Industrial Symbiosis in the UK

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Abstract

This article reviews the efforts of developing industrial symbiosis (IS) networks in Humber and Mersey Estuaries and in West Midlands in the UK, where the authors have, to varying degrees, been part of the efforts for identifying and establishing inter-organizational synergistic linkages with environmental and economic gains since Summer 2000. Following a generic review of technical, political, economic, informational, and organisational factors that can have major influences on the development and functioning of IS networks and the role of coordination bodies aiming to catalyse the system developments, major political and institutional elements relevant to IS developments and applicable to all three regions are outlined. Experiences from individual IS programmes are then shared and analysed in light of technical, informational and organisational factors and the attributes of coordination bodies. Such analyses indicate the dominating importance of the organizational factors such as the history of industrial development, intensity of social interactions among relevant parties, and their mental proximity. Experiences also reveal that the perception of regional parties about the coordinating bodies is influential on the effectiveness of development efforts. A set of recommendations drawn from the analysis is intended to inform further similar efforts under National Industrial Symbiosis Programme (NISP). The paper concludes by highlighting the need of aligning the functioning of emerging networks with the requirements of longer term sustainability, which imposes higher challenges on coordination bodies.

1. Introduction

Industrial Symbiosis (IS) networks, or synonymous concepts of eco-industrial parks and industrial ecosytems containing such networks, are regarded to manifest the regional application of the main principles of the emerging Industrial Ecology (IE) field (Ayres 1996; Ehrenfeld and Gertler 1997; Chertow 2000; den Hond 2000). There are varying definitions for IS and similar concepts, (see Appendix 1) implying different objectives, operational characteristics and system boundaries[1]. In essence, however, "IS networks harvest improvement potentials present at the inter-organisational interfaces via collaborative interactions among anthropogenic activities,

[1] According to Chertow (1999) Industrial symbiosis can take place within different system boundaries (within a company, between two companies, a group of companies co-located, or among firms organized virtually across a broader region (Chertow, 1999). This paper deals with IS networks formed by economic actors within a broader region. However, the arguments raised here are to a greater extent applicable to other types.

mostly located within physical proximity to each other. Webs of synergistic linkages emerging within IS networks allow improvements in the efficiency and effectiveness by which different resources are utilised, going beyond that which can be achieved by fragmented pursuit of improvements in individual units." (Mirata, 2002 – publication pending). More specifically, IS networks can offer potential for:

- Environmental benefits due to reductions in resource use, dependence on non-renewables, waste handling efforts, and pollutant emissions;
- Economic benefits emerging from reductions in the costs of resource inputs, production, and waste management and from generation of additional income due to higher value of by-product and waste streams;
- Business benefits due to improved relationships with external parties, and development of new products and their markets, and;
- Social benefits by generating new employment and raising the quality of existing jobs, and by creating a cleaner, safer natural and working environment.

Perhaps the best known, but definitely not the only, example of a an IS network is located in a Danish town called Kalundbourg. The linkage, which first started with the exchange of excess steam from Asneas power plant and surplus gases from Statoil refinery in 1970s, have today evolved into a network of synergistic linkages between the power plant, the refinery, a plasterboard manufacturer, a pharmaceutical plant, a sulphuric acid manufacturer, a cement company, local farmers, fish farms, and local community. These provide various environmental and business benefits for the region as well for individual companies.

As various examples of synergistic linkages, where resources embedded in waste and by-product streams have been revalorised (as documented by Desrochers (Desrochers 2000, 2002) the idea of IS is not new. However, despite their potential benefits and historical examples the number of comprehensive, operational IS networks is limited. This is mostly due to the fact that the development and operation of such networks are dependent on the presence (or the lack of) of the right mix of various determining factors rooted in *technical*, *informational*, *political*, *economic*, and *organisational* spheres. Perhaps, what is more novel about the concept is the recognition that emergence of IS networks could be catalysed by systematically addressing the determining factors so as to help the presence of those which will assist the desired development. There have been, and still are, many initiatives around the world where coordination bodies with different characteristics take(n) the challenging role of catalysing the development and functioning of IS networks (for examples see (Baas 1998; Côté and Cohen-Rosenthal 1998; Chertow 2000)).

In the UK, efforts to catalyse the development of IS networks started in Summer 2000 when the "Business Council for Sustainable Development – United Kingdom" (BCSD-UK[2], which by that time was BCSD-North Sea Region) assumed the role of facilitating an IS network development among the economic activities located in the Humber Estuary. Humber region Industrial Symbiosis Programme (HISP from hereon) sparked interest from other UK regions and similar programmes were initiated in West Midlands and Mersey Estuary regions soon after. Along with growing interest from additional regions (including Southampton, Teeside, Grangemouth, and Ireland) a UK wide National IS programme (NISP) is developed under the supervision of BCSD-UK. The authors of this paper have actively been involved, to varying degrees, in the

[2] BCSD-UK is a business association and is the regional affiliate of World Business Council for Sustainable Development. The main mandate of BCSD-UK is to contribute to the sustainability profile of businesses via the development and implementation of practical and profitable projects.

development of regional programmes in Humber and Mersey Estuary, and in West Midlands, as well as in the efforts of setting up a national programme[3].

This paper will first provide a summary of factors that are regarded as having major influence on the development and functioning of IS networks and elaborate on the roles coordination bodies can play in light of these determinant factors. Before sharing mainly relevant parts of our experiences from regional IS programmes in Humber and Mersey Estuaries, and in West Midlands and elaborating on the nation-wide IS programme, a review of some political and institutional elements that are applicable to all programmes discussed in the paper will be given. Our analysis of the lessons learned from various programmes intend to assist the efforts of developing new IS programmes and contributing to the progress of those which are under way.

2. Determinant factors of IS developments and role of coordination

The development of IS networks and the clarification of their operational characteristics depend on various, interrelated factors, emerging from different fields. A number of the important factors and their potential implications on IS networks are summarized in Table 1.

Table 1: Factors influencing the development and operational characteristics of IS networks.

Category	Elements constituting the factors	Potential areas of influence
Technical	• Physical, chemical and geographic attributes of in- and out-put streams; • Processing, utility (energy & water), logistics, and managerial needs & capacities; • Availability of reliable and cost efficient technologies to enable synergies.	• Number and diversity of potential symbiotic linkages • Extent of environmental, economic and social gains synergies may provide • Extent of investment & effort required to develop and maintain synergies
Political	• Overarching environmental policies • Nature of Laws and regulations • Taxes, fees, fines, levies • Subsidies, credits	• Incentives to develop and adopt environmentally desired technologies and practices (Clinton 1994; Porter and van der Linde 1995; Porter and van der Linde 1995)), and to form symbiotic linkages (Gertler and Ehrenfeld 1996; Ehrenfeld and Gertler 1997). • Disincentives by rendering synergies illegal (prescriptive) or economically unfeasible (due to l high transaction costs).
Economic & Financial	• Costs of virgin inputs, economic value of waste & by-product streams, and the impact of political elements (Esty and Porter 1998; Desrochers 2000; Desrochers 2001) • Cost saving, revenue generation potentials • Amount of necessary investment and cost of maintaining synergies (including transaction (Sinding 2000) and opportunity (Esty and Porter 1998) costs). • Payback time, return on investment (ROI)	• Extent of economic advantage and competitiveness gained (Esty and Porter 1998; Jackson and Clift 1998; Chertow 1999) • Decisions of private companies • Necessity for alternative source of finance
Informational	• Hesitance to disclose information • Availability of timely and reliable information from a wide spectrum of areas to the right parties. • An information management system systematically monitoring changing dynamics and assessing the desirability and feasibility of options	• Possibilities to identify synergies • Possibilities to operationalize synergies • Risk perception of companies
Organizational & motivational	• Trust • Openness to each other and to new ideas	• Presence/creation of the necessary institutional framework for collaboration

[3] Mr. Mirata has been seconded from the International Institute for Industrial Environmental Economics at Lund University, which has been an academic partner of BCSD-UK between July 2000 and June 2003. He took active part, as an action researcher, in formulating the methodology to be followed in the development of IS programmes and actively contributed to the efforts of developing regional programmes in Humber Estuary and West Midlands as well as the nation wide programme within the stated period. Mr. Pearce, on the other hand, has being actively involved in various important phases of regional programmes in Humber and Mersey Estuaries.

