour (about 43-60,000 cubic meters per year). In anticipation of this water exchange, the printing company redesigned their system with a counter-current cleaning loop. After use by the printing company, the water is sent to the WWTP, run by the Municipality of Landskrona Technical Department. This water contains about 0.2% ethanol. The Municipality of Landskrona Technical Department currently purchases and adds about 250 tonnes of ethanol to maintain proper treatment processes. By using the water containing ethanol from the printing company, the municipality could eventually reduce their ethanol additives by about 50 tonnes per year, saving them about 500,000 SEK per year (Pilkington and Scandiflex, 2004). It is possible that in the future, water will be reused in part of the cleaning process, which will mean a higher ethanol content and more savings for the WWTP.

Glass waste

The automotive glass manufacturer is involved with a second exchange of materials. The company produces three types of glass: green/clear, black, and glass with silver printing (for use in backlights). Both green and clear glass is internally recycled. The black glass is not internally recycled, but instead it is sold as a raw material for use in concrete and construction material. This connection is made with a Danish company outside of Landskrona because a connection couldn't be made with local firms. Although one partner is outside the IS network boundaries, this connection is made in the spirit of IS. It demonstrates that the principles of IS are present in companies and they are investigating connections not only presented by Landskrona coordinators but also those found by searching on their own.

Renewable energy

Two seed production companies are investigating the idea of using their seed waste as a renewable fuel source for district heating in Landskrona. The seed waste material is made of dust and shell (organic material surrounding the seed). In its present form, the dusty material presents an explosive risk during conventional combustion. The seed companies are considering making compressed forms of the dust waste and selling it to the Municipality of Landskrona Technical Department for heating. The municipality pelletizes dust from their wood for burning in the district heating system. The companies are looking to learn from the municipality in order to set up a similar system for their seed dust. There could be opportunities for the seed companies to collaborate on equipment if larger volumes are needed to justify the capital costs. One company now pays a community plant in Svalöv to accept their dust for burning. The other, dealing with sugar beets, now delivers their 'bad' seeds to a company in Lomma for heating purposes. The seed company would like to find a way to use this waste locally in combination with the dust waste. One barrier to using this dust will be the EU Directive 2000/76/EC that comes into effect in December 2005. According to the directive, the seed companies will not be able to landfill the dust and they will have to pay to burn the waste. The companies are currently working with the Environmental Department of the Municipality to see if the seed waste can be classified as renewable energy, the same as straw waste. This will allow the companies to sell their seed dust for district heating instead of having to pay for its disposal or burning. This dispute over definition is still underway.

Waste to Energy

The local waste management company provides about 5000 tonnes per year of combustible waste to the Municipality of Landskrona Technical Department for the district heating system. However, they will also be affected by the EU Directive. If a new tax for burning waste is introduced with the new directive, district heating managers and established waste incinerators will look for "good" burning material (high energy, non-mixed material). The Landskrona waste company will be able to benefit slightly from this new demand because they are able to provide sorted material that burns well. If the directive does not allow burning of these materials, the waste company will not be able to provide this type of energy for the community. Now, the waste management company is not able to make much profit on the fraction of the waste that is burned. They have decreased the amount of plastic waste material that is pelletized because this process is costly.

Storage capacity

One of the printing companies is involved in the exchange of storage space with another local company. The printing company became aware that their neighbor was in desperate need of more storage capacity, or they would have to relocate outside of Landskrona. The printing company was able to arrange the use of their extra storage space to help this company remain in the community. Although the neighboring company is not involved in the IS project, this connection demonstrates that the printing company has the mindset to communicate with their neighbor companies and seek ways to help each other remain viable.

Managerial Collaboration

The Landskrona network has expanded its scope to include managerial collaborations. Some of the companies are helping each other pursue EMS certification. There are four companies from the Landskrona IS network participating in the Step-By-Step EMS program. In the group setting, these companies help each other deal with issues that arise during the phases of establishing an EMS. Companies can use the group setting in numerous ways, such as for gathering information on a how do deal with specific regulations, benchmarking their progress, or simply helping one another maintain enthusiasm throughout the long process. This program approach helps companies increase their flexibility and work within their budget constraints. Companies that might not have attempted to establish an EMS now have a guided path to doing so, and decreasing their environmental aspects and impacts. This work also demonstrates the collaborative spirit of companies in Landskrona.

Personnel exchange

Two companies in the IS network, a printing company and a plastic packaging company, are looking into the potential of an employee exchange. Their cycles of downtime mirror each other, so that when one company has high volumes of production the other has very little, and vice versa. Although they are both specialized printing companies, they realize that there are many similar operations and retraining wouldn't be too cumbersome. They are now in the process of discussing the legal and insurance issues of allowing personnel to switch facilities when times are slow.

Transport Logistics

An area under investigation is collaboration in transport logistics among some of the companies. Company participants expressed their frustration with the railway organization's lack of response to Landskrona company needs or requests. Individually, the local companies could not gain the attention of rail transport organizations because each company represented too small of an opportunity for the rail. Now, the companies are coming together to organize their collective power so that they can gain influence over discussions with railway organization representatives.

Other

There were many connections that were evaluated as not feasible at this time. One connection that was not practical was the exchange of sulphuric acid and caustic soda. Some of the chemical companies and one of the metal plating companies looked into exchanging these waste streams. Sulphuric acid is a waste stream of some of the companies, and they buy caustic soda in order to neutralize this waste stream. Alternatively, the other companies produce caustic soda as a byproduct and neutralize it with sulphuric acid. However, an exchange was not able to be made because of the quality of the waste stream. The byproduct streams are not pure, containing high levels of organics from cleaning or other processes. The

companies would have to extensively purify the streams before use, and this is not economically beneficial for any of the companies. A second option considered and rejected was a more efficient arrangement of transportation routes between local companies and the company dealing with metal scrap. It was thought that companies would be able to have the waste management company transport their metal scraps directly from source facilities to the metal scrap company facility, instead of having the material deposited first at the waste management company or another facility of the source company. This was not agreed upon because of logistical complications, such as tipping fees and quality sorting activities. The sharing of job training activities was discussed with a few of the companies and it was found that this was also not an option for these members of the network. The companies have specialized training that did not overlap, and so it would not save any coordination efforts, time, or money to combine these training programs. A few companies thought that environment, health and safety training might be able to be coordinated, but again this is usually specific for the work context of the company. Potential connections that are still being evaluated for the future are materials transport logistics and recovery of solvents.

4.6 Beyond the IS Network

Sustainable development, in its traditional way of implementation, is limited in that it is mainly a policy or legislative approach, which means that companies or networks are usually told what *not* to do, instead of what can be done (Kisch, 2004). This approach places restrictions on companies and networks instead of opening up ideas for creative solutions to development problems. A new approach is needed that brings together people to brainstorm, evaluate, and eventually implement attractive opportunities and solutions.

One of the traps many businesses fall into is the thinking that in order to survive, you must be bigger and faster than all your competitors. This mentality puts an emphasis on expanding "economy of scale" operations and heads the business into mass production of its goods and services. However, large scale productions are not flexible enough to respond to the rapidly changing customer demands. This doesn't have to be the way to go, and in fact, there is an alternative and perhaps more effective option. A new paradigm of economic thought is emerging around the world that focuses on localization. This new paradigm, called the Distributed Economy (DE) by researchers at the IIIEE, is a challenge to the idea of centralized economies where mass production is emphasized. DE is just as the name implies, distributed. In this model, there is a network of smaller companies distributed in the area or region who emphasize competing on the basis of quality and the unique perceived value of their goods and services. There is a redefinition of where the centralization point is for many of the production systems, and a movement away from dependence on one central employer. If the distribution and parallel collaboration of organizations is systematic, this can help regions thrive in the long term. Peter Kisch, one proponent of this shift, describes it as "reinventing regions that have a rainforest of opportunities" (Kisch, 2004). Innovation must be supported in businesses of the region using the unique resources of that region. True development and innovation will not happen on the global level, as noted in the literature (see Section 2.2), but on the regional level. Within these regions, it is not the large companies who lead the way in innovation or creativity, but it is the small and unique sectors of industry and business. These must therefore be supported in their efforts within the framework of creating a distributed economy.

