Division of Science and Engineering

Methodology for Capturing Environmental, Social and Economic Implications of Industrial Symbiosis in Heavy Industrial Areas

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DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

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LIST OF PUBLICATIONS

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GLOSSARY

ABS	Australian Bureau of Statistics
APA (I)	Australian Postgraduate Award (Industry)
ARC	Australian Research Council
ARCSC	Alcoa Research Centre for Stronger Communities
AZN	Afvalverbranding Zuid-Nederland
BCSD-GM	Business Council of Sustainable Development Gulf of Mexico
BP Ltd	British Petroleum Limited
BREW	Business Resource Efficiency and Waste
CCA	Capital Centered Approach
CERES	Coalition for Environmentally Responsible Economics
CECP	Centre of Excellence in Cleaner Production
CHP	Combined Heat and Power Plant
CSBP Ltd	Cummings Smith British Petroleum Limited
CUT	Curtin University of Technology
DTI	Department of Trade and Industry
EIP	Eco Industrial Parks
GCC	Gladstone City Council
GIA	Gladstone Industrial Area
GAIN	Gladstone Area Industry Network
GRI	Global Reporting Initiative
HISP	Humberside Industrial Symbiosis Program
IE	Industrial Ecology
INES	INdustrial Ecosystem
IS	Industrial Symbiosis
KIA	Kwinana Industrial Area
KIC	Kwinana Industries Council
KWRP	Kwinana Wastewater Reclamation Plant
MITI	Ministry of Trade and Industry
MCDA	Multi Criteria Decision Analysis
NIA	Naroda Industrial Estate
NISP	National Industrial Symbiosis Program
OH&S	Occupational Health and Safety

PAG	Project Advisory Group
QAL	Queensland Alumina Limited
RDA	Regional Development Agency
SAM	Sustainability Assessment Model
SAMi	Sustainability Assessment Model index
SCM	Six Capitals Model
SD	Sustainable Development
SDOOL	Sepia Depression Ocean Outlet Line
SNB	Sliberverwerking Nood-Brabant
SMEs	Small and Medium Enterprises
TBL	Triple Bottom Line
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
UNCSD	United Nations Council of Sustainable Development
UNEP	United Nations Environment Programme
USA	United States of America
WB	World Bank
WCED	World Commission on Environment and Development
WMC	Western Mining Corporation now known as Nickel West

ABSTRACT

Industrial operations have been attributed to causing social and environmental problems such as: acid rain; greenhouse gas emissions, air, water and soil pollution; plus health problems to neighbourhood communities. With the 3P (people, planet, profit) approach for sustainability as the background, there have been movements to establish the concept of eco-industrial development in existing or new industrial areas from the planning stage onwards. Industrial ecology (IE) is the operation of an industrial ecosystem which is based on the principles of operation of a natural ecosystem. Industrial symbiosis (IS), one of the principal applications of IE, is defined as inter-firm collaboration, where a network of industries collaborates in exchange of products, by-products, information, resources and wastes to reduce their collective environmental footprint to achieve mutual benefits.

Industrial symbiosis is a collaborative process of industries geographically located in an industrial park, which facilitates and enables an exchange of products, by-products and wastes to reduce the collective adverse impacts of the emission during the operation of these industries. However, IS faces a number of barriers. Importantly, it has been identified that there is a critical impediment to implementing future IS practices in the area. This is because of the number of barriers such as technical, regulatory, commercial as well as informational. In addition, there is an absence of a proven and well established evaluation methodology to identify the benefits of such practice. The true implications of IS might therefore remain underestimated, thereby failing to convince industry, government and the community to realize the opportunities IS can bring in attaining goals of sustainability in their operations.

The aim of this PhD research was to develop and trial a method for capturing the life cycle environmental, social and economic implications of industrial symbiosis in heavy industrial areas. This research was based on multi-

disciplinary approach of examining environmental, social and financial aspects to develop an integrated method. In the Kwinana industrial Area (KIA), the primary research area in Western Australia, the opportunities were significant for such industrial symbiosis to happen because of the co-location of diverse industries. The research hypothesis that informs this thesis is that the assessment of implications of present IS might bring further opportunities for enhancing symbiosis between industries. Though the primary emphasis of the research was in the Kwinana Industrial Area, this approach could be applied to other heavy industrial areas. This site could be significant both nationally and internationally in providing a platform for business responses to regional sustainable development challenges, by documenting best practice and improving approaches for implementing industrial symbiosis.

This research addressed the objectives by using the developed Six Capitals Model (SCM) for identifying environmental, social and economic benefits. The values under these dimensions were analysed with regard to natural, ecosystem, human, social, financial and manufactured capitals for a project of wastewater reclamation for industrial use. Under the environmental dimension, the model revealed that resource conservation and resource security were achieved as a result of the operation of this project. These results are in line with the argument that industrial symbiosis secures and conserves resources due to the possibility of reclaiming the resources that were once discarded. Water contamination has been reduced as a result of the operation of this project. This indicator shows that there is an improvement in maintaining the ecosystem capital.

In terms of human capital, sharing information between industries and opportunities of sharing infrastructure and technology has been improved. Regarding community capital, sharing of information between industries and communities, has increased as a result of this project. Collaboration of government bodies, level of understanding about IS projects due to increasing communication between various stakeholders, and increase of employment opportunities are notable, as value has been generated for community capital since the project started. In terms of financial capital of the project, the majority of the participants did not gain any financial savings in terms of direct costs but rather accrued short term costs. This was due to the infrastructure cost involved as part of installation of pipes and pumps. It was also due to the high cost of the reclaimed water than the scheme water. In addition, the analysis showed that most of the participants of the project did not gain any savings in the indirect costs such as hidden and legal costs, such as permit costs, compliance costs, future fines and penalties. However, as part of manufactured capital, there were savings due to improved business opportunities as well as infrastructure, for business and community collectively.

The results of this thesis show that broader benefits of symbiosis can be achieved, not only from operation of the project, but also from the influence of processes of symbiosis. Among them are connection, communication and collaboration between the project partners. There has been a substantial increase in the networking of industries and formation of multi groups for addressing various issues faced by industry and community in the Kwinana. There has also been a further increase in the transparency of information dissemination and communication through industries council's website. In addition, there has been an improvement in the rate of participation of community members and groups in the Communities and Industries Forum (CIF) which resulted in the formation of further stakeholder groups by industries council as a platform for addressing the issues of industries and communities.

IS practices strengthen the EIP concept and increase the chances of sustainable industrial development regionally due to collaboration of community of businesses and local and regional community. IS also increases the reputation and license to operate in the community. There are many advantages for using the Model developed in the thesis to assess the benefits of IS. First, the values of ecosystem values maintained are able to be accounted for in addition to natural capital values. The Six Capital Model can also account human capital values in addition to community capital. The

Model also accounted the manufactured capital in addition to financial capital and it gives an opportunity to identify the value generated towards community and companies.

Finally, the Model enables a calculation of the internal costs and external costs and benefits so that industries are able to understand the real cost of the projects. One of the main advantages of this method is that with, right indicators, the intangible values of the IS process can also be assessed and reported.

Illustration: Arial view of Kwinana Industrial Area
(Source: Kwinana Industries Council)

CHAPTER ONE

INTRODUCTION

Industrial operations have been identified as causing environmental problems due to acid rain; greenhouse gas emissions, air, water and soil pollution. There are also reports of social and health problems to their neighbouring communities (Pittock 2007). According to Wilderer (2002), apart from positive economic effects of industrial development, concentrating industrial operations on a limited tract of land tend to exceed the threshold of the carrying capacity of the ecosystem surrounded. It is now well recognised that industries have a major responsibility not only to alleviate environmental problems, but also to do so in a socially acceptable way (Paton 2006). However, these aims should not limit the economic benefits to core business itself, particularly for the long term. A ‘triple P approach’ (planet, people and profit) is therefore essential for industry to address sustainability issues (Elkington 2004).

This thesis takes up the task of exploring and recording present implications of the collective management of the industrial environmental initiatives in an industrial area in terms of environmental, social and economic aspects. Since this research demands inter-disciplinary approach, it draws attention from social, physical and engineering sciences. The findings of this research could lead to identifying whether there could be a chance to further enhance broader industrial symbiosis opportunities as a way to achieve sustainable industrial development. This research therefore aims to identify a method or model to identify the implications of IS to industries and their communities.

1.1 Towards Industrial Sustainability

The ever increasing use of the terms “sustainable development” and “sustainability” during the past two to three decades in industrial sectors, government bodies and academia explains the measure of importance of this concept in the present world. It has now been realized that in order to efficiently utilize resources for the present generation as well as for future generations, there needs to be a different pattern of production and consumption of all kinds of resources. According to Byrne and Hoffman (1996), an alternative technological pathway can improve the relationship between nature and society, not only to maintain and sustain the needs of the present generation but also to justify the needs of the future generations. The pathway of development to sustain the present without compromising the future is the basis of sustainable development.

The Club of Rome published *Limits to growth* in 1972 (Meadows et al. 1972), which made a case for limitations associated with population growth. However, it was the publication of the Brundtland Commission report *Our Common Future* in 1987 by the World Commission on Environment and Development (WCED) which brought a new dimension to the concept of sustainable development. The Brundtland report defined sustainable development as “development that meets the needs of the present without compromising the ability of the future generations to meet their own needs” (World Commission on Environment and Development 1987, p.8). Since then, there have been many competing definitions that have emerged from various schools of thought. Most of these agree to stress the importance of inter-generational equity in using the earth’s resources, and that any tax burden and debt due to high living standards of the present generation should not affect future generations while at the same time allowing a fair cost to the benefits enjoyed by the present generation (Thompson 2003). However, assessing the un/sustainability (Bossel 1999) of consumption and production patterns is challenging, since it is difficult to explain the quantity and quality of the measure of sustainability for each region. One can only determine how the resource use was sustainable or unsustainable at that time. Finding alternative ways other than resource intensive use of resources is one way to maintain sustainability of these resources.

Achieving the goals of sustainability is a multi-dimensional approach which involves working collaboratively with different academic disciplines, along with the public, different levels of government, business and industrial sectors. As introduced earlier, with the triple P (people, planet, profit) approach for sustainability as the background, movements to establish the concept of eco-industrial development in existing industrial areas or new industrial areas from the planning stage onwards developed in various parts of the world. In the last decade a local and regional approach to creating more sustainable industrial parks and estates has emerged (Wilderer 2002). Networks of collaboration among companies to improve environmental and economic performance, and networks to exchange by-products are some of the approaches used in industrial areas (Chertow & Lombardi 2005).

It has been argued that industrial systems could be managed to function in the same mode as biological ecosystems. This means that a traditional model of industrial activity should be changed to a more integrated model, one which could be conceptualised as 'an industrial ecosystem' where consumption of materials and energy is optimized, generation of waste is minimized and the effluents of one process industry are able to be used as raw material for another industry or process (Frosch & Gallopoulos 1989, p.94). This approach argues that industrial ecology (IE) serves as a better means for the coordination of technology, industrial processes and consumer behaviour (Frosch & Gallopoulos 1989) and that it requires a systems approach to function.

The systems approach with the need for a multi disciplinary framework strengthens IE's application to achieve industrial sustainability. Industrial symbiosis (IS), one of the principal applications of IE, '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, p.314).

By reusing by-products and effluents of one industry as input materials for another industry, rather than disposing of them as waste, companies have the opportunities of saving the precious virgin material. This process also has the chances of reducing environmental damage from leaching contaminants from landfills back to the environment. Other gains can be saving in energy and gain in potential trade opportunities for the material retrieved. According to Young (1999), there may also be lowering of greenhouse gas emissions, while cutting the demand for raw materials and landfills. By using such inter-firm collaboration, a company can not only reduce its waste disposal costs, treatment costs, storage costs, regulatory costs, legal and liability costs but can also derive savings on costs of resources, savings through reputation and on its license to operate in the community (Deppe & Schlarb 2001; LeBreton, Casavant & Cote 2004; Schlarb 2001).

1.2 Research Context

Industrial symbiosis is a collaborative process of industries located in an industrial park, which facilitates and enables an exchange of products, by-products and wastes to reduce the collective adverse impacts of these industries. However, this thesis identified that IS faces a number of barriers. Importantly, there is a critical impediment to implementing further IS practices. This is the absence of a proven and well established evaluation methodology to identify the implications of such practice. The true benefits of IS might therefore remain underestimated, thereby failing to convince industry, government and the community to realize the opportunities of IS in attaining sustainability.

Finding a methodology to capture the implications of IS in the three dimensions of sustainability may help industries to report to the public and government their sustainability outcomes. According to supporters of a triple bottom line reporting system (TBL), realisation of environmental, social and economic dimensions, provides the organisation an opportunity to prepare for future challenges and environmental performances within an individual company (Elkington 2004; Suggest & Goodsir 2002). According to Elkington, organizations which have successfully driven change as a result of TBL reporting have identified a number of benefits, including benefits contributing to the increased market value of an organization. These can also include embedding sound corporate governance and ethics systems throughout all levels of an organization. Currently, many corporate governance initiatives are focused at the board level.

TBL helps to ensure a value-driven culture and should be integrated at all levels. A further benefit can be the improved management of risk through enhanced management systems and performance monitoring. This may also lead to more robust resource allocation decisions and business planning, as risks are better understood. Another benefit can be achieved through formalizing and enhancing communication with key stakeholders, such as the finance sector, suppliers, community and customers. In this way, an organization is able to have a more proactive approach to addressing future needs and concerns. Furthermore, there can be the benefit of attracting and retaining competent staff by demonstrating that an organization is focused on values and its long-term existence. Finally, there is the benefit of being able to benchmark performance both within an industry and across industries.

There have been several attempts to highlight the potential of industrial interaction to the industries and communities and the level of economic and social impact in Kwinana. The first effort was undertaken in 1990, and was subsequently updated in 2002 (Sinclair Knight Merz 2002). One of the components of the updated study was to identify the opportunities of sustainable industrial development through a review of industrial interaction and identify new resource saving, reuse and recycling opportunities. The study found 104 existing interactions between the core industries and argued for a potential for another 106 exchanges (Sinclair Knight Merz 2002). The SKM study had reported triple bottom line benefits mainly in the area of industrial interaction due to supply synergies. One example of supply synergy is the exchange between the manufacturer of lime and cement and the

Alumina refinery in Kwinana. This synergy was actually ‘designed in’, since the major output of lime manufacturing company is the input of the refinery (Power, Sandover & Glenister 2002).

Projects based on industrial symbiosis on the other hand consider by-product and utility exchanges which require a different set up of facilitation, commercial and operational arrangements between the partners. This is due to involvement of high risks and costs of reclamation and reuse of wastes. There also needs to be different mechanisms for accounting the implications of such processes. As a result, there is a greater need for accounting and documentation of implications of by-product and utility exchange synergies in order to identify the cost and benefits related to alternate uses of the resources, in addition to costs relating to storage, transportation and land filling. It was argued that the positive results of such accounting might trigger further enhanced symbiosis between industries for achieving sustainable development.

This research was based on a hypothesis that if a proper methodology was available to capture and report, the environmental, social and economic implications of the IS approach to sustainability, to different stakeholders, then the industries would be able to further pursue IS in order to improve environmental damages. The enhancement of IS could be achieved with the help of government incentives and regulatory flexibility. When combined with some deeper understanding of how the cost and benefits are distributed between the key stakeholders affected by individual projects, there is also an opportunity to further enhance the process of IS. This thesis suggests that such an analysis could then also assist in identifying a preferred mechanism to redistribute the cost and benefits (if required) between the stakeholders to ensure their active participation in planning and implementing any regional synergies.

1.3 Site Context

According to Korhonen (2001, p.255) opportunities for symbiosis are plentiful in natural ecosystems, where ecosystems of long-term survival is based on “diversity”. As explained earlier, application of industrial ecology in an industrial system is based on the concept that an industrial ecosystem can be built on the industrial system based on its diversity. In the Kwinana Industrial Area (KIA), the primary research area for this thesis, the opportunities appeared positive for industrial symbiosis to develop because of the co-location of diverse industries. Heavy industries such as oil, nickel and alumina refineries; manufactures of cement, pig iron, titanium dioxide are among the many industries located in this area. A number of chemical industries which produce ammonia, ammonium nitrate, cyanide, chloralkali, fertilisers, herbicides and other agricultural chemicals, inorganic chemicals. Producers of water treatment and other process chemicals are also located here (Sinclair Knight Merz 2002).

As Chertow points out, collaboration is the key to industrial symbiosis (Chertow 2000), this research has found that collaboration between main industries in Kwinana has highlighted that barriers, such as lack of sharing information, benefit and risk, could be improved. At present, an industry council representing the senior managers of the industries present in Kwinana organises networking opportunities through various committees. There are a number of industries collaborating in by-product exchanges in this area already. However, there are still barriers associated with the sharing of sensitive information, lack of economy of scale, and non-availability of information on materials and case studies. In addition, there continues to be distrust of industry by Government and the community, ongoing regulatory hurdles and concerns about industry-interdependence (Taylor 2002).

1.4 Research Aim and Objectives

Since the identification of the wide application of industrial ecology principles in Kwinana Industrial Area (KIA), through the SKM Kwinana Economic Impact Report in 2002, it was argued that further synergies might be possible between the industries located at the site (Taylor 2002). Taylor noted that business development and environmental improvement as a result of symbiotic relationships between companies might result in reducing the environmental harm and enhancing the social benefit of the industrial ecosystem, as well as of the natural ecosystem. These findings led to Kwinana Industries Council (KIC) and its members agreeing to a further exploration of the possibilities of enhancing IS as a way of achieving goals of sustainable development (Taylor 2002).

This in turn contributed to the development of a research project between Curtin University of Technology (CUT), the Australian Research Council (ARC) and Kwinana Industries Council (KIC) and its members. It was identified that there are three important components for identifying the enabling mechanisms of IS. They are: facilitating structures that encourage collaboration among industries (and other sectors) operating in the same industrial area; operational and contractual arrangements that enable commitment of the necessary resources for implementation of regional resource synergy projects; and evaluation methods that can track and quantify the environmental, social and economic benefits (triple bottom line) of regional resource synergy projects (Altham & van Berkel 2004). This PhD research is therefore the third component of an ARC Linkage project (LPO349203), entitled “Enhancing regional resource synergies through the application of industrial ecology strategies for sustainable development in the Kwinana Industrial Area”.

The aim of the PhD research was to develop and trial a method for capturing the life cycle environmental, social and economic implications of industrial symbiosis in heavy industrial areas. It was expected that development of the method to capture environmental, social and economic implications of IS could provide opportunities for industries to realise whether IS could be seen as a way to achieve goals of sustainable development. It was anticipated that the method developed would support decision-makers in industry, government and the community in their assessment of the potential implications of individual exchanges. The original objectives of the PhD research were to:

1. Identify and review the existing approaches to evaluate environmental, social and economic implications of industrial symbiosis in heavy industrial areas, both globally and locally;
2. Develop a method to track and quantify the environmental, social and economic implications of industrial symbiosis projects for participating businesses, neighbouring businesses, communities and the region as a whole;
3. Trial and evaluate the method in a selected heavy industrial area such as Kwinana with the participation of industry partners and evaluate its impact on decision making by community, government and industries regarding industrial symbiosis opportunities; and
4. Provide recommendations for various stakeholders to achieve better capture and assessment of environmental, social and economic implications of industrial symbiosis.

1.5 Scope, Limitations and Significance of the research

It was expected that identifying the implications of the projects would increase the potential for companies to work in a more sustainable way by further enhancing inter-firm collaboration. This inter-firm collaboration could decrease the production costs due to material, energy and water savings, as well as enabling savings due to intangible benefits such as maintenance of reputation and social license to operate with neighbouring organizations and community. It was also felt that it would benefit the natural environment by reducing the impact of net discharges of waste and emissions, as well as by decreasing the demand on natural resources due to reclaiming the by-products. The health status of both the public and the employees would also be improved in local communities. It was argued that there would be increased opportunities of job security and stability since employees chose to stay with an industry that undertakes environmental and social responsibility of their actions. It is also due to development of skills of employees and sharing these skills with other companies. Although the primary emphasis of the research was in the Kwinana Industrial Area, it was suggested that this approach could be applied in other heavy industrial areas in order to deliver benefits to the local community and industry. The partners involved in the ARC Linkage Project proposed that it would be significant nationally and internationally in providing a platform for sustainable business responses to regional sustainable development challenges, by documenting best practice and improving approaches for implementing industrial symbiosis.

The research design included an assessment of environmental, social and economic implications which would demand collection of data from the concerned industries practicing IS. The constraints of this research included not only discovering the unavailability of this required data but also the difficulty of accessing data from industries due to the nature of commercial arrangements and confidentiality. Many industries were not capable of providing financial and operational data to this research study due to the nature of commercial arrangements with their collaborating companies, and in some cases, the data was found to be absent even if the industry was willing to support the research study.

1.6 Thesis Outline

This thesis consists of ten chapters, and it should be noted that the contents of the Chapters four, five and six, have been presented in various conferences during the PhD timeline. The contents of Chapter seven is currently under second review for publication in *Progress in Industrial Ecology*, an international journal. Inclusion of these chapters may have resulted in some repetition of literature in certain sections. These papers are provided in the Appendices.

Chapter two is a literature review, which provides an insight into the theory of industrial ecology, industrial symbiosis and its history of application in industrial areas in order to achieve sustainability. It provides an overview of the current status of indicator development and approaches to assess integrated and sector sustainability of projects, not all of which are IS projects. The different methods of valuation of sustainability are also explained in this chapter. Chapter three describes the research methods chosen and the rationale for methodology is outlined.

Chapter four explains how triple bottom line accounting can be applied to different life cycle stages of industrial symbiosis projects. A framework was proposed to evaluate life cycle implications of projects and it was applied to three projects in order to test environmental, social and economic implications. The contents of this chapter were presented at the *4th Australian Conference on Life Cycle Assessment* organised by the Australian Life Cycle Assessment Society, in February 2005 in Sydney and subsequently a peer reviewed paper was published in *the Proceedings of the Life Cycle Society*.

The analysis of the cases of eco-industrial parks researched for this study, together with details from desktop research as well as field research, forms the content of Chapter five. Analysis of the first and second stages of the content of this chapter has been presented in the *3rd International Conference on Industrial Ecology for a Sustainable Future,* held in Sweden in June 2005. The importance of stakeholder participation in accounting for sustainability, particularly in social sustainability, is then described in Chapter six. This chapter contains an analysis of social capital literature and its link to social sustainability. It also proposes and discusses a proposed framework prepared to analyse the link between social capital and industrial symbiosis. Contents of this chapter were presented to the *5th Australian*

Conference on Life Cycle Assessment 'Achieving business benefits from managing life cycle impacts', held in Melbourne in November 2006.

Chapter seven focuses on the development of the Six Capitals Model (SCM) for assessing the implications of IS, and explains the context of the Model with selected indicators. The results of the application of this Model application in the context of a case study project, namely the Kwinana Water Reclamation Plant in Kwinana Industrial Area, form Chapter eight. General discussions analysing the overall research outcomes based on the objectives of the research and the advantages of this Model over other models in evaluating the broader benefits of industrial symbiosis form Chapter nine and Chapter ten describes the conclusion and recommendations for future research.

To summarise, this chapter has described the introduction of the research theme and the context and objectives of the research. An outline of the thesis was then described after portraying its scope, limitations and significance. The next chapter examines the current literature on the theories of IE, IS and its context for achieving sustainability in industrial areas. It also describes the current methods and indicators for evaluating the implications of IS.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter describes the current literature reviews of theory of IE, IS within the context of achieving sustainability in industrial areas. The theoretical concepts of sustainability, industrial ecology, industrial symbiosis and their applications in industrial areas in developing eco-industrial parks to reach regional sustainability of the area are explained in detail in this chapter. It also describes the current literature of indicator developments and frameworks for measuring sustainability. The chapter focuses on the need for caution when identifying indicators and its developments nationally and internationally. This chapter also introduces the different integrated models proposed for assessing the sustainability of a project in general from the sustainability literature.

2.2 Industrial Ecology

Industrial ecology emerged as a concept following the seminal publication of Frosch and Gallopoulos (1989), although Erkman (1997) argues that Japan deserves the credit as a country which had earlier adopted industrial ecology principles. According to Erkman, from the late 1960s, Japan recognized the high cost of industrialization. For example, the Ministry of Trade and Industry (MITI) commissioned one of its independent consulting agencies, The Industries Structure Council to solve the high cost of industrialisation during that time (Environmental Industries Office 2003). A collection of experts from various fields then explored the possibilities of orienting the development of the Japanese economy towards activities that would be less dependent on the consumption of materials, and based more on information and knowledge. Connecting economic activity in an ecological context, MITI published a final report in 1971 naming it ‘A vision for the 1970s’. At that time it was considered as too philosophical to accept (Erkman 1997).

In 1989, Frosch and Gallopoulos (1989), two of the US proponents of the industrial ecosystem concept, (a concept based on the natural ecosystem ability to accept and consume what was regarded as waste) argued that the traditional model of industrial activity should be changed to a more integrated activity where consumption of materials and energy is optimized, the generation of waste is minimized and the effluents of one process industry could be used as raw material for another industry or process. This approach argued that an industrial ecosystem serves as a better system for the coordination of technology, industrial processes, as well as consumer behaviour.

According to Graedel and Allenby(2003), IE is defined as:

> the means by which humanity can deliberately and rationally approach and maintain sustainability, given continued economic, cultural and technological evaluation. It is a system’s view in which one seeks to optimize the total materials cycle from virgin material, to finished materials, to component, to product, to obsolete product, and to ultimate disposal. Factors to be optimized include resources, energy, and capital (Graedel & Allenby 2003, p.18).

Graedel and Allenby argued that IE contributes not only in alerting society and industry of the damages caused by unsustainable ways of operation but also the alternative ways of operation to reduce these damages. In their analysis of the future of industrial ecology, they then redefined the previous definition, as “… the science of multiscale planetary stewardship, involving the practice of intelligent oversight of the planet as it undergoes natural and anthropogenically driven variability” (Graedel & Allenby 2003, p.338).

As described briefly in the last chapter, IS serves the purpose of connecting the diverse ecosystem of industries and alternative ways of operation to reduce the damages caused by traditional operation strategies. This alternate ways of operation may provide opportunities to maintain and manage mutual benefits following the lines of natural ecosystems.

2.3 Industrial Symbiosis

Industrial symbiosis (IS) is the local/regional application of the concept of industrial ecology, with an opportunity for further environmental improvement through inter-organizational influences that are more successful than the traditional environmental improvement opportunities. It also leads to competitive advantage and local/regional sustainability through the opportunities of networking.

The concept of symbiosis in nature is worth exploring before trying to more narrowly define IS. There are a number of scholarly articles that define the nature of symbiosis and its context in industrial symbiosis during the development of eco-industrial parks. Some of them are cited below, along with a dictionary meaning of symbiosis to give a more concrete definition. The term 'symbiosis' was taken from biology, where it was first used in the late 1800s to describe the intimate, mutually beneficial coupling of fungi and algae in lichens (Ehrenfeld & Gertler 1997). The Concise Oxford Dictionary describes symbiosis as "an interaction between two different organisms living in close physical association, especially to the advantage of both" ('Concise Oxford English Dictionary' 2004, p.1458).

Desrochers, who reviewed the history of IS, which he defined as reuse of residue from one operation to another, argues that it has a long genealogy and was in fact "prevalent in advanced economies" (Desrochers 2001, p.350). He argues that there are records of German industries turning waste material into products following the First World War. Harper and Graedel (2004), define IS as one of the three well-defined types of system studies which use a systemic approach to study materials within the context of industrial ecosystems. They argue that the advantage of this approach to the definition is that this behaviour often emerges within a system that may not be predicted by studying the individual actors in the system (Harper & Graedel 2004).

Industrial symbiosis (IS) has recently returned to the debate because of the continuous academic study and publication of analysis of the many symbiotic relationships developed between companies and a municipality at an eco-industrial park in Kalundborg, Denmark. It has become an interest of both academia as well as industry in a desire to find alternative ways to deal with unsustainable industrial practices by convincing wider stakeholders of the advantages of symbiosis. For example, the Production Manager of Asnæs Power Station from Kalundborg, Valdemar Christensen, tried to describe the relationship developed between the people of different industries situated close to each other and the community and the municipality that hosted them, when seeking alternative ways to solve ground water crisis as well as the problem of disposing their emissions and by-products. According to Christensen, IS is:

> ... a cooperation between different industries by which the presence of each... increases the viability of the other(s), and by which the demands [of] society for resource savings and environmental protection are considered (as cited in (Gertler 1995, p.15).

This definition clearly links IS to the biological concept of symbiosis. Kalundborg has since become an iconic example of symbiosis between the industrial community and the wider community. Brings-Jacobson (2005), who has studied the Kalundborg site for economic and environmental quantification, describes industrial symbiosis in terms of its inter-firm relationships. He categorizes it "as a concept of collective resource optimization based on by-product exchanges and utility sharing among different co-located facilities " (Brings-Jacobsen 2005, p.240).

In her analysis of a research project aimed at "uncovering" IS practices, Chertow suggests a way of distinguishing industrial symbiosis from other types of material exchanges. In her opinion, such exchanges should have a "3-2 heuristic" as a minimum criterion (Chertow 2007, p.12). Chertow argues that there should be a minimum of three different entities involved in exchanging at least two different resources for such a process to be counted as a basic type of industrial symbiosis. This review of literature found that most researchers agreed that in order to solve the problem of impacts due to unacceptable practice of resource usages and wastage of resources required some form of partnership between different entities. It also found that partnership provided more positive results than working alone in environmental management practices.

Creating partnership and collaboration is not easy when there are barriers associated with implementation of symbiosis of industries. For example, some barriers identified during the development of by-product synergy (BPS) demonstration project at the Tampico, Mexico included: technical, economic, geographic, regulatory, legal, business, social, temporal and informational (Young 1999). Lack of trust between industries, risk of exposure of commercial intellectual property, un-availability of data to exchange, conflicts in risk and benefits sharing, community and market acceptance, regulatory uncertainty plus access to capital are specific barriers preventing companies from greater implementation of IS (Fichtner et al. 2005). Harris also identified lack of clarity of concept, poor external information links/process, low waste quantity, isolation in previous business, core business focus, lack of internal communication, lack of managerial support, lack of time/resources, regulation-labelling as waste, liability, lack of financial incentives as barriers (Harris 2004).

During the review of case studies for this research, it was identified that industrial symbiosis is much more than simply by-product exchanges between industries co-located or geographically close to each other. This research has found that it also includes the developed relationship between the partners of different industries involved, which allows for sharing of information as well as risks and benefits. This in turn reduces the barriers of IS, such as lack of communication and information sharing due to commercial confidentiality. For example, according to Lowe (1997), the social interactions between the managers of key companies and between managers and the lower level employees were vital in Kalundborg for building trust and in the development of business relationships that became the foundation of their ongoing exchange networks.