- Risk perception
- Intensity of social interaction
- Mental proximity
- Decision power
- Organizational history

- Development of synergies
- Maintenance of synergies

Whether it is a private establishment, a public agency, a research institute, or an NGO a coordinating/ facilitating body is important for catalyzing the development and functioning of IS networks (Ayres 1996; Côté and Smolenaars 1997; Lowe 1997; Baas 1998; Young 1999; Burström and Korhonen 2001) mostly by trying to alter the determining factors in ways so that they are more supportive of the desired development. Two of the main roles coordination bodies play is related, but not limited, to providing assistance with informational and organizational issues.

Informational support

The main objective of the informational support is to identify possible developments along with their associated benefits for a region and inform relevant parties about these possibilities. In addressing the informational issues, coordination bodies can study the main resource flows associated with the focal region and thereby identify areas where major improvements regarding resource consumption or waste reduction is desirable. This can aid in developing objectives the network should achieve (Chertow 1999). Primary focus in providing informational support, however, is placed on assessing the needs and capacities of the economic activities in the region, with the intention of identifying complementarities. These needs and capacities are mostly related to the resource in- and out-puts of companies operating in the region, or that can potentially be based there, thereby uncovering the possibilities for material exchanges, cascading of energy and water, development of more efficient and effective utility and waste management infrastructures, and new businesses. Needs and capacities in these areas are, however, better suited for operations associated with significant flows of material and energy carrier streams. Based on an understanding that synergistic linkages can emerge from areas going beyond such in- and out-puts (Cohen-Rosenthal, 2000; Côté, 1998;Lowe, 1995), the focus of these efforts can be expanded to provide an inventory of processing, logistics, and management related needs and capacities of regional parties and identify additional opportunities for collaborative benefits. Disseminating information about technological alternatives and environmentally preferable practices, about markets and their dynamics, and on regulatory issues are also among the tasks coordination bodies can carry out to support IS developments. To assist the functioning of existing synergies and to help new ones to evolve, the informational support must remain a continuous process.

Helping to create the necessary institutional framework

Another area where coordination can contribute is related to the establishment of the necessary institutional framework. This can be done by identifying the key parties within a region, raise their awareness in related areas, provide communication platforms, and thereby facilitate the generation of the necessary common understanding and objectives, and collective commitment for their achievement. This should not limited to the companies and other parties within the region, and should be expanded to include communication and feedback channels connecting regulatory bodies, other policy makers and financiers to the programme, who can help overcome regulatory or financial hurdles, or can facilitate the development of necessary incentives.

The significance of coordination multiplies in cases where there is limited coordination, dependence, or communication among regional parties (Boons and Baas 1997), where operations are diverse and traditionally not related (Lambert and Boons 2002), or where there are foreseeable institutional barriers to cooperation (Ayres 1996). Also, for systems where a web of synergistic linkages is present (e.g. Styra region in Austria (Schwarz and Steininger 1997), or city of Jyväskylä in Finland (Korhonen, Wihersaari et al. 1999)) coordination is important for the diversification of interactions and providing further improvement potentials.

Role of guidance of coordination bodies

It is important to note that the coordination bodies actually become part of the IS networks, and based on their organizational attributes, may hold varying degrees of steering potential for the development. This recognition is important, not only, from the "effectiveness of catalyzing" effort, point of view, but also from that of "characteristics of emerging network". Although they cannot always be in a position to force better environmental performance in individual organizations (Boons and Baas 1997), it must be among their roles to provide guidance on actions required for longer-term environmental sustainability. This requires having a thorough understanding about different Industrial Ecology principles (pertaining to materials and products such as dematerialization, reduced depletion of non-renewable resources, increased dependence on renewables, and reduction of environmental damage stemming from different cycles of products' life) and fostering their application. In other words, it can be argued that the coordination bodies should think beyond the system elements they are currently working with, or those obvious solutions that provide the best economic result in the short run, and should identify and facilitate the realization of more changes that are desirable for longer-term environmental sustainability.

3. Industrial Symbiosis Programmes in the UK

In the UK, the efforts of systematically catalyzing the development of regional IS programmes started in Summer 2000 focusing on economic activities located around the Humber Estuary with BCSD-UK having the coordination role of the regional programme. Since that time, there has been increasing interest from other UK regions to initiate similar programmes. Today there are more than six programmes (three of those are covered more in detail in the coming sections) at different stages of their development and which are all linked to the recently launched nation-wide IS programme. Before going into the specifics of various regional and the nation-wide programmes, it is useful to touch upon generic elements of business, national policy, and regional governance elements that are relevant to all IS developments in the UK.

The business environment

In the UK, powerful drivers have combined recently to greatly increase the demand for clean technologies and processes and the more efficient use of energy, water and raw materials[4]. This need for higher resource efficiency in industry is being driven by a range of factors including:

- Competitive pressures to reduce costs through more efficient conversion of raw materials into products;
- Supply chain pressures to adopt more sustainable practices and to conform to environmental standards such as EMAS and ISO 14001;
- Legislation and regulations to encourage the recycling and reuse of waste materials and to use energy more efficiently backed up by fiscal instruments such as the Landfill Tax and the Climate Change Levy (covered in detail in the next section);
- Voluntary measures such as environmental reporting and benchmarking environmental performance
- Downsizing by companies, especially in traditional sectors such as chemicals, paper and metals, which has resulted in the inefficient use of resources such as land, infrastructure, utilities and services.

Techniques, such as waste minimisation, to identify and tackle resource inefficiencies and wastage within individual firms have been in use in the UK for many years. There have also been

[4] Enabling Business in Resources Management. A report for the Innovation and Growth Team for the Environmental Goods and Services Sector: DTI November 2002.

a wide variety of "waste minimisation club" projects in the UK (starting with the Aire & Calder Project) to facilitate companies in a given geographical area and/or in the same sector to implement waste minimisation through sharing best practice and learning from each other. These have been aimed mainly at management and manufacturing processes *within the companies* rather than attempting to identify synergies *between companies* e.g. by using one firm's waste material as a feedstock in another's.

Waste exchange schemes in the UK are also quite common but these focus mainly on "spot" exchanges of waste materials and do not consider the broader aspects of company resources and processes.