There are plans for establishing a research center in Landskrona, called the Distributed Economy Laboratory (DE Lab). This new DE Lab will act as a guide on the alternative development path to centralized human and natural capital production systems (Kisch, 2004). Working with local representatives, researchers in the DE Lab will try to demonstrate what

possibilities exist for regions and for the businesses within them. The process of "helping" a region will be more strategic, or cyclical, than in the present way. Now, there is a technological push, where research is often done by someone interested, a patent is acquired, and then the idea is "pushed" onto businesses for commercial development. A more strategic way is to work with businesses to jointly identify what products or processes can be improved, and what technology would be most appropriate for their unique situation (Kisch, 2004). A learning loop between e.g. a university laboratory and an industry is created because all are participating in the brainstorming and identification of options as well as the practical application. When new opportunities to use a region's natural and human resources are discovered, researchers at the DE Lab can bring together the right people and guide the search for solutions.

The DE Lab is a joint effort between Landskrona and the IIIEE researchers, with funding from Landskrona, NUTEK, and VINNOVA. VINNOVA is the Swedish Agency for Innovation Systems that supports research for sustainable growth. The DE Lab will secure their future financial situation by taking a percentage of the income from successful business projects or ideas. The research center would take on the risk of a company to develop an opportunity and then be paid back if the project was successful. This stake in the project would serve only to secure the future continuation of the center. The center will be open in Landskrona starting in the beginning of September 2004. The DE Lab would help spread ideas such as industrial symbiosis by supporting local research and development, gathering researchers from around the world, helping educate companies and individuals, and acting as a center for exchange of ideas and techniques. The practical work would include, for example, identifying regional and/or business strengths and opportunities, jointly creating project plans and schedules, and conducting research and implementation efforts of technology or other development changes. The success stories will then be spread throughout the region as well as internationally through educational, business, and government networks. The DE Lab plans to use the IS network in Landskrona as a platform for building up a portfolio of positive examples of innovative solutions to regional development.

5 Analysis

5.1 Sustainability Profile of Landskrona IS Network

Although the Landskrona network is in the early stages, its alignment with sustainability can still be evaluated. In fact, it is often in the early stages where the most change can be made in terms of alignment. This time can be critical for developing the right mindset, goals, vision, and educational direction for participants of IS. This section will discuss the characteristics of the business community, the kinds of incentives that exist (both within Landskrona businesses and emanating from the IS network project), and how these both relate to the sustainability framework considered in Section 3.3 and the future direction of the region. For those disincentives that exist, mitigations will be suggested.

ECONOMIC:

Awareness of local needs- The network creates an incentive for pursuing economic success by opening the minds of company participants. They see that they can think outside the box to solve their business problems and increase the efficiency and effectiveness of their operations. They also help solve problems of other local businesses, as they see that all of them are interdependent. A high level of awareness about the need to work with local issues lays the foundation for future collaborations in the direction of increasing sustainability of the community. For example, a printing company arranged to have a local company, DAD, rent their storage space. This arrangement allowed DAD to remain in Landskrona when their need for storage capacity was about to drive them elsewhere. Helping this company remain in Landskrona helps the community. With more businesses in the community, there is a greater diversity and larger tax base, both which help a community survive external economic pressures. Further, this connection demonstrates that the mindset of companies in the IS project actually extends to their other business contacts because DAD is not a participant of the IS project. This internal company motivation to strengthen local businesses supports the strategy of emphasizing local cooperation as a part of regional networking. The sustainability profiles of both the network and the region are enhanced by this type of interaction.

Support for new business developments- As described before, Office for Trade and Business in Landskrona was developed to help establish a stable economy for the community. This center actively supports the development of new businesses and business ideas in the community. A diverse base for the economy has helped Landskrona survive recent economic ups and downs in Sweden. The involvement of the business office shows that the community is concerned about having people devoted to maintaining the long-term health and success of the economy. Although outside the scope of the IS network, this type of push from the municipality demonstrates the long-term commitment of Landskrona to support balanced economic development efforts and improve the stability of the community. Support for new business developments also strengthens the network. New companies moving into an area find a support network already established. Network companies find new potentials for collaboration and inspiration. Together, they can increase their competitive edge.

No direct payback for early stages- Many companies involved in the network do not discover direct connections with other participants in the early stages. They therefore do not realize any payback for their investments of time and money (during the coordination and start up

process). For example, a local transport company was involved in the IS project in the beginning. They stopped coming to meetings and searching for connections, explaining that they were in financial crisis and didn't have the time for these meeting. Most of the companies involved would like to work on coordinating their transportation logistics. Perhaps if the transport company had been more involved, they could have used the network to provide more connections, more income, and an ability to remain in business. When companies don't realize the indirect benefits of using the IS project/network, this leads to a disincentive to continue participating in the IS project in the future. If some companies drop out, it could lead to others dropping out and an eventual collapse in the network because IS is based on collective success. This decreases the sustainability level of the network and therefore the network's role in supporting regional sustainability. .In order to mitigate this barrier, it is important to have a champion, an anchor, or someone who is successful in motivating companies to remain positive about the progress of the IS project. Companies need to be consistently reminded that this project is still in the early stages. The time perspective of establishing connections (whether physical or managerial) could be more like five to ten years instead of the quick turnaround that companies are used to. Cataloguing the "softer" benefits, for example quality of relationships with the municipality or community, ability to learn quickly from other companies' investment choices (lessons learned), and improved corporate image, could help demonstrate to the companies the value of remaining active in the IS project.

SOCIAL:

Broad definition of connection- From the very beginning, coordinators of the Landskrona IS project kept a broad scope for the types of connections that they sought to establish. Participating companies were asked to search for potential areas of collaboration that included not only transfer of "waste streams" and sharing of resources (water and energy), but also transportation and purchasing logistics, sharing of employees and capital (equipment and storage space), coordination of training programs, and group ISO 14001 certification. This broad scope helps the companies keep a more holistic view of the changes from which they are seeking to benefit. Maintaining a broad definition of "connection" provides an incentive to pursue actions that benefit not just the network but also over the long-term improves the social situation of Landskrona. For example, two companies in the printing sector are currently trying to devise an employee sharing scheme. This arrangement will help maintain a high level of employment in Landskrona and it will secure more stable jobs for the workers in the network. Another benefit of this arrangement is to increase the information sharing between the two companies; employees can gain new perspectives on how to approach processes by learning to work in the other company. Both the network and the region benefit from this type of approach.

Stressing the importance of a social network: The IS project provides an incentive for improving the social cohesion of Landskrona by consistently stressing the importance of a social network. In almost all interviews with participants, they stated that they placed importance on building up connections with the other participants. Many felt that they could observe an increase and improvement in the communication level among companies and between companies and the municipality. Most participants felt that even if the project were to stop, this social network, supported by monthly breakfast meetings and thematic group meetings, would continue. This demonstrates that the drive for long-term social improvement of Landskrona is also instilled in the culture of the community. In this sense, as one participant puts it, the IS project has acted as more of a catalyst to get companies together and talking. There have been other networks forming over the past few years that

help improve communication and collaboration potentials in Landskrona. One example is a network formed by five companies to solve a problem of increased crime in their neighborhood. Other networks can be found among the chemical companies and companies concerned about related health and safety issues. In a small community such as Landskrona, the same companies are often involved in more than one network. One member joked that it is like a club that just changes rooms and topics. Although this is a funny picture, it shows that the Landskrona business community has an open social culture which supports inclusiveness and facilitation.