As Paton pointed out, progress toward sustainability will require collaboration that overcomes the barriers born out of mistrust, conflicting incentives, and diverging priorities. He identified that recognising the opportunities for collaboration is only a single step toward cooperation, but it is a critical first step (Paton 2006, p.160). Cohen-Rosenthal (2000, p.245) points out the necessity of studying the role of connection in improving collaboration between different partners and suggests, "knowledge of kinds of waste streams can provide a means to determine potential linkages, but it doesn't link them; decisions by people do" and describes this process as a connection between the humans and organisations and stresses the power of symbiosis as equal to any connection between exchange of energy and materials to further enhance IS. According to Boons, the connection between various stakeholders and the corporation through stakeholder management is to perceive 'license to operate' a form of 'legitimacy' (Boons 2004, p.388). Literature cited above identified connection, collaboration and communication as important aspects in the process of IS.

Some researchers also identified the importance of human dimensions in improving the process of IS. Research undertaken in Sweden to evaluate the human dimensions of improving efficiency of material and energy use through increased integration of local actors found that attitudes to cooperation, the role of actors, and local roots of the company were crucial in increased integration (Wolf, Eklund & Soderstrom 2005). This research highlighted that among these factors, the importance of local roots (connections to the region where the industries were located) were more relevant in increasing exchanges since it would be easier to increase integration if companies have strong local roots. A development of the relationships and the building of trust between those located locally are noted as the reason for this increase in positive net benefits. Therefore not only the connections to the local region but also the connection between industries and stakeholders are considered as important in enhancing IS. This point is explored further in Chapter 6 when discussing the Kwinana site.

The main factors outlined as influencing the companies' decision to engage in IS networking by Starlander are institutional pressure, access to critical resources, increased efficiency and costs savings, and inter-organisational learning. In his study of organisation factors specific to Landskrona, and possibly to Sweden, he identified that perceived need by companies for increased local networking are important. The major organisational factors influencing the outcome of IS networking are: alignment with business reality, environmental maturity and commitment of the actors, existing institutional platforms and linkages, communication and trust, coordination and public/private partnerships (Starlander 2003).

The literature review above highlighted that processes such as connection, communication, and collaboration are frequently identified as important parameters for industrial symbiosis exchanges to takes place between the industries and various stakeholders such as employees and nearby communities, and local actors. Due to these processes, it is possible that exchange of raw materials, energy, water and by-products by two or more participants can be successful while collectively brining mutual benefits. As the literature points out, there are intangible outcomes that can be achieved out of these. These intangible outcomes include trust and developed relationships, reputation, license to operate, market opportunities, and innovation. Such outcomes are in addition to tangible environmental and economic outcomes resulting from successful reuse of by-products**.** This definition of IS which included the process behind the materials exchange, is used here**.** This thesis proposes that industrial symbiosis is more than by-product exchanges between the industries co-located together; it is also the exchanges resulting from developed relationships and trust resulting from the connection, communication and collaboration between industries and stakeholders which enhances the further by-product exchanges and mutual benefits.

Industrial areas practicing this approach are classified under the name 'Eco-industrial parks' and these have been defined as:

> A community of businesses that co-operate with one another and with the local community to efficiently share resources (information, materials, water, energy, infrastructure and natural habitat), leading to economic gains, gains in environmental quality and equitable enhancement of human resources for the business and the local community by President's Council of Sustainable Development for Eco-industrial Park Development (cited in (Wilderer 2002, p.19).

As this definition relates to the principles needed for achieving sustainability, it is important to consider the implications of eco-industrial parks in achieving such sustainability outcomes and the contributing mechanisms used. Industrial ecology (IE) in general and one of its applications industrial symbiosis (IS) in particular, are among the contributing mechanisms that can be used to achieve sustainability in eco-industrial parks.

2.4 Eco-Industrial Parks

The relationship between locality and industry and IS can be seen as an exemplar in the concept of the eco-industrial park (EIP). According to Boons and Janssen (2004), development occurred in Kalundborg was in response to specific local circumstances that stimulated the building of mutual trust among industries and created an environment for cooperative action.

Chertow (1999) distinguished five models of EIPs during her analysis of 18 cases of eco-industrial parks in USA. First, through waste exchange, this formalizes exchange opportunities and can be at local, regional, national or global levels. For example, municipal recycling programs by councils can become a third-party business, servicing commercial and residential customers who supply recovered materials. Collected materials can then be transported through the municipality to manufacturers of glass plants and paper mills. Second, within a facility, firm or organization where some kinds of material exchange occurs primarily inside the boundaries of an organization rather than between collections of outside industries. Third, the exchanges and synergies among firms co-located in a defined eco-industrial park where businesses and organizations are located in the equivalent of an industrial park. These can exchange energy, water, and materials, involving other partners "over the fence" at the same time. This approach can go further by sharing information and services such as permitting, transportation, and marketing. Examples given by Chertow include Londonderry, New Hampshire and Red Hills EcoPlex, Mississippi.

According to Chertow (1999), examples of the fourth type of industrial park include Kalundborg in Denmark and Guayama in Puerto Rico, where the primary partners are not nearby but are within about a two-three kilometres radius. Even though these areas were not planned into an eco-industrial park, their proximity allowed them to take advantage of already generated materials, water and energy streams within the boundary of the area. In other words, their contiguous spatial relationship enabled them to take advantage for their productivity. Chertow's fifth model is realized among firms organized across a broader region and these exchanges allow the benefits of industrial symbiosis to be expanded to encompass a regional economic community. Some of the examples given by Chertow include Brownsville, Texas and By-Product Synergy in Tampico, Mexico.

Chertow's analysis enables a deeper understanding of the division of the types of eco-industrial parks. It has been based on the proximity, location, diversity and nature of possible collaboration between industries. These are notable features for the success of industrial parks where the natural ecosystem thrives and survives on the four biological ecosystem principles of diversity, roundput, locality, and gradual change (Korhonen 2001, 2004). As this thesis demonstrate, the fourth example within Chertow's classification can be applied to Kwinana as the local firms are co-located for industrial symbiosis to happen at the inter-firm level.

During the literature analysis, it became clear that eco-industrial development can be considered as a framework for sustainable industrial development. According to Deppe and Schlarb (2001), this type of development has potential for industrial ecology, pollution prevention, environmental management systems, green building design, life cycle design, and design for the environment, green productivity, and other strategies to green businesses. Industrial symbiosis can therefore be conceptualised as a form of inter-collaborative environmental management strategy with potential for social and economic improvement. As such a framework relates to the principles needed for achieving the process of IS and its outcomes, it is important to consider the implications of IS in the context of sustainability. Further to the clarification of the above, Figure 2-1 explains the links between those concepts (Chertow 2000).

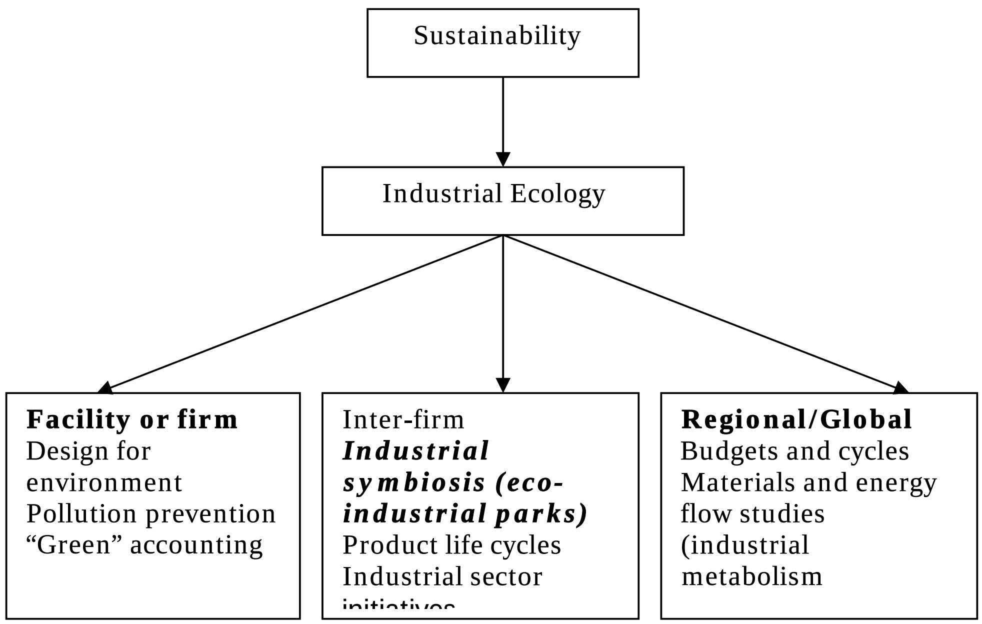

Figure 2-1: Operation of IE at three levels

Source (Chertow 2000, p.315)

2.5 *Industrial Symbiosis in the Context of Sustainability*

The literature reviewed about industrial symbiosis suggested that industrial collaborative networking strategies were helpful in achieving results such as: greater efficiencies in economy and time, reduction of conflict and increased innovation leading to sustainable development (Fadeeva 2004). This thesis argues that such collaboration is even more potent when the network actors have significant experience in working with each other. This type of partnership experience helps to solve highly complex issues or issues that are not clearly dealt with and interpreted during the course of the actual process.

Sustainability has different dimensions and most people tend to think that achieving the economic dimension is all about sustainability. Some experts in the financial and economic sectors suggest that the economic sustainability is the key theme in achieving sustainability. However, the proponents of this dimension do not go further and explain how addressing such economic dimension alone can bring holistic sustainability. Globally, the importance of maintaining and sustaining human society and its environment, in order to reach goals of sustainability, is considered as of utmost importance. There is an increasing trend in recognising the importance of environmental and social sustainability to achieve and maintain true economic sustainability. This has led to addressing the definition of environmental and social sustainability and how to achieve sustainability in terms of environmental and social dimensions. Some industries in the network of eco-industrial areas recognised that through IS, it is possible to achieve and maintain sustainability (Gertler 1995; Posch 2002).

2.5.1 Environmental Dimension

Over use of non-renewable resources by various industrial sectors not only creates problems of security of resources for future generations, but also pollutes the ecosystem with the solid, liquid and gaseous waste discharges produced during the processes of extraction, refining, manufacturing, use and ultimately disposal. Utility needs, such as electricity and water uses, for these purposes also create a set of pollution challenges to the environment. In addition, the use of various chemicals during such processes creates a hazardous environment not only for the people living nearby but also for people working on the site. Therefore, there are a number of environmental issues to be seriously considered by industries in their goals to reach environmental sustainability. Examples include their uses of renewable resources and innovative production practices which limit overexploitation of limited resources.

Industrial ecology, and particularly industrial symbiosis, provides an opportunity to utilise the waste generated by industry to be reused through inter-firm collaboration. Industrial symbiosis offers an approach to achieving resource efficiency by utilising the waste material generated by one company's process by another company as their resource. By doing so, the net emissions of solid waste, liquid waste, and gaseous waste to the environment surrounding the industries is diminished. As a result, a company can not only reduce their costs related to waste disposal, treatment, storage, regulatory issues, legal and liability issues, but can also make savings in resources costs and also avoid costly legal battles.

2.5.2 Social Dimension

Industrial symbiosis practices also provide social benefits for industries, as well as to their neighbouring communities. Benefits to industries can include the outcomes due to human capital achieved among the employees through shared health and safety practices, lower staff turnover and more innovative practices due to research and development, job retention due to skill development and training and the sharing of human resources due to trust and reciprocity. Better networking facilities also create benefits to industry partners. All these factors lead to the achievement of an enhanced reputation, market image and competitive advantage.

An in-depth analysis of the literature regarding, social benefits, social capital and its relation to social sustainability and industrial symbiosis is described in Chapter six.

2.5.3 Economic Dimension

It has been claimed by several authors that economic sustainability through industrial symbiosis can be achieved by avoiding environmental costs such as landfill, storage, treatment, and disposal (Deppe & Schlarb 2001). It has also been claimed that this can be achieved through savings on raw material due to the resource recovery of every material which was previously dumped as waste. Even though such processes of recovery can have short term costs, this thesis argues that long term benefits can be achieved out of these. Economic benefits are also achieved due to shared use of resources and infrastructure as a result of symbiosis. Most importantly, such economic benefits can be optimised through environmental and social achievements which create reputation and social license to operate the business. Industrial symbiosis proves a pathway for such achievement.

These processes may in turn lead to a competitive advantage with customers and suppliers. They can also provide an enhanced access to capital, as the finance sector continues to consider non-financial performance within credit and investment decisions.

In his recent research titled "Industrial symbiosis as a tool for more sustainable regions?" Mirata (2005) examined and searched for the influence of environmental and social dimensions for economic sustainability. His study confirmed that social benefits were the *least identified* among the three pillars of sustainability. Mirata argued that environmental sustainability is under threat from the depletion of natural capital in the form of non-renewable resources and ecosystem services. In terms of social sustainability, Mirata recognizes that the problem lies in the erosion of social capital, and he suggested that areas under threat included the cohesion of community, cultural identity, diversity, tolerance and humility. In addition, he also pointed out that compassion, patience, forbearance, fellowship, fraternity and social institutions were under threat. He recommended various strategies which could help to prevent the depletion of these capitals. They are realizing significant productivity gains and increasing the reliance on renewable resources; by developing more environmentally friendly products and processes, acquiring more cyclical behaviours in resource flows and by making investments to protect and enhance the quantitative and qualitative characteristics of natural capital. Mirata also stresses the importance of pursuing all these goals in development strategies and warns that if this is not undertaken, sub-optimal or even counterproductive results may prevail (Mirata 2005, p.8). He also makes a strong call for the need for assessment criteria and recommends one for further verification.

2.6 Indicators for Assessment

A review of literature on the indicators of sustainable development highlights the extensive attempts that have been made to date in this field (Parris & Kates 2003). Indicators have been developed for multiple purposes such as decision making and management, advocacy, participation and consensus building, and research and development. After the review of a dozen prominent examples by examining the similarities and differences in definition, motivation, process, and technical methods, Paris and Kates (2003) concluded that there are no indicator sets that are universally accepted or backed by compelling theory, rigorous data collection and analysis or influential policy. Parris and Kates (2003) found the reason for this was the ambiguity of the meanings associated with sustainable development, the plurality of purpose in characterizing and measuring it and a confusion in terminologies, data and methods of measurement. They proposed that accepting a distinction between terminology, data and methods would ease this confusion. They also proposed an analytical framework in order to clearly distinguish among goals, indicators, targets, trends, driving forces, and policy responses and also to highlight the need for continued research on scale, aggregation, critical limits and thresholds. Through this framework, goals, indicators and targets are selected according to the salience, credibility and legitimacy of each indicator initiative of the efforts to characterise and measure sustainable development. The framework also examines the technical characteristic of indicators, such as indicator initiative, scale, unit of analysis, selection criteria and finally aggregation method.

Suggest and Goodsir (2002, p.52) developed seven criteria to help determine appropriate indicators which can be adapted for capturing the implication of IS. The requirements of these indicators are that first, the indicator or the information from which it is calculated should be readily available. Second, the indicator should be relatively easy to understandable and third, the indicator must be about something that is measurable. Fourth, the indicator should measure something believed to be important in its own right. In addition, they suggest that there should only be a short time lag between the state of affairs referred to and the indicator becoming available. Finally, the indicator should be based on information that can be used to compare different geographical areas with international comparability. According to Suggest and Goodsir (2002, p.53), the most useful and well-designed indicators share a number of attributes. First, they reflect stake holders' concerns. Second, they are systematic rather than ad hoc, so that they begin to capture the interactions of systems. Third, they are clearly defined, understandable, reproducible, unambiguous and practical. Fourth, they enable benchmarking within or between companies where possible and practical, and finally they serve as an important tool in guiding management. These attributes are important when considering developing indicators, and in this research, these attributes are taken seriously.

The literature review on indicator development has revealed that there are a number of initiatives which have already been undertaken for developing indicators for measuring sustainability. Companies in general, or sector-wise, are already involved in the development of indicators to measure their performance in environmental, social and economic terms. They are using these indicators to communicate to various stakeholders. There are a number of integrated frameworks prepared by various groups to assess sustainability which can be used nationally, internationally, or can be used specifically for company focus. A summary of these follows. It was assumed that a mixture of these indicator frameworks could be applied in assessing the implications of IS also. These frameworks have been evaluated by examining their suitability in application to the IS case.

2.6.1 Global Reporting Initiative (GRI)

The Global Reporting Initiative (GRI) is an official collaborating centre of the United Nations Environment Programme (UNEP), funded by the Coalition for Environmentally Responsible Economics (CERES), and has the goal of enhancing the quality, rigour, and utility of sustainability reporting. Indicators used in the GRI initiative are grouped into three dimensions of conventional sustainability: environmental, social and economic. GRI organises performance indicators according to a category, aspect, and indicator. Table 2-1 shows the category, aspects used in GRI 2002.

Table 2-1: The category and aspects used in the GRI reporting system
Derived from (Global Reporting Initiative 2002)

Category	**Aspects**	
	Environmental	
Environmental	Materials Energy Water Biodiversity Emissions Effluents, and waste	Suppliers Products and services Compliance Transport Overall
	Social	
Labour practices and decent work	Employment Labour/management relations Health and safety	Training and education Diversity and opportunity
Human rights	Strategy and management Non-discrimination Freedom of association and collective bargaining	Child labour Forced and compulsory labour Disciplinary practices Security practices Indigenous rights
Society	Community Bribery and corruption	Political contributions Competition and pricing
Product responsibility	Customer health and safety Products and services	Advertising Respect for privacy
	Economic	
Direct economic impacts	Customers Suppliers Employees	Providers of capital Public sector

The definitions used by GRI within this hierarchy are aligned with international standards, but adapted to the GRI framework. There are numerous ways to use the 2002 Guidelines (Global Reporting Initiative 2002). For example, an organisation may choose to simply use them for informal reference or apply the Guidelines in an incremental fashion. Alternatively, an organisation may decide to report according to a more demanding level of “in accordance”. This level of reporting relies on transparency to balance the need for flexibility in reporting with the goal of enhancing comparability between reports.

The GRI Reporting System (2002) acknowledges that there are direct and indirect impacts of economic performance. Even though the indirect impacts are measurable, this system does not identify any indicators for measuring indirect impacts. Some of the aspects from all categories mentioned in the GRI reporting system can be useful to measure the implications of IS and it has been incorporated in this study.

A third set of GRI has also been published which has incorporated the changes recommended by various stakeholders. For example, social indicators from GRI 2002 under the numbering SO6 and SO7 are merged since both were identified as related primarily to legal issues around market practices (Global Reporting Initiative 2006). In addition, there are already sector specific indicators developed by GRI, mainly for mining and mineral processing industries (Azapagic 2004).

2.6.2 United Nations Commission on Sustainable Development Framework (UNCSD)

As suggested by Labuschagne, Brent and Erck (2005) this framework is used mainly for the evaluation of governmental progress towards sustainable development goals. The main difference between GRI and this framework is that this addresses the institutional aspect of sustainability in addition to the social, environmental and economic aspects. It has 15 main themes and 38 sub-themes, but does not address all of the criteria relevant to the business community. As for example, it does not address the operational or project level of business issues (Labuschagne, Brent & van Erck 2005).

2.6.3 Wuppertal Sustainability Indicators

The Wuppertal Institute proposed indicators for the fourth dimension of sustainable development, such as institutional aspects similar to the UNCSD. Here, the indicators are applied both on a macro-(national) and micro-(business) level. The United Nations Development Programme (UNDP) Human Development Index has been adapted to form a Corporate Human Development Index to address the business social sustainability. The Corporate Human Development Index consists of three main components and includes the quality of industrial relations and labour conditions, education (i.e. input and maintenance of human capital) and income level and distribution (Labuschagne, Brent & van Erck 2005).

2.6.4 Sustainability Metrics of the Institution of Chemical Engineers.

The sustainability indicators published by the Institution of Chemical Engineers (IChemE) are for measuring the sustainability of operations within the process industry in 2002. Within the environmental dimension, resource usage, emission, waste and effluents are used as indicators. This framework strongly favours environmental aspects, as well as quantifiable indicators that may not be practical in all operational practices, for example at the early phase of the project's life cycle (Labuschagne, Brent & van Erck 2005). Workplace and society are the main indicators in the social dimension and in the economic dimension, profits, value and tax are used in additional to investments. In each dimension, there is a provision of adding items which are important according to the needs of the organisation.

2.6.5 Government of Australia

A project by the Australian Government in 2002 has developed the Australian Best Practice indicators and methodologies for environmental, social and economic performance indicators. These are intended to support voluntary reporting by organisations in Australia. This framework was prepared in accordance with the Global Reporting Initiative (GRI), which provides environmental, social and economic indicators at an international level. The Australian Government's framework includes more social indicators than the GRI in order to accommodate Australian conditions (Department of Family and Community Services 2003). With this Report as a guide, the Department of Family and Community Services prepared their own triple bottom line report on their commitment to social, environmental and economic performances (Department of Family and Community Services 2003).

A study conducted in Australia and funded by various government agencies such as Prime Minister's Community Business Partnership, Department of

Industry, Tourism and Resources; Environment Australia and CISCO systems identified current strands of thought and action in Australian companies about triple bottom line measurement and reporting. As a result the Prime Minister's Community Business Partnership has been established to encourage strong and active collaboration between the community and business sectors to achieve mutual goals and develop creative solution to regional problems and to strengthen community ties (Suggest & Goodsir 2002). Table 2-2 shows the indicators used in some of the above frameworks.

Table 2-2: Sustainability indicators
Derived from (Labuschagne, Brent & van Erck 2005)

Dimensions	**Various Initiatives**		
	UNCSD	**Sustainability metrics of ICE**	**Wuppertal Sustainability Indicators**
Environmental	Atmosphere, Land, oceans, seas and coasts, fresh water biodiversity	Resource usage emission waste and effluents additional items	Resource use (extraction)
Economic	Economic structure consumption and production patterns	Profit, value and tax investments additional items	GNP innovation competition growth rate
Social	Equity, health, educations, housing security, population	Workplace society additional items	Healthcare housing social security unemployment
Institutional	Institutional framework institutional capacity	none	Participation gender balance justice
Inter linkages	none	none	Env_Eco (resource intensity of production, jobs, services, companies, regions) Eco_Soc (HDI: income disparity, long levity, education Env-Soc (Transport intensity, distribution of access to environmental resources)

The next section has identified some frameworks where such indicators have been integrated into their reporting.

2.7 *Models/Frameworks for Assessing the Sustainability of Projects*

All the indicator sets described above have been used widely in practical situations. For example, GRI indicators are widely used by companies such as Western Mining Company (WMC), in their reporting system. Table 2-3 describes the recent trend in accounting sustainability with indicators and it is clear that systemic inside-out characteristics are more acceptable than mechanistic top-down approaches (Richardson 2004). Richardson (2004) argues that going beyond the three capital approach of Triple bottom line towards the use of networks using a whole system concept enables a more effective model.

Table 2-3: Different approaches to sustainability accounting
Derived from (Richardson 2004, p.43)

Mechanistic: top down	**Systemic: inside out**
System understood in terms of component parts	Emergent characteristic of the whole system are different from the characteristics of its component parts
Focus on capitals and money values	Focus on network patterns
Separate silos and trade-offs	Synergistic relationships, feedback loops and virtuous cycles
Measures static 'snapshots' in time	Measures patterns of change, adaptation and learning
Focus on measuring quantities relating to sustainability performance	Focus on enhancing qualities of sustainability
Reduced complex systems to a single denominator	Embraces diversity and complex patterns
Tools adapted from economics and accounting	Tools adapted from holistic sciences (physics, evolutionary biology and ecology)

2.7.1 Triple Bottom Line Accounting (TBL)

Triple bottom line accounting is a term used for integrated accounting of environmental, social and economic accounting. It was coined by Elkington (2004), who describes TBL as:

> Triple bottom line focuses corporations not just on the economic value they add, but also on the environmental and social value they add - and destroy. At its narrowest, the "triple bottom line" is used as a framework for measuring and reporting corporate performance against economic, social and environmental parameters. At its broadest, the term is used to capture the whole set of issues and processes that organizations must work with to create positive economic, social and environmental value (Elkington 2004 p. 3).

Elkington pointed out the new transitional trends in engaging stakeholders and these are explained further in the Table 2-4.

Table 2-4: New transitional trends in engaging stakeholders
Derived from (Elkington 2004)

Established focus	**Emerging focus**
One-way passive communication	Multi-way, active dialogue
Verification as option	Verification as standard
Single company progress reporting	Benchmarkability
Management systems	Life cycles, business design strategy
Inputs and outputs	Impacts and outcomes
Adhoc operating standards	Global operating standards
Public relations	Co-Operate governance
Voluntary reporting	Mandatory reporting
Company determines reporting boundaries	Boundaries set through stakeholder dialogue
Environmental performance	"Triple bottom line" environmental, social and economic performance

TBL can potentially be used at various system levels, from a national economy down to an individual company (Kolk & van der Veen 2002). Within an individual company, by monitoring and reporting social, economic and environmental performances, organizations can better prepare for future challenges and opportunities, including those traditionally considered intangible, such as reputation (Parris & Kates 2003). According to Elkington, organizations which have successfully driven change as a result of TBL reporting have identified a number of benefits, including benefits contributing to the increased market value of an organization (Elkington 2004). These can also include embedding sound corporate governance and ethics systems throughout all levels of an organization.

According to Elkington, currently, many corporate governance initiatives are focused at the board level. TBL helps to ensure a value-driven culture and should be integrated at all levels. A further benefit can be the improved management of risk through enhanced management systems and performance monitoring. This may also lead to more robust resource allocation decisions and business planning, as risks are better understood. A third benefit can be achieved through formalizing and enhancing communication with key stakeholders, such as the finance sector, suppliers, community and customers. In this way, an organization is able to have a more proactive approach to addressing future needs and concerns. Fourth, there can be the benefit of attracting and retaining competent staff by demonstrating that an organization is focused on values and its long-term existence. Finally, there is the benefit of being able to benchmark performance both within industries and across industries (Elkington 2004).

A number of models have been prepared by private companies in order to assess the sustainability of their projects. These include, for example, BP's (oil refinery) Sustainability Assessment Model (Baxter, Bebbington & Cutteridge 2004), Shell's sustainability matrix (Cunningham et al. 2005) and Alcoa's multi-capital approach (Alcoa World Alumina Pty Ltd 2004). In these examples, integrated approaches to assess the benefits of sustainability are used. For example, in the sustainability assessment model, environmental, social, economic and resource capital are assessed in an integrated way (Baxter, Bebbington & Cutteridge 2004).

2.7.2 Sustainability Assessment Model (SAM)

Sustainability Assessment Model (SAM) is an accounting tool developed by British Petroleum (BP) in collaboration with Genesis Oil and Gas Consultants, Inchferry Consulting and the University of Aberdeen, which is used for measuring operational sustainability of projects (Baxter, Bebbington & Cutteridge 2004). It tracks significant economic, resource, environmental and social impacts of a project over its full life cycle and then translates these impacts into common measurement bases such as monetary values. It is a form of full cost accounting and attempts to identify all of the internal and external costs and benefits associated with a particular project. The result of this process can be produced as both graphical representations of the positive and negative impacts, as well as the construction of an index (SAMi) of how well the particular project performs. This information may then be fed back into the project evaluation processes, either to inform the redesign of the project or to be integrated into future project planning processes (Baxter, Bebbington & Cutteridge 2004).

SAM has been used as a sustainability assessment tool for a number of projects, such as landfill and tree planting and also in U.K.'s oil and gas industry, five hydrocarbon developments in the U.K. and in New Zealand for decision making. It is also being considered for use in other sectors worldwide. The process involves a generic four-step approach: first to define the focus of the costing exercise (whether it is a project or product); second to specify the scope or limits of analysis (that is, what subset of all possible externalities is to be identified); third, to identify and measure the external impact (which involves making the link between a cost objective and the externalities arising from the cost objective); and fourth to cost external impact (monetization of the externalities, or determination of the fuller costs that are associated with, but that are not already captured, by the current accounting).

SAM also assesses project performance and also allows for comparisons between projects, therefore enabling a ranking of projects. It informs specific design decisions such as development scheme selection, concept selection or decommissioning scheme. It also assesses the overall sustainable development performance of an industry sector, which could be on a one off basis or to assess performance trends of the sector. It assesses an organization's overall performance, thus informing the direction of, both short term and long term, company strategy. SAM also measures impacts through 22 performance indicators in environmental, social, economic and resource capital. Finally, SAM also monetizes all these indicators in order to allow comparison between them.

2.7.3 World Bank's Capital Centered Approach (CCA)

The World Bank's method of a capital centered approach emphasizes that social capital is as important a factor as other forms of capitals, such as natural capital, produced capital, and human capital. These capitals constitute world's wealth in order to gain economic growth and development (The World Bank 1997). In this thesis, the CCA approach can assist in influencing an analysis of the presence of social capital on the development of the industrial area effectively, or the relation between industry and its hosting community. It could also assist top level managers, and employees under them to improve certain parameters within their control, such as information sharing, coordination of activities and group-lending schemes.

The World Bank's reports defined the capitals as follows. Financial capital is the money that is invested in some activities that will produce more money. Natural capital consists of three major components, non-renewable resources, renewable resources and the environmental services to maintain it. Produced capital will be the physical assets that are generated by applying human production activities to natural capital, and that are used to provide a flow of goods and service, whether in the business sector, in homes, in communities, or in the public sector of governments and non-profit organisations. Human capital refers to the productive capacities of an individual, both inherited and acquired through education and training. Social capital consists of the networks, norms, relationships, values and informal sanctions that shape the quantity and co-operative quality of society's social interactions (The World Bank 1997).

2.7.4 The Seven Questions Framework

In order to find out how mining and minerals operations and projects contribute to sustainable development, the North American Chapter of Mining and Minerals Sustainable Development (MMSD) developed a framework based on seven components. These components are engagement, people, environment, economy, traditional and non-market activities, institutional arrangements and governance, and synthesis and learning (Mining Minerals and Sustainable Development 2002). The framework consists of seven questions for seven components described above as a means of assessing if the net contribution to sustainability of a project is positive or negative. The approach is also used for assessing sustainability by asking various questions related to these themes (Hodge 2004).

2.7.5 Framework for Manufacturing Industries

Labuschagne, Brent and van Erck (2005) developed a framework to assess the sustainability performances of a company and its operational activities and tested this in a South African manufacturing industry. They argued that corporate social investment should not be the only component of social dimension of sustainability of an industry. The approach separates corporate responsibility strategy into operational initiatives and societal initiatives before developing a framework. According to this framework, social sustainability consists of aspects including internal human resources, external population, stakeholder participation and macro social performance. Based on such a framework, a combination of monetary valuation and multi criteria decision analysis techniques (MCDA) was evaluated to further explore the integration of the results into decision making practices. The results of the application of this framework confirmed later that a quantitative social impact assessment method cannot be applied for project and technology life cycle management purposes in industry at present due to unavailability of quantitative data to prepare mid-point values (Labuschagne & Brent 2006).