Relevant government policies and elements of legislative framework

In a policy guidance document, a report on resource productivity (RP) by the UK Cabinet Office, RP is identified as a "key to change" in achieving sustainable development. RP is defined as "measuring the efficiency of the economy in generating output without using natural resources – including the resource provided by the capacity of the environment to absorb waste and pollution", and is acknowledged as vital for providing sustained environmental and economic benefits. This report recognizes that, among others, the Government has an important role to play in creating the right incentives and help overcome barriers including information deficiencies, limited access to finance, and skill shortfalls. One of the most important elements of this policy document is its recognition of two different types of barriers, namely those "that prevent the take-up of measures already beneficial on both economic and environmental grounds" as well as those that "prevent the take-up of measures that would be environmentally beneficial, and should be economically beneficial, but which for some reason are not." (Government Office, 2001)

The landfill tax, and climate change levy (CCL) are two of the important policy elements that are of high relevance for IS programmes. The former, is applicable to almost all kinds of landfilled waste and provides incentives to reduce the amount of, and to recover more value from generated waste streams and find alternative means for their treatment. The climate change levy, on the other hand, gives incentives to industrial and commercial activities to reduce inputs of selected energy carriers, or switch to environmentally preferable sources. Co-generation of power and heat is also passively encouraged by allowing for tax reductions or exemptions for high quality combined heat and power (CHP) units, and heat, steam, and "waste as defined by statue" are not taxable carriers of energy (HM Customs and Excise 2002). These policy elements provide incentives for businesses increase their resource use efficiency and encourage them to create more cyclical resource use patterns. Although their implications are more on selected product/material streams rather than resource use in general, legislations extending the producers' responsibilities on their products at the end of their service life (applicable to packaging materials, vehicles, and electrical and electronic equipment) are also important in terms of closing resource loops.

There are, however, also some policy elements that can potentially block or hinder the development of synergistic linkages. Special waste regulations and substitute fuels protocol are examples of such elements. The former is prescriptive in terms of methods to be used in handling of certain waste streams considered hazardous and can restrict their use for alternative purposes. The latter, on the other hand, requires intensive testing, modeling, and public consultation procedures prior to allowing cement and lime kilns to use alternative materials as fuels. Although special waste regulation can be prohibitive for synergies involving waste streams it regulates, it offers the flexibility to consider particular cases for exemptions. These regulations are designed to assure that potential synergies do not give rise to any adverse environmental impacts. However, from the viewpoint of companies, they are mostly perceived to be adding to the transaction costs of synergistic linkages, and can hinder their development due to economic considerations.

Regional Development Agencies (RDAs)

In England, RDAs are assigned the objective of promoting business efficiency and contributing to sustainable development (UK Office of the Deputy Prime Minister 1999). These organizations' prime concern is to foster economic development, however, sustainability is increasingly gaining importance on their agendas and environmental quality is seen as a prerequisite to attract inward investment (Advantage West Midlands 2001; Yorkshire Forward 2001; North West Development Agency 2002). However, RDAs are characterized as having "considerable institutional capacity for economic development functions, but weakly developed capacity on environmental matters." (Gibbs and Jonas 2000) Consequently, RDAs seem to welcome the conscious efforts to develop regional networks aligned with IS principles within their administrative boundaries as an effective way of addressing the challenge they face. The fact that most of the regional programmes under development receive significant support of various sorts (including direct financing) from RDAs is a clear manifestation of this argument. Sustainable development at a regional level in England is a key item on the agendas of the regional assemblies and government offices. Unlike the RDAs, these organizations do not have direct access to significant funding streams but they can play important roles in the stimulation of regional players to get involved in initiatives such as IS and in the priorities for European Regional Development Funds.

The Devolved Administrations in Scotland, Wales and Northern Ireland are all actively involved in sustainable development strategies and are also important potential players in the initiation and funding of IS programmes.

National Industrial Symbiosis Programme (NISP)

Background

The overall aim of NISP, which is co-ordinated by BCSD-UK, is to bring existing IS network developments under the same umbrella, facilitate the development of new programmes and act as a hub among those regional programmes thus setting the foundation for a nationwide IS programme. The specific objectives of NISP include the following:

- To develop a national industrial symbiosis programme, delivered on a regional basis and designed to significantly reduce industry's contribution to waste generation and to help it to be more eco-efficient;
- To collect and disseminate information about the development of products from waste streams and the development of markets for recycled waste;
- To provide a practical methodology by which business can respond to the government strategy on resource productivity;
- To Identify and disseminate information regarding best practices and strengths in terms of developing IS networks;
- Identify the political, legislative, economic and technical barriers to the development of IS networks and communicate them with relevant decision makers to facilitate implementation.

Target regions where IS programmes are at various stages of development are:

- Yorkshire and the Humber (Humber IS Project)
- West Midlands (West Midlands IS Project)
- North West (Mersey Banks IS Project)
- Scotland (Grangemouth)
- North East (Teesside)
- South East (Southampton).
- Ireland.

The management structure of NISP is depicted schematically in Figure 1.

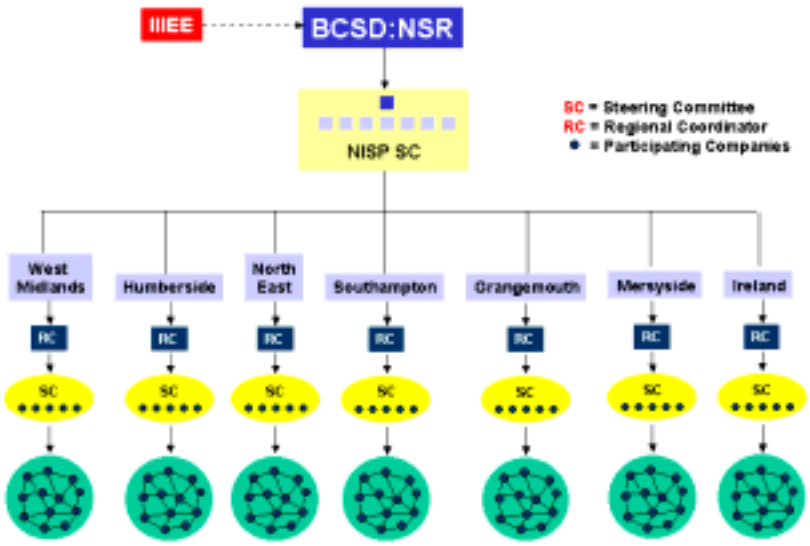

Figure 1: *NISP Management Structure.*

NISP, in time, aims to create synergistic linkages among different regions and promotes the use of a uniform methodology, and particularly a standardized data collection approach, in all the regions to ease this ambition.

Description of the Programme

The development of IS programmes in individual regions involves four main phases:

Awareness Raising and Recruitment

In this phase, the regional co-ordinator identifies the key parties whose involvement in the programme is desirable. The identified parties are then introduced to the programme and its objectives, potential benefits, practical implications using different means of communication.

Interested parties are then brought together in a workshop marking the official launch of the programme where similar issues are communicated in a collective manner. If the time and resources allow, it is desirable to carry out an initial review in the region to identify potential benefits an IS programme can provide both to the region as a whole and to individual parties. The launch event not only initiates the formation of a communications platform, which has proven to be one of the backbones of the programme, but also results in the establishment of a regional steering group. In addition, it encourages those attending the workshop to participate in the programme and helps to identify other organisations to be recruited. Following this event, the regional co-ordinator and steering group members work on gaining commitment from the identified companies and organisations to their participation in the programme.