(Mis)Understanding the role of the municipality: Although most companies understand that they participate on equal levels with the other members of the IS project, there is some amount of ambiguity in the role of the municipality, especially of the environmental department. Some company representatives explained that they thought having the environmental department in the project would increase the ease of working with them on regulatory issues. They would like to see interaction with the municipality more on a collaborative basis instead of having the municipality act solely as the "enforcer." In some cases this can be true; the environmental department is working with companies on the legal classification of some of their waste that they would like to use as a source of renewable fuel. In other cases, this is not true; one company has not made any headway in permit negotiations. Representatives from the municipality have expressed slight concern that some companies are using the project as a way to informally discuss company specific issues with the department. For both sides, the boundaries and changing relationships are not clear. This was also noted as a concern in a prior evaluation of this IS network (Starlander, 2003) and has not yet been resolved. This can be described as a discontinuity of expectations and can lead to misunderstandings between the companies and municipality. If left unchecked, this can erode the IS project by having ill feelings develop between participants. In the extreme case, some participants could drop out of the project, as one company has indicated it may do so. In order to maintain the strength of the communication and trust level in the community among companies and between companies and municipalities, the coordinators of the IS project can act as a facilitator of open discussions on this topic of expectations and roles in order to mitigate any mounting resentments.

Increasing the education level of community members: Currently, the IS project provides no incentive for companies to help increase the education level of Landskrona. Community members have noted a decline in the education level in the community over the years. For sustainable regions, it is important to have a high level of education and employment opportunities that encourage students to pursue higher education. Supporting higher education levels in the region will help network companies have a more skilled pool from which to hire employees. There is a plan under development by the coordinators of the IS project that could mitigate this oversight in the social pillar of moving towards sustainability. This is the start of the DE LAB, as outlined in Section 4.6. This center of applied research could contribute to improving the social fabric of the community and the companies operating there.

ENVIRONMENTAL:

Reducing environmental impacts within a company- Due to the strong environmental department of the municipality, Landskrona is considered to have some of the highest environmental standards in the country. A representative from the municipality claims that over the past thirty years, companies have improved their environmental performances by about 75%. Heavy polluters have either changed their practices or left Landskrona and there

has been a general shift in thinking. This has helped Landskrona be higher on the environmental scale. The environmental department of the municipality has been a great force behind this improvement. In order to remain in business in Landskrona, there is a large incentive to reduce ambient concentrations of toxins (such as air and water emissions levels) in order to comply with regulations. Companies in Landskrona can be considered mature, with most having environmental and quality management systems in place for many years. The IS project has supported the reduction in environmental aspects and impacts by encouraging companies without management systems to participate in group certification for ISO 14001, the Step-By-Step program (see Section 4.3). This program helps companies develop better ways to mitigate or eliminate environmental impacts from their activities. There are four companies participating in this program and about 50% of the companies in the IS project already have certification. Companies also have an internal economic drive to reduce energy and resource consumption. Most companies realize that these are not fixed costs, but can be reduced by changing processes or developing ways to recover losses (e.g. selling waste heat to the district heating loop). Overall, the drive for reducing environmental impacts is systematic and strong in Landskrona.

Reducing environmental impacts collectively- There is a mixed level of motivation for companies to reduce environmental impacts collectively. When there is a clear economic gain involved, companies are active in pursuing collaboration possibilities. These physical connections are shown in Section 4.3. Although the network is quite new, there are already some success stories for resource reduction and waste elimination. There are also a couple participants actively working on options to reduce waste disposal and increase the use of renewable energy sources. There are many participants who are not sufficiently motivated to pursue possibilities for collaboration. Some companies' participation levels have dropped significantly over the past two years and some others seem unwilling to initiate contact with others for the purposes of discussing specific opportunities. It seems that the group is split between those who are quite positive and active in the network, and those who view it as a financial obligation or a curiosity. When interviewed, almost all participants acknowledge the economic and environmental benefits to these types of collaborations. The natural incentives for collaborating with others to reduce environmental impacts (and achieving reduced levels of ambient concentrations of toxins) therefore exist, but the motivation level for overcoming barriers is waning for some. This can be mitigated by expanding the search for connections to companies located outside of Landskrona but within the Öresund Region. Coordinators can help in identifying viable options and facilitating meetings of those parties who should be involved. Often, companies that have not found local connections get frustrated. Giving them new opportunities to collaborate can maintain the desire to act collectively to reduce environmental impacts.

Greening of Feedstocks- The efforts to change the feedstocks of the companies and the community from fossil fuels to renewable fuels have not been so successful so far. One company reported that when the time came for updating their equipment, they actually switched their wood burning boilers back to oil burning ones (SW). Two companies are looking into providing renewable energy fuel for the district heating system in Landskrona by using agricultural wastes. Upcoming regulations may deter these efforts. The new EU Directive regulating what is allowed to be burned might not allow the agricultural wastes to be defined as renewable fuel sources. This would inhibit the greening of Landskrona's energy supply. There may be a regulatory incentive for the Landskrona community to switch to renewable fuels. One of the stated aims of the region is to reduce the use of non-renewable natural resources. If this is incorporated in plans for Landskrona and associated with concrete targets, the municipality may place pressure on companies to help contribute

to these targets. However, as regional plans are still in the discussion phase, it is too early to speculate on whether this could really become a solid incentive for companies to, either collectively or individually, decrease Landskrona's use of non-renewable feedstocks.

Viewing the life-cycle impacts of production- Interviews showed that those companies using an EMS are aware of the need to examine life-cycle impacts of their businesses. This includes product impacts after leaving the boundaries of the production company. Those companies in the network that have been involved in changing their products to more environmentally benign forms (5 companies) all have ISO 14001 certification. Those (2 companies) who expressed skepticism about changing their core business products also said that their upper management was not interested in pursuing certification of an EMS. Although this is not a large sample size, there is a small correlation with working with a management system and being concerned about the life-cycle impacts of a company's entire business. By supporting the EMS certification process (mainly through the Step-By-Step program), the IS network coordinators can, though indirectly, positively influence companies to begin the greening of their products.

Participating in the business of recycling and waste reclamation- Four of the companies in the IS network have recycling activities as a core part of their business. These companies base their profits on materials that otherwise would simply be landfilled or incinerated. Some of the recycling methods are new innovations in material recovery. Due to the nature of their businesses, there is an inherent incentive for them to participate in and increase their waste reclamation activities, or recycling efforts, for the community of Landskrona and beyond. For the other companies, there is no obvious incentive for them to do the same. This perhaps can be a positive thing in the beginning, though, as it keeps the focus of participants away from waste while the network is still developing. The IS network in Landskrona is still trying to establish an open mindset for participants and support the vision of a network based around more than waste. In the future, coordinators may be able to increase recycling and waste reclamation activities by providing technological assistance.

Changing of Business Models- Some participating companies are beginning to enter the sphere of the production-consumption loop. They are working with customers to design products or services to be more eco-efficient. This is a positive step forward for these companies. So far, however, it was made apparent from interviews that companies are not considering moving to a more service- or information-based approach. Without this shift, the potential for rebound effects of increased efficiency will exist. As it is still early in the network formation, this type of business model change may be more appropriate for future years when companies have been made fully aware of and educated about the potential benefits of pursuing dematerialization. Coordinators can play a role in the transition of companies away from "business as usual" by providing information and guidance in this area to companies.