2.7.6 Framework for Mining and Minerals Industries

Azapagic (2004) developed a framework of sustainable development indicators specifically for the mining and minerals industry. This framework comprises economic, environmental, social and integrated indicators, which can be used both internally, for identification of "hot spots", and externally, for sustainability reporting and stakeholder engagement (Azapagic 2004, p.651). Azapagic argues that this framework is suitable for sustainability reporting as well as for internal use by different types of companies, and could be used as a tool for assessing the level of sustainability of either a sector or an individual company. Table 2-6 provides the summary of the key sustainability issues for the mining and minerals sector considered by Azapagic.

Table 2-5: Sustainability issues in the mining and minerals sector
Derived from (Azapagic 2004, p.644)

Economic issues	**Environmental issues**	**Social issues**
Contribution to GDP and wealth creation Costs, sales and profits Distribution of revenues and wealth Investments (capital, employees, communities, pollution prevention and mine closure) Shareholder value Value added	Biodiversity loss Emissions to air Energy use Global warming and other environmental impacts Land use, management and rehabilitation Nuisance Product toxicity Resource use and availability Solid waste Water use, effluents and leachate (including acid mine drainage)	Bribery and corruption Creation of employment Employee education and - skills development Equal opportunities and non-discrimination Health and safety Human rights and business ethics Labour/ management relationship Relationship with local communities Stakeholder involvement Wealth distribution

The indicators proposed by Azapagic (2004) are compatible with GRI general indicators, thus contributing to a further standardization of sustainability reporting. During the development of indicators using this framework, life cycle thinking also was incorporated and mainly developed specifically for industrial minerals, metallic and construction minerals. It is mainly developed because the various industry stakeholders (such as employees, trade unions, contractors, suppliers, customers, shareholders, creditors, insurers, local communities, local authorities, governments, and NGOs) have differing specific sustainability interests. For example local communities, local authorities, Governments, NGOs, insurers, employees and trade unions have strong interest in social sustainability issues (Azapagic 2004).

2.8 Towards a Framework of Analysis

This chapter concludes by highlighting a summary of the many frameworks and indicators analysed. The methods/models identified described above include those identified for assessing general and sectoral sustainability of projects. These methods were prepared by sector-specific industries for assessing the sustainability of their projects. For example, the SAM model prepared for BP has been used as a sustainability assessment tool for a number of projects, including a landfill project, a tree planting project, U.K.'s oil and gas industry, five hydrocarbon developments in U.K and also for decision making by the company in New Zealand and it is also being considered for use in other sectors worldwide. SAM is a method where the values can be monetised into one value SAMi, however according to Richardson (2004) by trying to monetise the values of environmental resources, the value of intense synergistic relationship between the different elements of the ecosystem could be undermined, as in the case of a wetland project she describes (Richardson 2004, p.40). Since the value created by securing and maintaining ecosystem services will be undervalued by monetising, she argues that there needs to be an alternative method which can identify the values qualitatively for every improvement made.

The alternative method chosen by World Bank uses the stocks of capital approach instead of flows of capital. In order to measure benefits, measurement of capital appears to be a better alternative since it shows the accumulation and regenerative capacity of this process rather than the causes of impacts and the quantity of damages. Positive aspects of projects are considered as more important in this approach. While the World Bank's approach of considering five capitals to assess the value generated was useful for the purpose it was created for, it became clear through a review of the literature for this research, that industrial symbiosis not only recovers and reclaims natural capital but it also maintains ecosystem capital such as air, water and soil quality. It was felt necessary, therefore to account for ecosystem capital value generated in order to measure real benefits and so the World Bank's approach was found to be insufficient.

This thesis has therefore developed a Six Capitals Model (see Chapter seven) by modifying the World Bank's framework as a way to highlight the generated values of IS. As Richardson (2004) argues, choosing actions for short term profit need not be necessary to generate profit for a longer term. There is a risk in sustainability assessment that it only includes items that can be accounted and extracted into monetary values. Since most of the environmental and social benefits are intangibles, converting them into monetary values will undermine the real value of benefits of IS. IS also creates an opportunity to bring the small and medium businesses operating near the premises of big industries together in finding solutions for impacts. Symbiosis also opens the way for small and medium enterprises (SMEs) to open their doors for finding the solutions they have been looking for with the help of shared facilities and infrastructure prepared during the symbiosis process.

This chapter has described the various indicator frameworks developed in measuring sustainable development with some of them which uses an integrated approach. An appropriate framework has been selected from the list and developed further to measure the implication of industrial symbiosis, both operational and organisational. The Model developed is further explained in Chapter seven. The next chapter describes the design, methods and data collection of the research. It also explains the limitations faced during these stages.

CHAPTER THREE

RESEARCH DESIGN

3.1 Introduction

The previous chapter examined the theoretical concepts and existing evaluative methodologies related to this research and this chapter now illustrates the design of the research and explains the context within which the research was undertaken. It describes the methodology on shor-tlisting of case study areas to six for detailed research. Furthermore, it explains how selection of a case project was undertaken to apply the Social Capital Model (SCM) developed in this research. Case study research methodology is also briefly explained here. Finally, it outlines how the research was evolved.

3.2 Research Design

The research started with the objective of finding a method to capture the environmental, social and economic implications of IS in heavy industrial areas. A detailed review of the existing theories and frameworks were carried out as a first step. This was undertaken through the collection of information from scholarly journal articles, materials from industrial websites, conference proceedings, consultancy reports and local government documents. During this review, it was revealed that there were large numbers of industrial areas claiming that they practiced industrial symbiosis. At the same time, it was understood that there were only limited industrial areas that continued to function as eco-industrial areas. Even though some of these areas were evaluated for their environmental and economic performances, there were no studies that investigated the environmental, social and economic implications of IS in an integrated way.

3.3 Site Selection

The selection of industrial areas for this research study was undertaken in four stages. During the first stage, the information of eco-industrial parks was collected on the basis of a number of criteria associated with the type of industries involved in the park, the summary of existing processes and the problem being addressed. The background of the implementation of the IS process, the advantages of this initiative, plus the incentives from various bodies to initiate this process were also investigated. In addition, the time-frame for the development, the contact addresses of the facilitators and financial providers, and the barriers faced during facilitation were investigated for further research. This review identified over 60 cases of industrial parks that had engaged in industrial ecology initiatives. They included industrial sites from North America, Africa, Europe, Asia and Australia. The first stage of selection is shown as (S-I) in Figure 3.1. The first stage was carried out from April to October 2004.

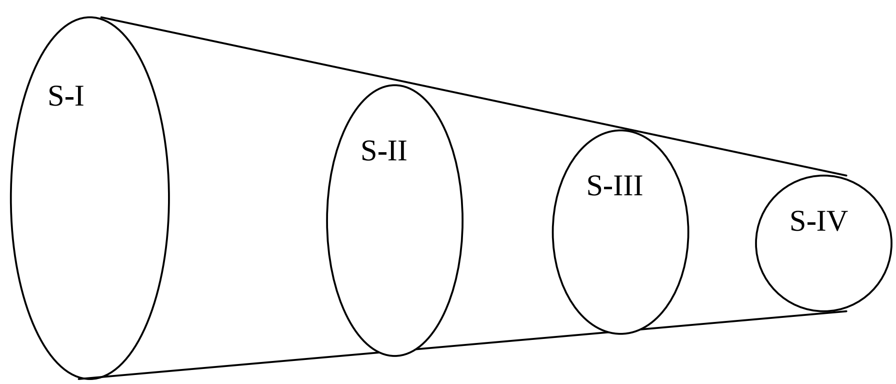

Figure 3-1: The stages of selection of case studies for research

On further analysis of the data on the eco-industrial areas/parks, the original list was reduced to 15, on the basis of unavailability of detailed information as well as a contact to facilitate the supply of primary data for further research.

This stage of selection of cases is shown as a second section (S-II) in Figure 3-1. This data collection was carried out during the period between November 2004 and April 2005.

During this stage of the process, it was realised that, out of fifteen industrial areas that were listed as eco-industrial parks (EIPs),, only a small number of EIPs were operational. The other EIPs were either under the implementation stage or were non functional. The efforts to collect further details of new information about progress from EIPs through the identified contact persons by e-mails had very limited success only. It was then decided to collect further data by telephone interview. During telephonic conversations with the available contact persons, it became clear that most of the areas selected from North America (table 3.1 has) had ceased operation due to the difficulties associated with financial support from the Government. Details of the Asian EIPs were also unable to be collected because of the absence of a contact person or a facilitator in these cases. Therefore, based on the unavailability of current operational details and lack of success of this approach, all 15 cases were again screened for identifying the most operational ones. Subsequently, four industrial areas from Europe and two cases from Australia were selected for further analysis and study based on the operational stages of the projects undergoing IS process. It was believed that aspects of different life cycle stages of the projects would be able to be captured if projects from these EIPs were selected. This is shown as the third stage (S-III) in Figure 3-1.

At the stage 3 (S-III) as shown in Figure 3.1, the EIPs selected from Europe were Kalundborg, (Denmark), Moerdijk, (The Netherlands), Rotterdam, (The Netherlands), and Humberside, (United Kingdom). The two national cases were - Kwinana, (Australia) and Gladstone (Australia). Kwinana was selected as the prime case study area of this research. Since the researcher faced enormous difficulty in obtaining commercial data electronically or by telephone from managers of the selected international cases and selected stakeholders, it was decided at this stage that in order to further investigate the best international examples of IS projects, a personal visit to some of the companies was necessary. This was undertaken in June 2005.

Table 3-1. *The industrial parks which are shown in bold are the ones selected for visitation in the third stage for detailed analysis.*

Table 3-1: Industrial areas selected in the first round of evaluation

Region	**Country**	**Case study areas**
Europe	Austria	Upper Styria Recycling Network
	Denmark	**Kalundborg**
	France	Troyes
	Finland	Jyvaskyla
	Germany	Karlsruhe
		Heidelberg/ Rhine-Neckar
	Italy	Falck steel plant area,
	Norway	ORA Eco-park
	The Netherlands	**Rotterdam**
		RiVu - Den Bosch
		Moerdijk
	Scotland	Fourth Valley
	United Kingdom	**Humber**
North America	Canada	Burnside, Halifax,
		Alberta Heartland
		Montreal (x 2)
		Alberta
		Sarnia Lambton
	Mexico	Tampico
	United States of America	Phillips Eco-Enterprise Centre, Minnesota
		Londonderry, New Hampshire
		Devens, Massachusetts
		Triangle, North Carolina
		Riverside Eco-Park: Burlington
		TXI, Texas
		North Texas

Region	**Country**	**Case study areas**
		Brownsville, Texas
		Fairfield, Baltimore
		Cape Charles, Virginia
		Red Hill, Mississippi
		Dow Chemicals, New Jersey
Africa	South Africa	Kugar
Asia	China	Chong Yuan
		Lubei Chemical
		Guitang Group
		Baotou, EIP
		Taihu Baisin
		Zhaozhuang
	India	Harora,
		Naroda Industrial Estate
	Indonesia	Bugangan Baru Industrial Estate
	Japan	Cement and beer clusters
		Ebara Corporation-Fujisawa EIP
		Fujisawa Factory
		Kawasaki (Eco-town)
		Muko River basin
		Kokubo Eco-industry park
	Taiwan	Corporate synergy system
		Waste Exchange Information Centre
	Thailand	Leam Chabang
		Map Ta Phut
	Singapore	Jurong Island
	South Korea	Daedeok Techno valley,
Australia	New South Wales	Illawarra Hunter
	Queensland	Brisbane/Carole Park
		Gladstone
	Victoria	Altona
		Geelong
	Western Australia	**Kwinana**

3.4 Data Collection on Sites

A semi-structured questionnaire was prepared to collect information regarding specific projects in each area. The data collection was developed to enable electronic analysis. A brief summary of the known aspects of operations at each site was prepared following after the first literature review. This summary was sent with the questionnaire to the selected EIPs for further verification. Further for more detailed information regarding the enabling mechanisms of industrial symbiosis in each project was requested to the EIPs. The details of the questions prepared are provided in the section below. (A copy of the questionnaire is included as Appendix 1).

Data collection from the six industrial sites was planned to undertake by gathering information from some representatives of industries, academics, community groups, consultants and Government agencies. At this point too, a decision was taken to incorporate stakeholder participation and obtain their views of the IS projects for all areas selected. From the various industries, data were collected from the environmental managers, quality and safety engineers, in addition to plant managers or consultants of the projects of selected industries. For example, in the Moerdijk region in the Netherlands, the quality control engineer from the waste incinerating company was prepared for interview along with environmental manager from Port Authority, and in Kalundborg, the quality and safety advisor from the Plaster Board Company as well as the senior consultant and the co-ordinator from Kalundborg Industrial Symbiosis Institute were agreed for interview. In the Humberside program in the U.K, data were collected from a number of stakeholders including consultants and the representatives from the local municipal council. In the Rotterdam IS region, academics from Rotterdam University and Delft University as well as consultants from BECO were participated in the interview process. During the visit to all these industrial areas, the details of enabling mechanisms of IS of at least one specific case project were collected from the companies visited.

3.5 The Case Sites

As part of the larger ARC Linkage Project (see Chapter one), the Kwinana Industrial Area (KIA) and the Gladstone Industrial Area (GIA) were chosen as national cases to study in detail the industrial symbiosis approaches of every project in operation. In order to further understand the approaches taken to implement projects in these areas, a similar questionnaire to that used in the international analysis was used for each project. Subsequently a detailed analysis of 22 projects under the by-products exchange category was carried out for KIA. These 22 synergy projects were further narrowed down to 16 icon synergies, identified by the companies concerned. This was agreed to in discussions undertaken during the meetings with the managers concerned. In a similar way, six project synergies at GIA were also analysed with a similar questionnaire in order to identify the initiatives and implications of industrial symbiosis in GIA. This was undertaken by collecting information by telephone conversation with the managers concerned with those projects. Finally, the Kwinana Water Reclamation Plant (KWRP) was selected as one of the case projects from Kwinana to apply the developed model. .

3.6 Case Project

The KWRP project from KIA was aimed at reclaiming treated effluent by using reverse osmosis and membrane filtration technology. This reclaimed water would be used by the industries in order to reduce the usage of scheme water. It was also one of the key projects, with the highest number of collaborative partners. It was decided, therefore, that the KWRP project could be used as a case study to reveal the benefits of an industrial symbiosis process such as networking and collaboration, in addition to the benefit to the operation of the project. This selection was done on the fourth stage of selection of cases for study as shown in Figure 3-1. An analysis of the same case study was undertaken during the beginning of the method development, which developed a life cycle triple bottom line framework and applied, and is elaborated on in the following chapter. This framework analysed the operational benefits of the project in its life cycle.

3.7 Framework and Model Development

Drawing on the academic literature analysed in the previous chapter as well as data collected from the six industrial areas, a framework was prepared to identify the potential successes of the projects and the best implemented strategies (chapter 5). A model was then developed to assess and identify the broader environmental, social and economic implications of these IS projects. In order to trial the model developed, the iconic project was selected from KIA and information was collected using the developed model.

Since the KWRP was identified as an ideal case project for assessing and measuring the various outcomes achieved due to project and process success, the 'Six Capitals Model' (chapter 7) was applied to this case. This process was carried out by collecting information from key participants of this case project using prepared questions based on selected indicators. (This questionnaire is attached as Appendix 2).

3.8 Case Study Research

As the project developed to a single case study design, the methodological rationale for this was analysed through a literature review. Case study research typically involves the observation of an individual unit (Burns 2000), for example, a student, a family group, a community or an entire culture. In order to qualify as a case study, the subject of study should be an entity in itself that this must be a bounded system. According to Yin (2002), case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. Yin (2002) proposes that although the single study is useful in representing critical, extreme or unique case studies, multiple cases are more complete and robust.

A case study approach also allows for the collection of data from as many sources as possible to strengthen the robustness of the research findings. For this research, it was a combination of interviews, observations and archival records. These case study data are analysed by building an explanation about the case. The field work and the data collection can be undertaken before finalizing research questions and hypothesis, which is a common approach in case study research. In summary, the KWRP provided the characteristics of a classic single case, within a bounded system, as identified by (Yin 2002).

3.9 Data Collection and Analysis

According to Eisenhardt (1989) analysing data is the heart of building theory from case studies. As Eisenhardt explained, the data collection for this thesis study was undertaken using a mixed method including desktop research, interviewing with semi-structured questionnaires, telephone interviewing and field visits. The questionnaires were prepared using a semi-structured format, to collect information from the contact persons in Australia and overseas regarding details of enabling mechanisms of industrial symbiosis projects in their area. This questionnaire contained questions such as: when, who, and how initiatives of IS were undertaken generally in a company and specifically for a project. It asked about costs, the lead time of the project, as well as any perceived environmental, social and economic benefits of each individual project.

The data collection for the Kwinana and Gladstone sites was undertaken using a combination of both telephone and personal interviews. The duration of the interview was organised for an hour, but in some cases it was extended to two hours, particularly where there were a number of IS projects. The information collected was analysed to compile a baseline understanding and was collected from those companies who were already participants in industrial symbiosis activities, as well as those who were planning to become involved in the future.

In order to apply the Six Capitals Model, data were collected using selected questions based on indicators. This was done by interviewing environmental/plant managers of the companies which collaborated in the KWRP project. Data were gathered from the participating industries, the owner and operator of this project,-namely the West Australian Water Corporation, as well as government agencies and community representatives. The KWRP project has five industry partners and only one of these five industry members of the KWRP project declined to participate during the validation of the model.

During the preparation of questionnaire for the application of SCM, a set of scales was developed to collect data as to whether the capital under investigation was achieved by the stakeholders. The scales were selected in the order 1 to 5 where: 1, strongly disagree; 2, disagree; 3, neutral; 4, agree; and finally 5, strongly agree. The questionnaire was prepared using indicators to measure the values of the capital as described in the model. A system of scores was then used to collect information in all categories. This scoring system has the advantage that the study could gather confidential information which otherwise would not be made available. The benefits were measured using indicators in terms of percentages in four categories from 0-25, 25-50, 50-75, 75-100. The representation of values in percentages was designed to help disseminate information while at the same time protect the confidential information provided by companies to calculate these values. The social benefits were measured by using selected indicators in gathering responses from the same personnel using Likert scales (Burns 2000). However, not all the companies who participated were prepared to give values of capital in percentages.

The Likert scale method is a simpler method of attitude measurement. The subjects are asked to indicate their agreement or disagreement to various attitude statements selected by a researcher regarding a particular topic. Each statement is usually scaled on a five point scale, ranging from strongly agree as being most favourable attitude statement to strongly disagree as the least favourable point. These scales can be valued from 1 to 5 (depending upon the number of possible choices) and then summed up to provide the numerical values of the answers to all questions (Burns 2000).

There are many advantages of using the Likert method. First, this provides greater ease of preparation. Second, the method is entirely based on empirical data of subjects' responses, rather than the subjective opinion of judges. Third, the method produces more homogeneous scales and increases the probability that a unified attitude is being measured. The validity and reliability for this method are reasonably high. There are some disadvantages however, as this method is not more than an ordinal scale. The total score for an individual system has little clear meaning, since many patterns of response to the various items may produce the same score.

3.10 Limitations to Research Method

In the case of Kwinana, primary data were mainly collected from managers of environmental/safety/plant and community groups. As there was limited opportunity to collect primary data from community groups and Government representatives in the Gladstone site, the study relied on academic colleagues and industry managers for any primary data collection and such secondary data that had been published in analysing the views of community stakeholders and Government representatives.

It was also found that gathering quantitative data regarding the costs and benefits as a result of the reuse of any by-products was difficult. There were some cases of quantified benefits of industrial exchanges available in the literature. However, it was impossible to collect any quantitative data on the benefits, including social benefits, from any of the project cases selected. Most of the companies contacted were reluctant to disclose any information for research due to their confidential commercial arrangements with their partners. A further reason for being not able to identify the benefits was due to the companies not gathering such data themselves. Commercial sensitivity of data also prevented industries from sharing data. It was interesting to note that lack of sharing information was one of the main barriers identified from the literature as to why industries face difficulties in implementation of industrial symbiosis projects. Another barrier was the lack of a transparent methodology to measure and report the environmental social and economic implications.

This thesis has therefore had to pioneer an approach to identify an appropriate methodology to measure the intangible benefits associated with industrial symbiosis.

The limitations associated with the gathering of quantitative information led the researcher to revisit the industrial symbiosis theory and practice to better understand its wider applications. A review of the literature associated with eco-industrial parks also helped to better understand what can be termed as the ‘reality’ of IS and to help redefine its applications and benefits in the context of a social dimension. This second stage of the research data collection was more fruitful and, during this stage, data were collected from the industry participants of the KWRP project, community and Government representatives of KIA as the focus case study. This was undertaken by applying the Six Capitals Model to identify values attributed during this project. Using 38 questions from the indicators chosen, the value of each capital was identified and analysed. This has been undertaken in Chapter eight.

3.11 Summary

To conclude, this chapter summarises the design of research methods including site selection, data collection on sites, as well as selection of sites for the case project, and data collection methods. It also summarises the limitations experienced during the selection of sites and collection of data. The next chapter provides the TBL framework developed to identify the life cycle environmental, social and economic implications of the projects. It also provides the application of this framework for three projects in the case site and the results of application.

CHAPTER FOUR

A LIFE CYCLE TRIPLE BOTTOM LINE FRAMEWORK APPLIED TO INDUSTRIAL SYMBIOSIS PROJECTS

4.1 Introduction

The previous chapter outlined the process of developing an overall approach for methodology to enable an analysis of the research question. This chapter outlines the method developed combining life-cycle thinking and TBL approach to assist in identifying the full spectrum of potential benefits of industrial symbiosis projects, including the economic, social and environmental costs and benefits to industry and the community. This research suggests that such a method could be used as an aid for project evaluation by decision makers to gauge their industrial symbiosis projects' effect on regional sustainability. While a large number of "triple bottom line" accounting methods have been developed and promoted, these concentrate on reporting against sustainability criteria or indicators and have not been developed as a tool to aid decision makers, which would require the comparison of alternative solutions. The method was used to review three examples of industrial symbiosis projects from the Kwinana heavy industrial area namely a water reclamation plant, a cogeneration plant and gypsum recycling.

4.2 Industrial Symbiosis

As discussed in detail in Chapter two, industrial symbiosis can involve a range of practices including, but not limited to, the sharing of facilities and equipment, water management including water cascading, water recycling and wastewater recovery, capture and supply of gaseous emissions as by-products (i.e. NO_x, SO_2 and CO_2). It also involves energy management, including steam recovery, reuse and cogeneration, plus materials management including materials recovery and reuse, waste management including converting waste streams to by-products and bulk-up recyclables to make collection cost-effective, and collaboration in transport, storage and logistics between companies.

Modern environmental management, together with industrial symbiosis, employs a holistic definition for waste. Here all non-product outputs including solid waste, air, water and land emissions are classed as waste. This practice greatly expands the volume of materials that have the potential for reuse. For example, the waste inventory implemented as part of the Tampico by-product synergy demonstration project identified that half the waste volume of participating companies were gases and gaseous waste (50.9%). The next two major waste streams by volume are water (30.4%) and contaminated soils (13.52%) respectively (Young 1999, p.8). There are many eco-industrial parks which are being established internationally. However, most of them do not implement industrial symbiosis, with less than 20% of the eco-industrial parks exchanging by-product, energy and/or materials (Proctor, Deutz & Gibbs 2002). Furthermore, a study conducted in 2002 by the University of Hull reported that out of 60 identified eco-industrial parks projects, only 33% were operational, some 28% were in the planning stage and 13% failed. Rest of the cases were unable to predict in the categories mentioned above (Gibbs, Deutz & Proctor 2002). This finding indicates that despite its compelling logic, the application of industrial symbiosis remains limited and challenging.

4.3 Triple Bottom Line Accounting

In general, industrial symbiosis is documented in financial and environmental terms during the reporting of companies' performances, thereby neglecting the third pillar of sustainability. The true sustainability advantages of industrial symbiosis are not fully realised, nor reported, and this thesis argues that triple bottom line accounting should overcome this impediment by allowing improved identification and reporting of the environmental, social and economic benefits of industrial symbiosis projects. While many sustainability reporting methods have been developed, the majority of these do not aid decision makers by allowing them comparison of 'before' and 'after' impacts of different acceptable and workable solutions. The selection of relevant and useful indicators is critical to this process.

According to Richards (1999), it is important that the indicators selected satisfy three criteria. These are relevance, practicability and appropriateness. First, relevance ensures that entrepreneurs consider the indicators selected important to their future decision-making. Practicability ensures that the measurement and monitoring of the indicators is practical, reliable and within the resources available to the business. Finally, appropriateness ensures that the indicators reflect actual impacts, and coincide with the company's long-term aims.

Some more general guidelines can be kept in mind when deciding which indicators to use. Indicators or metrics try to simplify measurement and communicate complex events and trends. The information pyramid begins with data. Data were processed into trends, which are refined into indicators, and at the top of the pyramid are indexes. There is an important difference between inputs, process, outputs and outcomes; what goes in is not the same as what comes out (SustainAbility 2002). All indicators should be measured within the corresponding system boundaries. This thesis argues that the method of development to evaluate the full implication of industrial symbiosis projects should adopt life-cycle thinking. As it is a pre-requisite for any sound sustainability assessment, life cycle thinking suggests that economic, social and environmental implications need to be considered for each stage of the synergy project's life cycle (i.e., planning, design, construction, operation, maintenance and decommissioning) (Rebitzer et al. 2004; Sonnemann et al. 2001).

Given the diversity of indicators currently available, there is a need to select a practical number of indicators that reflect the major economic, social and environmental impacts of the project. It is also necessary to ensure that they are not highly correlated, as this may lead unconsciously to "double accounting", with resulting potential to mislead decision makers. Selecting 3-6 indicators for each category applicable, giving a total of 9-18 indicators to the individual project, could be considered appropriate for the initial development of this method. If a larger number of indicators were promoted, with the flexibility to choose, there may be a temptation to select those that tend to show the project in a good light, which could also mislead decision makers.

The measurement of indicators needs to reflect the change in impacts caused by the project. It also needs to measure the change in performance of the area before and after the industrial symbiosis project, as well as the total impacts of the project. Many of the indicators chosen could be difficult to measure in financial terms, however quantifiable impacts should be included and ranked to aid decision making if possible.

Sustainability indicators can be divided into two main categories; capital or stock or flow (inputs and outputs) indicators. Examples of these indicators generally used in each dimension are given in Table 4-1.

Table 4-1: Examples of stocks and flows in TBL accounting

	Stock or capital indicators	**Flow or input/output indicators**
Economic	Industrial asset (share value comprising) Physical Goodwill Public infrastructure	Profit Income Investment Wages Taxation revenue
Environmental	Natural resources Water quality Air quality Biodiversity	Energy consumption and efficiency Water consumption and efficiency Material consumption and efficiency Land, water and air emissions. Land clearing
Social	Educational qualification Participation in decision making Skill levels Workforce Community	Hours of training Education and training costs Community development expenditure

These two classes of indicators should be kept separate if possible to minimise confusion. In general, capital indicators (i.e. natural capital) are harder to measure, and would enable lag and are affected by flow indicators. This is because the flow has a direct impact on the capital indicator, while the degree of correlation may vary. Capital accumulation will also be affected by the degree that new skills or resources are retained and used, or diminish over time, reflecting the effectiveness of programs.

4.4 Economic, Social and Environmental Indicators

4.4.1 Economic Indicators

To date, the development of economic indicators has been the most advanced of the three sustainability pillars. Economic indicators should reflect all life cycle economic costs that can be identified and should include direct and indirect costs of the project and the costs avoided, plus any revenue from the sale of the by-product materials, energy, or water. Korhonen, Okkonen and Niutanen (2004) argue that accounting for indirect effect is the greatest benefit of industrial ecology over traditional waste management practice. This economic costing should also consider intangible as well as tangible costs, as far as practicable.

The practice of accounting for the life-cycle and total cost of the project allows improved comparison of options with high upfront capital costs and lower operating costs, with options with lower up-front capital cost but higher operating cost. Utilisation of this process also takes into consideration the life-span of projects and any refurbishment and scheduled maintenance requirement for the project.

Publicised indicators for economic impacts of sustainable development projects include generation of local business opportunities, generation of capital works, sales, profit, wages paid, taxation revenue, tangible environmental costs, and transport costs (Global Reporting Initiative 2002;

Korhonen, Okkonen & Niutanen 2004; Labuschagne, Brent & van Erck 2005; Parris & Kates 2003).

The potential difference between direct cost and total cost of waste management is illustrated in Table 4-2.

Table 4-2: Direct and indirect waste costs
Derived from (Chertow 1998, p.36; van Berkel et al. 2002)

	Reported value as % total waste costs (range)	
	Direct %	Indirect %
External	25 (10-50)	55 (10-75)
Internal	10 (5-20)	10 (5-20)

This table gives some indication of the mix of economic cost to a company for waste disposal, and illustrates that direct costs are often a poor indication of total waste disposal costs, with direct costs often only accounting for 25% of total costs in some cases (Chertow 1998, p.36). The balance includes loss of raw material within the waste and their replacement, the labour used to collect and transfer the material for collection, cost of management systems, licensing and administration cost, and cost of equipment to handle or treat waste.

4.4.2 Environmental indicators

The development of environmental indicators is not as well advanced as economic indicators and, if indicators are available (e.g. toxicity impacts), core data for characterisation may not be available. This thesis argues that environmental indicators must comprehensively reflect short and long-term environmental impacts of the project throughout the projects' life cycle stages. Environmental impacts avoided should also be included in the assessment, as in many projects this may be one of the major environmental advantages of the project. Indicators may also identify if the environmental impacts are local, regional or global. Quantifying environmental impacts can be very difficult, and when this is the case, literature suggests that it is vital to list the potential impacts and assign the direction of impacts with an estimate of the size ranging from minor to major. There are examples of indicators for environmental impacts, of sustainable development projects. These include land use, biodiversity, energy consumption, water consumption, air, land and water emissions, and material consumption (Global Reporting Initiative 2002; Korhonen, Okkonen & Niutanen 2004; Labuschagne, Brent & van Erck 2005; Parris & Kates 2003)

4.4.3 Social indicators

The development of social indicators is the least well developed of the three pillars of sustainability indicators. Social indicators should reflect the short- and long-term impact of the project on the local and wider community. The indicators selected must reflect how the project impacts on the community's ability to control its future and its quality of life. Such social impacts can be very difficult to quantify and, because of their similarity to environmental impacts, it is important that they be listed. It is also necessary to decide whether or not the impact is positive or negative and some indication of the magnitude from minor to major to assist decision makers. Social impacts avoided should also be included in the assessment, as in many projects this may be one of the major social advantages of the project.

Publicised indicators for social impacts of industrial symbiosis projects include job creation, job security, skill level, health and wellbeing, community stability, education standards, level of community services, crime rates or sensory stimuli. Sensory stimuli include impacts of aesthetics, noise, dust, and odour which also need to be considered (Global Reporting Initiative 2002; Korhonen, Okkonen & Niutanen 2004; Labuschagne, Brent & van Erck 2005; Parris & Kates 2003).