Data Collection

This phase involves the collection of quantitative and qualitative information from the participating companies in a format that allows synergies to be identified and linkages to be made within the network. Governed by a confidentiality agreement if necessary, data regarding the organisation's inputs and outputs, their processes and operational attributes, their needs and capacities in terms of production, utilities and logistics infrastructure, human and information resources is gathered in this phase. In NISP, the data collection will be facilitated by the use of specially designed

information database that will enable information to be shared by the other networks so as to identify synergies between the regions

Analysis and Identification of Synergies

In the next phase, the collected data for each company is analysed to identify areas where there are specific needs in terms of the supply of and demand for materials, resources and facilities. The database then facilitates the matching of supply to demand within the network. The most direct linkages are communicated directly and quickly to the interested parties within the terms of the confidentiality agreement. Other potential synergies are communicated more widely within the network to encourage participants to follow-up the opportunities. Where necessary, the regional co-ordinator, with support from NISP, will assist the participating companies with the analysis and specialist expertise to identify the synergies and linkages.

Implementation and Support

The last phase involves facilitation and support to help the network members to realise the identified synergies. This includes identification of barriers (e.g. technical, resource and financial) to implementation and the provision of help with overcoming them. At this stage engaging parties other than those participating in the programme and linking into regional or national sources of support and funding may be necessary. The process of overcoming barriers to enable additional synergies to evolve, as well as collecting and analysing data to identify new opportunities continues as part of the programme support. This phase also covers widening the network to include other sectors and/or parts of the region.

While synergies confined to respective regions are given priority, under the NISP umbrella similar analyses are carried out to identify synergies among parties located in different regions. The BCSD-UK and NISP steering committee, formed by representatives from individual regions, will carry the responsibility of identifying and facilitating the realisation of these synergies. This process is significantly assisted by the information management structure adopted for the programme and in particular the *NISP Database*. The information management structure adopted for NISP is schematically represented in Figure 2.

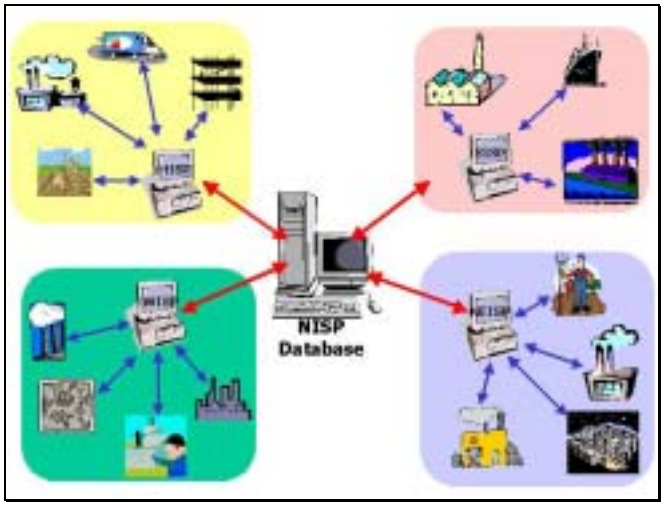

Figure 2: NISP Information Management Structure.

Current Status of NISP

Financial support, from the Onyx Environmental Trust and the DTI, for the establishment of NISP was confirmed in the Spring of 2002. This was followed by a workshop of interested parties,

hosted by the DTI. Since then, BCSD-UK has been working to help with the establishment of the various regional programmes and the development of the software for the database. A NISP web site has been launched in March 2003.

Funding for a number of the regional programmes, including those in the Yorkshire and Humber region, West Midlands and Scotland has now been confirmed and a decision on the project in the South East is imminent. The programmes in Humber Estuary, in West Midlands and in the North West (Mersey Banks) are elaborated on in the coming sections.

Humber Region Industrial Symbiosis Programme (HISP)

Programme Gestation

The Humber Estuary is located on the East coast of England, dominated by organic and inorganic chemicals, oil refining, food processing, furniture, iron and steel and other metals processing industries that are spread along both the south and north banks of the river.

The idea of initiating an IS programme in the Humber region originated from a global oil and gas company having major operations in the area. Besides having taken part in another IS programme in Tampico, Gulf of Mexico the main motivation for this company to support the initiation of HISP was to seek support for a CHP plant, proposed by a consortium lead by the same company. BCSD-UK, by then a newly formed organization less than a year old, agreed to support the efforts in the region and assumed responsibility.

Awareness raising, recruitment and data collection

Initially, persons from the coordinating team in Tampico were brought in to the region to assist raising awareness among regional parties and possibly share some of the coordination responsibilities. In their approach, participating companies were required to sign a contract for their involvement in HISP, implying to channel a certain percentage of their economic from possible synergies, to the coordinating body. This, and other elements of the approach adopted at this time did not gain acceptance by the local companies.

BCSD-UK was eventually assigned to be the main coordinator of HISP, and initiated the collaboration with IIIEE, regarding the development of the programme. As a new organization in the region, BCSD-UK first focused on establishing contacts with relevant parties, including local authorities, private companies and business associations and continued the efforts of raising awareness. Alongside these efforts Enviros consulting was contracted to perform an initial review in the region. This review focused on two existing proposals in the region: one related to the installation of a 475 to 650 MW CHP plant and the other to a chemical feedstock pipeline bundle to cross under the Humber river, and connect the industries from the north and south banks (Humber Bundle). Findings of an earlier study (carried out by the regional trade and development support agency for chemical industry), examining the possibilities for integration among local companies, mostly from chemicals and oil and gas sectors, were also reviewed in the initial study to identify potential synergies. Approximate quantification of economic, environmental and social benefits of synergies that can potentially arise with the implementation of these main initiatives, proved to be significant. These include:

- substantial reductions in CO_2, SO_2 and NO_x emissions (3.3 Mt, 48 kt, and 11 kt per annum, respectively) associated with CHP generation as compared to conventional methods;
- removal of significant amounts of hazardous cargo (750 000 t) from surface transport;
- substantial savings on energy bills for the existing large energy users in the area;
- considerable increase in productive output (~ 800 M £/y) and employment (~ 2 400 positions) with the development of new businesses taking advantage of feedstocks to be

made available by Humber Bundle and access to competitively priced energy from the CHP[5].

Upon completion of the initial study, HISP was officially launched in a full day event in October 2000, with over 70 participants from diverse range regional public and private organizations. The event has not been as effective as desired for generating awareness and commitment for the programme. A limited number of companies decided to get involved in the programme, while some others gained the misleading idea of HISP being something only for large energy users on the south bank and for those who can benefit from the Humber Bundle.

Due to an unsatisfactory number of companies joining the programme, following the launch, the coordination team had to merge the efforts of increasing the number and diversity of organizations participating in the program with the collection of data, under a confidentiality agreement, from those who agreed to take part in the programme. Over a period of six months, more than one hundred and fifty companies were contacted and one-to-one meetings were held with over seventy of them. In these meetings, managers were thoroughly informed about HISP, and those who expressed interest were provided with a standardized data collection form. This way of interaction with companies had certain advantages as decision makers from various organizations were given more time and attention to acquire a thorough understanding about the attributes of the program, while the coordination team gained access to useful qualitative information about companies and relevant regional dynamics. This approach, however, fell short in demonstrating the collective commitment and created hesitancy among managers partly, because it failed to demonstrate the presence of other interested parties.