Participation in Cleaner Production Project- As mentioned earlier, some companies involved in the IS network participated in the Landskrona cleaner production project. These companies saw large successes, including reductions in energy, chemical, and water use and economic gains. Interviews with participants from these companies reveal an open-mindedness to examine their businesses and see what changes could be made in order to work with others. Through the network, experiences such as these are encouraged to be shared. For example, in the first physical connection to be established, one of the companies redesigned their processes to be more efficient in their use of water before accepting second-hand water from the other company. This previous success, and sharing of experiences,

provides an incentive for these companies and those working with them to think about improving, or greening, their processes. This can eventually lead to increasing energy, material and resource efficiency. Creating incentives for companies to switch to more renewable energy resources is currently not addressed in the context of the network.

This assessment of the alignment of the Landskrona IS network with a vision of sustainability is summarized in Table 5-1. This table shows whether there are incentives that currently exist within the network to following a sustainable path.

Table 5-1 Summary of Incentives for Landskrona IS Network Companies to Pursue a Vision of Sustainability

	Incentive Exists	Incentive Not Yet Addressed	Mitigation
ECONOMIC			
Maintain and improve diversity	X		
Keep companies participating in collaborative schemes (IS project)		X	• Maintain enthusiasm with project champion/coordinators • Catalogue "soft" benefits • Respond quickly to companies' needs
Pursue balanced economic development efforts	X		
SOCIAL			
High level of employment	X		
Social cohesion and inclusiveness	X (for business community)	X (for general society)	• Combine efforts with Öresund Region Committee for cultural and social integration plans
High education level		X	• Increase education level of community through DE Lab and collaboration with nearby universities • Use DE Lab to improve sophistication of companies to create high level jobs
ENVIRONMENTAL			
Reduction of company-specific environmental impacts (ambient concentrations of toxins)	X		
Collective reduction of ambient concentrations of toxins	X	X	• Expand boundaries of collaboration to Öresund Region where appropriate • Help brainstorm or identify new connection options • Include company members "on the floor" in the pursuit of this goal
Increase of recycling	X		
Increase of material, resource and energy efficiency	X		

Substitution of renewable resources for exhaustible ones		X (legislative barriers)	• Work with local authorities to include renewable energy goals in regional plan • Facilitate talks between companies and authorities about defining organic waste as renewable energy
Greening of Feedstocks		X	• Work with companies to create goals, targets, and action plans for increasing the use of more environmentally benign feedstocks
Greening of Products	X		
Greening of Processes	X		
Waste Reclamation		X	• Provide technological assistance for developing more economic techniques
Dematerialization		X	• Educate and guide companies on new business models that use a more service- or information-based approach

5.2 Alignment with Regional Sustainability Efforts

The previous analysis focused on how well the IS network was aligned with general criteria for sustainability. This section will look at the location-specific nature of the network and assess where the network fits in the regional context.

5.2.1 Landskrona Municipality

Local authorities from Landskrona state that there are plans for the development and implementation of an environmental program that helps achieve Swedish national goals. Industries have been invited to take part in the creation of this program as well as general regional development plans. Since a solid structure is not yet in place, it is difficult to assess how well the IS network is already aligned with the community vision of sustainability. In this case, it would be beneficial to encourage companies to really get involved in the creation of the plans. The companies can then give their input into how they would like the municipality to look, and how the IS network can help them move in that direction. If they are more interactive there is a greater chance of avoiding conflict between industry and government. There is a greater opportunity to collectively create a progressive, achievable vision for Landskrona.

Many companies may feel that they do not have the time to devote to planning meetings with local authorities. In interviews, almost all IS network participants stated that taking time for these types of issues is always difficult. In this case, the companies can really start to rely on the new network they created. A participant or coordinator from the IS network can be chosen to represent the companies in the network at the regional planning meetings, acting as the voice for all interests. Often, a consolidated voice is more powerful so there could be a double benefit of saving some people time and having a more effective interaction level.

Although plans have not been made identifying priority areas in Landskrona, through observation and interviews it is apparent that there are certain areas that stand out as unsustainable in the long term. These are the lack of social integration and the falling level of education. Suggestions on how to improve the network's participation to improving these areas will be discussed in Section 5.3.

5.2.2 Skåne Political Region

Region Skåne has established four areas of focus for a sustainable future, as well as nine specific environmental goals (see Section 4.2). Work in the IS network supports the active pursuit of eight out of the nine environmental goals (reporting on the connection between environment and human health has not been addressed). The companies on their own, or working with each other, recognize the benefits to environmental work. This is excellent alignment between the efforts of the companies and the desires of the region. Some of the objectives within the four priority areas are also addressed. The strongest connections within the priority areas are in attractiveness and sustainability. Within these two areas of focus, the IS network is working on reducing release of toxic substances, improving safety, increasing collaboration, and establishing more research and development (R&D) centers. There is so far no indication that the priority areas of growth and balance are on the agendas of businesses within the IS network. These two areas address mostly social issues, an aspect that has been noted as not fully integrated in the foundation of the IS network.

5.2.3 Öresund Region

The creation of an IS network in Landskrona is directly in line with plans for the Öresund Region to promote "networking and knowledge diffusion" (one of the four policy areas). All three of the main priority areas of the Öresund Committee (see Section 4.3) are being actively pursued by the Landskrona IS network. The Landskrona IS network, together with the Kalundborg IS network, will hopefully form the base of a successful collaboration project. This can be used as a success story for the new region and show the benefits of collaboration within the clusters and across the Sound. The creation of the DE Lab in Landskrona will help fulfill the OECD recommendation for an innovation center. When the IS network is managed as a part of this center, it will be easier to integrate all three levels of planning—Landskrona, Skåne, and Öresund— within the pursuit of sustainability for the IS network.

5.3 Bridging the Gaps to Sustainability

The Landskrona network is in the early stages of IS. Companies are just beginning to recognize a social web and acknowledge the increase of communication among companies. In the transition from a traditional regional model to one where there is a fully functional cluster or network, Landskrona is in the early stage of the predevelopment phase (see Figure 3-6). A strong foundation has been established in this network, both by the inherent maturity and high level of responsibility of the companies, as well as by the positive coordination and education efforts of researchers at IIIEE. At this early stage, it is important to build on this foundation and work to tackle issues not yet addressed. Maintaining a high education and awareness level of participants is key to making certain that the network will continue on a path beneficial for companies and the region.

5.3.1 Economic

The main gap in the economic aspect of the network's sustainability is in keeping companies motivated to maintain active in the network and working for the common good. Keeping companies enthusiastic in participating can be difficult when they can't find immediate paybacks for their involvement. Many SMEs have a hard time sparing the time and resources to devote to this type of work. Therefore, it is important to improve the "soft" benefits until hard financial benefits can be found. A suggestion from one participant was to increase the efforts on group marketing of the network. Positive publicity for the companies

can help increase sales or open up new doors for companies with limited marketing budgets. Building the reputation of Landskrona as home to progressive, clean companies will create some of these soft benefits like a sellable image. Another way to make sure companies realize the significance of this work is to keep the IS network project in the consciousness of participants. Coordinators must be prepared to respond rapidly to the questions and needs of companies so that participants feel like things are moving along. Employees from the companies should also be kept aware of what their company is attempting to do with the IS network. This can be done e.g. through short email updates, a bi-monthly employee briefing, or having the coordinators speak with a sample of the employees. More people will be aware of the project goals and can think of ways to create collaborations. Many times, ideas come from employees working at the process level who just needed to be asked different questions. In this way, the same half an hour needed to update two company representatives will update 200 and many more people will use their creativity.