4.5 Application of a TBL Approach to Projects

The results of an application of a TBL method on three industrial symbiosis projects in the Kwinana Industrial Area (KIA) are discussed in the following section. These descriptions are accompanied by tables that list the indicators of economic, social and environmental impacts for each of the project stages, with an indication of their magnitude and beneficial nature to the companies involved.

4.5.1 Wastewater Reclamation

As a major planning initiative by the Water Corporation in 1994, the Wastewater 2040 Study identified future water demands and constraints in Kwinana (Addison 2004). This report predicted that treated wastewater from the Woodman Point Wastewater Treatment Plant (WWTP), after further advanced secondary treatment, could become a major new water resource for some Kwinana industries.

In 1998, the Kwinana Water Link study was undertaken by the Water Corporation in collaboration with industry and government to investigate water use efficiency and provide for better environmental management in the Kwinana Industrial Area. This study found that by 2007, industries in Kwinana would be using around 35 GL per annum, up from 19 GL per annum in 1997, an increase of 84% between 1997 and 2007 by projecting historical water use (Addison 2004).

Following these studies, the Water Corporation announced its plan to build the largest water reclamation (Government of Western Australia 2003b) plant of its type in Australia, in the Kwinana industrial strip. At a cost of $A 29m, it was proposed that this plant would expand Perth’s water use options and help achieve the aim of the West Australian Government’s State Water Strategy to reuse 12% of the treated wastewater by 2012 (Government of Western Australia 2003b).

In 1999/2000, a community consultation process was undertaken to enable the highlighting of issues of concern which could be addressed before the project was implemented. The community response to the initiative was considered as overwhelmingly positive from the results of KIC survey of community attitudes 2000 (as cited in (Water Corporation of WA 2003).

According to Water Corporation, major environmental benefits identified were essentially two-fold (Water Corporation of WA 2003). First, that the reclamation plant would free up scheme water (6 GL/year) previously used by industries and second, that treated industrial discharges would be transferred from an ecologically sensitive coastal area to a deep water outlet (providing for better dilution of industrial contaminants from the treated industrial effluents). It was argued that the trade-off would create an increase in energy and chemicals used in the operation of the plant. The plant now extracts 24 ML/day. Of this, 17 ML/day is suitable for industrial use, and this equates to one third of Kwinana's total increase in water demand between 1997 and 2007. The balance of 7ML/day contains the concentrated waste and is discharged into the ocean. Industry, in turn, discharges 6.1 ML/day of industrial wastewater through the ocean outlet into the ocean. Prior to this project, this 6.1 ML/day was discharged into Cockburn Sound after treatment with the approval from regulatory authorities.

The KWRP plant involves a number of stages of operation. According to Walker (2003), the process begins with the drawing of 24 ML/day of effluent from the SDOOL. This water is secondary treated at the Water Corporation Woodman Point Sewage Treatment Plant and the effluent is then filtered to remove coarse particles (larger than 2 mm) which may have entered the effluent stream. It is also treated with sodium hypochlorite to form a chloramine residual to control biological fouling on the microfiltration and reverse osmosis membranes. The water is then passed through a highly sophisticated Memcor submerged continuous micro-filtration (CMF-S) process using hollow fibre membranes. This removes particles down to 0.2 micron including suspended solids, bacteria, and large colloids which force the filtrate through trains of reverse osmosis membranes in the next stage.

This process removes most dissolved salts, as well as larger organic molecules, in addition to any residual bacteria and viruses (Walker 2003). Overall, this produces 17 ML/day of industrial water at a quality suitable for use by major Kwinana industrial customers. The total dissolved solids (TDS) target for this process is 50 mg/L, significantly lower than most drinking water provided in Perth of TDS 200 mg/L (Water Corporation of WA 2003). Figure 4-1 outlines the water balance for discharging to Sepia Depression Outlet Ocean Lane (SDOOL) post-KWRP (2004).

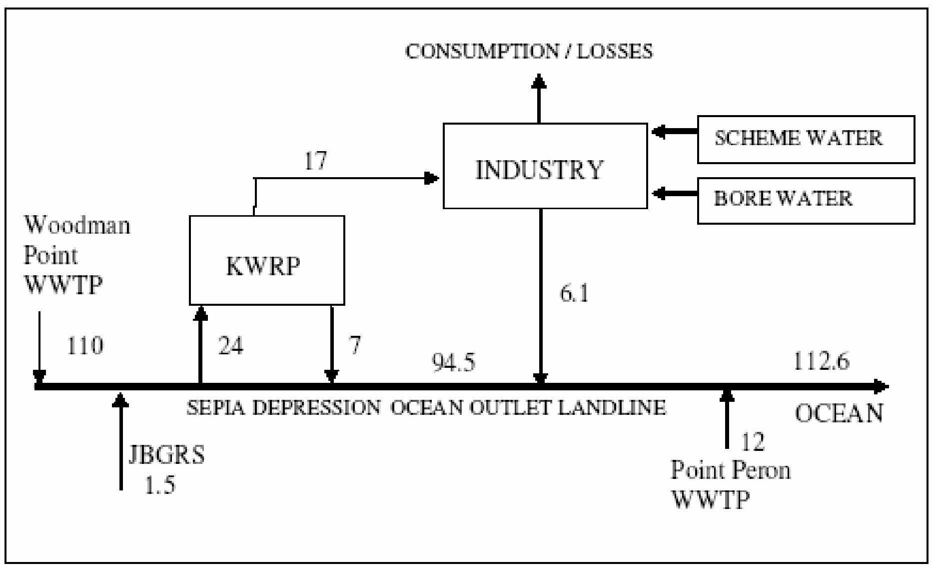

Figure 4-1: Water balance of SDOOL post-KWRP (ML/day)
(Source: (Water Corporation of WA 2003, p.3)

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One of the companies using this KWRP water is HIsmelt Pig Iron Plant, whose future water usage was calculated as 18ML/d for the first stage commissioned by end of 2004. Other companies that are accessing the water include: BP Oil Refinery, whose water demand is 1.5ML/d; CSBP fertiliser plant, whose demand at 2.0 ML/d; Edison Mission Energy, whose demand is 3.0 ML/d and is expected to remain unchanged. Tiwest also has a demand of 2.2ML/d industrial water and its demand for the future is unchanged (Water Corporation of WA 2003). Table 4-3 lists the economic, social and environmental costs and benefits of the project prepared in a framework of the project's life cycle stages, as compared with the current practice of groundwater extraction and industrial discharge into Cockburn Sound.

Table 4-3: Life cycle environmental, social and economic implications of KWRP
(Source: Prepared from identified indicators)

Life cycle stages	**Environmental**	**Score**	**Social**	**Score**	**Economic**	**Score**
Planning and Design (1998-2002)	Material & energy use and impacts from pilot tests.	-	New skills developed for planning and designing of the water reclamation plant. Community commitment in planning.	+ +	Wages for planning & designing team. Generate business for local suppliers. Capital investment.	+ + -
Construction (2003-2004)	Land for plant and infrastructure. Material & energy use for plant and pipe infrastructure.	- --	Job creation as construction and manufacture of supplies. Skill enhancement as the result of a new technology.	++ +	Wages for construction workers. Generate business for local suppliers. Tax generated from wages paid. Capital investment.	+ + ++ --
Operation (Nov 2004 +)	Scheme water conservation. Water quality and eco-system improvement in coastal zone. Energy use and GHG emission. Chemical use.	+++ +++ - --	Improved recreational value of coastal zone and reduced health risks to community. Job creation and security. *	++ ++	Water security for industry users. Better opportunities for tourism and aquaculture in coastal zone. Tax generation. High grade water for industry. Increased water cost for industry.	++ ++ + + +
Refurbishmen t Every 5 years(Walker 2003)	Waste from refurbishment. Material and energy use for refurbishment.	- -	Maintain water security. Job creation (temporarily).	+++ +	Wages. Generate business for local suppliers. Capital investment.	+ + -
Decommission (2029)	Land reclamation. Recycling of material. Waste from decommissioning .	+ + -	Temporary job creation. Permanent job loss. Loss of water security.	+ -- ---	Wages from temporary employment. Loss of business for local suppliers. Value from recycled material.	- - +

--- major negative, -- negative, - minor negative, 0 neutral (may involve a shift in impact i.e. a shift of jobs from mining to recycling), + minor positive, ++ positive, +++ major positive, GHG: green house gas, +Efficient technology compared to 20 years ago which is 30% cheaper now and could be considered an economic benefit (Walker 2003)

Job creation and security would principally be because of industries using the KWRP water, together with increased tourism and aquaculture in waters of coastal zone and not the plant itself which will be fully automated

It has since become apparent that for KWRP, implications of industrial symbiosis over most of the life cycle stages showed positive social and economic benefits except in the decommissioning stage, shown in Figure 4-2.

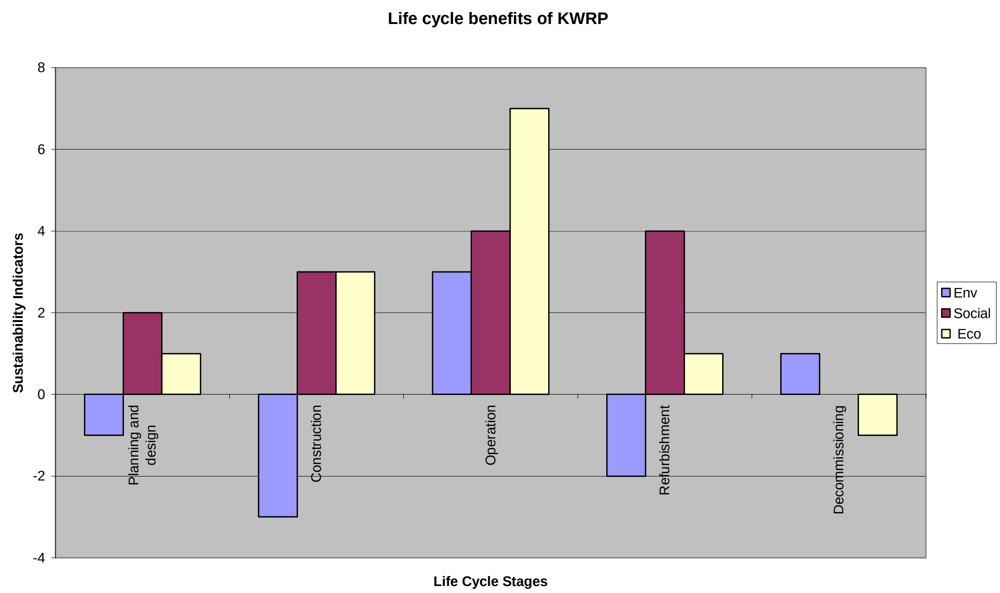

Figure 4-2: Results of life cycle stages of KWRP

These benefits were measured with the indicators such as job creation, security of potable water, and an increase of amenity value due to reduction of discharge of polluted water in the nearby Cockburn Sound. Environmental benefits were negative in most of the life cycle stages, except in operational and decommissioning stages as a result of materials and energy during construction and generation of waste during refurbishment.

Following an analysis of primary data from different stakeholders (industries and communities) that was completed during method development, it now appears that there are more than operational benefits that could be achieved due to this project. It was identified that an additional assessment method was necessary to include the benefits of the process of IS in addition to operational benefits.

4.5.2 Recovery of Steam

This section describes the operation of a cogeneration plant in general and, the results of the investigation of impacts using the developed life cycle TBL framework of the cogeneration plant in Kwinana. Cogeneration, often referred to as CHP (combined heat and power), produces both electricity and steam from a single operation, and the combined fuel efficiency is higher than the boiler and generator it replaces. To utilise the steam effectively, the facility needs to be co-located within 2km of a steam user. Cogeneration offers dramatic advantages in efficiency and much lower air pollution than conventional technologies. A wide variety of cogeneration technologies generate electricity and meet thermal energy needs simultaneously at the point of use (direct heat, hot water, steam, process heating and/or cooling). In contrast, conventional heat and power generation discharges large quantities of low grade heat into the environment. Figure 4-3 compares the typical fuel input needed to produce 35 units of electricity and 50 units of heat using conventional separate heat and power.

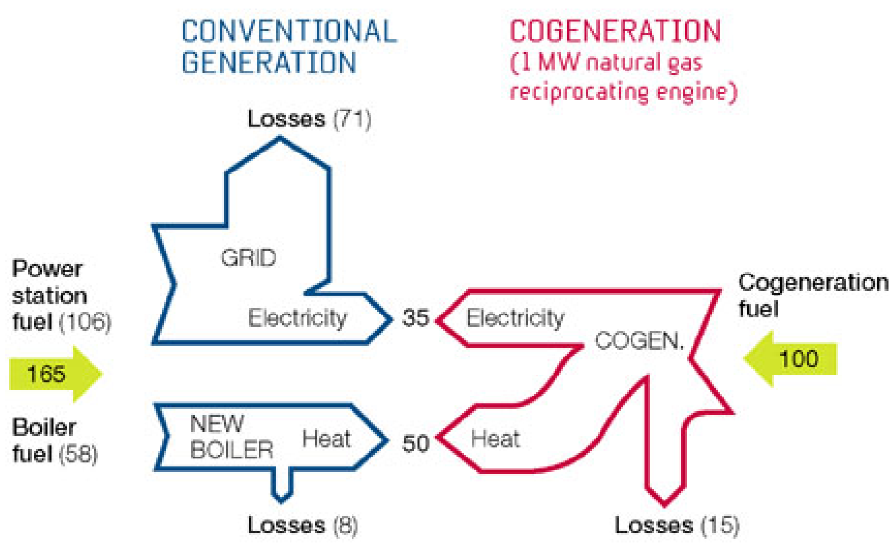

Figure 4-3: Cogeneration efficiency
Source: (Sustainable Energy Authority Victoria 2004)

Table 4-4 lists the economic, social and environmental costs and benefits of the project by the project's life cycle stages compared with the operation's separate facilities for power generation and steam product.

Table 4-4: Life cycle environmental, social and economic implications of recovery of steam
(Prepared from identified indicators)

Life cycle stage	**Environmental**	**Score**	**Social**	**Score**	**Economic**	**Score**
Planning and Design (1995)	Material & energy use and impacts from pilot test.	-	New skills developed for planing and designing the cogeneration plant. Community commitment in planning.	+ +	Wages for planning & design team. Generate business for local suppliers. Capital investment.	+ + -
Construction (1996)	Land for plant and infrastructure. Material & energy use for plant and pipe infrastructure.	- -	Temporary job creation as construction and manufacture of supplies. Skills enhancement as a result of a new technology.	+ +	Wages for construction workers. Generate business for local suppliers. Tax generated from wages paid. Capital investment.	++ + + --
Operation and maintenance (1996+)	Chemicals use. Impacts avoided energy efficiency and gain, with associated reduction of GHG. Improved use of refinery gas.	- ++ ++	Permanent job creation.	+	Sales of power and steam. Further refinery efficiencies as a result of greater and more realistic steam supply. Wages for plant operators. Tax generation.	++ ++ + +
Decommission (2044)	Land reclamation. Recycling of material. Waste from decommissioning.	+ + -	Temporary job creation. Permanent job loss	+ -	Wages. Recycling of waste material.	+ +

--- major negative, -- negative, - minor negative, 0 neutral (may involve a shift in impact i.e. a shift of jobs from mining to recycling), + minor positive, ++ positive, +++ major positive

As an example of the environmental benefits, the Kwinana Mission Energy cogeneration plant (now known as Kwinana Cogeneration plant) avoids 170,000 tons of CO_2 compared to separate operations for power generation and steam production. Edison Mission Energy Kwinana operates a 116-megawatt gas-fired cogeneration facility located on the BP Refinery (BP) site in Kwinana. The plant also generates 2,800 tonnes per day of steam. Two thirds of the electricity generated is sold to Western Power (Western Australia's state energy provider), with the balance sold to BP. BP is currently Edison Mission Energy's is sole steam client. Edison Mission Energy receives refinery fuel gas from BP, which is used to fire boilers. This energy source supplies approximately 15% of Edison Mission Energy requirement, but volume fluctuates depending on BP's production activities and the type of crude oil processed. Steam demand continually fluctuates depending on production processes at BP. Figure 4-4. is graphical representation of the results of implications of this project.

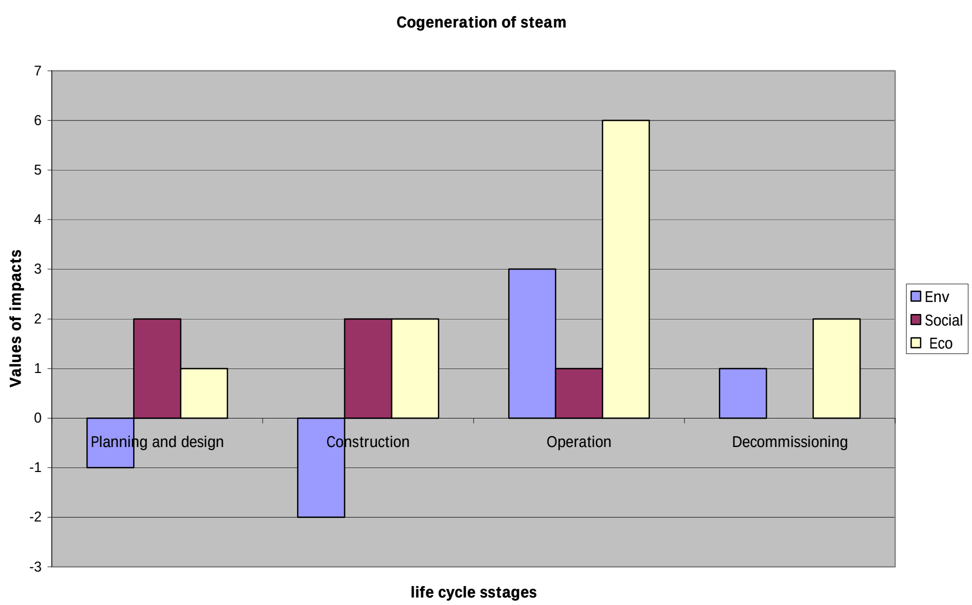

Figure 4-4: Results of the life cycle stages of recovery of steam

The results of the use of the above framework of lifecycle stages combined with TBL implications for cogeneration of the use of fuel gas as alternative fuel in addition to natural gas are analysed. The results show that there are social and economic benefits from reusing the fuel gas for steam production.

At the same time during decommissioning stage, there were no social benefits. Environmental benefits were positive during operation and decommissioning stages.

4.5.3 Reuse of Stockpiled Gypsum

This section describes the various sources of gypsum in general and the results of the investigation of impacts of gypsum reuse using developed life cycle TBL framework. Gypsum is a by-product of many industrial processes within heavy industrial areas and it has a variety of uses, including cement manufacture, wallboard manufacture and promotion of soil stability. The major sources of gypsum are generated through the process of desulphurization at power generation plants, where sulphur from flue gases is "chemically bonded" using limestone. This desulphurization generates a large amount of chemical gypsum as a by-product. Producing gypsum to the quality specification required for by-product exchange may require increased operator awareness to limit contamination (Department of Primary Industries Water and Environment 2004).

Gypsum produced by CSBP Ltd as a by-product from the manufacture of phosphoric acid in the Kwinana Industrial Area, has been stockpiled on the site. CSBP has extensively reviewed reuse options for this 1.3 million tonnes of material, including the its use in plasterboard, sale to farmers, and its use in soil amendments (Wesfarmers 2004). Gypsum improves the soil structure in clay-based soil, which allows for improved root penetration and plant growth, water perpetration and moisture retention. It also improves soil stability and reduces dust and water erosion. It was determined that the material could be utilised by Alcoa to improve plant growth and soil stability in their residue areas. Alcoa started utilising waste gypsum from CSBP in 2002 and continues to take this material on an ongoing basis, using approximately 10, 000 tonnes each year because of its ability to achieve soil amendment (Summers, Guise & Smirk 1993). Recently, an agreement has been signed with Manna Enterprises for the gypsum to be used for soil improvement properties by mixing with lime kiln dust (Wesfarmers 2004).

Table 4-5 lists the economic, social and environmental costs and benefits of the project by the life cycle stages compared with the past practice of CSBP stockpiling the gypsum and Alcoa purchasing virgin gypsum.

Table 4-5: Life cycle economic, social and environmental implications of gypsum (Prepared from identified indicators)

Life cycle stage	**Environmental**	**Score**	**Social**	**Score**	**Economic**	**Score**
Recovering from stockpile	Reduction of stockpiled waste.	+	Reduced hazards associated with stockpile.	+	Reduction of liabilities encountered with gypsum stockpile.	+
Use of gypsum	Improved site rehabilitation. Reduced water erosion. Reduced dust.	++ + +	Improved amenity value of rehabilitated site.	+	Reduced liability. Improved vale of rehabilitated site.	+ +
Gypsum Mining	Avoided impact from gypsum mining. Reduced transport.	++ +	Reduced jobs in mining.	0	Mine operations.	0

Figure 4-5: Results of life cycle stages of gypsum reuse

--- major negative, -- negative, - minor negative, 0 neutral (may involve a shift in impact i.e. a shift of jobs from mining to recycling, in this case from the mining of gypsum to recycling of gypsum), + minor positive, ++ positive, +++ major positive

The results of the analysis show that during the stages of recovery and use of the stockpiled gypsum, there were positive benefits in all aspects of the operation. Environmental and economic benefits were higher during the stages of using the recovered gypsum. The results are graphically represented in Figure 4-5.

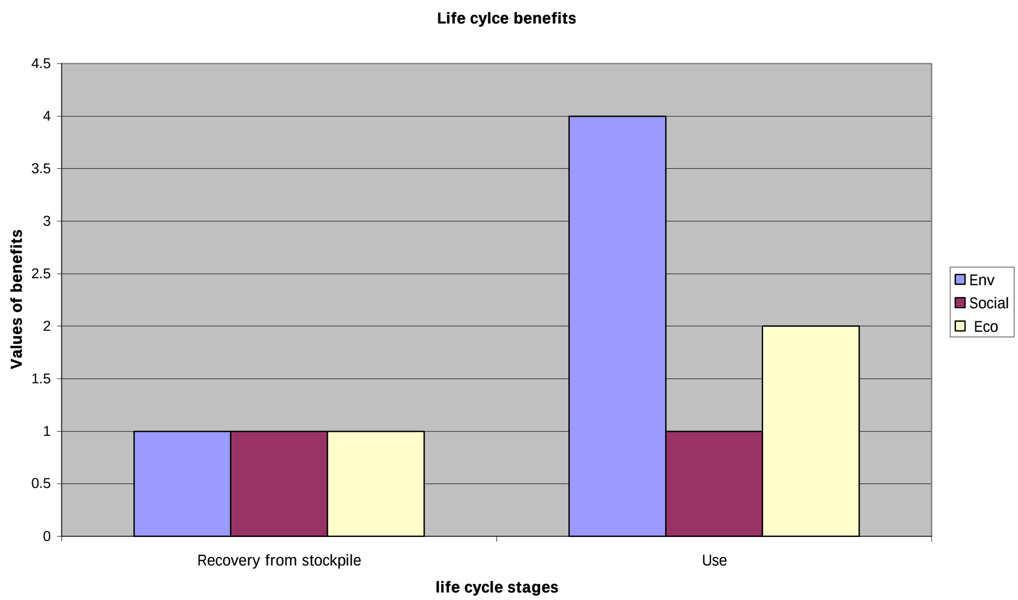

Figure 4-6: Results of life cycle stages of gypsum reuse

4.6 Summary

The application of industrial symbiosis provides businesses with the opportunity to contribute to sustainable development at the local level, by reducing net wastes and emissions, virgin material input, water and energy, by reducing operating costs and liabilities, and by providing jobs and community amenity value. Even though a considerable number of examples exist globally, the review of the literature undertaken in this study has highlighted that the overall potential of industrial symbiosis has not yet being fully realised.

One of the problems encountered was the difficulty in quantifying and allocating economic, social and environmental benefits for participating companies and affected communities, as well as industry and the community at large.

This chapter reported on the scoping outcomes of research into the development and evaluation of a TBL framework, including social impact methods for industrial symbiosis, with particular reference to heavy industrial areas. A project lifecycle approach was illustrated in a qualitative framework describing three existing synergy projects in the Kwinana Industrial Area. These included a wastewater reclamation project to reclaim tertiary-treated wastewater into superior grade industrial process water. This project would help defer treated industrial effluent discharge from an ecologically sensitive coastal zone to open ocean. In addition, a cogeneration facility, in which excess refinery fuel gas and natural gas for efficient and reliable generation of steam and electricity, was utilised. Finally, the recovery of stockpiled waste gypsum for construction and rehabilitation of bauxite residue storage areas was also achieved.

These preliminary results provide testimony tor the overall net economic, social and environmental benefits of the projects, over and above the sound project economics that were promoted as the principle reasons for their implementation. Further development of methods and quantification is necessary, and may prove to be the most useful in cases where straight financial project evaluation does not provide compelling evidence for project implementation.

The next chapter summarises the finding from the examination of eco-industrial parks after analysing various issues collected from the questionnaires, interviews, and forms the academic literature. It also provides a framework for further research.

CHAPTER FIVE

ANALYSIS OF ECO-INDUSTRIAL PARKS

5.1 Introduction

This chapter provides the key findings from a study of eco-industrial parks, both nationally and internationally. A large number of eco-industrial parks (EIP), with principles of industrial ecology and practice of industrial symbiosis in industrial areas around the world, were examined by this study. The review identified that some of these industrial areas have originated as either "self-organized" or "partly/ fully planned" in order to bring goals of sustainable development (Chertow 2007; Desrochers 2002; Ehrenfeld & Gertler 1997; Gertler 1995).

Since the research focused on a method for capturing environmental, social and economic implications of IS in operational industrial areas, existing approaches in evaluating environmental, social and economic implications of IS in these industrial areas was first carried out. The practical aspects of the success on EIPs was also examined and explained as a result of the review. The identified benefits in these areas show that there are possibilities to achieve local/regional sustainability through practice of IS in an industrial system if these areas also address the social issues and try to identify the benefits of a social focus.

The research identified that quantified implications of industrial symbiosis in terms of the triple bottom line benefits (environmental, social and economic) were limited. Most cases evaluated either the economic and environmental benefits or economic benefits alone. According to Chertow (2005), some cases reported economic savings by determining the extent to which companies cycling by-products can capture revenue streams or avoid disposal costs; those businesses receiving by-products avoid transportation costs. Environmental benefits have been identified by measuring changes in consumption of natural resources and in emission to air and water through increased cycling of materials and energy. These savings are calculated either for aggregate of total network of companies practicing industrial symbiosis, for individual companies, or even for individual trades.

5.2 Benefits of Eco-industrial Development

From the literature review, it became clear that the studies that recorded social implications of industrial symbiosis were very few, even though there were acknowledgements that there were intangible social benefits. It is important to view what factors impact the environmental, social and economic gains before trying to assess and measure them. Research carried out at Cornell University (USA) identified some potential benefits of adopting eco-industrial development across communities, environment and business as shown in Table 5-1 (Deppe & Schlarb 2001).

Table 5-1: Potential benefits of Eco-Industrial Development
Source:(Deppe & Schlarb 2001, p.9)

Communities	**Environment**	**Business**
1. Expanded local business opportunities 2. Improved tax base 3. Community pride 4. Reduced waste disposal cost 5. Improved environment and habitat 6. Recruitment of higher quality companies 7. Improved health for employees and community 8. Partnership with business 9. Minimised impact on infrastructure 10. Enhanced quality of life near Eco-industrial park 11. Improved aesthetics 12. Good jobs	1. Continuous environmental improvement 2. Reduced pollution 3.Innovative environment solutions 4. Increased protection of natural ecosystems 5. More efficient use of natural resources 6. Protection and preservation of natural habitat	1. Higher profitability 2. Enhanced market image 3. Higher performance workplaces 4. Improved efficiency 5. Access to financing 6. Regulatory flexibility 7. Higher value for developers 8. Reduction of operating costs(i.e. energy, materials) 9. Reduction in disposal costs 10. Income from sale of by-products 11. Reduction of environmental liability 12. Improved public image 13. Increased employee productivity

This research undertaken highlights the social, environmental and economic benefits for community, environment and business when analysing the potential advantages of eco-industrial development. The benefits of eco-industrial development, as shown in Table 5-1, consist of both quantifiable and intangible aspects. For example, the intangible benefits include the elements such as the enhanced quality of life near the eco-industrial park, the improved aesthetics of the location, and community pride. From the business perspective, it can also be seen from this table that there are many potential intangible rewards of IS, such as enhanced market image, regulatory flexibility, improved public image and increased employee productivity. In conclusion, in addition to measurable environmental and economic benefits, IS leads to a number of important intangible benefits in the three dimensions of sustainability.

5.3 Evaluation of Existing Methodologies

During the detailed review of eco-industrial parks, it was revealed that even though there were claims of benefits due to IS practices, there was an absence of a standard methodology used to evaluate and estimate the benefits.

As explained in Chapter 3, during the second stage of analysis of data of eco-industrial parks from North America, Europe, Asia and Australia were reviewed to identify any evaluative methodologies used by them. Five cases were derived from North America: Brownsville (Texas), Guayama (Puerto Rico), North Carolina, Sarnia Lambton (Ontario), and Tampico, (Mexico). Six cases from Europe were identified: Humberside (U.K.); Kalundborg (Denmark); Moerdijk, (The Netherlands); Rotterdam, (The Netherlands); Satakunta, (Finand); and Styria, (Austria). Selected cases from Asia included the Naroda Industrial Estate, (India) and the Waste Exchange Information Centre, (Taiwan). In addition, two national cases, Kwinana and Gladstone in Australia, were also selected for this study. As explained in Chapter three, difficulties in getting the latest information from all these areas meant that the researcher had to select and analyse four best practice international areas and two national areas. An explanation of the analysis of the four international cases from Europe and the two national cases from Australia is now provided in more detail.

5.3.1 Humberside, UK

Located on the East Coast of England, The Humber Estuary is home to many industrial operations located to the north and south of the Humber River. Major industries in this area include organic and inorganic chemicals, food processing, iron, steel and other metal processing, plus oil refining.

Initiatives of an industrial symbiosis program in this region originated from an oil and gas company having major operations in the same area, with the knowledge and awareness gained through participating in industrial symbiosis programs in Tampico, in the Gulf of Mexico, which was overseen by the Business Council for Sustainable Development, Gulf of Mexico (BCSD-GM) (Mirata 2004).

The oil and gas company initially sought the support of BCSD and subsequently BCSD formed a UK initiative for developing a Combined Heat and Power Plant (CHP) of 475-650 MW and a chemical feed stock pipeline (Humber Bundle) to cross under the Humber River to connect the industries from the north and south banks in order to avoid the hazardous transport of chemical by-products.

Preliminary evaluation of these projects commissioned by Humber Chemical Focus identified the potential benefits of reduction of the emissions of carbon dioxide (3.3Mt per annum), sulphur dioxide (48 kt per annum) and nitrous oxides (11 kt per annum). It was also realised that the Humber bundle could also remove 750,000 tonnes per annum of hazardous cargo from surface transport. It was found that substantial energy cost savings could considerably increase productivity output by 800 M pound per year and employment of 2400 positions due to potential new projects while taking advantage of the Humber bundle in addition to the competitively priced energy from the CHP (Mirata 2004, p.973).