Nevertheless, over twenty five companies, from diverse sectors (oil and gas, organic and inorganic chemicals, energy and water utilities, food processing, packaging, logistics, ferrous metals, mining, furniture, port facilities, and retail), are now involved in the program. A steering committee formed by representatives from BCSD-UK, different industry sectors, and local authorities, and one industry association has executive responsibility for the program. This management structure is considered important in germinating ownership for the project by its main beneficiaries. However, there is no individual company in the region that has assumed the role of project champion and which encourages others to take part in HISP.

Data analysis

Due to lack of company specific data the programme has not yet moved into the formal, detailed and precise data analysis stage. However, based on the information gathered by former relevant studies in the region, by the initial review, and by the interviews with regional parties various existing and probable synergistic interactions were identified. These are depicted in Figure 3. Other than those involving direct exchange of materials or energy, effluent and waste treatment, analytical services, logistical services, and managerial support to SMEs, were identified as areas where collaborative action can provide benefits in the region.

Implementation and support

The construction of the CHP plant is now underway. Consequently, in a few years time, parts of the benefits attached to the utilization of power and steam from this plant should be realized. Other synergies involving the transformation of wood waste into wood chips and waste edible oils into bio-diesel has also recently become functional.

[5] These values were derived based on certain assumptions, and their value can fluctuate depending on the assumptions' validity.

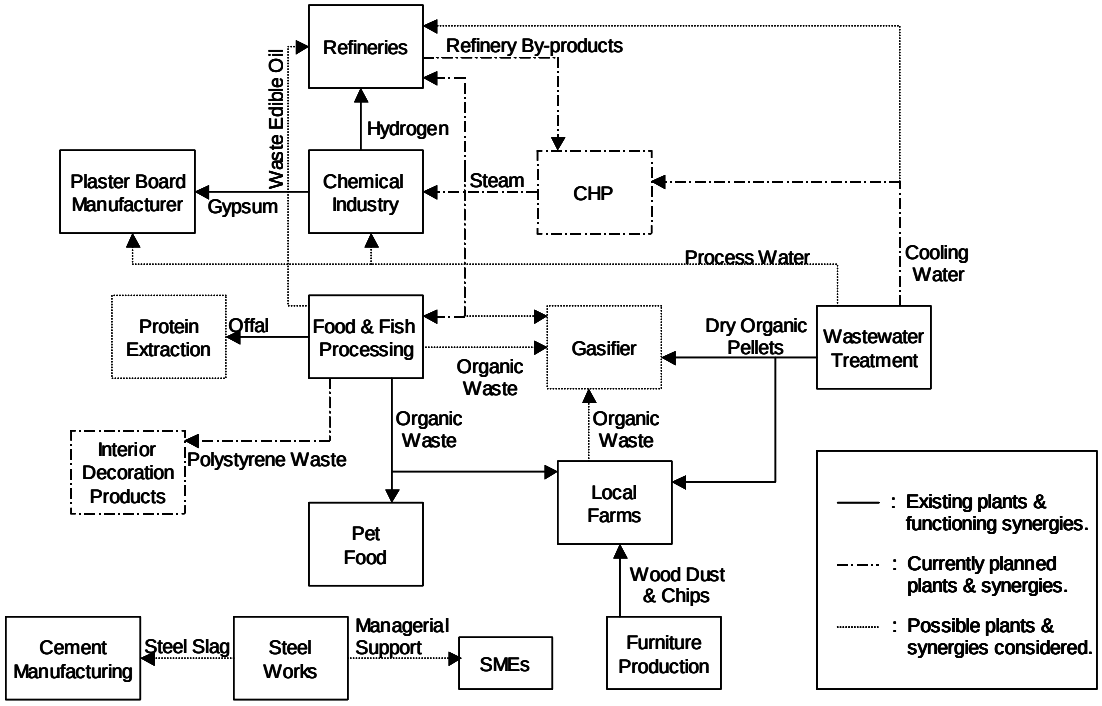

Figure 3: Existing, planned and possible synergies identified in the Humber region.

Coordination efforts with HISP had to be reduced for some time after Autumn 2001, due to lack of financial support. Recently the programme started to regain pace thanks to financial support provided by the RDA for Yorkshire and Humber region. Consequently, currently efforts are underway to recruit a critical mass of companies for the programme. Following this, the coordination team will aim to gain access to desired data, and carry out the analysis with the intention of identifying additional synergies for the region. Next the foci will be placed on identifying possible barriers against the development of the identified synergies, and help overcome those. It is important for the programme to engage more parties from industries other than those from chemicals and oil and gas sectors.

West Midlands Industrial Symbiosis Programme (WISP)

One of the prime achievements of the HISP has been to spark interest from different parts of the country to develop IS programmes in their regions. West Midlands (WM), which is located some 200 km. Northwest of London and covers the areas around Birmingham, was the first of those regions. Major sectors in the region include automotive and aircraft manufacturing, metal production and fabrication, plastics and rubber, agriculture and food processing, ceramics and glass, logistics and service industries.

Project Gestation

A well established regional environmental business association (Midlands Environmental Business Communications – MEBC) was informed about HISP and initiated moves to replicate it in WM. BCSD-UK provided training to MEBC personnel about the details of an IS programme, and shared their experiences about HISP. MEBC assumed the regional coordination role for the West Midlands IS programme in (WISP).

Awareness raising and recruitment

The preliminary study for this region was limited to the identification of key parties whose involvement was desirable. Largely as a result of their already existing connections, within a short period of time MEBC was able to have representatives from around 10 selected regional organizations (private companies from diverse range of sectors, local administration, and research institutes) interested to join a half-day meeting, where participants were informed about the details of IS programmes, about HISP and other applications elsewhere, and they had the opportunity to listen to the experiences of a company representative from Humber area. Unlike the experiences in the Humber region, the remainder of the meeting was highly interactive, where the participants discussed means of taking the programme further with project coordinators and exchanged ideas with each other regarding potential areas of collaboration.

Within a month, the WISP was officially launched in an event with even higher numbers of participating companies where a project advisory group was formulated. This group is chaired by the managing director of one of the local companies acting as the project champion and he now also encourages others to participate in the WISP. Currently, without even having an explicitly active recruitment stage, 20 companies from diverse sectors are involved in the WISP.

Data collection and analysis

Although, official data collection process has not yet been started, a number of potential synergies have already been identified, owing to intensive interactions among the project participants and openness to cooperation. The feasibility of these is still being evaluated, while one identified synergy has already become operational, providing economic, environmental and social benefits. This consists of the conversion of 5 000 tons/year of waste edible oils into bio-diesel, also producing glycerol, used as a base material for other products, as a by-product. The processing capacity is planned to be increased to 50 000 tons/year in near future. Figure 4 depicts the implemented and considered synergies as part of WISP.

Within the scope of the WISP the information management system is advanced and is equipped with an electronic data collection interface. This is an important development for IS programmes, as it can shorten the time and effort required by the companies to provide data, accelerate the data gathering process for the project coordinators, give the flexibility for updating data, and allow the companies to access certain part of others' data according to their access allowances. This tool is being tested in pilot companies located in the region and recently been fully operationalised.