5.3.2 Social

The social aspect of the network's sustainability is lacking in stimulating both education and social cohesion. Here, coordinating with the DE Lab and the Öresund Region efforts can address some of these concerns. One of the projects in the Öresund Region is in increasing cultural education for people located in the region. The main drive for this project is to facilitate Swedes and Danes in working closely together. In Landskrona, there are also difficulties in cultural understandings because of the large populations of immigrants. Companies have expressed concern because the indirect outcome of lack of social integration is lack of employment and ultimately higher crime levels. Landskrona can combine efforts for cultural education with Öresund so that the local focus is expanded from Swedish-Danish exchange to a multi-cultural exchange. This might be outside the scope of IS network activities, but inside the sphere of influence of the DE Lab acting as a more comprehensive program than the network alone. DE Lab activities will be vital to increasing the education initiatives and level in Landskrona. It is hoped that in 2-3 years the center could set up an environmental education exchange where visitors could come for field research. Landskrona is traditionally not a town for highly educated people, so this could raise the sophistication level of systems in industries. It would also increase the flow of researchers to Landskrona. If combined with courses given through the center or in nearby universities in conjunction with the center, the education level of Landskrona people could increase. A four-week masters teaching module in IS is currently under development in coordination with the IIIEE. There would be an incentive for people to pursue higher education because they would have better opportunities to work within local industries. This would also help create an identity for Landskrona as a center of innovation and collaboration. In this way, the IS network as a part of the DE Lab could improve both the economy and social characteristics of Landskrona.

5.3.3 Environmental

For the environmental side, companies are sufficiently motivated to reduce environmental impacts. This is due to both the strong legislative push and the maturity of the companies in realizing the benefits of environmental work. The environmental aspect that is not quite as strong is reducing collective environmental impacts when there is no clear, fast economic payback. To change this situation, it might be necessary to selectively expand the network to include companies from the greater Öresund region. Connections for reducing environmental impacts and increasing economic benefits cannot be forced where they don't exist. Instead, these connections could be found by expanding the scope of the search. For

companies now a part of the network, it is also important to continue small group meetings centered on themes of connection. In smaller groups with a narrower focus, time can be spent more efficiently exploring what options do exist within the present system. The second environmental aspect that is not strong in the network is the conversion to more renewable energy sources. This is due to legislative barriers. Companies, coordinators, and local authorities are now working together to address this issue. This type of cooperation will help resolve this oversight in the pursuit of sustainability in the network.

5.4 Supporting IS Network Participants

Often, companies are focused on the practical application of connections solely as it applies to their company or the company with whom they may exchange materials or resources. In order for the direction of the IS network to both achieve the practical applications of theory and maintain a progressive, positive direction for the community, it is necessary to have a researcher involved until the network is completely self-reliant. Although company participants emphasized their desire to have researcher involvement in coordinating the IS network, this does not necessarily mean that the present situation is ideal. There are a few ways that researchers and companies can improve this relationship so that effectiveness, efficiency, and quality levels of interaction are increased both in the short and long-term and for both the network and the region.

5.4.1 Short-Term: Network Sustainability

The first step in making changes that can be implemented quickly is to have the coordination of the IS network physically located in Landskrona, instead of in Lund as it is now. The distance between Lund and Landskrona is not large, but it is enough to require unnecessary effort in communicating. When coordination is run from Landskrona it is easier for participants to arrange more informal meetings or discussions on short notice when questions arise.

Throughout this research, it became evident that companies are beginning to feel frustrated with the slow pace of progress or change from the IS network. In the large network meetings, connections that were seen by companies as quite small and possibly insignificant were not discussed. These were only discovered later through individual interviews. However, when participants at the group meetings were shown a diagram which brought together all the small pieces of progress that had been made so far, the enthusiasm level increased visibly. This demonstrates that it is necessary for participants to be reminded of the bigger picture. It is hard to realize the significance of a little step forward within one company until it is placed in the context of all the efforts. By seeing the collective picture of progress, it is easier to maintain enthusiasm and motivation. One service that coordinators can do to help advance this IS network into more mature stages is to provide updates for participants of how the collective picture of success is changing.

From interviews and observations of meeting attendance, it is clear that there are not enough companies involved who have both the resources and commitment to continue the project by themselves. Lack of resources could be in the area of both time and money to devote to working towards maintaining a cohesive, evolving IS network. They do want a Landskrona presence in the coordination and organization though. Many have expressed desire for having a continued presence of an institution such as the IIIEE. The enthusiasm and motivation level of participants at all levels can be better sustained with researcher efforts to keep ideas and progress made in the forefront. Continual communication and interaction,

where all the pieces of change are put together in a big picture, can help make mentality, behavioral, and technical changes systemic instead of sporadic. With continuous support, participants can slowly ensure that the right conditions are established for a successful, sustainable network and region.

5.4.2 Long-Term: Network and Regional Sustainability

In the case of Landskrona, researchers from IIIEE are acting as coordinators who guide the network through the transition from an emerging network of collaboration to a self-sustaining network pursuing sustainable approaches. These researchers have expertise in strategic management and are able to help companies establish a group vision and manage the transition. This can be accomplished in a series of meetings or workshops where participants go through exercises in backcasting. As shown in Figure 3-7, backcasting involves starting in the future. A future vision is agreed upon, with consideration for company needs as well as regional (both political and functional) plans. Then the companies work backwards towards the present to set up milestones of what needs to be in place in order to ensure achieving success. This would serve as the master plan, with companies deciding on more specific goals and targets along the way to the future vision. As mentioned in section 5.3.1, one of the gaps is that not all network stakeholders are involved in the process of creating and sustaining the IS network. Right now, mainly upper level managers act as representatives from companies. Before a master plan is created, it might be in the best interest of those involved to broaden stakeholder involvement so that underrepresented interests are not left out of long-term plans.

Throughout the transition from the present to the future, there should be collective learning and education initiatives. This can be done through the DE Lab, whose focus will be partly on increasing the exchange of knowledge and know-how in businesses in order to stimulate innovation. For example, companies may decide that part of their long-term vision is a more locally-based business flow. In order to achieve this part of the future vision, some changes will have to occur in stages. Milestones can be to have a certain percentage of revenue from local transactions, a larger number of locally owned businesses, or a certain level of employment of people living locally. Companies would work backwards with the coordinators to see what needs to be in place for these things to happen. Perhaps a new differentiated product needs to be developed that satisfies a local need or that uses the local resources (both human and natural) in a new, more effective way. The DE Lab can then help research these options or provide training for employees, related business partners, and others. When a comprehensive plan is established, these kinds of efforts can be placed in context and executed more strategically.

6 Conclusions and Recommendations

IS represents integrated efforts at collaboration among organizations in a local area network. These inter-dependent relationships are seen as closely related to natural system functions and efforts to remain in balance with them. The type of interaction stressed in an IS network therefore has the potential to lead to more sustainable environmental, social, and economic practices. However, case studies of IS around the world usually show a large discrepancy between theory and practice. It is understood that there will never be an achievement of the "ideal" network or region. Nevertheless, as networks mature, IS practitioners may be able to guide networks in progressing more smoothly and successfully towards sustainability. The objective of this thesis is to evaluate the potential for IS networks to evolve towards regional sustainability efforts. Focusing on the Landskrona IS network in Sweden, it aims to increase understanding, and possibly strengthen, the connection between IS and regional sustainability. The work then examines how industrial symbiosis practitioners can bridge the gap between theory and practice, and steer their network's progress to follow a path that better supports long-term, sustainable plans. The main results of the thesis are shortly summarized in the following sections. Conclusions are drawn about the development of the Landskrona IS network and recommendations are made to improve the future development of IS networks in general.