Even though the initiative started around 2000 with an awareness workshop and an invitation to around approximately 70 companies, this project development has been slow. A project advisory group (PAG) was formed with participation of members from BCSD-UK, members from around 20 companies, local authorities and an industry association. After one and a half years of inactivity due to loss of funding, the initiative picked up momentum in 2003, with funding and support from the regional development agency (RDA), Yorkshire Forward.

The Humber industrial symbiosis program (HISP) catalysed interest in several other regions in U.K., initially in West Midland and Mersey Bank. This program served as the platform to launch the National Industrial Symbiosis Program (NISP) in 2003. In early 2005, NISP was granted £13 million funding from the Government's Business Resource Efficiency and Waste (BREW) programme. Since then a number of programmes have been initiated with a large number of companies in the U.K, are participating for example, Anglican Water Services, UK Coal Mining Ltd, and Conoco Phillips,

A number of synergies have already been implemented in Humberside, and the CHP plant had been built as a result of the incentive that the plant was exempt from the Climate Change Levy. The HISP program secured or saved 87 jobs, and avoided land fill of materials of 183,000 tonnes per annum. It also helped to identify potential economic benefits of £800 million per annum to the region, with an additional potential 960 direct and 1,440 indirect jobs (Mirata 2004, p.973).

It was interesting to note that while the initiative had support from the local authorities and consultants, leadership from the industries involved was missing during the initial stages. Once this leadership was provided to industries, and a regional branch of the multi-national company was obtained as project champion, the importance of "diversity" was accepted as a crucial point and the initiative became more fruitful (Mirata 2004 p. 974).

During the interview concluded with the facilitators of this program, it was determined that membership is free for businesses and, as a result, businesses are interested in utilising the opportunities created by facilitators by bringing environmental agencies and governments on board. Facilitators from NISP pursue IS as a business opportunity. Therefore, the issue of running IS business opportunities as “core business” has not surfaced in this program. This program also has not been faced with the issue of “sensitive information sharing”, since the facilitators only target information that is needed for creating potential business opportunities. An important initiative to reuse wastewater of 3 million cubic meters after proper treatment in order to save scheme water from industrial purposes in the Humber Bank is a potential project in this area (Interview respondents, 2005, 8 June).

A crucial learning from the NISP program is the importance of support from government and environmental agencies. Environmental agencies often recommend the NISP program as a ‘best practice’ example to other companies that need assistance (interview respondent, 2005, 8 June). The support from the municipal council was also evident as office facilities and staff were provided by them for NISP to run this program. They also received support from government, as this program was successful in many regions of U.K. Since NISP was subsequently successfully introduced in three regions, such as York, Humberside and North Lincolnshire, with these regions receiving funding of over £1 million from the European Union. Nationally, NISP has received Business Resource Efficiency and Waste (BREW) funding of £13 m through the UK government for the 3 years starting from April 2005. The BREW program is part of a £284 m initiative to help businesses manage resources more efficiently and cut waste. The program recycles revenue generated through increases in landfill tax to fund a range of free services and has targeted support for businesses and specifically targets waste minimization, the diversion of waste from landfill and improvements to resource efficiency.

5.3.2 Kalundborg, Denmark

The town of Kalundborg is situated 70 miles (112km) from the city of Copenhagen. It consists of five municipalities, with a population of approximately 20,000. There are five major processing industries and a waste processing facility located within a 130 square kilometre area. Research undertaken confirmed that these companies were established in Kalundborg due to its attractive deep-water harbour and other professional and geographical attractions. The Danish Government offered a number of incentives for industries to move to this area as part of a Government strategy to locate industries away from the city of Copenhagen (interview respondents, 2005, 16 June).

The Kalundborg industrial area is the most frequently published 'best practice' example of the practice of industrial symbiosis. The history of Kalundborg symbiosis activities began in 1961. A project was developed and implemented to use surface water from Lake Tisso for a new oil refinery that was established in 1959. This was due to a scarcity of ground water and is usually explained as the first example of symbiosis. The collaboration of the city council of Kalundborg was evident from its involvement in building pipelines for this project with financial support from the refinery.

The exchange of by-products between companies commenced later, when the plaster board company Gyproc started to use fuel gas from the oil refinery in 1972 (Gertler 1995). After a decade and a half, the companies concluded that they had effectively "self-organised" into what is probably now the best-known example of a working industrial ecosystem, utilising symbiosis. The relationship developed by the power station with a plaster board manufacturing company in Kalundborg is worth exploring. When the power station chose to use scrubber technology to reduce sulphur emission from its plant, the resultant product of chemical gypsum helped the plaster board company to reduce its mining of natural gypsum. The plaster board company used the gypsum from the power plant as the by-product of the adoption of the scrubber technology. This resulted not only in cost savings but also a reduction in environmental emissions for both partners (Ehrenfeld & Gertler 1997; Lowe 1997).

The Symbiosis Institute of Kalundborg started to facilitate coordination of industries on behalf of the Industries Council in 1995. According to this Institute, the principles and features of industrial symbiosis in Kalundborg are cooperation and communication. The main benefits achieved through this regional network are conservation of natural and financial resources, reduction in cost of production, material, energy, insurance, treatment and liabilities. The Institute also suggest that improvement in operating efficiency and quality control were achieved as well as improvement in the health of the local population. Besides achieving enhanced public image, additional income through the sale of by-products and waste materials was also achieved (interview respondents, 2005, 16 June).

Results of a detailed academic study of exchanges of by-products in Kalundborg identified that though quantitative aspects do explain the immediate logic of the selected high-value industrial symbiosis (IS) exchanges, there are other perspectives which should be considered for a full explanation of why low value exchanges are even further pursued (Brings-Jacobsen 2005). A quantitative assessment was undertaken in this study to calculate the economic and environmental perspectives of some of IS projects in Kalundborg. This assessment has evaluated operational arrangements of water and steam related exchanges and has shown that both substantial and minor environmental benefits accrue through IS. According to Jacobsen (2005), the assessment showed that motivation from the companies for the exchange was not directly linked to the value of by-product or waste, but was mainly due to upstream or downstream operational performance. Jacobsen further explained the reason for implementing IS and it became clear that, even though quantitative analysis of wastewater exchanges between the power plant and the refinery showed minor benefits and higher risks, companies were ready to participate in the IS exchanges. His analysis concluded that human intervention by individual agencies and also social factors may have been the driving forces behind these projects.

The exchanges in Kalundborg are between five industries, the municipality and a waste management facility. Currently, there are 21 projects that include the by-product exchanges from this industrial system according to the senior consultant (interview respondent, 2005, June 16). Collaboration between major industries resulted in a project to produce bio-ethanol from sugar beet waste, with funding from US Government and partnering with an oil refinery also producing a further opportunity to enhance symbiosis in Kalundborg. However, success of this project depended on a change in Government policy.

5.3.3 Moerdijk, the Netherlands

Moerdijk is an industrial area situated near the Hollands Diep in the Southern part of the Netherlands and close to one of the main waterways in the Netherlands. This industrial area was established around 35 years ago, when the Shell Oil Company based in Rotterdam faced space constraints. Shell planned to shift some of its operations from Rotterdam to Moerdijk with help from the Dutch Government to organise the present land as the industrial area. Further development of industries was established in this brown field area by 1995 and it has grown to include some 400 companies today. However, the concept of industrial ecology in this site commenced later in 1998, with the help of multi stakeholders including Government bodies such as local and regional councils, environmental agencies, as well as an Industries Council. The Port Authority manages this area on behalf of the Industries Council. Projects developed in this area are working mainly under the principles of collaboration and cooperation in order to maximise benefits of by-product exchanges between them. The Port of Moerdijk facilitates the coordination of exchanges, with participation from the Industries Council and provincial and municipal agencies, plus water authorities.

A partnership managing the utilisation of waste includes NV Afvalverbranding Zuid-Nederland (AZN) a municipal solid waste incinerator company with capacity of 636,000 tonnes pa which was commissioned in 1997. Other partners include Essent, a supplier of electricity, gas, and heat to private businesses, Omya, a market leader in Europe as a producer of high quality lime products such as whitening agents for the paper industry, Shell, which focuses on bulk production of petrochemicals and delivery, and Sliberverwerking Nood-Brabant (SNB), the largest sludge processing company in the Netherlands established more than ten years ago. SNB processes around 400,000 tonnes of sludge cake a year. It was discharging flue gas to the atmosphere after treating it to a satisfactory level, until finding a partner Omya to utilise the by-product. SNB's exchange of CO_2 to Omya mutually benefits each other since Omya was searching for a CO_2 supplier to further expand its production process (Sliberverwerking Nood-Brabant (SNB) 2004). AZN, Shell and Essent are also in a symbiotic relationship in the utilisation of steam and electricity (interview respondents, 2005, 23 June).

5.3.4 Rotterdam, the Netherlands

The Port of Rotterdam has a very important role in the generation of income regionally and nationally, as it earns almost 7% of the national income and one quarter of the regional income. It is expected that both the direct and indirect benefit of IS will increase by several percent a year until 2020, particularly as a result of the expansion of the transport and distribution sector and the chemical and supplier industries. Therefore, the integration and collaboration of industries would bring more opportunities to reduce the associated environmental impact and improve the social and economic status of the community and industries.

Initiatives in the Rotterdam industrial area in integrating industries such as the Industrial Eco System project (INES) were funded by programs from the federal government, provincial government and the municipality, and operated with the help of consultants in order to collect input and output data and facilitate industrial symbiosis. Recently, it was realised that the projects to restructure the area to improve its performance for the future needed a different approach due to lack of ongoing funding support from government. Also it was realised that that park management was very important in associating companies and commercial management of areas, as a result of its nature as a brown field (already established) industrial area. This becomes essential for reasons of safety, industrial area routing through the park, shared parking places and transport arrangement for goods, all of which are related to the size, location and structure of companies organised in this area (interview respondents, 2005, 22 June).

5.3.5 Gladstone, Australia

Gladstone, situated on the central Queensland coast about 540 kilometres north of Brisbane, has a population of about 40,000 in the region which extends from Boyne Island in the south to Yarwun in the north. The Gladstone area has been strategically earmarked by the Queensland State Government for significant future industrial development by large industry. The Gladstone State Development Area is a 14,000 ha land bank that has been specifically reserved for large-scale resource processing, metals smelting and downstream manufacturing industries.

Major industrial operations have been part of the Gladstone region since Queensland Alumina Limited commenced its operation in 1967. Other industries located within the region include a major power station, cement manufacturing, aluminium smelters, plus chemical manufacturing and large port facilities and utilities providers. There are nine major industries operating in the region that form an association called the Gladstone Area Industry Network (GAIN), which also collaborates with the Gladstone City Council.

The latest developments in Gladstone Industrial Area (GIA) can be demonstrated by a research project on “developing local synergies in the Gladstone Industrial Area” by the Centre for Social Responsibility in Mining in the University of Queensland. Under the auspices and financial support of Centre for Sustainable Resource Processing, this study was conducted in GIA to find opportunities for further development of symbiosis (Corder 2005). This project is planned to identify the opportunities for the re-use or recycling of waste and by-products from one industry to another industry within the Gladstone region.

5.3.6 Kwinana, Australia

The Kwinana Industrial Area (KIA) is located south of Perth in Western Australia and was established in 1952 to cater for the construction of an oil refinery on the shores of the Cockburn Sound. Western Australia is the largest and most sparsely populated state in Australia. The State has rich natural resource endowments, including - but not limited to - iron ore, bauxite, gold, nickel, mineral sands, natural gas, oil and coal. Agriculture, mining and processing and manufacturing all provide employment, development opportunities and wealth. Heavy process industry is concentrated in a few industrial areas, of which Kwinana is by far the largest and most diverse.

KIA's many features make it a world-class industrial area. Its deep-water port is capable of handling bulk cargo. Kwinana is linked via road and rail to the Fremantle container port and the eastern states of Australia. Kwinana is strategically placed for export markets, having direct shipping access to South East Asia. About 3,600 people work in the area's core industries, and many more in related sectors and service jobs. The total economic output of the area exceeds A$4.3 billion annually (SKM 2002). With its concentration of industries and close proximity to the coast, the Kwinana Industrial Area plays a very important role in the economy of Western Australia, and in the local community. KIA has long been recognised as a cornerstone of the Western Australia's economy.

In 1991, the core industries in the area established the Kwinana Industries Council (KIC), whose original purpose was to organise the required air and water monitoring collectively for the industries in the area. This was mainly in response to increased government and community pressure to manage industrial hazards and air- and watersheds, and to protect the sensitive marine environment in the adjacent Cockburn Sound. The Council now addresses a broad range of issues common to Kwinana's major industries, and seeks to foster positive interactions between member companies and between industry and the broader community. Thirteen major industries are currently full members of the Council, and twenty-three other industries (predominantly medium sized operations and service providers) are associate members.

The activities carried out by the peak industry organisation to promote awareness and implementation of regional synergies in the area includes the convening of the KIC Eco-Efficiency Committee (EEC), which is the industry working group which regularly meets once a month to discuss opportunities of exchanging energy, water, by-products and waste streams. Also taking part is the Communities and Industries Forum (CIF), a multi stakeholder forum that meets bimonthly. There are also other committees, such as the Environmental Planning Committee, the Public Safety Committee and the Health Committee under this Council to oversee issues and find remedies in these areas as well.

The Kwinana Industries Council attempted to capture industry's contribution to sustainable development in its economic impact study. The first effort was undertaken in 1990 and found 27 exchanges between 13 companies. This study was updated in 2002 and it found 104 existing exchanges between the core industries, and a potential for another 106 exchanges. Both these studies included by-product, utility and supply synergies in this area. The SKM report selected three main criteria for analysing the social aspects of the impact of industrial areas. These include, direct and indirect employment provided by industries to neighbourhood and wider community, services, plus social initiatives provided by industries and industry attempts to understand and positively respond to significant local community issues. Although this study captured benefits which were impressive, at least one of the principal contributions was not captured. This was the pooling of expertise among companies, between companies, local government and the community as well as those of shared laboratory facilities, OH&S procedures and expertise, and eco-efficiency practices. Also not captured were intangible social benefits resulting from company staff committing their time and money to community initiatives, such as programs and educational partnerships with Kwinana high schools to increase the retention rates of students (Altham & van Berkel 2004).

In 2002, the Kwinana Industries Council (KIC) established the Kwinana Industries Synergies Project, which was designed to improve the economic, social and environmental outcomes of industry (Taylor 2002) by working co-operatively together. This was in order to convert wastes into useable products, reduce the generation of wastes, reduce greenhouse gases by improved energy efficiencies, reduce the use of fresh water, increase the reuse of treated wastewater, and reduce the wastewater discharges into Cockburn Sound. This was discussed in detail in the previous chapter.

According to the study by Sinclair Knight Merz (2007) for 81% of the industries in Kwinana, sustainability is a real concept and only 24% out of this is limited to a business sense. More than half of industries approach sustainability by initiating organizational and management change and by incorporating sustainability assessment into decision making process. For several companies, the responsibility for sustainability extends to board members and the CEOs for several companies. It has been understood that 24% of the industries will integrate sustainability principles into their processes in the future and more than 60% will make improvements in their approach to sustainability.

5.4 Analysis

Current case studies of IS in six eco-industrial parks, conclude that intangible benefits, particularly the social benefits, of IS have not been assessed in detail in contrast to quantifiable economic and environmental benefits. Measuring intangible benefits could be a difficult task, which requires a different approach in methodology. The intangible benefits include not only social, but also environmental and economic aspects. Table 5-2 shows the demographic details of the areas investigated.

Table 5-2: Demographic details of Eco-industrial Parks

EIPs	Area (sq km)	Population (*1000)	Major industries	Year of establishment of industrial	Year of initiative of IS
Kalundborg, Denmark	130	20	5 major industries such as power station, pharmaceutical, oil refinery, waste recycle company, plasterboard manufacturing	1959	1962
Rotterdam, The Netherlands	100	590	Oil refineries, chemicals, petrochemicals, steel manufacturing, agri-business	1960	1992
Moerdijk, The Netherlands	26	36,8	Oil refinery, plaster board, organic waste recycling, sludge incinerator, energy supplier, transporting companies	1970	1998
Humberside, United Kingdom	15,400	5,000	Organic and inorganic chemicals, oil and gas refineries, power station, agriculture, food processing, iron and steel	1960	2001
Gladstone, Australia	210	50	Chemicals, refineries, smelters, power station	1967	2001
Kwinana, Australia	120	20	Power stations, oil refinery, metal refineries, manufacturing, chemicals and fertilisers, cement, iron and steel manufacturing, Cogeneration plants	1950	1986

5.5 Key Features Influencing Success of Eco-Industrial Parks

Detailed analysis of EIPs from Europe and Australia have proved certain key points that portray these industrial areas as the best practice cases in terms of industrial symbiosis. The review of these international cases confirmed the theoretical concepts identified in the literature about the success of IS projects. It was identified that connection, (Boons 2004; Rosenthal 2000) communication (Wilderer 2002) and collaboration (Chertow 2000) between industries were important in enhancing industrial symbiosis. In addition, it was found that the roles of different stakeholders in establishing connection, communication and collaboration were crucial for the success of symbiosis projects. For example, the active role of local municipal councils, environmental agencies and port authorities was noted in many of the areas studied. In addition, the role of regulatory and policy makers of regional and national government bodies were evident in many of the areas selected. This section will describe stakeholders and their role in implementing IS as derived from the analysis undertaken.

It was understood from the analysis of projects that the role of local, regional and government bodies such as councils, regulatory bodies and policy makers were instrumental in the success of the IS projects in Rotterdam, The Netherlands; Moerdijk, The Netherlands; Humberside, United Kingdom; Gladstone and Kwinana in Australia. Government bodies act as policy developers and regulatory bodies and, in both; the roles they play are a crucial part in enhancing industrial symbiosis. For example, , the regulatory framework of the Danish government was instrumental in encouraging the evolution of industrial symbiosis in Kalundborg according to the manager of the company interviewed in Kalundborg. This was reinforced by the evidence presented by Ehrenfeld and Gertler (1997)

Local and regional government bodies also have a prominent role in bringing more benefits to industry and community through industrial symbiosis. The funding program and support through regional development agencies (RDA) were the motivation to further enhance symbiosis programs in the Humber and Yorkshire region. In Gladstone, Australia, the Sustainable Gladstone study was initiated with the help of the Environmental Protection Agencies and the Federal Australian Greenhouse Office. In the case of Kwinana, the Western Australian Government’s water strategy target of achieving 20 per cent re-use state-wide by 2012 was a catalyst to enable the wastewater reclamation project (KWRP) to increase the reuse potential of wastewater. This project helped conserve scheme water use, as well as reduce wastewater discharges to the sensitive marine environment near Kwinana. This was discussed in more detail in the previous chapter.

It was identified that the Municipality as a local actor was important in initiating industrial symbiosis. This point was confirmed by others researchers. For example, Burstrom and Korhonen identified the role of Municipality in initiating, coordinating the development of eco-industrial parks and in accelerating industrial symbiosis in Kalundborg as their role as technical body during the beginning of industrial symbiosis (Burstrom & Korhonen 2001). The Municipality of Rotterdam and the Port Authority are working together at present to contribute to sustainability through the Havenplan-2020 which demonstrates the important role of Municipalities.

The active role of industries, such as Industries Council bodies and its members, in implementing IS were obvious in most of the case studies. For example, the INES project in Rotterdam was defined and designed as an industrial ecology project by Deltalinqs, an Industries Council (Baas & Boons 2004). The role of the Industries Council was recognised as instrumental in furthering the enhancement of industrial symbiosis in other areas. The initiation of an 'economic impact study', 'the Kwinana industries synergies project', 'the enabling mechanisms for improving IS' are some of the initiatives of the Kwinana Industries Council. In Kalundborg, the Industries Symbiosis Institute acts on behalf of the Industries Council in initiating further symbiosis. The Port Authority of Moerdijk also acts on behalf of the Industries Council in Moerdijk from 1998. In Gladstone, the Gladstone Area Industry Network (GAIN) was formed by the nine members of the industries present in the region, and its role is also to improve the initiation of symbiosis.

The role of communities in improving IS was also identified from this study. As identified from the case studies that, this was influenced by certain factors, such as the number of population, the location and size of the area and the diverse industries located in an industrial area. For example, the small population of community (20,000) and small number of industries in a small area such as in Kalundborg (Table 5-2) has influenced positively the enhancement of industrial symbiosis in many ways. It was also confirmed by the Symbiosis Institute that the “short” mental distance made the informal connections necessary for developing trust between the industrial community as well as the local community. Even though Kwinana is located relatively closer to the city with a large number of industries the active presence of community organisations in the Communities Industries Forum, a multi stakeholder program initiated by Kwinana Industries Council, ensures that concerns of community organisations are heard and responsible actions are taken by the industry. On the contrary, Gladstone, a relatively large industrial area away from the city with small number of industries and double the population compared to Kwinana, may have contributed to the comparatively slow contributions to symbiosis by communities and governments.

From the literature, it was clear that connection, communication and collaboration (3C), was important to bring internal and external partners together to successfully implement industrial symbiosis projects in the various cases. A framework developed on the basis of these processes from the case studies also shows the connection between levels of social capital needed between different partners to reach outcomes, such as sustainability in every aspect. The review also identified that such symbiosis is much more than by-product exchanges between industries co-located or geographically close to each other. It was identified that it is the result of the developed relationship between the partners of different industries involved, and also with communities and governments closer to industrial area, which enables the trust that is essential to allow the sharing of information to occur. These include both risks and benefits equally, thus reducing the barriers such as lack of sharing information, plus risks and benefits due to commercial confidentiality. As a result of this process, outcomes such as ‘license to operate’, ‘market opportunities’, ‘innovation’ and ‘reputation’, emerge as intangible benefits, in addition to more tangible environmental and economic outcomes. This can be achieved through development of social capital between industries, between industries, communities and government. These features are shown in Table 5-3.

Table 5-3: Industrial areas and its success factors

Eco-industrial parks	Evidence of support from stakeholders	Presence of 3C	Reported benefits
Kalundborg, Denmark	Industry, municipality and Government	Collaboration and communication	Environmental and economic
Rotterdam, The Netherlands	Industry, local and regional Government,	Collaboration, communication	Environmental and economic
Moerdijk, The Netherlands	Industry, and Government	Collaboration and co-operation	Environmental and Economic
Humberside, UK(Mirata 2004)	Consultants as facilitators, Councils, regional government	Collaboration	Environmental , social and economic
Kwinana, Australia	Industry, government as policy formulators, community	Connection, communication, collaboration	Environmental, social and economic
Gladstone, Australia	Industry, Community and Government	Connection	Environmental, social and economic

This thesis suggests that industrial symbiosis can therefore be defined as the process of connection, communication and collaboration between industries, communities and government, leading to successful exchange of raw material, energy, water and by-products between two or more participants so as to bring environmental, social and economic benefits collectively, to attain mutual benefits. This chapter argues that industrial symbiosis can be one way of leading to more sustainable development in industrial areas by contributing to sustainability goals by industry, community and government through economic opportunity, environmental restoration and social justice.

As has been argued previously, this review of literature has highlighted the lack of a standard integrated methodology that can be used to measure outcomes of industrial symbiosis. Economic and environmental net benefits are often calculated using quantitative engineering calculations and by the aggregation of costs and benefits in the case of projects such as Kalundborg (Brings-Jacobsen 2005). Even though there were observations of social benefits as intangibles in these cases, there was a limited attempt to measure it (Chertow & Lombardi 2005). This was mainly due to many reasons, often related to explain as the unsuccessful attempts to measure the social dimension of IS.

Since most of the industries in Kwinana consider sustainability as a real concept and the objective of a large number of industries is to enable industrial integration (Sinclair Knight Merz 2007), measuring sustainability should be done in terms of environmental, social and economic dimensions in order to understand the real costs and benefits, including any externalities. The research undertaken in this study identified the gaps in estimating environmental, social and economic implications. Therefore, an integrative methodology assessing the net benefits of industrial symbiosis applications in an industrial area needs to be an approach that can take the issue of sustainability to enable a deeper analysis.

5.6 Summary

After an extensive literature review of the selected industrial areas, this chapter concludes that there is no point in further comparing the quantity of implications/benefits, since all these areas started at different times, have different objectives, and were set up according to different conditions of land tenure. It is no longer possible to compare quantification of benefits due to the passage of time, but it could be useful to identify tangible and intangible implications individually.

As Erkman (1997) pointed out, the concept of industrial ecology is particularly valid when one analyses the key elements of industrial ecology and studies it according to the whole system concept with the definition of system boundaries outside the company, and the use of key technologies as a crucial component to achieve the transformation from an unsustainable industrial system to a sustainable one. According to Agarwal and Strachan, there has been a move in the progress of industrial ecology from material and energy flow aspects to human dimensions, strategic management and policy perspectives, which also play an important role in assisting in the realization, systematization and further development and management of such activities (Agarwal & Strachan 2006).

The study of eco-industrial parks in more detail revealed that by-product exchanges achieved through industrial symbiosis show environmental and economic benefits for the industries involved (Brings-Jacobsen 2005; Chertow & Lombardi 2005). However, environmental and economic benefits alone will not be sufficient for industrial actions to achieve sustainability, as it is clear from the literature on sustainability that social dimensions have an equally important role in achieving sustainability. Moreover, industries recognized the fact that in order to be competitive in the market, they have to put social sustainability on agenda in their strategic development. One of the barriers encountered by industries was the difficulty in identifying and allocating economic, social and environmental benefits in an integrated way for participating companies and affected communities, as well as industry and the community at large.

In Chapter four, an approach to better understand the environmental, social and economic implications of three industrial symbiosis projects has been described (Kurup, Altham & van Berkel 2005). This approach provided an opportunity to look at the sustainable implications of replacing industrial needs of water and energy by reclaiming treated wastewater and fuel gas, respectively. This approach has explored the entire life cycle of these projects by qualitatively assessing various implications through the analysis of secondary data collected from public records. It is concluded that the development of additional methods of quantification was necessary and would likely be more useful in cases where straight financial project evaluation does not provide compelling evidence for project implementation.
Since the KWRP project is an ideal candidate for assessing and measuring various outcomes achieved due to project and process success, The Six Capitals Model was applied in this case. This process was basically carried out by collecting information from key participants of this project, through questions prepared using selected indicators. This questionnaire 2 is provided in Appendix 2.

To conclude, this chapter has detailed the analysis of the eco-industrial parks that were studied. It also provided the key findings from the analysis. The next chapter provides the findings of the framework developed, based on the results of the analysis from this chapter. It analyses the social capital and its influence on enhancing industrial symbiosis and sustainability. The results of the application of this framework in the main case study area and the case project are also provided.

CHAPTER SIX

STAKEHOLDER PARTICIPATION IN EVALUATING THE SOCIAL BENEFITS OF INDUSTRIAL SYMBIOSIS

6.1 Introduction

This chapter aims to explain the identification of the framework of social capital link to IS on the basis of the results of the analysis of eco-industrial parks which was discussed in the previous chapter. It discusses the relationship between industrial symbiosis and social capital in a systems concept to analyse the sustainability of industrial symbiosis. A review of social capital literature has also highlighted here. A schematic framework of the importance of the relationship between various stakeholders to achieve social capital is explored. The relationship between industrial symbiosis and important processes, such as connection, communication and collaboration (3C approach), from the analysis of data (previous chapter) to improve IS are also explored in this framework. The chapter further explores this proposition by examining the influence of this framework within the context of an industrial area and a successful industrial symbiosis project, namely the Kwinana Wastewater Reclamation Plant (KWRP) in Kwinana. This chapter argues that when identifying the broader benefits of industrial symbiosis, the specific benefits of the process of industrial symbiosis should also be considered.

6.2 Stakeholder Participation

Participation creates opportunities for stakeholders to establish a sense of ownership in the project underway. This is an important aspect for achieving support for any development. This dialogue around a sense of ownership develops the trust essential for building social capital, a fact well recognised by governments in their demands for stakeholder contributions to environmental and social impact assessments. Providing appropriate and meaningful participation from a variety of stakeholders enables the achievement of many benefits, including quality information for planning and decision making, up-to date feed back about community perceptions and attitudes, and an early identification of potential issues (Cuthill 2003).

Stakeholder participation in sustainability issues has been recognised as the key to any future success, since there has been an appreciation of benefits due to the level of participation in decision making in projects before preparing documents for public comment. Stakeholder participation is understood as referring to participation by citizens impacted on by the change or issue, within a social arena by development projects. More recently, the concept of participation is now being related to rights of citizenship and to democratic governance, and there is a recognition that stakeholders and their interests provide on important information source for creating meaningful sustainability indicators (Azapagic 2004). Involving stakeholders who are relevant to a business is also an important way of getting a balanced awareness, since excluding one set of stakeholders can influence the outcome or create a barrier to achieving goals. One example is within the mining and resources sector, which has been addressing their sustainability challenges by paying more attention to the concerns of the various stakeholders. The project initiated as part of the Global Mining Initiative, named Mining, Minerals and Sustainable Development (MMSD) offers proof of this process (International Institute for Environment and Development 2002).

6.3 Accounting for Social Benefits

Research conducted at the International Centre for Corporate Social Responsibility reviewed key elements of the social accounting literature and identified that the greater focus was on enabling stakeholder voices as a contribution to the development of stakeholder accountability and democracy (O'Dwyer 2004). This research also pointed out the importance of considering the voice of non-managerial stakeholders, instead of placing the organisation as the centre of analysis, which is more usual.

The review of the literature on the importance of stakeholder participation has highlighted a number of projects that have been undertaken in order to account for the social dimension of sustainability in a sector-specific industry with stakeholder processes. For example, one project used stakeholder involvement to identify sector-specific key aspects of assessment of the social dimension for a biotechnology industry (Geibler et al. 2006). In this research, eight aspects were identified and further indicators have been developed. These aspects include health and safety, quality of working conditions, employment, education and training, knowledge management, innovation potential, product acceptance and social benefit. In addition, there have also been attempts to develop a calculation procedure based on Life Cycle Impact Assessment, the Social Impact Indicator (SII), for the measurement of social impacts of manufacturing industry in South Africa (Brent & Labuschagne 2005). However, the authors concluded that at present, with the limited amount of data available, a quantitative social impact assessment method could not be applied (Labuschagne & Brent 2006).

As the previous chapter outlined, despite identification of intangible social benefits of industrial symbiosis in industrial areas, there have been no detailed records of its measurement. This research identified that participation of stakeholders is a vital component in identifying the concerns and benefits in every life cycle stage of a project. This would prevent the failure after the conceptual stage of a project by being able to assess the net contributions in every stage.