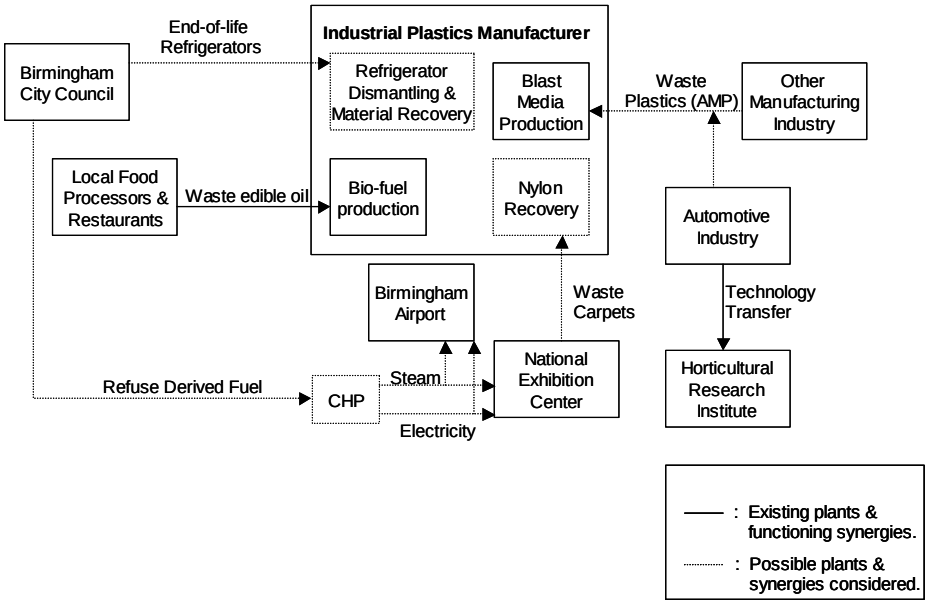

Figure 4: Synergies identified in West Midlands IS programme.

Mersey Banks Industrial Symbiosis (MBIS) Project

Project Gestation

The MBIS project originated early in 2001 following a meeting between BCSD-UK and the North West Chemicals Initiative (NWCI) that was facilitated by one of the members of BCSD-UK based in the North West who had also been involved in the pilot study for the Humber IS project. NWCI is an organisation, jointly funded by the North West Development Agency (NWDA) and the industry, to improve the competitiveness of the Chemicals Cluster in the region. It manages a number of projects, determined by the industry, that are in line with the NWDA's Regional Economic Strategy.

The potential to develop an IS project in the North West, based on experiences in the USA, Mexico, Denmark and the Humber project, was quickly recognised by the NWCI. A critical early step was to find someone with local industry experience to manage the project and particularly to get things moving with raising awareness and recruiting participants. One of the large local chemicals companies, Ineos Chlor, which is a member of NWCI was able to help by seconding one of its senior managers to fulfill this role. A small project committee was established to guide and support the project manager.

Awareness and Recruitment

It was agreed at an early meeting of the project committee to focus the project initially on an industrial area on the north and south banks of the Mersey that has a concentration of refining, petrochemicals and chemicals companies. There are also a number of companies operating in other process industries in the area including food and paper. This area was selected because:

- There are a large number of chemicals and related industry companies in a compact geographical area hence facilitating the process of establishing the links.

- Although there has been a considerable amount of integration in the past due to the common ownership of the companies (i.e. by ICI), this has been eroded by recent re-organisations and changes of ownership.

- There is sufficient local autonomy to enable site managers to make decisions to participate without referring back to their parent organisations.

- The project manager was based in the area and already had good contacts with many of the local firms.

A list of potential participating companies was drawn-up and a profile for the project, covering its objectives and scope, was produced and sent to these firms. This was followed-up by the project manager to determine levels of interest and to arrange initial meetings with some of the key target companies to encourage their involvement. These approaches were also used to make companies aware of the Project Launch Workshop to be held at the end of October 2001. An important objective was to identify a leading figure from the local industry to chair the Workshop and to promote the benefits of participation. The manager of the Shell oil refinery at Stanlow agreed to fulfill this role. The NWCI was able to facilitate this phase of the project due to its high level contacts with its member companies in the area.

42 people representing 31 companies and organisations attended the Project Launch Workshop. This proved to be a very useful vehicle for getting the project moving due to:

- The enthusiastic support and involvement of the Chair and other members of the project group who acted as facilitators in the "break out" session

- The extent to which many of the delegates had already been "warmed up" through the initial contacts by the project manager

- Useful feedback from the "break out" groups on the experiences of collaboration with other companies, the perceived barriers to the project and the level of interest in participation.

- Financial contributions to the project that were confirmed at the end of the workshop.

14 companies agreed to participate either at the workshop or shortly afterwards, a further 6 joined during the next few weeks after follow-up by the project manager and the total number for the data collection phase rose eventually to 22. The majority of these are involved in the manufacture of oil, petrochemicals and chemicals products but there are also some suppliers of products and services to the industry e.g. energy, water, waste management and analytical services.

Data Collection

The data collection methodology was based on a questionnaire that was designed by the project manager with inputs from the project committee. It drew on the recent experience of data collection in a Mass Balance Study for the Base Chemicals Industry[6] and on the Humber IS Project. The questionnaire was checked for functionality by two of the participating companies before finalising.

Discussions were held with the BCSD-UK regarding the potential use of the software that was being produced for the NISP. Since this software was still in the development phase, it was decided not to use it for the MBIS project at this stage.

[6] Undertaken by Enviros as part of the National Mass Balance Programme funded with support from Biffaward.

The project manager visited each of the participating companies to explain the project in more detail, to go through the questionnaire and to discuss and agree timescales and responsibilites for completion. The participating companies were then followed-up to encourage them to complete and return the questionnaires as soon as possible. In the event, this part of the process took much longer than anticipated. Originally, it had been estimated that the data collection could be completed in around 3 to 4 months. In practice, it took nearly a year. The main reasons for this delay were:

- The lack of time and resources available to the participating companies to gather the required information and to complete the questionnaires

- The low priority allocated to the above tasks due to competing responsibilities associated with core business activities.

During the early stages of the project, attempts had been made to obtain public sector funding to support the project management and facilitation but this was not forthcoming. The project was funded through the in-kind contributions associated with the secondment of the project manager, cash from the participating firms and administration support from the NWCI. Subsequently, the project manager joined the NWCI and continued to work on project under the auspices of this organisation. As a result, the resources that were allocated to the project were more limited than had been anticipated particularly for the data collection phase to support the companies in the completion of the questionnaires.

Data analysis

The analysis of the information from the questionnaires was completed early in 2003 and reports have been sent to each of the participating network members. Around 100 opportunities for synergies have been identified covering, specific opportunities for the individual firms as well as general opportunities for the network as a whole. The project manager is providing a “brokerage” role in putting network members in touch with each other where there are opportunities for links to be made. To date the network members have expressed positive interest in following-up about one third of the identified opportunities.

The opportunities fall into two main categories:

- Network members with available materials, services and facilities that could be used by others in the network

- Network members with specific needs in terms of products, services or facilities that could be provided by others in the network or by shared facilities/services.