6.1 Alignment of IS Networks and Regional Sustainability

A review of IS networks in general and of the Landskrona IS network in detail reveal that the full range of economic, social, and environmental issues are only partially addressed in these inter-organizational collaboration schemes. If the claim is to be made that organizations practicing IS are on a path to sustainability, it is critical for these organizations to incorporate all three aspects of sustainability (economic, environmental and social) in their pursuits. There have been great strides in progress in IS, from companies addressing aspects such as increased diversion of waste to landfill, reduction of energy and water consumption per unit of product or service, reduction of emissions and increase of company revenues from sale of by-products. However, social issues are often overlooked and it is evident that IS networks focus on limited parts of material cycles. It is not expected that IS participant companies will immediately close all materials cycles, but there is a need for them to extend the boundaries of focus beyond production loops. Companies should also realize the benefits of closing consumption loops and decreasing the total material throughput. There has not yet been this type of fundamental paradigm shift in the thinking of the people involved. The Landskrona case provides a comprehensive view of what kinds of efforts have been made to improve the economic, social, and environmental situation of the companies involved and the region in which they work. The network is assessed using general criteria for sustainability (see Figure 3-5) as well as from a regional context to judge the alignment with location-specific sustainability goals.

As was shown in the analysis of this study (refer to Section 5), the Landskrona IS network satisfies a great deal of the criteria for sustainability of a network. Within Landskrona, motivations exist for pursuing or maintaining economic issues such as diversity, balance, and local networking strength. Network participants are beginning to realize the possibilities that network participation offers. Raising awareness of the broad scope of what an IS network can encompass and achieve is an ongoing process in Landskrona. On a regional scale, locality issues are not yet acted upon. Many of the network companies are international, and they deal with national or international suppliers and customers. This means that the wealth

generated from company activities does not necessarily remain in the region. This could become an area of concern for the future of the region.

Social aspects, mainly social cohesion and education levels, are not concentrated on in the operation of an IS network. In Landskrona, the network does not yet address increasing the education level of employees or community members. It has been noted in interviews that the education level of Landskrona is decreasing. With high education, people can more quickly learn new skills and techniques, modify behaviors, and have the know-how to pursue creative or innovative solutions. In the long term, having a lower education level of employment pools may negatively affect the ability of companies in the network to increase their sophistication or human capacity levels. When a company employs people with higher education levels, it has a greater ability to adapt, evolve, and respond to changing business climates. As a whole, the network may be less able to make progress without the necessary sophistication of its parts. From a regional perspective, a major issue for social sustainability is the enhancement of social cohesion and inclusiveness. This is especially critical for communities in and around Landskrona, where there are large immigrant populations as well as close proximity to Denmark and its diverse culture.

From an environmental viewpoint, the Landskrona IS network is quite advanced. Landskrona is known for its strong environmental position and companies are under great external and internal pressure to improve environmental performance. Therefore, incentives exist for reducing the release of environmental pollutants. Researchers have also been educating company participants on the importance and advantage of pursuing collective efforts of reducing environmental emissions using a more preventative approach. Interviews reveal that a growing awareness is evident in the mindset of participants. The network shows effort in the greening of products and processes, and incentives exist for increasing recycling as well as material, resource, and energy efficiency efforts. Two areas not yet acted upon by the network are in the greening of feedstocks, most notably the change to more renewable sources, and pursuit of dematerialization strategies. This seems to be the general trend for IS networks; these types of development require a commitment for large system changes. There must be a shift in the "business as usual" model if networks truly wish to pursue closing more of the loops. This system evolution not yet happening or planned for in IS networks.

In summary, the economic and environmental pursuits of the IS network seem in line with network and regional sustainability goals. The main areas of concern are in the social aspects and in environmental aspects which require a large change in core business practices.

6.2 Bridging the Gaps to Sustainability

The Landskrona IS network has not fully adopted progressive change. The network does not yet satisfy the criteria for pursuing sustainability goals of Skåne and Öresund. In the future, the network may not be fully aligned with the developing needs of the region. If left on the same development track, there would be gaps in the network's effort to approach sustainability. Areas currently not managed by the network should be addressed early so that participants and coordinators can build a strong foundation of education, awareness, and competence to achieve change. With this strong foundation, a network will be better able to adapt to new needs or goals that arise from its region.

There are three main actions that can be undertaken to bridge the gaps to sustainability. The first is to use the newly created DE Lab to strengthen the support of Landskrona IS network

participants. Activities that might be outside the normal scope of the companies involved, such as multi-cultural exchange programs, field courses with local universities, or alternative fuel development projects, can still be pursued with company input and effort. Companies may not be able to engage in these types of changes on their own, but they may be successful when brought together not just in their IS network but in a greater regional endeavor. The applied research center could act almost as a supra-network, ensuring that regional projects are coordinated so that synergistic effects can be realized.

The second action is to more closely coordinate the work of the IS network, the DE Lab, and actors from the Skåne and Öresund Regions. One gap not usually addressed in IS network literature is the input and support of stakeholders not typically included in IS network management schemes. For sustainability of the network, stakeholders may include upper management, employees (or chosen employee representatives for larger companies), and/or other board members. When network and regional interests are going to be integrated, it is important to include community and governmental stakeholders in order to represent regional interests. The Landskrona IS network tries to address this through the inclusion of government representatives and national reference group participants. These and other community actors play a key role in supporting initiatives such as educational programs and they can demonstrate their involvement or encouragement by sending the right market signals to companies who are e.g. starting cleaner production projects. The expanded scope of stakeholder involvement allows network participants to more closely coordinate their efforts with those of regional committees or organizations. Many of the projects of the Öresund Region are parallel to the aims of the Landskrona IS network. Benefits can be maximized by joining efforts with all parties involved. In the end, a stronger region can be created by having more people work on projects that will improve the sustainability of the region and networks within it.

The third, and perhaps the biggest bridge to the identified gaps in sustainability, is a coherent, long-term vision and associated action plans that bring all of these concerns together. Many networks are run on an ad-hoc basis where connections are pursued in light of financial benefits without seeing the larger, regional picture. There is a need for an overlying joint vision and strategy that places connections in the context of long term goals for achieving success. When working to achieve a long-term vision, it is easier to see where gaps arise in a network's actions. For example, many networks are anchored around a fossil-fuel based industry. Without a long-term goal of moving towards more renewable fuels, there is no awareness for the need to develop action plans to change the industry itself. However, if the network analyzes the whole picture of their network and its connection to the region, the vision may include transitional steps for reducing reliance on fossil-based fuels. There are many steps that can be decided upon, for example to increase research and development efforts on alternative fuels. The major step that will occur, though, is that the need for change is recognized and planned for.

6.3 Supporting IS Network Participants

In many ways, the examined IS network is on the path of sustainability, but some key aspects are still missing. It is important to address these gaps early and figure out with participants how to create the right incentives and conditions to ensure long-term success for the network and the region. At the current stage of the network, a large contribution that coordinators can make is facilitating the creation of conditions for a self-sustaining network committed to sustainable approaches. As outlined in Section 5.1, some actions that coordinators can take include helping to:

- Maintain enthusiasm of participants by responding quickly to companies' needs and providing updates on small as well as large changes;

- Sustain participation levels through times of slower change or less visible financial benefits by cataloguing "soft" benefits;

- Expand, as appropriate, the level of participants both internally, with company employees "on the floor," and externally, with companies in the greater Öresund Region with whom collaborations would be beneficial;

- Brainstorm, identify, and plan for new connection options;

- Facilitate communication between regional representatives and network participants in order to ensure that longer-term goals are agreed upon and planned for.