6.4 Social Benefits and Social Capital

Over the past two decades, social capital has been understood as a concept that enables a more detailed appreciation of what can be considered as a ‘flight from community’. Evidence suggests that as individualism has strengthened, communality has declined. This has been demonstrated by evidence drawn from a decrease in volunteering, increased demands on governments for services, and a heightened lack of overall trust (Stone 2001). In Australia, the Federal Government implemented a Stronger Families and Stronger Communities Strategy in 2000, with the express aim of placing a greater focus on community building. The Stronger Families and Stronger Communities Strategy have adopted policies which encourage the building of partnerships within communities between individuals, businesses, industry and all levels of government. This has resulted in a draft report on Triple Bottom Line Reporting in Australia and a Guide to Reporting Against Social Indicators based on Global Reporting Initiative (GRI) structure (Department of Family and Community Services 2003). Within the Federal system in Australia, state governments have also recognised social capital as a component of sustainability, for example, in research investigating social capital in five New South Wales (NSW) communities (Onyx & Bullen 2000) and within the Western Australian Sustainability Strategy (Government of Western Australia 2003a).

A review of the literature on social capital identified a number of definitions which explain the necessity of norms, networks and trust in order to facilitate co-operation, or both co-operation and co-ordination, in attaining mutual benefits. For example, MacGillivray suggests that social capital is the stock of networks, stakeholder relationships and shared rules that help organizations and their surrounding communities work more effectively, and that action that can be termed ‘creative trust’ (MacGillivray 2004). MacGillivray’s definition of social capital has been used in this research from this point onwards to further analyse its link with social benefits. This link was identified in the literature as social capital being conceptualised as ‘creative trust’.

Table 6-1 contains the different definitions of social capital identified during review of literature for this research.

Table 6-1: Definition of social capital

(Derived from various sources which are provided in the table)

Authors of social capital	Definitions
Robert Putnam (1995) as cited in (Australian Bureau of Statistics 2002, p.4)	"features of social organization, such as networks, norms and trust that facilitate co-ordination and co-operation for mutual benefit"
WHO (1998) as cited in (Australian Bureau of Statistics 2002, p.4)	"the degree of social cohesion which exists in communities. It refers to the processes between people who establish networks, norms and social trust, and facilitate co-ordination and co-operation for mutual benefit".
OECD as cited in (Australian Bureau of Statistics 2002, p.4)	"networks, together with shared norms, values and understandings which facilitate cooperation within or among groups".
James Coleman (1988) as cited in (Australian Bureau of Statistics 2002, p.4)	"consisting of aspects of social structure, obligations and expectations, information channels, and a set of norms and effective sanctions that constrain and/ or encourage certain kind of behaviour".
MacGillivray (MacGillivray 2004, p.121)	"...the stock of networks, stakeholder relationships and shared rules that help organizations and their surrounding communities work more effectively".
Bourdieu, Putnam and Coleman as cited in (Stone 2001, p.4)	"...as a resource to collective action, the outcome of which concerns economic well-being, democracy at the nation state level, and the acquisition of human capital in the form of education respectively".

In order for social capital to be effective, bonding and bridging and linking between various stakeholders are important parameters. In the case of IS, bonding between employees, bridging between business and nearby communities and linking with government departments will not only reduce any uncertainties related to the social license to operate, and market image, but will also help to create and sustain innovative capacities, and the reputation of the companies involved. These can then be seen as the intangible assets which are the benefits of social capital development and can also be seen as the benefits of industrial symbiosis due to development of human and community capital. In a study in the U.K., the Department of Trade and Industry (DTI) recognised seven types of intangible assets. These include relationships, knowledge, leadership and communication, culture and values, reputation and trust, skills and competencies, and processes and systems.

MacGillivray also introduced a four-way matrix to measure social capital with creativity and trust as the two foci. Table 6-2 shows the indicators suggested for managing and measuring social capital. Figure 6-1 shows the social capital identified between employees, society and the company by MacGillivray.

Table 6-2: Indicators of measuring social capital
Source: (MacGillivray 2004, p.129)

Aspects	**Bonding**	**Bridging**
Creativity	*Innovation 'at work'* 1.Time spent on innovation/investments in R&D 2. Average years of service (Rookie index) 3. Number/ratio of project ideas accepted or rejected	*Brainwaves in 'the third place', among friends and strangers* 1. New products as percentage of total turnover 2. Staff serving on committees of local organisation 3. Percentage of staff who worked for competitors
Trust	*Building the brand through shared ethos, mission, morale, story-telling, gossip* 1. Length and quality of relationship with suppliers and clients, 2. Employee share ownership and retention rates, 3. Existence of independent enthusiast's clubs/ websites	*Marketing the brand by example and reputation* 1. Reputation/trust in company, 2. Brand value/reputation as place to work, 3. Level and scope of local community engagement

Figure 6-1 shows the social capital identified between employees, society and the company.

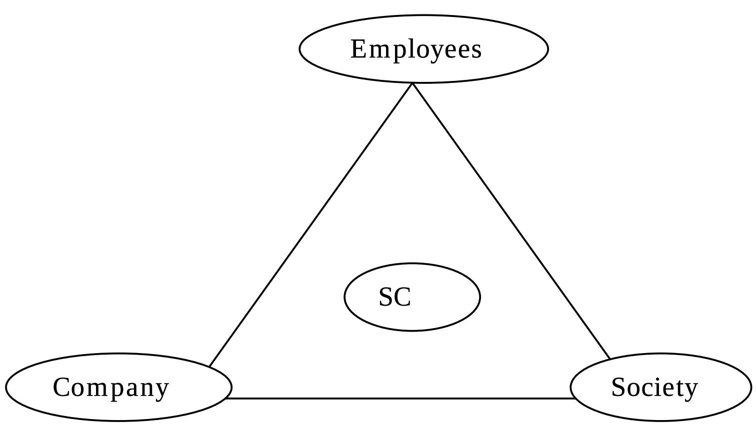

Figure 6-1: SC refers to social capital
Source: MacGillivray (MacGillivray 2004, p.122)

6.5 *Benefits of Social Capital*

According to MacGillivray (2004), social capital reduces the transaction costs associated with a business and can also encourage cooperative behaviour and trust. Social capital also allows the binding together of human capital essentials such as individual skills and intelligence of the work force with the organisation's collective memory and ability to innovate. Although building social capital does not remove uncertainty regarding information sharing, the process undertaken may create mutual knowledge about how it can be used in different situations. It has been recognised as being able to improve the quality of education in schools, which demonstrate lower drop-out rates in religious and tight knit communities (The World Bank 1997). It can also lead to lower youth unemployment and enhanced well-being in students (Australian Bureau of Statistics 2002). Building social capital can also have an effect on growth, equity and poverty alleviation through organised information sharing and co-ordination of activities. Bardhan (cited in (The World Bank 1997) suggests that collective decision making through peer monitoring can assist in building a common set of norms and local-level sanctions. Policy areas such as health and well being, families, community safety and crime are usually identified as crucial indicators of social capital strengths as well as education, employment and training, arts and culture, sport and recreation, housing and transport (Australian Bureau of Statistics 2002). A more detailed appreciation of the issues facing communities in relation to these indicators can be identified through stakeholder involvement and dialogue.

This review of the literature suggests that theoretically, there are benefits of industrial symbiosis that are related to the richness of social capital. For example, social capital helps business to benefit through innovation and created trust between the stakeholders. As discussed in the previous chapter, the social benefits of industrial symbiosis have not been recorded in the academic literature, even though this is one of the main components of sustainable development. One of the reasons for being able to measure social benefits in these cases may be due to the fact that social benefits continue to be perceived as spin-off benefits from environmental improvements and benefits. Another reason may be that quantifying social benefits is a challenge that requires further attention with an agreed definition of industrial symbiosis and appropriate indicators utilizing a different approach in methodology.

6.6 Framework Linking Industrial Symbiosis and Social Capital

In the case of the eco-industrial park in Kalundborg, Denmark, the self-organised nature of industries was created through the previously existing social networks and associated mutual trust (Eilering & Vermeulen 2004). In addition, it was identified that the symbiosis between top level managers and the employees was also important in improving industrial collaboration. Such active symbiosis can create an atmosphere to enable information sharing, coordination of activities and group-lending schemes (The World Bank 1997).

In essence therefore, industrial symbiosis provides an opportunity to create further social capital between various companies as well as between the companies and their various stakeholders. The key to industrial symbiosis according to Wilderer (2002) is communication and is collaboration according to Chertow (2000). The connection or linking between the project partners also contributes to the enhancement of industrial symbiosis practices (Cohen-Rosenthal 2000). It could be argued that the outcome of social capital, such as connection, communication and collaboration between industrial partners, has contributed to further enhancement of industrial symbiosis in Kalundborg. In addition, the involvement of local government agencies such as the local municipality can be seen as crucial to the success of the many industrial symbiosis projects in Kalundborg, since municipal council members acted as technical co-ordinators.

In the previous chapter, an analysis of various case studies of industrial parks demonstrated that industrial symbiosis enabled the development of a framework of industrial symbiosis. This framework demonstrated the importance of stakeholder's involvement and social capital in identifying and assessing sustainable outcomes through connection, communication and collaboration.

Figure 6-2 is developed from Figure 6-1 within the context of a system boundary of a heavy industrial area and its possible neighbourhoods and stakeholders. Here, the outer triangle shows the essential link between industries, communities, and government in the area, in order to have social capital developed between them. This figure is an illustration of the findings of these essential links. It doesn't necessarily mean that the stakeholders' roles are on the order they are represented in the figure or equally important. As an example, the project 'waste to energy' in Kwinana had failed to initiate partly due to community protest and partly due to lack of regulatory support from Government. The second triangle (which is shown with dashes and dots) shows the essential drivers of industrial symbiosis between the stakeholders. The third triangle defines the sustainability components of industrial symbiosis.

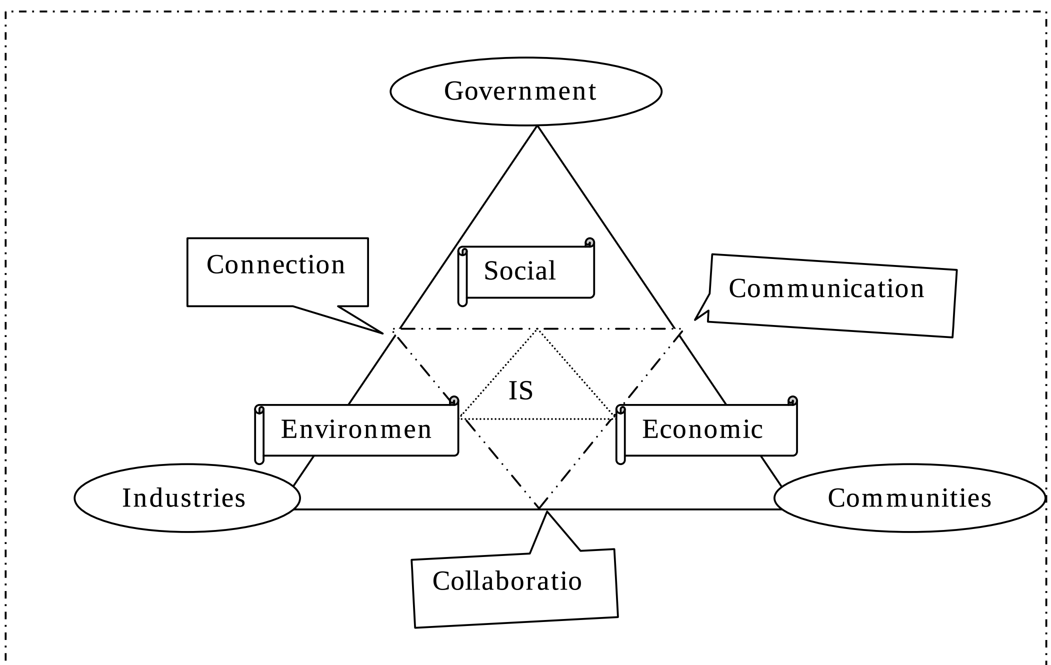

Figure 6-2: Framework of social capital applied in KIA

These findings were applied in the case study area to establish the interconnection between the stakeholders. This framework is now used to explore the link between social capital, industrial symbiosis and sustainable development with in the context of Kwinana Industrial Area (KIA) with the KWRP as a case study.

6.6.1 Kwinana Wastewater Reclamation Plant (KWRP)

In Chapter 4, the KWRP project was described in detail, with the life cycle implications in environmental, social and economic terms. The proposed model developed in Figure 6-2 demonstrates that industries, communities and government agencies have important roles to play in developing and implementing this project. This is further illustrated in Figure 6-3.

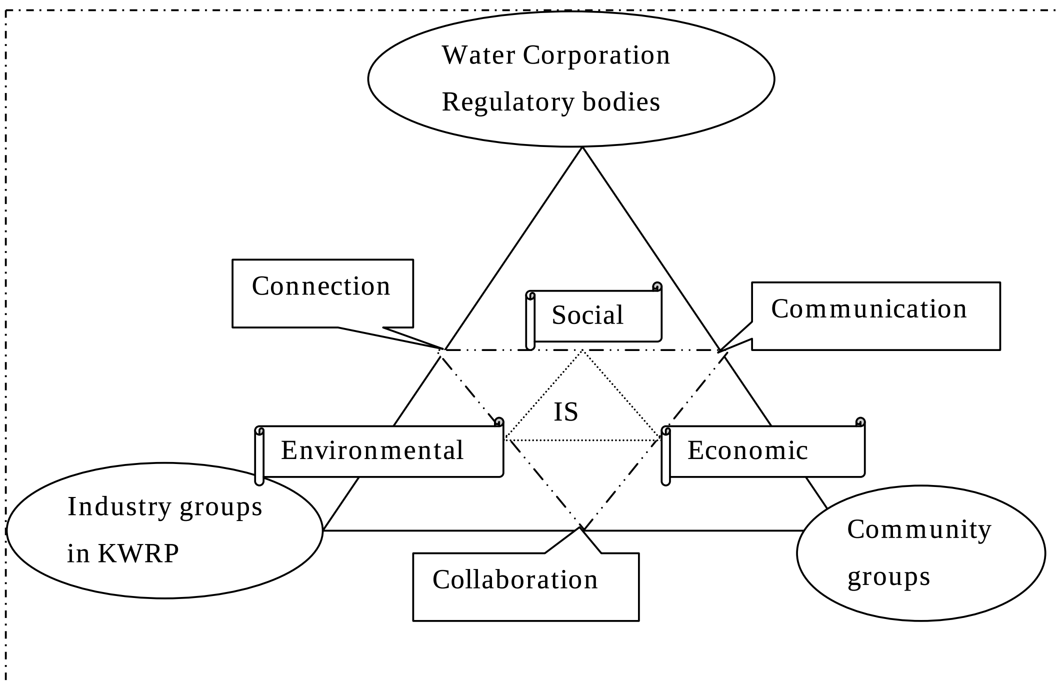

Figure 6-3: The proposed framework in KWRP's context

The KWRP project grew out of Water Link project, which started in 1998 with the initiative between industries, government and communities (Water Corporation of WA 2003). When examining within the framework developed, it can be understood that the 3C approach was evident as a success factor in this project. For example, community consultation was established in

December 2000 as the baseline communication aspect for industrial symbiosis. Collaboration between inter-firm industries was vital to the successful delivery of this project, as there are a number of industries participating in it. Communication and collaboration between various stakeholders made the connection necessary for the Water Link project to catalyse into a successful industrial symbiosis project, even after the planning and construction phases. It can be seen that identified parameters in Figure 6-3, such as connection, communication, and collaboration, were deemed to be important for this project from the very first life cycle stage.

6.7 Summary

This chapter detailed the importance of stakeholder participation in achieving social sustainability; the main component in achieving sustainability is through enhancing industrial symbiosis. It reported on the possibility of examining at broader benefits of industrial symbiosis in order to achieve sustainability in the relevant industrial community and areas, with the help of stakeholders to achieve intangible social benefits. This chapter has also established the importance of enhancing social capital in order to increase industrial symbiosis opportunities. It concluded that to analyse the benefits of process and intangible outcomes of industrial symbiosis, there needs to be further expansion of the dimensions of the three pillars of sustainability. The next chapter describes the development of the model to assess the values of various capital generated or restored as a result of IS project and the process.

CHAPTER SEVEN

DEVELOPMENT OF SIX CAPITAL MODEL (SCM)

7.1 Introduction

This chapter continues from the finding in Chapter 6 that there are broader benefits of industrial symbiosis that go beyond mere exchanges of material or energy between the industries. The objective of this chapter is to introduce the method developed to assess the broader implications such as the tangible and intangible benefits of industrial symbiosis (IS) projects. This chapter describes the method to assess the broader benefits of IS to the participants of the project by measuring various capital benefits achieved. The chapter makes two conclusions. First, that in order to identify the tangible and intangible benefits, the Six Capitals Model does provide a useful tool which also enables a deeper appreciation of the impacts on the community, as well as benefits to those companies participating in the project. Second, that industrial symbiosis ensures not only physical exchange of material, energy and by-products, but also establishes the necessary linkages between parties to enable such exchanges to occur.

7.2 Benefits of Eco-industrial Development

In Chapter five, research carried out at Cornell University (USA) was described and which identified some potential benefits of adopting eco-industrial development across communities, environment and business. This research highlighted the benefits for community, environment and business when analysing the potential advantages of eco-industrial development. It is argued that IS leads to a number of important intangible benefits in the three dimensions of sustainability, in addition to tangible benefits.

As outlined in Chapter three (research design), this current research adopted an international methodology in which data collected from eco-industrial parks from Europe and Australia were analysed in terms of their success and failure in implementing IS projects, and also in terms of the benefits of these projects. It was found that there was a gap in having a useful framework for analysis of benefits of IS in these case studies.

As described in Chapter five, the results from cases of IS in six eco-industrial parks, as well as other published works on Kalundborg, conclude that intangible benefits, particularly the social benefits, of IS have not been assessed in relation to quantifiable economic and environmental benefits. This thesis suggests that measuring intangible benefits has previously proved to be a difficult task, one which requires a different approach in methodology. This chapter uses the framework developed (explained in chapter six) using "Social Capital" as a focal point to assess the intangible benefits of IS in eco-industrial parks in an integrated way (Kurup & Stehlik 2006). The intangible benefits include not only social, but also environmental and economic aspects as described previously in the research of Cornell University.

7.3 Model for Assessing the Broader Benefits

It was concluded in Chapter four that the need for an additional model/method development was necessary where straight financial evaluation does not provide compelling evidence for project implementation (Kurup, Altham & van Berkel 2005). A model to evaluate the broader benefits of IS that includes intangibles has been developed by drawing on the World Bank's Capital Centered approach. The World Bank developed the 'Capital Centered' approach for its assessment of sustainability of the funding they provided for developing nations. Development of various dimensions and indicators for measurement was based on the concept that even though natural resources were counted as wealth, human resources were more important and should therefore also be counted as wealth (The World Bank 1997). This enabled the action of the role of people and society, especially the human factor and went at length some way to explaining why countries with similar natural resources and similar investment in produced assets might react in a very different growth pattern with different levels of well-being and environmental quality. The World Bank identified that in addition to natural capital, and produced assets, human capital and the not so well-explained social capital may well contribute to economic capital if properly protected. Further details of the capital centered approach and its benefits were explained in Chapter two as part of the literature review. Each capital is defined in Table 7-1.

Table 7-1: Definition of various form of capital

Derived mainly from (The World Bank 1997)

Name of capital	**Definition**
Natural capital	Includes the resources necessary for industries to perform business operations
Ecosystem capital	Includes the ecosystem services needed for restoring or regenerating the environment where industries operate with sufficient air, water and soil quality (Cork et al. 2002) and biodiversity
Human capital	Skills and capabilities of people who are related to industry's operations directly or indirectly for example, employees, contractors, suppliers
Community capital	Communities of interest as place based which involves communities reside nearby industrial area as well as employees
Manufactured capital	Includes produced capital, infrastructure established for efficient running of the business like construction of pipelines, laboratory facilities, shared treatment facilities and water and energy utilities, sewage treatment systems, transport services such as roads, rails
Financial capital	Includes investment, income generated through sale of by-products, savings achieved through avoided landfill cost, treatment cost, regulatory and legal cost, storage cost, intangible cost and benefits

In order to measure the broader benefits of industrial symbiosis, which are more than just environmental, social and economic benefits, TBL framework had to be expanded to cover the values regenerated or restored in natural and ecosystem, human, and community and financial and manufactured capitals. The concept of assessing various capitals would deliver more outcomes since it would give an opportunity to not only look at environmental and economic values but also of skills, networks, individual and societal assets which are identified as important aspects of social benefits. It also helps to measure the value of the series of norms, networks, cohesion, and trust which are important in achieving societal license to operate, reputation and market image in companies, both internally and externally. This allows for the examination of integrated results of indicators, as well as the importance of each capital for integrated results. Figure 7-1 shows the expansion of TBL framework for measuring broader implications of IS.

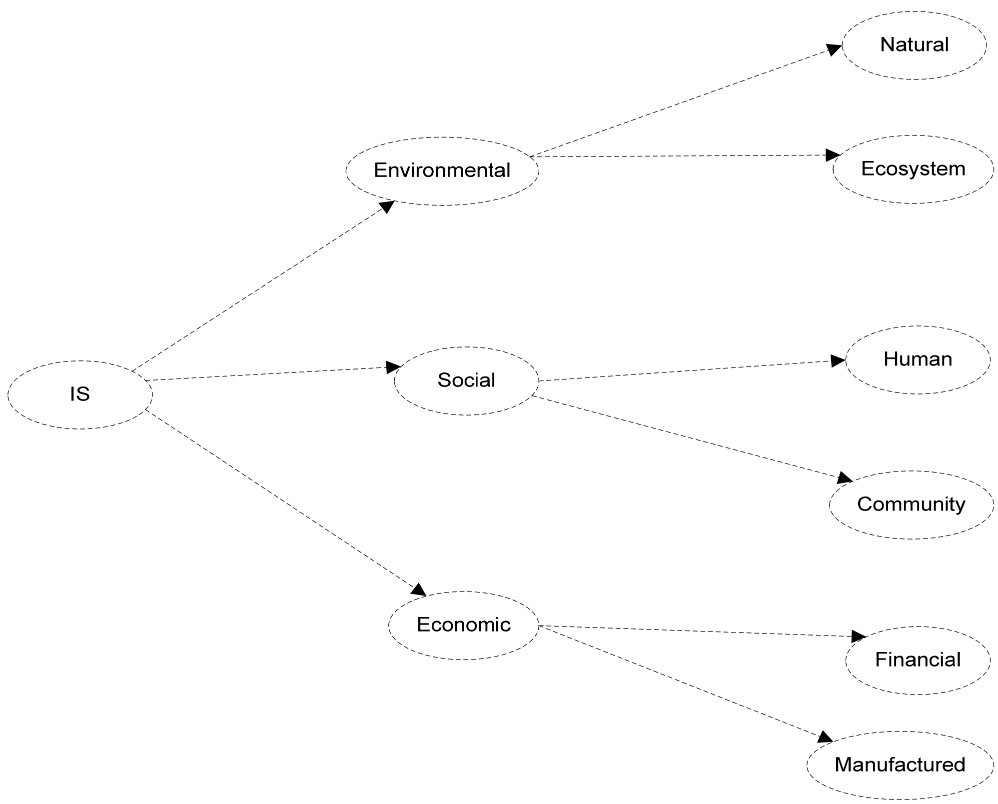

Figure 7-1: Expansion of TBL framework into Six Capitals Model (SCM)

The model highlights the importance of all the capitals to a successful IS. The proposed model, with various forms of capital and its integration, is shown graphically as part of six corners of a hexagon which is embedded in the triangle of triple bottom line dimensions as shown in Figure 7-2.

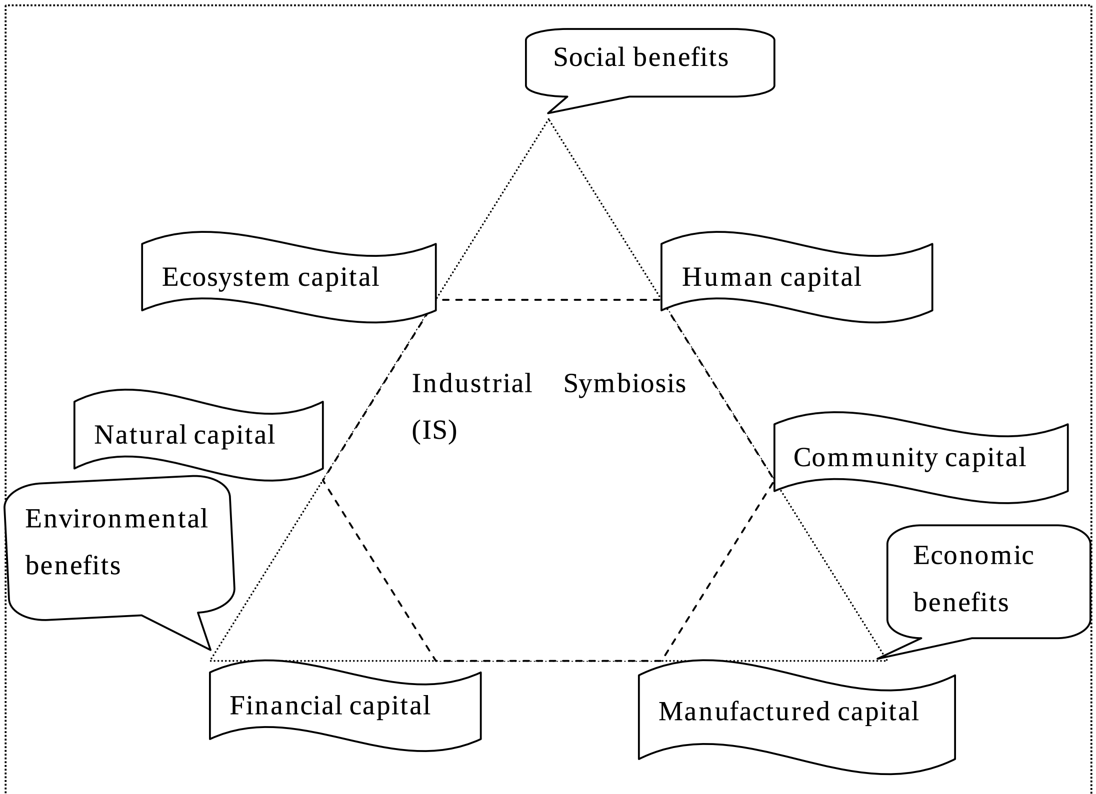

Figure 7-2: Schematic representation of an integrated SCM

Environmental benefits are achieved by the preservation of natural resources as well as the regeneration and maintenance of eco-system services. The ecosystem services include not only life support services like maintaining air and water quality, flood protection, pollination and control of pests, but also life full-filling services like provision of cultural, spiritual and intellectual stimulation and maintenance of other species for their existence value (Cork et al. 2002). The environmental benefits can be accounted for by calculating natural resource capital and ecosystem capital. Stocks of natural capital are assessed for conservation ability and security of resources for economic improvement. According to Feldman and Blaustein (2007) ecosystem services play an indispensable role in communal life and essential in sustainable economic relations. Ecosystem capital can be assessed to explore the value of ecosystem maintenance due to improvement in water, air, land, soil quality and biodiversity.

The Social Capital Model expands the social benefits of industrial symbiosis, into benefits of achieving stocks of human capital and community capital. The research explored whether it could also assist in measuring the internal and external achievements of IS. Human capital is determined by measuring the capital increased or decreased due to improvements on health and safety, skill development, network improvement and stability of work forces. The improvements in the ability to contribute to innovation potential, networking, engagement, trust, and abilities for bonding, bridging, and linking of employees/individuals related internally to the project are also examined. For example, an opportunity of training and skill development, in addition to a safe and healthy working environment for employees, creates an atmosphere for employees to be more productive. According to a report developed by the Mining, Minerals, and Sustainable Development (MMSD), the provision of safe and healthy atmosphere and improvement in skills through training improves employee motivation and productivity, lower absenteeism or turnover, and union disputes (Azapagic 2004; International Institute for Environment and Development 2002).

Community capital is assessed by measuring the opportunities of participation of communities, the level of sharing of information, the level of networking between community and industry. It is also assessed by the reputation created by industries among the community, engagement of industries in capacity building, the level of complaints from communities. The increase of school retention rate by the children in the community, job security, any job creation opportunities among the community members, and companies' social licence to operate in communities close to industries.

The proposed model enables economic benefits to be measured by separately calculating financial and manufactured capital. Economic capital is assessed by calculating the savings made through avoided capital costs, such as direct costs, indirect costs, legal and liability costs, as well as intangible costs. A total cost assessment method is used for quantifying the cost of a normal business, which involves quantifying different costs such as internal, external, hidden, legal and liabilities, and less intangible costs according to EPA methodology (White, Becker & Goldstein 1992). Any improvement in business opportunities, infrastructure, and quality of life will then be used to measure manufactured capital. The value of manufactured capital adds to economic capital from the value of manufactured goods, improved infrastructure and security of jobs and additional outcomes as intangibles.

7.4 Summary

This chapter has described the Six Capitals Model (SCM) developed for this thesis on the basis of reviewed theoretical concepts of industrial symbiosis and social capital, as well as from field studies of practical examples of various industrial areas from Europe and Australia. This chapter has described the importance of measuring intangible benefits in addition to tangible benefits. It proposes a model to measure the benefits using the various capitals, including natural, ecosystem, human, community, manufactured and financial for assessing the overall benefits of successful industrial symbiosis projects. It suggests that the environmental, social and economic implications of industrial symbiosis can be assessed by utilising a rigorous methodology. The chapter also provides the indicators and the approach utilised to test the model framework in practice.

The next chapter describes the results of the application of this model to a case project. It explains the results of the value of various capitals that are increased or restored, by using the responses from the partners of the project.

CHAPTER EIGHT

APPLICATION OF THE SIX CAPITALS MODEL (SCM)

8.1 Introduction

This chapter describes the results of an application of the Six Capitals Model (SCM) in assessing the implications of IS project. It provides a brief introduction to the project selected for the application of the model and the reasons for the selection of the project. It also describes the procedures involved in data collection for testing the model. The chapter identifies the values of human and community capitals in the social dimension, in addition to the values of natural and eco-system capitals in the environmental dimension plus the financial and manufactured capitals in the economic dimension of an IS project. These capitals are assessed separately in order to identify their individual value added for each capital due to a successful industrial symbiosis project. The values of these capitals are graphically represented in this chapter and capitals including natural and ecosystem in the environmental dimension are represented together in Figure 8-1. The values of social benefits are shown separately as human capital and community capital in Figure 8-2 and Figure 8-3 respectively as this dimension has a large number of indicators. The economic benefits consisting of both financial capital and manufactured capital are represented together in Figure 8-4. The case project adopted to enable the SCM to be assessed is Kwinana Wastewater Reclamation Plant situated in the Kwinana Industrial Area. This project has been touched on briefly in previous chapters. The following section describes it in more detail.

8.2 Kwinana Water Reclamation Plant (KWRP)

According to the Western Australian Water Corporation, this project had two distinct components (Water Corporation of WA 2003, p.v).

First,

> treatment of about 24 million litres (ML) /day of secondary treated wastewater from the Woodman Point Wastewater Treatment Plant to a high quality industrial grade and to supply of this water to industry participants in lieu of scheme water supply,

and second,

> the receipt and disposal of wastewater streams from the industry participants for disposal to the ocean via the Sepia Depression Ocean Outlet Line (SDOOL).