Examples that have emerged from the project in these two areas are shown in Table 2.

Table 2: MBIS Project – Examples of Potential Synergies

Materials, services and facilities available	Materials, services and facilities sought
1500 tonnes of heavy naphta	Additional product storage capacity
1000 cardboard boxes (currently landfilled)	Flammable liquid packing service
1300 tonnes of di-calcium phosphate	Product drying and milling service
5000 tonnes of fatty acid residues	Covered space with utilities
Ammonium cumen phosphate	Combined heat and power plant (shared)
Laboratory facilities	
Wide range of storage tanks	
Conference facilities	
Distribution services	

Advice on HS&E	
Underutilised reverse osmosis unit	

There are also a number of specific opportunities that are currently the subject of confidential discussions between the interested parties.

The project manager is now working with the network members to initiate the links and to stimulate implementation of the synergies identified. A report on progress is due to be produced in near future and it is hoped to include the information from this report in the final version of this paper.

There is scope to extend the project by introducing new network members from other sectors in the area (e.g. a large power station has expressed interest in joining) and by establishing other IS projects elsewhere in the North West. There is particular interest in setting-up an IS project, on a brownfield site in the region, to integrate the activities of a group of companies, operating in the waste management and recycling sectors,

4. Discussion

The IS programmes in the UK are in their early stages of development, nevertheless, they reveal valuable messages relevant both for the continuation of the existing programmes and for the initiation of new ones. Although none of the regional programmes has progressed too far in terms of identification and/or implementation of synergies, the pace with which the concept was spread to new regions was significant. This spread can be attributed to various factors. Firstly, the industrial actors are under increasing pressure to improve their environmental profile, and most of them have already collected the, so-called, low hanging fruits, i.e. internal improvement potentials that didn't involve excessive costs. Therefore, for businesses looking into inter-organisational interfaces for the next wave of improvement potentials appear attractive. This is supported by national policy elements that not only emphasise the importance of resource productivity, which partly can be achieved by more cycling patterns of resource use, but also in the last few years materialized into fiscal instruments encouraging the companies to move in directions somehow aligned with IS principles. Last, but not least, regional development agencies, which have increasingly became responsible for balancing economic development with other pillars of sustainability, but are not all that well equipped to address environmental challenges, have a welcoming approach to the concept. In some regions, this includes allocating the necessary financial support to get IS projects off the ground.

As also observed in the cases from different UK regions, coordination bodies hold the potential of catalyzing the development of IS networks. At least they can initiate the movement in the right direction mostly by raising awareness, helping to create the foundation of a common institutional framework, and by assisting information management. However, as Boons and Baas (Boons and Baas, 1997) emphasized, "coordination does not automatically mean cooperation". Although germination of cooperative linkages took place in different programmes, at this stage their number and scope are too limited to qualify the emerging structures as IS networks. Therefore, a thorough analysis of the effectiveness of coordination cannot be given at this stage.

There are no agreed upon "success criteria", regarding the development of IS programmes, and none of the programmes have yet finalized the assessment of full set of possible synergies and initiated the efforts of operationalising them. Therefore, it is not possible to assess the respective successes of different programmes based on the environmental and economic performances they can or will deliver. Therefore, the discussion here, is limited to respective successes of different programmes in "establishing elements of desired institutional frameworks" including participation from diverse sectors, trust, intense interaction among parties, and commitment to the achievement of common goals, regarded important for IS networks.

Although all three documented cases followed the main steps of the same methodological framework for their development, there were noticeable differences in the nature and pace of

developments in different regions. An inquiry into the characteristics of some of the determining factors listed earlier in this paper can help provide a partial explanation to such differences.

In the Humber region, the development process has been rather slow and although there are interested parties from a diverse range of sectors, the sense of commitment to the programme as well as the intensity of interaction among different companies is still weak. The reasons for these can be linked to the following. Unlike other regions where chemicals and oil and gas industries are concentrated, the Humber is characterized as having low levels of integration among chemical and oil and gas industries, owing to the fragmented industrial development history. Currently, there is limited production of bulk petrochemicals and basic organic chemicals (with the exception of BP Chemicals) in the area, which can form the sources for a wide range of chemical derivatives. There is also a concentration of specialty chemicals producers, relying on specific feedstocks coming from outside the region. Another sector with strong presence in the region, inorganic chemicals, does not have much compatibility either. Last but not least, there is a mismatch between the scale of refineries and the chemical companies in the area. Consequently, the technical factors observed in Humber region were not as effective as one may encounter in other regions dominated by chemical and oil and gas industries.

Poor compatibilities in technical attributes within the dominant sectors, in addition to limiting the possibilities for material connections, can also be connected to weak presence of organizational elements favoring collaborative action, i.e. the chemical and oil and gas companies in the region do not have organizational cultures familiar with direct inter-firm cooperation, perhaps because such connections have not been in the agenda of the firms in the past (although, co-operation on issues such as skills, training, health and safety issues and access to local sub-contractors for maintenance work takes places among regional companies via a recently formed business association called Humber Chemicals Focus) – evidence of. Resistance to collaboration, however, is more evident in the food-processing sector in Humber region as there are bundles of companies competing for the same market segments. Despite some recent efforts initiated by regional bodies aiming to address common environmental problems faced by food processing companies, they are still reluctant to have an open dialogue with others from the same sector.

Another important attribute observed in the Humber region is related to limited decision-making power of the facility managers. Most facilities, particularly in chemicals and oil and gas sector, belong to national and multinational corporations whose headquarters, where decisions pertaining IS programme can be taken, are located elsewhere. This lack of local decision power presents additional hurdles for securing the necessary commitment for the programme, and for establishing a cooperative business environment. Also it is important to note that the history of the coordination body in Humber, which aimed to bring organizations together under the same umbrella was relatively short. Moreover, there was weak business ownership for the programme, which reduced the level of valuable peer pressure. Last, but not least, the official launch of the programme in this region placed too much focus on chemical and oil and gas sectors, and industries with large energy usage, possibly giving the misleading signal to the other companies from other sectors that there was little in IS programme for themselves.

The relatively faster progress, distinctly stronger commitment from regional companies to the programme, and higher intensity of interaction in West Midlands, on the other hand, is mostly attributable to the following. First, companies are historically familiar with materials reuse and recycling activities, mostly due to the nature of their operations. Moreover, unlike the Humber region, the majority of the companies have their headquarters in the region and host managers having adequate decision-making powers. There is also little doubt that being a reputable organization, already having an established network of connections with local businesses, made the efforts of the coordination body to catalyse the desired development much more effective. It is also worthwhile to consider the fact that the exercise of introducing the concept collectively to the local businesses has been more successful in this region, and there has been clear business ownership for the programme.

Although dominated by similar industry sectors as those in Humber region, operations on Mersey Banks significantly different attributes. This is mostly attributable to the historical fact that the industrial development in this region has taken place under common ownership and in a much more integrated fashion. Consequently, not only there are more possibilities for technical compatibilities, but also inherited organizational cultures, which are more accustomed to inter-organisational collaboration. The social embeddedness of both the organization, which supported coordination, and the project manager have also made a positive contribution to the relatively rapid development in this region. Higher concentration of decision making powers, and strong business leadership to take the programme further are, like in West Midlands, other positive characteristics of this region which resulted in faster developments. It is recognised, however, that the industrial focus in this programme was confined to a narrow segment of sectors (mainly chemicals and refining) and that there is a need to extend the initiative to other industries in the Mersey Banks area as well as to other parts of the North West region.. Different attributes observed in documented cases, which have likely to have significant influence on the nature and pace of the developments in these regions are summarized in Table 3.