Many recommendations can be made for improving parts of the network and network alignment, but ultimately they need to fit into a grand scheme. With a network focused on a holistic, systematic view of industry and society, it is a logical step to create a holistic view of the future of the network. Coordinators can support network participants by facilitating the creation of a group vision and action plan that incorporate the strategies from the sustainability framework (see Figure 3-5) as well as regional goals and objectives. In the Landskrona case, IIIEE researchers have expertise in strategic management and can therefore lead the network and other regional participants through transitional changes. Researchers can lead the network in backcasting exercises (see Section 3.5) and help formulate a coherent, comprehensive plan for transitioning through the phases of change.

Throughout the network development, it is necessary to support participants both technically and organizationally. Researchers can educate companies on the use of tools that can be helpful in achieving IS goals, such as increasing efficiency, and closing material, production, and consumer loops. The initiation and management of strategies to implement the greening of processes, feedstocks, or products using e.g. DFE, LCA, EMS, or CP can be facilitated with researcher expertise. On the more organizational side, researchers can support the network by maintaining a broad, balanced view of individual company, network, and regional concerns. Consistently broadening the mindset of participants helps ensure that aspects of sustainability will not be overlooked in actions. For example, working with participants to explore options of employee exchanges as well as waste exchanges boosts the strength of the social responsibility of the network, an area that might be lacking otherwise. Researchers have the expertise to support identifying and coordinating exchanges and the ability to maintain a broader vision for the network. While companies focus more on the practical applications of individual projects, a researcher can focus on the comprehensive view of how all the companies fit together and how they can be guided to more effectively advance a long-term vision of sustainability.

6.4 General Conclusions

In the early stages of an IS network, there is great opportunity to steer development in a direction of higher sustainability. The Framework of Sustainability criteria can be applied to IS networks as a general litmus test to determine which areas of sustainability are currently addressed in the network's operations. To adjust the picture of network sustainability to the local situation and priorities, more specific regional goals and objectives should be integrated with the sustainability criteria. In Landskrona, many companies entered the IS network

under advantageous conditions for future success. The companies are mature in their environmental performance, committed to sustainability, and eager to pursue a broad range of connection possibilities. Landskrona has a strong sense of community and entrepreneurship, and encourages diversification through the local municipality. These conditions help Landskrona to progress rapidly.

For other networks in Sweden and around the world, these initial conditions may not exist in this combination. More work may be required to help the individual companies achieve a higher maturity level. The network setting can facilitate individual improvement, as the Landskrona example of group EMS certification demonstrates. To achieve this, more group education and guidance should be provided on the use of tools or approaches such as: design-for-environment, environmental management system, life cycle analysis, cleaner production, alternative fuel development, and/or service business models. While implementing these tools and approaches, companies should work together for group motivation, benchmarking, or technological coordination to achieve a higher level of success while using fewer resources.

Even if the starting point of the companies is at an earlier stage of development than seen in Landskrona, a long-term focus is critical for any network. It ensures that, while creating inter-dependencies in an IS network, the sustainable development of companies on an individual basis is not hindered. For all networks, regardless of the network's or the participating individual companies' maturity levels, a need exists to develop and continuously evaluate a comprehensive vision in order to progress towards the next level of sustainability. Coordinators and company participants alike must be aware of the incentives and dynamics created in their network considering the desired future development of the network. With a consistent, concerted effort to fully pursue economic, social, and environmental components of sustainability, IS networks successfully participate in the "science of sustainability."

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INTERVIEWS (In Person)

2004- June 10	Charlotta Barthelson, charlotta.barthelson@mf.landskrona.se, Environmental Inspector, Miljöförvaltningen (City of Landskrona Environmental Administration), Landskrona Kommun
2004- June 10	Högni Hansson, hogni.hansson@mf.landskrona.se, Director, Miljöförvaltningen (City of Landskrona Environmental Administration), Landskrona Kommun
2004- June 11	Anderz Boij, anderz.boij@pilkington.se, Process Improver, Pilkington Automotive Sweden AB
2004- June 11	Erik Behmer, erik.behmer@pilkington.se, Technical Manager, Pilkington Automotive Sweden AB
2004- June 15	Bertil Winér, bertil.winer@dsm.com, Safety/Quality Assurance Manager, DSM Resins Scandinavia AB
2004- June 15	Claes Hallberg, claes.hallberg@haldex.com, Environmental Coordinator, Haldex Brake Products AB
2004- June 15	Roland Rundqvist, roland.rundqvist@parajett.se, Operational controller, Parajett AB
2004- June 16	Lars Jansson, lars.jansson@sabwabco.com, SAB Wabco Nordic AB
2004- June 16	Sofia Herstadt, sofia.herstadt@sabwabco.com, SAB Wabco Nordic AB

2004- June 17	Lena Johannesson, lena.johannesson@syngenta.se, Manager- Pre-commercial seeds department, Syngenta Seeds AB
2004- June 17	Staffan Aronsohn, staffan.aronsohn@basmetal.se, Managing Director, BASMetal AB
2004- June 17	Claes Nilsson, claes.nilsson@inla.se, Director, Utvecklingsstiftelsen (Development Foundation in Landskrona)
2004- June 22	Lars Hansson, Lars.hansson@embra.se, Technical Manager, Embra AB
2004- June 22	Lars Siljebratt, lars.siljebratt@glocalnet.net, TEM
2004- June 23	Ulf Helgesson, ulf.helgesson@scandust.se, Managing Director, ScanDust AB
2004- June 23	Johann Magnusson, johan@galvanoverken.se, Managing Director, AB Landskrona Galvanoverk
2004- June 23	Kåre Larsson, kare.larsson@tv.landskrona.se, Director, District Heating and Water Distribution and Treatment Department, Tekniska Verken (City of Landskrona Technical Department), Landskrona Kommun
2004- June 24	Anders Nilsson, anders.nilsson@sweed.com, Svalöf Weibull
2004 July 13	Mats Hafström, mats.hafstrom@lsr.nu, Development and Marketing Manager, Landskrona Svalövs Renhållnings (LSR) AB
2004- July 16	Erik Vestergård, ErikVestergard@rohmhaas.com, Technical Manager, Rohm and Haas Nordiska AB
2004- July 27	Bjorn Sneckenborg, bjorn.sneckenborg@flexmed.se, Sales Manager, Flexmed AB
2004- August 12	Noel Brings Jacobsen, ++0045 287 54 080, Administrative Director, Öresund Committee
2004- August 13	Peter Kisch, peter.kisch@iiiee.lu.se, IIIEE

Abbreviations

BCSD-UK	Business Council for Sustainable Development- United Kingdom
CFC	chlorofluorocarbon compounds
CP	Cleaner Production
DDT	Dichlorodiphynyltrichloroethane
DE	Distributed Economy
DFE	Design for the Environment
EC	European Commission
EIP	Eco-Industrial Parks
EMS	Environmental management system
EPA	Environmental Protection Agency
EU	European Union
IE	Industrial Ecology
IIIEE	International Institute for Industrial Environmental Economics
INES	Industrial EcoSystem Project (in Rotterdam)
IS	Industrial Symbiosis
LCA	Life Cycle Assessment
n.d.	No data available
NGO	Non-governmental organization
NISP	National Industrial Symbiosis Programme
NUTEK	Swedish National Board for Industrial and Technical Development
OECD	Organization for Cooperation and Development
R&D	Research and Development
SEK	Swedish kronor
SME	Small to medium sized enterprises
TEM	Foundation of Technology, Environment, and Management
TEQM	Total environmental quality management
VOC	Volatile organic compound
WCED	World Commission on Environment and Development
WWTP	Waste water treatment plant

Appendix A: Swedish Parliament's 15 national environmental quality objectives for ecologically sustainable development (Svenska miljönätet, 2004).