This plant is the most advanced state-of-the-art project ever undertaken in Australia to recycle treated wastewater to industry. Reclaimed water from this project specifically will be used for cooling and steam generation purposes for the industries. KWRP can produce up to 6 giga litres of water every year, enabling the Water Corporation to supply 5 giga litres to its industrial customers. This reclaimed water used by industry will free up scheme water up to 5 giga litres every year, which is up to 2% of the scheme water demand of Perth City of approximately 2 million population (Water Corporation of WA 2003).

The demands of water needed for operation of each processing industry vary. For example, for a metal ore, around 5 grams of water is required per gram of final product manufactured (Graedel & Allenby 2003, p.109). Current and the future demand of industries for water from this project have been identified in this case. It is about 48% of the capacity of KWRP currently and in future when KWRP is upgraded to treat 27 ML/day, demand may increase up to 66%. The largest user of the reclaimed water is the pig iron plant, a new plant in the area and one which has received approval from the State Government on the condition that it would use mainly reclaimed water for its business operations. KWRP project would be able to deliver water to its industrial customers at its full capacity by December 2007 (Water Corporation of WA 2007). Figures 8-1 and 8-2 show the present and future demands of industries for the reclaimed water from this plant.

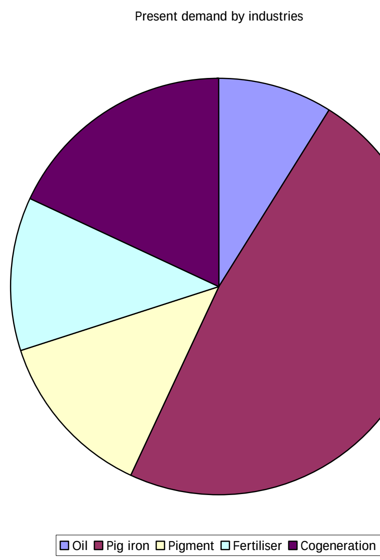

Figure 8-1: Usage of KWRP water by participating industries
(Derived from Public Environmental Review, (Water Corporation of WA 2003)

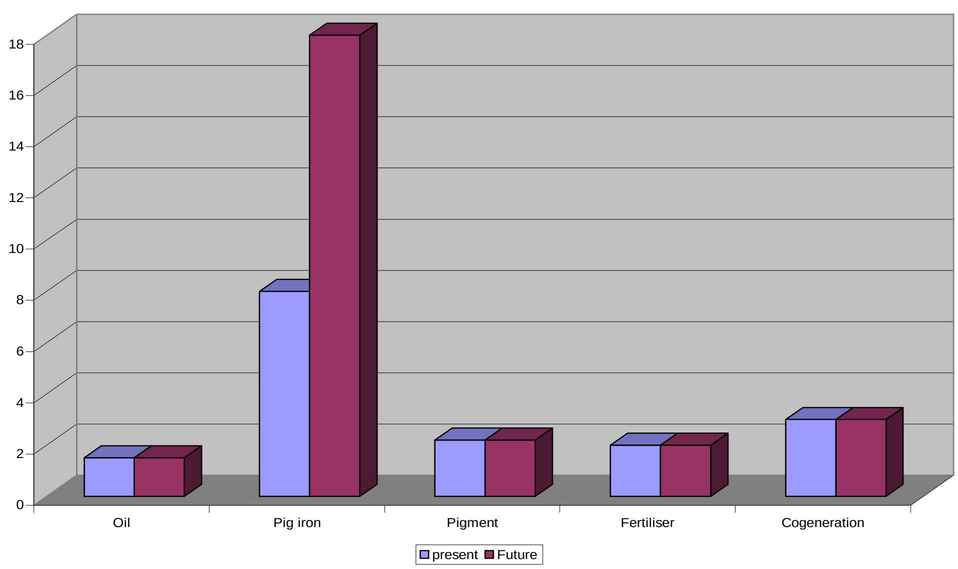

Figure 8-2: Present and future water demands of KWRP
(by the same industries (Derived from Public Environmental Review, (Water Corporation of WA 2003)

8 3 Selection of KWRP as a Case Project

The KWRP project was selected for applying the Six Capitals Model (SCM) (Kurup & Stehlik 2007-in press) for a number of reasons. First, this project has the highest number of participants involved from the KIA. The project therefore is ideal to test the effects of broader implications of symbiosis, in addition to the effects of its operational implications. Second, during the first stage of detailed data collection from Kwinana Industries, every partner of this project has identified KWRP as an 'iconic' project for the company. Third, it has two components as mentioned before which enables two way exchanges between the companies participating and the supplier of the reclaimed water, which makes the project viable to operate within the definition of a symbiosis project (Chertow 2007). The KWRP project has already been under operation for over two years and already delivered around 3.6 GL of treated water to its industrial customers (Water Corporation of WA 2007).

The challenge of water availability has changed the way industries use water for their purpose. Many industries in Kwinana have already taken initiatives to further reduce the present water use as part of their company strategy. At present, the industries in Kwinana use 32.7 giga litres (GL) per year of water and the projected demand for 2021 would be 69.6 GL/year including future demand of the present industries as well as demands of future industries (Kwinana Industries Council 2006).

8.4 Indicators Selected

A total of 38 indicators were used in the questionnaire to identify the value of all the capital gained through this project. There are some values already available for the indicators in the environmental dimension from the documents in the public domain such as the environmental impact assessment report of this project. For example, the potential reduction of value of CO2 emission, particulate matter, Total Suspended Solids (TSS), Biochemical Oxygen Demand (BOD), Mercuric, Arsenic are already available, it was decided that these indicators should not be used in the questionnaire. Indicators have been selected based on the potential implications of this project on the natural capital, ecosystem capital, human capital, community capital, manufactured capital and financial capital. Table 8-1 shows the category, criteria and indicators used in the model.

Table 8-1: Indicators to measure values of capitals
(Derived from the SCM model)

Category	**Criteria**	**Indicators**
Environmental benefits	Natural capital (NC)	resource conservation
		resource security
	Eco-system capital (ES)	water contamination
		dust emission
		impact of noise
		air emission
Social benefits	Human capital (HC)	productivity
		retention of employees
		job security/creation
		sharing occupational health & safety programs
		investment in research & development
		sharing of infrastructure & technology
		sharing of human resources
		Employee management relations
		information sharing between companies
	Community capital (CC)	Perception of communities in regards to environmental health
		Communication about the project in the community
		Opportunities of educational partnership for school children
		Employment opportunities
		Complaints from community
		Sharing of information between community and industries
		Level of understanding about IS projects among community
		Opportunities of public relations
		Networking between industries and communities
Economic benefits	Manufactured capital (MC)	Business opportunities
		Infrastructure facilities for industries
		Public infrastructure
	Financial capital (FC)	Labour costs
		Equipment costs
		Raw material costs
		Compliance costs
		Permit costs
		Cost of penalties/fines
		Cost of future liabilities

8.5 *Results and Discussion*

The interviews with environmental managers of the participants of the KWRP project assisted in building on evidences already gathered from the public domain. Each participant of this project identified the implications of the symbiosis process and the operation of this project for their company. The results of the values of each capital for industries were calculated by finding an average value of the answers collected from the managers of the companies participated in order to analyse combined effect of the project. The results of the value of each capital identified by all other stakeholders (community, regulatory agency, utility provider) are also presented as an average value. These results were presented in a radar chart. This result shows that the implications of this project are different for each company participated. As highlighted in Chapter three (methodology) there is an absence of data in the respective table, as not all scores and percentages were provided by the partners. The following presents the analyses of these results.

8.5.1 Natural and Ecosystem Capital

Natural capital was identified with resource conservation and resource security as the two main indicators. Strong positive results were recorded by most of the participants, as well as by the community groups and Government bodies including the utility provider. Through the KWRP project, industries have achieved value added benefits on conservation of scheme water, as well as maintenance of security of resources, both of these were important for the industries involved. The importance of security of resources in this case relates to conservation of water, which is as vital as conservation of any other major resources. The simple example is the case of pig iron plant which was given the approval by the department of environment that they use reclaimed water for their operations. Table 8-2 shows the values of natural and ecosystem capital. The values of percentages were not included in the table because of the unavailability of data in every column. Some companies provided the value added in terms of capital by percentages and these are provided with explanation without inclusion in the picture.

Table 8-2: Values of natural and ecosystem capitals

Capital	**Indicators**	**Combined average**	
		Companies	**Stakeholders**
NC1	**Increase of water conservation**	**5**	**4.9**
NC2	**Increase of water security**	**4.25**	**4.0**
ES3	Reduction of air emissions	2	1.6
ES4	**Reduction of water contamination**	**4**	**3.3**
ES5	Reduction of dust emission	1.5	1.4
ES6	reduction of noise	1.75	2.0

The table shows that water conservation and water security ranked positive showing values 5 (strongly agree) and 4.25 (agree) in the Likert scale respectively. The values from the stakeholders' assessment also show positive and their values matched with the companies' results. Some companies were prepared to score the percentages they achieved in these indicators and it was found that the percentages achieved for each company varied from 0-25% to 75-100%.

Ecosystem capital was identified using the indicators of maintaining ecosystem services such as air, water and land/soil quality (Cork et al. 2002). Licensed or unlicensed discharge of effluent from companies in an industrial area is a common phenomenon which can pollute the marine environment and ecosystem services near the industrial area (Richards et al. 2002). Prior to the KWRP project, industries were discharging their treated effluent into the nearby sensitive marine environment using licensed approval from the regulatory authorities. Through the acceptance of water from KWRP project, there were constructive actions by all the industries to reduce their licensed discharge into the marine environment. This was achieved by agreeing to participate in the costly option of discharging their wastewater into the ocean 4 km away from the previous discharge point through an alternative pipe line run by the Water Corporation, the provider of treated water. When ecosystem capital was analysed, it secured the value of 4, since there was reduction in water contamination due to diversion of discharges from the sensitive marine environment-Cockburn Sound. In this case, one company achieved reductions in water contamination between 75-100%. For example, it was anticipated that there would be reductions of total phosphorus (TP) (37.5%), total suspended solids (TSS) (38.1%), Arsenic (27.5%), Cadmium (55.3%), Mercury (33.3%), and Zinc (10 %) of the previous discharge from the three companies (Water Corporation of WA 2003, p.56). It could be confirmed from the Table 8.2 that even though other parameters had been selected to test the eco system capital, the project did not achieve any significant reduction in noise or dust. The results of both natural and ecosystem capital are graphically represented together in Figure 8-3.

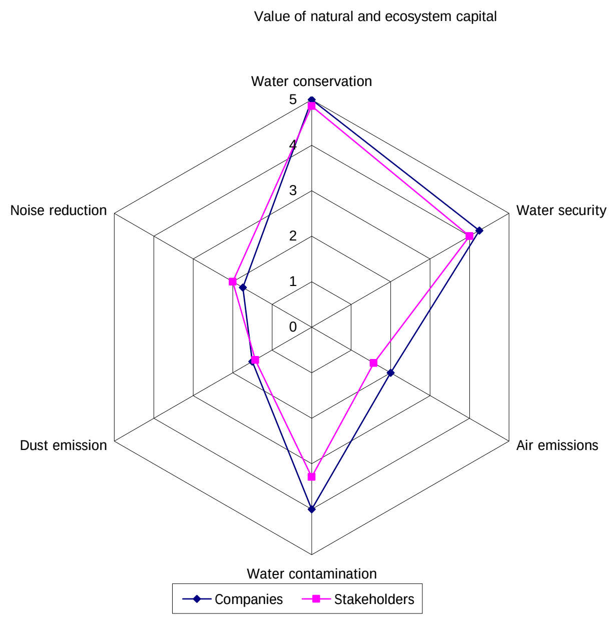

Figure 8-3: Graphical representation of natural and ecosystem capital

Secondary data also shows that more than 50% of resources could be conserved as a direct result of this project. It has been identified that the decision by industries to use an alternative water source, in this case reclaimed wastewater, could avoid the loss of revenue if there were restrictions on a needed resource. It can be seen that security of water was achieved through the conscious effort by industries to replace scheme water and ground water by using reclaimed wastewater from the wastewater treatment plant. Conservation of resources as well, as security of resources, are equally important for achieving business case successfully and IS would be the catalyst in this case. Selecting the costlier option of a discharge point away from the sensitive marine environment provided the opportunity for industries in restoring the same which is also important in maintaining the license to operate in the community.

8.5.2 Human Capital

The value of human capital was identified using indicators such as opportunities for productivity, retention of employees, creation of jobs, shared human resources, investment in training and development, innovation potential, job security and opportunities for shared network improvement, research and development and occupational health and safety. In the case of human capital, the opportunities of shared infrastructure and technology were affirmed and agreed by both companies and stakeholders, showing a value of 4. These values are provided in the Table 8-3.

Table 8-3: Values of human capital

	Indicators	**Combined average**	
		Companies	**Stakeholders**
HC7	Productivity of business	2.5	2.6
HC8	Retention of employees	1.75	2.4
HC9	Creation of jobs	2.25	2.6
HC10	Shared occupational health & safety programs	1.5	2.4
HC11	Investment in research & development	2.75	3.1
HC12	**Opportunities of shared infrastructure & technology**	**4**	**4.0**
HC13	**Information sharing between companies**	**4.5**	**4.6**
HC14	Sharing of human resources between companies	2.5	2.7
HC15	Employee management relations	2	3.0

The results showed that opportunities for sharing infrastructure and technology were improved and one of the partners of this project identified this to be around 25-50%. Information sharing between companies also increased considerably and one company indicated that it is between 75-100%. The value of 4.5 and 4.6 from companies and stakeholders show that this could be due to the establishment of trust and developed relationship between those companies and stakeholders that they were ready to share information. Sharing of human resources between the companies is also increased between 0-25%. The results show that investment in research and development has also increased and it is between 0 and 25%. Other indicators in the Table 8.3 did not score any positive values as these values were yet to improve due to this project. Figure 8-4 shows the values between 1 to 5 and the value above 4 have been taken as value added to the capital and the values below 3 shown no improvement.

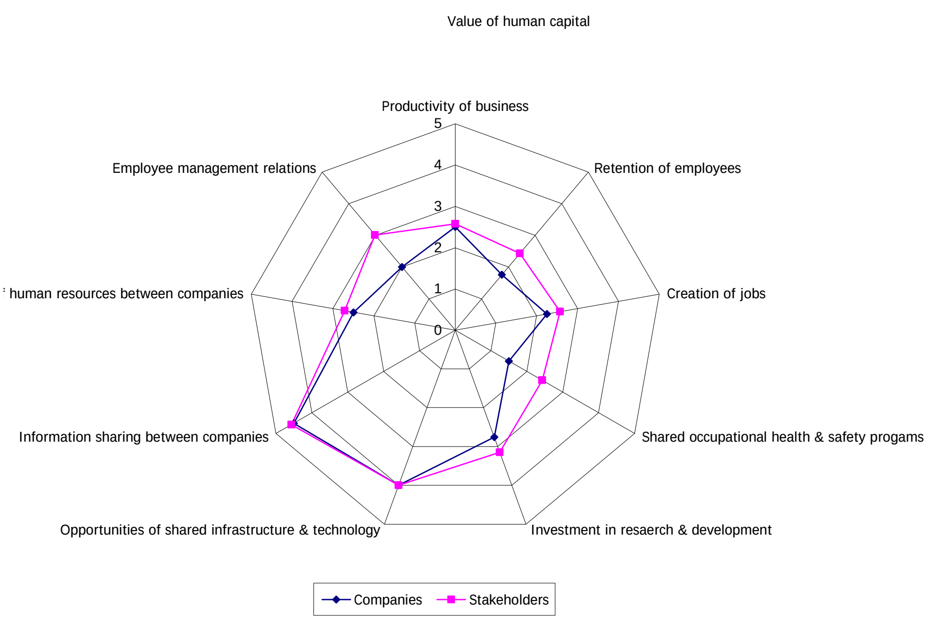

Figure 8-4: Graphical representation of human capital

8.5.3 Community Capital

Community capital scored very high values, with indicators such as participation and engagement with sharing of information between industries and communities, and between industries. Table 8-4 shows the combined average of values of indicators from companies and stakeholders.

Table 8-4: Values of community capital

	Indicators	Combined average	
		Companies	Stakeholders
CC16	number of complaints from communities	2.5	3.0
CC17	**Sharing of information between communities & industries**	**4.25**	**4.4**
CC18	**Level of understanding about IS projects**	**4**	**4.1**
CC19	Networking between industries & communities	3.25	3.3
CC20	Perception of communities regards to environmental health	3.25	3.4
CC21	Opportunities for more public relations	2.25	3.0
CC22	**Publicity about the project**	**4.25**	**4.4**
CC23	opportunities of educational partnership	3	3.4
CC24	Employment opportunities	3	3.7
CC35	Site visit opportunities of communities to industry's premises	3.5	2.6
CC36	**Collaboration of Government bodies**	**4.25**	**2.0**
CC37	Collaboration of communities	3	2.6
CC38	**Industries' stand towards government and community**	**4.5**	**2.3**

Sharing of information between communities and industries scored value above 4 for both companies and stakeholders, confirming that stakeholders agreed with the companies that there was an increase in information sharing. The level of understanding about IS projects and publicity about this particular project also gained values more than 4 from both companies and stakeholders. The value of these indicators also suggests that there was an increase in participation and engagement from the community. From the companies' point of view, the collaboration of government bodies has also gained values positively due to this project and hence industries' stand towards government and community has changed positively. The results of the indicators such as number of complaints from the community, networking between communities and industries, and opportunities for more public relations are yet to improve collectively even though it improved considerably according to individual companies. Figure 8-5 indicates the values of indicators of community capital, and values above 4 shows the positive impact of the project.

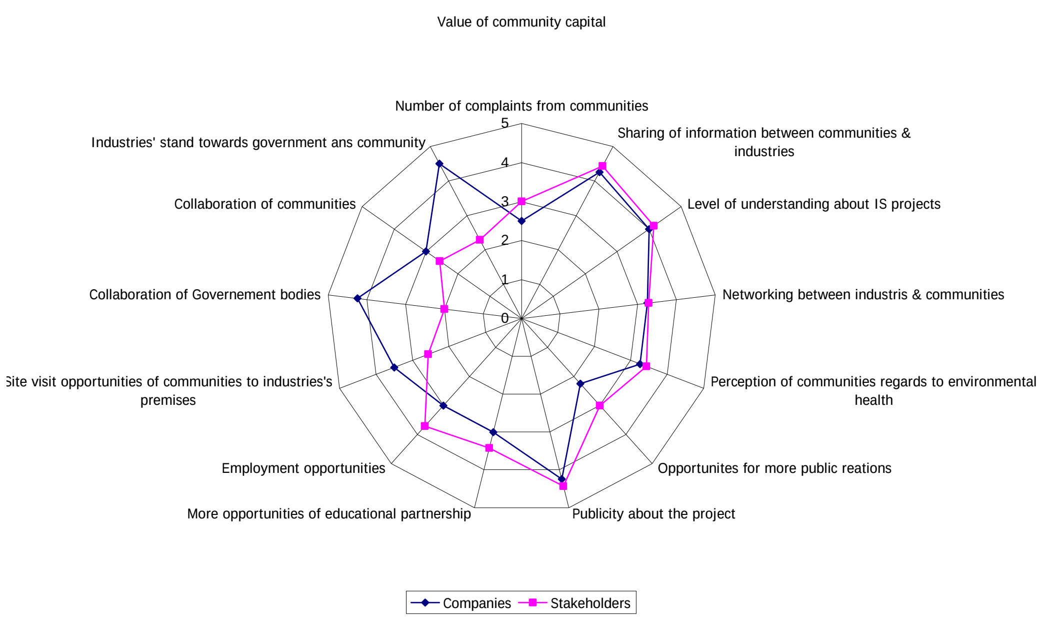

Figure 8-5: Graphical representation of community capital

In terms of percentages, a score of 0-25 % was achieved by both sharing of information between industries and communities, as well as between companies. Most of the companies were reluctant to provide the percentages of increase in value of community capital, though they agreed that there was generation of this capital due to this project. At the same time, the results from one company show that collaboration of government bodies has increased between 75-100%. Publicity about the project scored 0-25% indicating that communication between industries and communities achieved a satisfactory level. Industries' stand towards government has improved and the results show that it has increased between 75-100%.

Industrial symbiosis was also found to be positively influencing the sharing of information between industries. It can be argued that this may result in a readiness to share resources that are critical to every one and may end up in joint use of resources.

Participants from community, government and industry were equally positive about the level of communication and the participation results. Analysis of social capital literature suggests that this may result in the development of trust and hence the social license to operate. License to operate according to the chairman of Royal Dutch Shell is defined as “the activities which societies allow a (company) to undertake as a private, profit making enterprise. In other words it defines what a company can and cannot do” (Burke 1999, p.10). Advocates of participative decision making argue that positive engagement of local communities often helps build local understanding and acceptance, which could avoid costly hostility (Gibson 2006). This could have been advantageous to Shell, UK, where costly undertakings had to be carried out to prevent further hostility between communities and the company (Burke 1999). On the other hand, lack of participation and support from the Government turned out to be costly when a company in Kwinana had tried to act on the principles of utilising other’s by-products as their raw energy input. The project had failed to implement.

8.5.4 Financial and Manufactured Capital

When calculating the financial capital of the project, it was assumed that there would be reduction in costs such as direct, indirect/hidden, permit and compliance, penalties and future liabilities as per the literature mentioned in the previous chapters. It was also assumed that these cost reductions would lead to cost savings. Costs are separated into three categories in this case according to the literature. Costs involving raw material, labour and equipment were considered as direct cost or usual expenditure. For the case of indirect cost/ hidden cost to be accounted, permit as well as compliance cost needs to be included. Since future liabilities and legal costs need to be incorporated in the financial capital as externalities, values of legal and liabilities costs are also to be accounted for finding the externalities. For analysing the values of manufactured capital, opportunities of increase of infrastructure for business as well as community were included as indicators in addition to creation of business opportunities. Table 8-5 shows the combined average of increase or decrease of financial and manufactured capital.

Table 8-5: Values of financial and manufactured capitals

	Indicators	Combined average	
		Companies	Stakeholders
MC25	Business opportunities	2.75	4.0
MC26	**Infrastructure for industries**	**4.25**	**3.1**
MC27	**Public infrastructure**	**3**	**4.1**
FC28	Labour costs	2.75	2.7
FC29	**Equipment costs**	**3.75**	**4.3**
FC30	**Raw material costs**	**4**	**2.9**
FC31	Compliance costs	3	2.4
FC32	Permit costs	2.75	2.6
FC33	Penalties/fines	2.75	3.3
FC34	Future liabilities	2.75	2.4

In the case of manufactured capital, there was an increase in public infrastructure as well as company infrastructure within the range of 75-100%. From the stakeholder's point of view, business opportunities increased due to this project. Companies also recognised that there had been an increase in the infrastructure for their operations. There were a number of initiatives generated after the success of this project. The second stage of this project is already on the pipe line to decrease the use of scheme water and strengthen the reuse concepts (Sinclair Knight Merz 2007). Stakeholders also recognised that the public infrastructure has also made available due to this project.

In the case of financial capital, the results show that there was a reduction in direct costs which was reflected in the individual member's answers associated with raw material, labour and equipment. It was found that some companies enjoyed the reduction of cost due to raw material availability, since secondary material was available as by-products of other companies. For example, the raw material cost was reduced up to 75-100% for one particular company. The cost of equipment was also reduced due to this project, but to a lesser degree for some companies. At the same time, there was a 0-25% reduction in hidden costs such as compliance and permit cost for one company as a result of this project. However, it escalated for other companies as a result of the realisation of number of risks involved. Figure 8-6 shows the values of financial and manufactured capital.

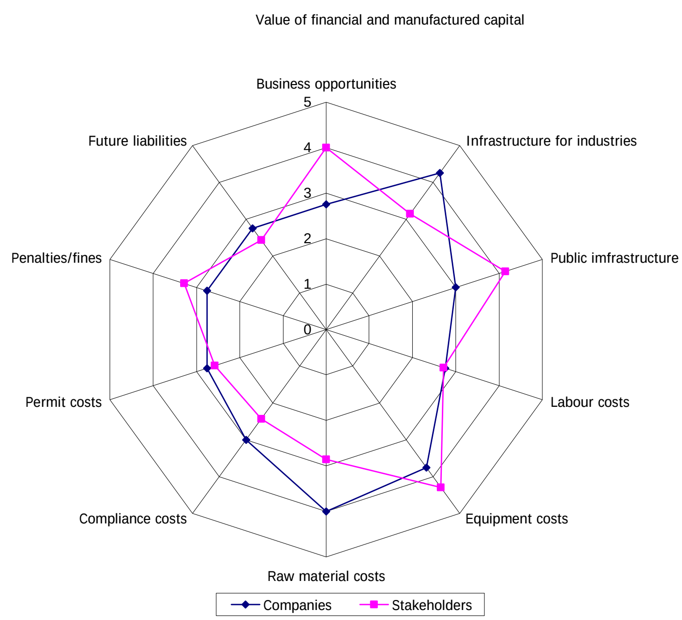

Figure 8-6: Graphical representation of financial and manufactured capital

Due to the unavailability of percentage data from all companies participated, it was difficult to prove that reduction of compliance and permit cost was achieved for every partner as a result of this project. Regarding fines/penalties and future liabilities costs, the data show that there was no reduction in cost achieved. On the other hand, there was actually an increase in cost involved as a result of incorporating the future liabilities of this project for most of the companies, as well as for the provider of reclaimed wastewater. Overall, there weren't any net savings for most of the companies involved.

The overall results show that inter-firm collaboration is leading to both short-term and long term environmental and social achievements for industries and the communities around them. The results also show that even though there are costs associated with collaboration for industrial symbiosis, there are anticipated long term benefits. These are achieved as a result of combined action for securing all capital resources and are also achieved due to positive action by companies in protecting the environment and community nearby, which provides them with reputation and social license to operate.

8.6 Summary

This chapter illustrated the results of the trial of the Six Capitals Model (SCM) which was validated by applying it to the KWRP project. The results show that there are broader benefits of IS to industries, community and government if the project is successful. Through the SCM, it was shown that the values generated towards human capital and community capital could be identified. Regarding economic benefits, it was shown that even though the cost of the project was high for the short term, the longer term costs (hidden costs) would be balanced due to industrial symbiosis processes. In terms of the environmental benefits achieved by IS, natural capital as well as ecosystem capital was generated and protected through this project. Values of intangible benefits, such as reputation, social license to operate, importance of information sharing, connection, communication and collaboration between stakeholders were able to be identified through this Six Capitals Model and there were proven results of the success of industrial symbiosis through its benefits. The next chapter provides a general discussion about the overall research by evaluating the objectives and results of this research.

CHAPTER NINE

GENERAL DISCUSSION

9.1 Introduction

This thesis addressed a number of issues on the research topic 'the evaluation of methodologies in capturing environmental, social and economic implications of industrial symbiosis'. This chapter discusses the findings of the thesis by bringing together each objective against the outcomes. It also discusses the contribution of this research to the academic field. In addition, the limitations experienced by the researcher while carrying out a multi-disciplinary research are discussed.

9.2 Research Objectives and Outcomes

Objective 1: Identify and review the existing approaches to evaluate environmental, social and economic implications of industrial symbiosis in heavy industrial areas both globally and locally.

9.2.1 Outcome 1

The first outcome of the research was the development of a baseline assessment report which compiled the review of the eco-industrial parks and existing approaches to evaluate environmental, social and economic implications of industrial symbiosis. It also identified the publicised information about the environmental social and economic benefits collectively or either as individual projects of IS. During this review, it was identified that many industries recognised only the environmental and economic benefits of industrial symbiosis for example, due to emission reduction, reduction in the quantity of waste sent to landfills, raw material savings, savings due to less storage requirements and treatments of waste. This study has found that some industrial areas have been successful in recognising the need to collaborate with other industries and communities nearby. Industrial areas planned with the initiative of government incentives alone have failed to continue its operation when these funding opportunities have ceased. Industrial areas which have the back up support from an Industry Council as well as the city, town council or local government continued to maintain the momentum in initiating more projects of industrial symbiosis.

During the analysis of about sixty industrial areas globally which claim practices of industrial symbiosis, it was found that there were only a limited number of studies concentrating on evaluating social benefits in addition to the environmental and economic outcomes. This confirmed previous research which found that a sound strategy for addressing social dimension of industrial symbiosis for sustainability is less developed (Mirata 2005).

It was also recognised that establishing a consensus among these limited studies and practices was very difficult since each region which practices industrial symbiosis had its own characteristics. These characteristics were influenced by the diversity of industries, economies of scale of materials of exchange, locality of place, facilitators of the practice and, finally, the type of material involved. At the same time, these efforts should be encouraged on a regional basis for the future development of further symbiosis in these areas.

> *Objective 2: Develop a method to track and quantify the environmental, social and economic implications of industrial symbiosis projects of participating businesses, neighbouring businesses, communities and the region as a whole.*

9.2.2 Outcome 2

A framework was developed for analysing the life cycle environmental, social and economic implications of IS during the first stage of the research, prior to reviewing various industrial parks in detail (Kurup, Altham & van Berkel 2005). This framework was developed using the indicators compiled from the literature and it was applied to three projects of the KIA. The details of this framework and its application are explained in Chapter Four.

It was found that the life cycle TBL analysis was most useful in analysing the operational implications of projects undertaken on by-product exchanges. Since the implication of each life cycle stages of the project can be measured with this framework, it would be appropriate in measuring the implications of the stages prior to the actual operation. It was identified that this analysis would help in future as a baseline study when the project would be under further assessment during operation and it would allow verification of the previous results. It was concluded that these preliminary results would provide testimony for the overall net economic, social and environmental benefits of the projects, over and above the sound project economics which were the principle reasons for their implementation. The thesis concludes that the framework is helpful in identifying the operational benefits of an industrial symbiosis project.

The life cycle method for measuring TBL aspects of an industrial symbiosis project however limited the identification of broader sustainable benefits, which was identified during the analysis of field data including intangibles. These intangible are identified as part of the development of IS due to the developed relationship, trust, networking and collaboration. Since the life cycle framework was limited in addressing the benefits of collaboration and networking of industries, further methods of development was necessary. It was anticipated that a method addressing broader benefits would likely be most useful in cases where conventional financial project evaluation did not provide compelling evidence for project implementation. This confirmed earlier research undertaken by Bring-Jacobson that exchanges in Kalundborg were initiated “across the factory fence”, even though only short term economic benefits were achievable and it might have been due to “soft factors” (Brings-Jacobsen 2005, p.253).

Even though there is as yet not an agreed method present to identify the social benefits of IS, the importance of the social dimension of IS to achieve the goal of sustainability has gained more attention recently. There have been increasing calls for addressing social dimensions and inherent social phenomena of industrial ecology from both academics and industries (Mirata 2005; Vermeulen 2006).