Table 3: Observed characteristics of different UK regions that influenced the development of IS programmes.

Programme Attribute	Humber Region	West Midlands	Mersey Estuary
Industry Structure	Result of a relatively recent, fragmented industrial development. Low levels of integration within and among sectors. Technical constraints to integration.	Long history of presence in the region. Higher levels of integration within sectors.	Long, common ownership history in chemicals sector in the region. Higher levels of integration within chemicals and oil and gas sectors.
Position of coordinating body	New in the region. Not involved from the very beginning.	Closely recognized part of a multi-sectoral network. Initiated the development.	Closely recognized part of a uni-sectoral network. Initiated the development.
Project championship	No real sustained championship.	Industry led championship.	Industry led championship.
Original Institutional framework	Decision centers outside the region. Limited familiarity with and intention for relevant cooperation/collaboration. Diverse group of interested companies.	Decision centers in the region. Historical familiarity with materials reuse and recycling. Diverse group of interested companies.	Decision centers in the region. Historical familiarity with materials exchange. Limited diversity in interested companies.
Awareness raising and commitment	Centered around specific initiatives. Fragmented and gradual.	Generic. Collective and at an early stage of network development.	Generic. Collective but limited sectoral coverage.

On the sustainability of IS networks

As good as it may sound, IS is not exempt from being "a tool only as good as the intentions to use it". In the relevant literature reflecting on the nature of actions necessary to achieve long-term sustainability, the need for fundamental changes, more far reaching than incremental improvements in the existing production and consumption systems, is emphasized (McDonough and Braungart 1998; Solem and Brattebo 1999), which can be driven by the development and wide-spread application of innovative solutions (Ehrenfeld 1997). The solutions that solely focus on retrofitting the existing systems with necessary elements are likely to fall short for realizing adequate progress in the desired direction. As certain attributes of existing production and consumption systems are the main reasons underlying the problems we are faced with, solutions that leave those attributes intact cannot be of the type that are required for longer term sustainability. Development and implementation of innovative substitutes in a wide range of areas to replace the undesired elements is needed instead. Finding the right balance between more radical, longer-term changes versus some "quick fix" solutions can become a rather frequent challenge facing IS practitioners. The danger lies in promoting actions based on inadequate considerations, narrow and short-sighted visions, and in persuasion of certain short

term gains at the expense of preventing or delaying the identification and implementation of other vital changes. Similar risks are associated with IS applications in that the synergies:

- may reduce the incentives for implementing preventative measures;
- can prolong the lifetime of inefficient technologies and increase the viability of highly unsustainable industries by providing justifications, and even economic benefits, for apparent inefficiencies and creating increased dependence on them; and
- may weaken the incentives for innovation and lock-in existing practices making necessary change more difficult due to higher interdependencies.

It is a repeated fact that the evolution of existing systems exemplifying the IS networks in operation (e.g. those in Kalundborg, Styra, Jyväskylä) are dominantly motivated by the economic benefits they provide (Ehrenfeld and Gertler 1997; Schwarz and Steininger 1997; Korhonen, Wihersaari et al. 1999; Korhonen 2001). It is also commonly, and quite rightly, stressed that the evolving networks will, to a greater extent, be shaped by economic considerations (Chertow 1999) and should provide sufficient benefits measured in conventional monetary or competitiveness terms to their members (Cote, 1998;Lowe, 1995;Cohen-Rosenthal, 2000 ;Esty and Porter, 1998). Unfortunately, however, usually actions driven by such considerations appear to favor retrofitting necessary elements to existing systems to capture that part of environmental improvement potentials that are coupled with sufficient short-term economic benefits, leaving the core functioning of the systems more or less intact and therefore falling short in their contribution to sustainability. There is, consequently, a necessity to give more weight to the assessment of environmental performances of proposed actions and to their conformance with longer term sustainability requirements. This is likely to require deployment of analytical techniques other than, or in addition to, economic ones (e.g. analyses based on the concept of exergy (Ayres, Ayres et al. 1998; Connelly and Koshland 2001; Seager and Theis 2002) appear to be a promising alternative). In the case of IS programmes in the UK, this is of particular importance as the policy guidance document, mentioned earlier, recognizes the economic barriers to the implementation of actions with far reaching environmental benefits. Analyses giving more consideration to the environmental profile of various alternatives considered in different regions can provide useful feedback in these aspects, and can possibly catalyze the development of necessary mechanisms to overcome the barriers. However, BCSD-UK, the other regional coordinators, and RDAs are not strongly motivated or well-equipped to carry out such analyses. This gap, however, can and should be filled by active participation of bodies, such as university departments or research institutions, which can perform such analyses.

On the importance of nation wide IS programme

A nation-wide IS programme is an important and valuable development. Its importance amplifies owing to the fact that its development will be coordinated by a central body, because: Firstly this setting will allow the application of a uniform approach for developments in different regions, and will enable making necessary modifications on a timely basis, based on the feedback received from other regions. Second, as the data will be gathered in a uniform manner and be compiled centrally, along with the progressing knowledge, these data and knowledge can be used for other purposes, in addition to promoting regional synergies. These may include:

- Identifying synergies that can arise among different regions;
- performing out assessments that regional parties may not be interested in carrying out, such as exergy[7];
- helping to identify technological bottlenecks applicable to a wider group of actors and thereby sending the right signals to technology developers;

[7] Exergy is defined as the ability of a system to perform useful work until it comes into equilibrium with its surrounding. It is believed to be a useful measure for resource depletion, as well as environmental damage. …

- disseminating information about good practices and facilitating their adoption in other regions (this is already taking place);
- providing feedback from a wider group of programmes involving diverse activities and thereby assisting policy development with better guidance.

5. Appendix 1 – Selected Definitions of Industrial Symbiosis and Eco-Industrial Parks

Concept	Definition
Industrial Symbiosis	Highly inter-dependent relationship between two firms, exchanging materials and energy in a mutually advantageous manner, each contributing to the welfare of the other. (Manahan 1999)
	The part of industrial ecology… [which] engages traditionally separate entities in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity. (Chertow 2000)
Eco-Industrial Park	A community of manufacturing and service businesses seeking enhanced environmental and economic performance through collaboration in managing environmental and resources issues including energy, water and materials. By working together, the community of businesses seeks a collective benefit that is greater than the sum of the individual benefits each company would have realized if it optimized its individual performance only. (Lowe, Moran et al. 1998)
	A community of businesses that cooperate with each other and with the local community to efficiently share resources (information, materials, water, energy, infrastructure and natural habitat), leading to economic and environmental quality gains, and equitable enhancement of human resources for the business and local community. (President's Council on Sustainable Development 1996)
Industrial Ecosystem	In an industrial ecosystem the traditional model of industrial activity… is transformed into a more integrated system, in which the consumption of energy and materials is optimised and the effluents of one process serve as the raw material for an another process. (Frosch and Gallopoulos 1989)

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