1. Reduced Climate Impact

2. Clean Air

3. Natural Acidification Only

4. A Non-Toxic Environment

5. A Protective Ozone Layer

6. A Safe Radiation Environment

7. Zero Eutrophication

8. Flourishing Lakes and Streams

9. Good-Quality Groundwater

10. A Balanced Marine Environment, Flourishing Coastal Areas and Archipelagos

11. Thriving Wetlands

12. Sustainable Forests

13. A Varied Agricultural Landscape

14. A Magnificent Mountain Landscape

15. A Good Built Environment

Appendix B: List of Reference Group Participants (Starlander, 2003)

National Reference Group
Organizations
The Swedish Environmental Ministry (Miljödepartementet)
Swedish Environmental Protection Agency (Naturvårdsverket)
Swedish Business Development Agency (Verket för näringslivsutveckling- NUTEK)
The Swedish Environmental Management Council (Miljöstyrningsrådet)
The Confederation of Swedish Enterprises (Svenskt Näringsliv)
The Association of Swedish Environmetnal Managers (Näringslivets Miljöchefer)
Skåne County Government (Länsstyrelsen i Skåne län)
The Environmental Department of the Municipality of Landskrona (Miljöförvaltningen Landskrona Kommun)
The Office for Trade and Industry of the Municipality of Landskrona (Utvecklings Stiftelsen i Landskrona)
Sustainable Business Hub
Local Company representatives
IIIIEE representatives

International Reference Group	
Organisation – Country	**Contact Person**
VTT – Finland	Allan Johansson
University of Joensuu – Finland	Jouni Korhonen
Business Council for Sustainable Development – UK	Peter Laybourn
Yale School of Forestry and Environmental Studies – USA	Marian R. Chertow
MIT Technology, Business and Environment Program – USA	John R. Ehrenfeld
Øresund Environment	Noel Brings Jacobsen
Norwegian University of Science and Technology's (NTNU) Industrial Ecology Programme – Norway	Helge Brattebo
Institute for communication and analysis of science and technology (ICAST), Applied Industrial Ecology Programme	Suren Erkman
Erasmus Centre for Environmetnal Studies, Erasmus University – Netherlands	Leo Bass
Kalundborg Centre of Industrial Symbiosis – Denmark	Noel Brings Jacobsen

Appendix C: List of Companies Participating in the Landskrona IS Network (Starlander, 2003)

As of September 2004

Company Name	Sector and Activity	Number of Employees	Turnover (SEK)
AB Landskrona Galvanoverk	Metal works: electroplating of metal objects with zinc and chromium using drum and conveyor lines.	8	6 MSEK
BASMetal AB	Metal works: collection, sorting, and pre-processing of various sorts of metals for recycling	11	n.d.
Boliden Bergsöe AB	Metal works: recovery and recycling of lead and zinc from car batteries discarded in Nordic countries	130	265 MSEK (2002)
DSM Resins Scandinavia AB	Chemical: production of binders for paint manufacturing by emulsifying various monomers in water and solvent based solutions	54	139 MSEK
Embra AB	Cement distribution: intermediate storage and handling of cement in port terminals	4	100 MSEK (2001)
Flexmed AB	Printing: water-based printing, coating and slitting of a wide range of flexible peelable and non-peelable packaging materials	33	82 MSEK (2002)
Haldex Brake Products AB	Automotive components: production of brake parts for heavy vehicles	550	730 MSEK
Landskrona Svalöv Renhållnings (LSR) AB	Waste management: collection, transportation, sorting, treatment and off-site recycling of household and industrial waste; on-site production of plastic pellets for combustion: on-site production of woodchips for combustion; landfilling and biogas recovery of organic waste and household waste; composting of garden waste	15	56 MSEK (2003)
Miljöförvaltningen Landskrona Kommun (City of Landskrona Environmental Administration)	Public agency: regulates and enforces laws, issues permits, and performs inspections regarding all activities creating environment and health impacts; disseminates environmental information (with preventative focus) to community	13	n.d.
Parajett AB	Printing: communication and printing solutions	220	215 MSEK (2002)

Company Name	Sector and Activity	Number of Employees	Turnover (SEK)
Pilkington Automotive Sweden AB	Automotive components: production of toughened glass to be used as backlights, sidelights, and rooflights (windows) by various car manufacturers	109	200 MSEK
Rohm & Haas Nordiska AB	Chemical: production of water-based suspensions by mixing acrylic based monomers with water and other chemicals and producing water borne polymer suspensions	90	461 MSEK (2001)
SAB Wabco Nordic AB	Rail vehicle components: production of brake components for rail vehicles	130	3 BSEK (group)
Scandiflex AB	Packaging: production of printed and unprinted plastic laminate for food packaging	55	125 MSEK
ScanDust AB	Metal works: recycling of filter dust from stainless steel industry	65	150 MSEK
Svalöf Weibull AB	Agricultural products: breeding and production of various agricultural and horticultural seeds	60	1.1 BSEK (group)
Syngenta Seeds AB	Agricultural products: breeding and production and packaging of sugar beet seeds	220	54 MSEK
Tekniska Verken Landskrona Kommun (Municipality of Landskrona Technical Department)	Public agency: maintenance and operation of all infrastructure, including water and energy utilities, of the Municipality of Landskrona	82	300 MSEK
Thorn Lighting AB	Lighting equipment: production of components of indoor and outdoor lighting equipment	82	300 MSEK
Trioplast AB	Packaging: production of mono- and co-extruded films and printed packaging material	180	220 MSEK
Utvecklings-stiftelsen (The Development Foundation in Landskrona)	Public Agency: authority in charge of trade and industry matters; project leading body that markets Landskrona to attract companies, individuals, ideas, and projects to the area; aids in project management and financing; new business advisor and broker of risk capital	3	10 MSEK (2000)

Appendix D: List of interviews and discussions with Landskrona IS Network participants

Company/Organization	IS Participant	Date of Interview/Discussion
AB Landskrona Galvanoverk	Johann Magnusson	June 23, 2004
BASMetal AB	Staffan Aronsohn	June 17, 2004
DSM Resins Scandinavia AB	Bertil Winér	June 15, 2004
Embra AB	Lars Hansson	June 22, 2004
Flexmed AB	Bjorn Sneckenborg	July 27, 2004
Haldex Brake Products AB	Claes Hallberg	June 15, 2004
IIIEE	Peter Kisch	August 13, 2004
Landskrona Svalövs Renhållnings (LSR) AB	Mats Hafström	July 13, 2004
Miljöförvaltningen Landskrona Kommun	Charlotta Barthelson	June 10, 2004
Miljöförvaltningen Landskrona Kommun	Högni Hansson	June 10, 2004
Öresund Committee	Noel Brings Jacobsen	August 12, 2004
Parajett AB	Roland Rundqvist	June 15, 2004
Pilkington Automotive Sweden AB	Anders Boij	June 11, 2004
Pilkington Automotive Sweden AB	Erik Behmer	June 11, 2004
Rohm and Haas Nordiska AB	Erik Vestergård	July 16, 2004
SAB Wabco Nordic AB	Lars Jansson	June 16, 2004
SAB Wabco Nordic AB	Sofia Herstadt	June 16, 2004
ScanDust AB	Ulf Helgesson	June 23, 2004
Svalöf Weibull	Anders Nilsson	June 24, 2004
Syngenta Seeds AB	Lena Johannesson	June 17, 2004
Tekniska Verken, Landskrona Kommun	Kåre Larsson	June 23, 2004
TEM	Lars Siljebratt	June 22, 2004
Utvecklingsstiftelsen	Claes Nilsson	June 17, 2004
	IS network in board meeting	June 24, 2004
	IS network in board meeting	August 23, 2004
	IS network in planning workshop	September 8, 2004