In its development to assist in the establishment of a method to address the social dimension in addition to environmental and economic dimensions, this research has concentrated on investigating further findings about the social dimensions and their influence on IS and regional sustainability. This thesis has developed a framework for linking social phenomena and its influence on social capital and industrial symbiosis in order to identify the importance of social capital. To achieve this, a review of literature of social capital and how it could be useful to achieve social benefits when applying IS practices were undertaken. This was discussed in detail in Chapter Six. This research has identified that industrial symbiosis provides an opportunity to create further social benefits between various companies as well as between the companies and their various stakeholders.

As the social dimension of IS and its link to social sustainability are established, further expansion of a proposed method for finding an alternative methodology was undertaken. A model was developed by modifying the World Bank’s capital centred approach. This model has been adopted as an alternative method and has been named as the Six Capitals

Model (SCM). This method developed is the first approach established to track and identify the social benefits of industrial symbiosis.

This refined Model allows the researcher to address the implications of environmental, social and economic dimensions in an integrated way. It also allows the identification of the implications of IS projects for industry and community.

It was found that using this SCM, intangible benefits such as reputation, social license to operate, innovation, competitive advantage and information exchange and sharing of human resources and technology were able to be evaluated. The SCM could combine the tangible benefits of IS, thus making it a more comprehensive model. The thesis argues that the SCM would help identify the tangible and intangible benefits of IS in various capital forms. This is important to provide extra weight to intangible issues of collaboration in developing relationships across sectors. As previous research suggested, giving more weight to intangible issues of collaboration in logistics and human resource management has resulted in sustaining strong longer lasting connections and interest in the case of Landskrona project (Mirata 2005). According to Mirata, such issues were proven to be laying the foundation for more by-product exchanges.

The advantage of SCM over previous methods is that this method is able to assess the environmental, social and economic benefits and costs of IS in an integrated way based on information provided by the companies. This Model requires only relative data from industries for analysis, rather than the absolute data, which are confidential and have commercial and competitive implications. As this research has confirmed, most of the industries are not prepared to share their confidential data in raw or absolute form. However, such companies may be prepared to share such data in a relative or qualitative manner for external use, while keeping the commercial confidence.

Objective 3: Trial and evaluate the method in selected heavy industrial areas including the Kwinana industrial area with the participation of industry partners and evaluate its impact on decision making by community, government and industries in relation to industrial symbiosis opportunities.

9.2.3 Outcome 3

The validation of the SCM revealed a number of findings. The results of application of the Model on the case project suggest that there are clear social benefits of industrial symbiosis in terms of achievement of human capital and community capital. The Model thus validated the argument of this thesis that there are social benefits from IS for industries and communities and they are not just the spin-off gains from the environmental benefits. This study has found that these benefits are accrued as mainly intangibles and therefore needed an alternative methodology to interpret them.

Under the environmental benefits, natural capital was identified with resource conservation and resource security as the two main indicators. Strong positive results were recorded by most of the participants, as well as by community groups and Government agencies including the utility provider. Through the KWRP project, industries have achieved value added benefits by conservation of scheme water, as well as maintaining security of resources, which was important for the industries involved. The importance of security of resources is as vital as conservation of any other major resources as identified in the case of reuse of secondary effluent in Gladstone (Corder 2005). Ecosystem capital was identified using the indicators of maintaining ecosystem services such as air, water and land/soil quality. When ecosystem capital was analysed, there was reduction in water contamination due to diversion of discharges from the sensitive marine environment of Cockburn Sound.

Social benefits of industries and communities were identified using human capital and community capital indicators. The value of human capital was identified using indicators such as opportunities for productivity, retention of employees, creation of jobs, shared human resources, investment in training and development, innovation potential, job security and opportunities for shared network improvement, research and development and occupational health and safety. In the case of human capital, the opportunities of shared infrastructure and technology were improved in this case.

When analysing community capital, sharing of information between communities and industries scored positively for both companies and stakeholders, confirming that stakeholders agreed with the companies that there was an increase in information sharing. The level of understanding about IS projects and publicity about this particular project also increased according to both companies and stakeholders. The values of these indicators also suggest that there was an increase in participation and engagement from the community. From the companies' point of view, the collaboration of government bodies has also gained values positively due to this project. Industries' stand towards government and community has changed positively. The results of the indicators such as the number of complaints from the community, networking between communities and industries, and opportunities for more public relations is yet to improve collectively even though it improved considerably according to individual companies.

Economic implications are identified using this model under financial and manufactured capitals. Under the current life time of this project which started operation in the end of the year 2005 (when data were collected from the partners, there were only one company received the reclaimed water from this project and others were waiting for the infrastructure and other facilities to complete). In the case of financial capital, the results show that there was a reduction in direct costs which was reflected in the individual member's answers associated with raw material, labour and equipment. It was found that some companies enjoyed the cost reduction since secondary material was available as by-products of other companies. The cost of equipment was also reduced due to this project, but to a lesser degree for some companies. Hidden costs escalated for most of the companies as a result of the realisation of number of risks involved.

The immediate results in the case of KWRP show that the overall costs of installing pipelines and other accessories, in addition to the high cost of reclaimed water over scheme water, outweigh the benefits achieved short term. However, industries are prepared to absorb this cost in anticipation that in the long term, the reputation of the industries created by the image as sustainable industries would mostly outweigh the short term cost.

In the case of manufactured capital, it was identified that there was an increase in public as well as company infrastructure. Companies recognised that there has been an increase in the infrastructure for their business operations. Stakeholders recognised that the public infrastructure has also made available due to this project. From the stakeholder's point of view, business opportunities also increased due to this project. There were a number of initiatives generated after the success of this project. For example, the second stage of this water reclamation project is already on the pipe line to decrease the use of scheme water and strengthen the reuse concepts further (Sinclair Knight Merz 2007).

The 3C framework was also confirmed for the success of this project from the beginning of the life cycle of this project such as connection, communication and collaboration of the various stakeholders from the very beginning of the project. Using this model, it was able to identify the benefits of IS to community and other stakeholders associated with industry and its operations. It can also be used as an external reporting system to measure and report tangible and intangible outcome to various stakeholders.

Objective 4: Provide recommendations for various stakeholders to achieve better capture and assessment of the environmental, social and economic implications of industrial symbiosis.

9.2.4 Outcome 4

This research has contributed a model and filled the gap in identifying the environmental, social and economic implications of IS to the academic field. The research suggests that Six Capitals Model (SCM) could be used as a measuring tool to identify and capture the implications of the IS internally for the verification by the industries and as an external reporting tool to other stakeholders. It can be used to assess implications of the whole industrial area in addition to measuring for sector-specific projects. The results of the measurement would enable industries to report to Government to show that industries are working towards the goal of sustainability.

By having a methodology to evaluate and identify the integrated environmental, social and economic implications, industries could be better prepared to demonstrate various stakeholders (including government) of the importance of incentives to improve and enhance further opportunities of symbiosis. Since collaborative operations of industries bring benefits to industry, community and government, this Model will help to initiate future policies to integrate diverse industries together during planning stage of an industrial area. This process will maximise the economic and social benefits and minimise environmental damages caused by industries.

9.3 Scopes and limitations

Using the SCM would give industries an opportunity to identify the net implications of industrial symbiosis. SCM would not only help the industries to assess the net benefits but also identify the areas the industries need to improve in order to achieve sustainability of operations. The model could also bring the collaborative benefits of inter-organisational co-operative activities. In addition, it could be used to identify and assess the net implications of an industrial area as a whole or geographic region resulted from IS.

Results of this research would help increase the potential for companies to present the results to decision makers to act on the need for regulatory flexibility and other incentives to operate in a more sustainable way. This would ultimately decrease production costs through material, energy, water and by-product exchanges with neighbouring organisations. It would also benefit the natural environment due to reduction of the net discharges of waste and emissions, as well as by decreasing the demand on natural resources. The status of public health would also be improved in local communities due to reduced emissions to air, land, and water. There would be increased opportunities of job creation, job diversity and security due to increase in business opportunities. Implementation of IS projects would benefit broadly as the collaboration of various stakeholders would encourage further opportunities in the local and regional areas. Though the primary emphasis of the research was in the Kwinana Industrial Area, this approach could be applied in other heavy industrial areas in order to identify benefits to their local community and the industry.

Assessment of environmental, social and economic implications would demand collection of data from the concerned industries practicing IS. The constraints of this research included both unavailability of the required data, as well as the reluctance of data-sharing for research due to commercial in confidence arrangements with participants of the symbiosis projects. In addition, many industries were not capable of providing financial and operational data to a research study due to the confidentiality policies. In some cases, the data were absent even if the industry was willing to support the research study.

9.4 Summary

This chapter summarised the main findings of the research against the stated objectives of the study. It also discussed the scope and limitations of this research. The next chapter outlines the conclusions from this research and makes recommendations for further research.

CHAPTER TEN

CONCLUSION

This chapter summarises the results from the research. It also discusses potential benefits of this research for industry, government and the community and concludes by providing some recommendations for future research.

Industrial operations have been identified as causing social and environmental problems such as: acid rain; greenhouse gas emissions, air, water and soil pollution; plus health problems to neighbourhood communities. With the 3P (people, planet, profit) approach for sustainability as the background, there have been movements to establish the concept of eco-industrial development in existing or new industrial areas from the planning stage onwards.

Industrial ecology (IE) is the operation of an industrial system which is based on the principles of operation of a natural ecosystem. Industrial symbiosis (IS), one of the principal applications of IE, is defined as inter-firm collaboration, where a network of industries collaborates in exchange of products, by-products, information, resources and wastes to reduce their collective environmental footprint to achieve mutual benefits.

However, IS faces a number of barriers such as technical, regulatory, commercial as well as informational. There is also an absence of a proven and well established evaluation methodology to identify the positive implications of IS. The true benefits of IS might therefore remain underestimated, thereby failing to convince industry, government and the community to realize the opportunities IS can bring in attaining goals of sustainability in their operations.

The aim of this research was to develop and trial a method for capturing the life cycle environmental, social and economic implications of industrial symbiosis in heavy industrial areas. This research was developed upon the multi-disciplinary approach of examining sciences from environmental, social and financial to develop an integrated method. The research hypothesis is that the assessment of implications of existing IS practices might prove the benefits of IS to the various stakeholders and bring further opportunities to enhance symbiosis between the industries in an industrial area.

It was concluded during the literature review, that there was an absence of an integrated method to capture the implications of industrial symbiosis towards industries and other stakeholders. This finding resulted in developing a new model called Six Capitals Model (SCM) to capture the implications of IS. This new model was applied to a project in the Kwinana Industrial Area of Western Australia.

The application of the Six Capitals Model (SCM) to assess the benefits of – Kwinana Water Reclamation Plant,(KWRP), an IS project in KIA produced mixed results. The project, KWRP was commissioned to reclaim effluent from a wastewater treatment plant after tertiary treatment using microfiltration and reverse osmosis for industrial use. The values of net implications in terms of various capitals, such as natural, ecosystem, human, community, financial and manufactured, were identified with this Model. The tangible values generated due to the operation of the project, as well as the intangible values of the symbiosis process were identified. The intangible benefits were measured in qualitative terms. Some of the indicators are change in shared infrastructure, shared human resources, information sharing, investment in skill development and training, engagement, and participation.

Under the environmental dimension, the values of natural capital and ecosystem capital were identified. Indicators such as resource conservation and resource security showed net positive values due to the start of the operation of this project. These results are in line with the argument that industrial symbiosis secures and conserves resources due to the possibility of reclaiming the resources once discarded. Under ecosystem capital, reduction of water contamination was identified as positive due to this project. Other indicators such as odour, noise, and air emissions didn't show any improvement in the positive direction. Moreover, this project has increased the use of chemicals and energy as part of the treatment which were not to be ignored.

In the social dimension of industrial symbiosis, the results of the presence of human capital values showed that there were substantial increases in this capital due to this project. For example, about 75-100% increase was noticed by one company itself in the category of indicator 'the sharing of information between industries'. All other companies also agreed that there were an increase in the sharing of information. It was also noted that there was also opportunity for sharing infrastructure and technology between the partner industries. This result coincided with the information attained from the experience of Naroda Industrial Estate (NIA) in India where IS practices were applied (Wilderer 2002). Though this case is in the context of a developing country perspective, increase of human capital creates business opportunities even in the context of developed countries, since opportunities of knowledge-sharing are evident regardless of whether it is a developed or a developing country. In this case of the project, other indicators also highlight an improvement in human capital values for some of the companies individually. These are: shared occupational health and safety programs, investment in research and development, and employee management relations. The project concludes that an increase in human capital might leads to economic development (Cuthill 2003).

In regards to community capital, sharing of information between industries and communities has increased due to the KWRP project. The analysis found that there has been a 75-100% increase in collaboration between government agencies, an increase in level of understanding about IS projects (0-25%), an enhanced communication between various stakeholders (75-100%) and an increase in employment opportunities. These are notable increases in value that have been generated for community capital since the project started. It can therefore be seen that the true benefits of symbiosis are achieved not only from the operation of the project but also due to other social factors such as increase of connection, communication, networking and collaboration. This result confirms other studies that IS practices strengthen the EIP concept and increase the chances of sustainable development regionally due to collaboration of community of businesses and local and regional community (Chertow 1999; Cohen-Rosenthal 2000; Wilderer 2002). As outlined in Chapter two, the definition of EIP developed by the President's Council on Sustainable Development emphasizes the collaboration of the business community and local community in achieving environmental quality, enhancement of human resources and economic gains (Wilderer 2002).

In terms of economic dimension of the KWRP project, the participants of the projects did not gain any savings in hidden and legal costs, such as permits costs, compliance cost and future fines and penalties. The value of raw material cost was reduced up to 75-100% for one particular company. There were some savings on raw material costs (0-25%) for some companies. For some other companies, there were no savings, as there was cost associated with those providing infrastructure including pipelines and pumps. The majority of participants achieved no savings but rather accrued costs due to pipe and pump installations in addition to the high cost of reclaimed water. It is interesting to note that the companies were prepared to pay these costs for gaining long term economic benefits, since they realized that the security of resources in the long run is important for their business to operate successfully.

The thesis has highlighted that the second component of the KWRP project which receives industry's wastewater after pre treatment has the benefit of reducing the pollution load from industries from discharging to the immediate environment. For example, industries are prepared to pay for diverting the discharges from the immediate environment of Cockburn Sound to a more distant place where pollutants can be dispersed into the ocean. The concentrations can be minimised easily due to dispersion and through the Sepia Depression Ocean Outlet Landline (SDOOL).

The companies participated in this project also realised the importance of attaining a good reputation among the businesses and local community. For example, secondary data collected shows that there will be an appreciable reduction in the total discharges of contaminants into Cockburn Sound, since companies have agreed to participate in this project to divert the pollutant loads. By participating in KWRP project, a 19% reduction (from three companies alone) from the total anthropogenic load of total nitrogen (TN of 880 kg/d) will be achieved in the Cockburn Sound (Water Corporation of WA 2003, p.56). Similarly there will be reductions of total phosphorus (TP) (37.5%), total suspended solids (TSS) (38.1%), Arsenic (27.5%), Cadmium (55.3%), Mercury (33.3%), and Zinc (10 %) of the previous discharge from the three companies (Water Corporation of WA 2003, p.56). According to Water Corporation, there will be a Governance model to the KWRP to manage and govern the discharges to the SDOOL and to the Sepia Outlet. A Sepia Depression Outlet Stakeholder Liaison Group was also formed to oversee whether industries are exceeding the acceptance limit of nutrients during discharge to Sepia Outlet. These findings prove that importance of stakeholder participation and acceptance by industries in Kwinana.

The results in this case showed that though there were not major financial benefits from this project anticipated, the industries involved were prepared to pay the cost for discharging primary treated effluent away from Cockburn Sound in order to maintain their reputation and social license to operate in the community. This argument may be true for some countries with high regulatory conditions of fines and penalties. In the case of industrial areas in the Peoples Republic of China, however, the regulatory fines are lower than the cost of abiding by the law by providing pre-treatment facilities for complying with emission standards (Geng & Guang 2005). Inter-firm collaboration can be a solution in these cases, as the results of this study confirmed that in the long term, shared infrastructure for treating and reclaiming wastewater and other by-products will benefit the entire industrial community and local community. This will bring savings in the long-term due to reduction in waste disposal costs, treatment costs, storage costs, regulatory costs, legal and liability costs, but can also make savings on costs of resources, savings through reputation and the license to operate in the community.

This thesis concludes that there are several advantages for using the SCM to assess the benefits of IS. First, it assesses the values of ecosystem values created in addition to natural capital values. The Six Capitals Model will be able to identify the social benefits in terms of human capital and community capital. It also values the manufactured capital separately from financial capital. It therefore gives an opportunity to identify the value generated both to community and companies. These values can be used to identify the areas where the improvement needed. The model examines and calculates the internal and external costs and benefits. Industries will therefore be able to prepare to understand the real cost of the projects. By using this method, an integration of quantitative and qualitative data is also possible. One of the main advantages of this method is that with the right indicators, the intangible values of the IS process also can be assessed and valued. This thesis concludes that the Model does enable the intangible benefits associated with industrial symbiosis to be identified, analysed and integrated into a more detailed appreciation of the impacts of the symbiotic relationships.

The results of this thesis show that the there are broader benefits of symbiosis that have been achieved, not only from operation of the project, but also due to the influence of processes of symbiosis. There has been an increase in the networking of industries and formation of multi groups for addressing various issues faced by industry and community in the KIA. There has been a substantial increase in the transparency of information dissemination and communication for example, through industries council's website. In addition, there has been an increase in the rate of participation of community members and groups in the communities and industries forum, a multi stakeholder group established by industries council as a platform for addressing the issues of industries and communities. IS practices strengthen the EIP concept and increase the chances of sustainable industrial development regionally due to collaboration of community of businesses and local and regional community.

As part of the future research program, it was anticipated that this Model could be refined overtime by incorporating the results of application to projects of different geographical and organisational setup. Future analysis of data from the same project could also strengthen the Model. Social Network Analysis could be applied in the research site to verify the influence of symbiosis processes.

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APPENDICES

Industrial Synergies for Sustainable Development in Heavy Industrial Areas

Division of Resources and

Centre of Excellence in
Cleaner Production

Telephone +61 8 9266 4520
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Email j.altham@curtin.edu.au
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DATE

NAME
POSITION
ORGANISATION
ADDRESS1
ADDRESS2
COUNTRY

Dear XXX,

I am part of an Australian research team conducting a major research project on ***Industrial synergies for sustainable development in heavy industrial areas***. The project has a number of active industry partners, and is managed under the umbrella of the Kwinana Industries Council. After an exhaustive examination of the available literature we have identified 22 heavy industrial areas in 15 countries that we consider best practice in industrial symbiosis. In our opinion the **NAME OF AREA** is one of these. We are therefore seeking your support in this innovative project.

The Centre of Excellence in Cleaner Production is Curtin University's primary avenue for applied research on the business case and agenda for sustainable development. The Centre[1] has established a strong research and teaching commitment to industrial symbiosis. At its core, industrial symbiosis is about achieving synergies between industries and other organisations operating in a region, in particular through the exchange of materials, water and energy, either as products, by-products or waste. An introduction to industrial symbiosis in Australia and the Kwinana Industrial Area can be found in the paper, Industrial symbiosis for regional sustainability: an update on Australian initiatives.

Despite its compelling logic, industrial symbiosis faces a number of barriers. Our research will investigate such barriers and develop and pilot test innovative mechanisms for overcoming these. The research includes:

- A global baseline assessment of organisational arrangements for regional synergies in heavy industrial areas,
- The development and trialling of facilitating structures to improve the communication between companies, and increase knowledge of material, energy, water and waste flows and identifying synergistic opportunities.
- The development and trialling of operational and contractual arrangements that manage risk, minimise cost and equitably share benefits of inter-company cooperation.
- The development and trialling of evaluation tools, for synergies opportunities that properly cover social, economic and environmental perspectives.
- The investigation of supportive institutions and policies to increase the development of regional synergies.

The global[2] baseline assessment, the subject of this request, involves the research team gaining an in-depth understanding of the development of industrial exchanges, in particular exchange of material, energy and water in heavy industrial areas.

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[1] For further details visit the project's homepage http://cleanerproduction.curtin.edu.au/industry/is.html
[2] To ensure a global perspective Europe (6), America (7), Asia (7) and Australia (2) networks have been approached.

Industrial Synergies for Sustainable Development in Heavy Industrial Areas

We would like to obtain the views of three stakeholder groups in each heavy industrial area: industry, community and government. As we are not starting from scratch we have summarised our current understanding of industrial symbiosis in your heavy industrial area. Please amend this summary as you see fit, and provide us with any recent material published, references, or weblinks on industrial symbiosis. I would appreciate the opportunity to talk over the telephone at a mutually agreeable time to further expand on your responses.

The information you provide will be analysed with other information and responses from the Kwinana Industrial Area and will be consolidated in a comprehensive case study. The comprehensive analysis of all areas will enable us to gain a better understanding of key factors for successful and innovative industrial synergies. This will assist to increase knowledge on how better to advance industrial symbiosis, together with identifying common and unique barriers to their establishment and expansion. The research will also promote learning by sharing for participants in this work. These results will be presented at appropriate conferences, in relevant journals and available on the project's website http://cleanerproduction.curtin.edu.au/industry/is.html. The information on each heavy industrial area will be consolidated in a comprehensive and detailed case study, which will be published upon approval from the participants in the individual heavy industrial areas. Any further research publications (such as reports, journal papers and conference presentation etc.) can then be complied from the case study without renewed approval from the participants.

Furthermore, you may withdraw your consent for participating in this research at anytime. The completion of this questionnaire is acknowledgment to the research team of your organisation's willingness to participate in this research, the University also requires that you complete the attached consent form and return it to me.

Industrial Synergies for Sustainable

Development in Heavy Industrial Areas

Please download the document and complete it electronically if possible, then Email or fax the completed questionnaire to j.altham@curtin.edu.au or fax +61 8 9266 4811.

We request your collaboration in this exciting project and if you have any questions please contact me.

Sincerely yours,

Jim Altham

Dr William (Jim) Altham
Postdoctoral Research Fellow
Centre of Excellence in Cleaner Production
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Industrial Synergies for Sustainable

Development in Heavy Industrial Areas

Case History

The Kwinana Industrial Area (KIA) was established in 1952 with the construction of an oil refinery. The KIA has been Western Australia's premier heavy industrial precinct for more than 40 years and its prevailing level of prosperity will ensure the area remains a significant contributor to the State economy into the 21st century. Its location 35kms south of Fremantle on the shores of Cockburn Sound has promoted the co-location and unique integration of a diverse blend of industries. Kwinana's framework of heavy industry provides employment for 12,500. Indirect employment represents around 25,000 people. Future forecasts for employment related to industrial expansion in the region is estimated as an additional 11,500 jobs.

The Kwinana Industry Council is driving an exciting new initiative, called the Kwinana Industries Synergies Project, which is designed to improve the economic, social and environmental outcomes by industry working co-operatively together to:

- Convert wastes into useable products
- Reduce the generation of wastes
- Reduce greenhouse gases by improved energy efficiencies
- Reduce the use of fresh water and reuse treated wastewater
- Reduce wastewater discharges into Cockburn Sound.

The published material reported 104 current exchanges and 106 potential or under investigation, some examples of these are listed below.

Current Synergies

- TiWest converts waste hydrochloric acid from its pigment production into ammonium chloride for synthetic rutile production
- TiWest supplies waste heat to Western Power for a joint venture Cogeneration power plant
- Nufarm supplies waste HCl to Tiwest
- CSBP supplies of waste hydrogen and CO_2 to Air Liquide for conversion into commercial gases
- CSBP supplies gypsum to Alcoa
- WMC supplies waste CO_2 to Air Liquide and BOC gases for conversion into commercial gases
- WMC supplies calcium carbonate waste to Cockburn Cement for cement manufacturing
- WMC supplies Ammonium Sulphate to CSBP & others
- Edison Mission Energy and BP operate Cogeneration Plant in Joint Venture??
- BP & BOC supply hydrogen for the Clean Urban Transport for Europe (CUTE) bus project
- Western Power supplies fly-ash by for use as construction material ??
- Water Corporation supplies process water from the Kwinana Water Reclamation Project to HISmelt, CSBP. BP, Edison Mission and TiWest
- Alcoa supplies bauxite residue to Eco max for Sewage Effluent Treatment
- Alcoa supply hydrate to Australian Fused Materials
- CSBP supply CO_2 to Alcoa for carbonisation

Potential Synergies

- Red mud processed and the sand supplied by Alcoa for construction sand
- Slag supplied by HISmelt to unidentified customer
- Alcoa co-generation
- CO_2 supplied from CSBP to Alcoa for red-mud carbonisation

Industrial Synergies for Sustainable

Development in Heavy Industrial Areas

COMPLETE ONE PART 1 FOR EACH COMPANY/ORGANISATION

Part 1: Involvement in industrial symbiosis activities from your organisation's perspective?

1.1: When did your organisation first get involved in industrial symbiosis?

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1.2: How did your organisation get involved in industrial symbiosis?

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1.3: Why did your organisation get involved in industrial symbiosis?

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1.4 What does your organisation do to contribute to the development of synergies in the area?

____

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COMPLETE ONE PART 2A FOR EACH COMPANY/ORGANISATION

Part 2A: Detailed description of current synergies

List material exchanges that your organisation participates in, and which one do you consider as an icon example for the organisation?

Part 2B: Detailed description of potential exchanges

List potential exchanges would your organisation consider participating in?

____

____

____

____

Please copy and complete one part 2 A for each implemented exchange listed above.

Supply material ☐ or Receive material ☐

2.A.1: Name or type of exchanged material (ie. steam, water, by-products, CO_2, SOx, waste etc.), include details on volume/amount exchanged per year if available?

Company Name_________________________________Material________________________

____Amount ________________________Units

Name of collaborating company and/or sector? ______________________________________

2.A.2: Lack of communication and/or networking between potential exchange partners is considered as a major barrier to industrial symbiosis.

Where did the idea for the exchange originate from?

____

____

____

How did your company become aware of potential benefits for the other synergy partners?

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2.A.3: A sound understanding and evaluation of all economic, social and environmental implications of exchange projects, may lead to greater implementation of resource synergies. Please estimate the benefits of the exchange for your organisation, and quantify if possible?

Economic (ie cost savings, increase in revenue, risk management etc.)

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____

Social (jobs, community services, improved skills and job security, law and order etc)

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Environmental (reduction of waste to landfill, improvements in air and water quality etc)

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2.A.4: Please provide details on the costs and lead time for development and implementation of this exchange.

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2.A.5: What methodology was used to help identify and develop the exchange opportunity ie. did the exchange result from for instance, regional waste inventory or an input/output analysis?

____

____

2.A.6: What type of technology, equipment and /or infrastructure was put in place to enable the exchange?

____

____

____

2.A.7: What contractual arrangements has been setup to govern the exchange ie joint venture, shadow price (if not commercial sensitive)?

____

____

____

2.A.8: Are there any risks to the company from involvement in this exchange?

Environmental: ____

Business: ____

Other ____

2.A.9: How did you cover these risk in contractual terms (if not commercial sensitive)?

Please copy and complete one part 2 B for each potential exchange listed above

Supply material ☐ or Receive material ☐

2.B.1: Name or type of potential exchanged (ie. steam, water, by-products, CO2, SOx, etc.), include details on volume/amount exchanged per year if available?

Company Name: ______________________ Material ______________________

______________________ Amount ______________________ Units

Name of possible partner or sector? ______________________

2.B.2: What benefits could this exchange bring to your organisation?

2.B.3: What do you consider are the major barriers to the implementation of this exchange (ie. finding partner, not core business/ limited incentive, community opposition, capital etc)?

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2.B.4: What do you consider is required, or needs to be changed to ensure that this synergy will be implemented within the next 3 years?

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COMPLETE ONE PART 3 FOR EACH ORGANISATION

Part 3: Any further comments on industrial symbiosis in general to increase its adoption?

Industrial Synergies for Sustainable

Development in Heavy Industrial Areas

On behalf of the research team thank-you for taking the time to complete this questionnaire, and I will be in contact when all results have been collated and analysed. As a reminder can you please forward material or web-links to material published on your heavy industrial region.

Jim Altham

Industrial Synergies for Sustainable

Development in Heavy Industrial Areas

"QUESTIONNAIRE" CONSENT FORM

I ______________________________ have been nominated by the ________________________________ (organisation) operating in the __________________________ (industrial area) as the primary contact for my organisation, and have received and read the introductory letter attached to this consent form. My organisation agrees to take part in the research on ***Industrial Synergies for Sustainable Development in Heavy Industrial Areas***, conducted by the Centre of Excellence in Cleaner Production, Curtin University of Technology. Furthermore I agree that any follow up telephone discussion can be recorded and transcribed to assist the researcher to accurately capture the detailed content of the discussion. However, I know that my organisation has the right to withdraw from the research at any time without explanation, and in the event of such withdrawal request all material supplied to the research team will be destroyed or returned to my organisation as requested.

My organisation understands that all information provided is treated as confidential and will not be released by the research team or the University. My organisation understands that the information provided will be consolidated in a comprehensive and detailed case study on industrial synergy in Kwinana Industrial Area. The developed case study will only be disclosed publicly upon my written consent, such consent not to be withheld unreasonably.

Name & signature

____

Position

____

Organisation:

____

Curtin University of Technology

Industrial Synergies for Sustainable

Development in Heavy Industrial Areas

Date

____

Principal Investigator

____

Date

____

Please return by fax to Jim Altham on +61 8 9266 4811; on receipt of your, fax I will counter-sign the consent form and return fax the completed form.

Methodology for capturing environmental, social and economic implications of industrial symbiosis in Heavy Industrial Areas

DATE

NAME
POSITION
ORGANISATION
ADDRESS1
ADDRESS2
COUNTRY

Curtin University of Technology

Division of Resources and Environment

Centre of Excellence in

Telephone +61 8 9266 4520
Facsimile +61 8 9266 4811
Email j.altham@curtin.edu.au
Web: cleanerproduction.curtin.edu.au

Dear XXX,

I am part of an Australian research team based at Curtin University of Technology which is conducting a major research project on *Industrial synergies for sustainable development in heavy industrial areas*. This research is being led by Professors Jonathan Majer and Daniela Stehlik and is being auspiced by the Centre of Excellence in Cleaner Production. This project has a number of active industry partners including the Kwinana Industries Council. A research advisory group consisting of: Alcoa World Alumina Australia, BP (Kwinana) Refinery and CSBP (Kwinana) Ltd is active in this project.

My role in this study, as a PhD student, is to find a ***methodology for capturing environmental, social and economic implications of industrial symbiosis projects.*** "Industrial symbiosis is defined as the process leading to successful exchange of raw material, energy, water and by-products between two or more participants as well as the outcome which collectively brings industrial symbiosis in order to attain mutual benefits".

We have selected the Kwinana Water Reclamation Plant (KWRP) as a project case from Kwinana Industrial area because of its success in implementation within a reasonable time with active participation from a range of stakeholders. We are seeking your support in assisting in the gathering of data in order to verify a model being developed to assess implications of industrial symbiosis projects. As someone who had been identified as being a stakeholder in the KWRP project, I am writing to arrange a suitable time to visit with you and ask a series of questions. For your information, I have attached a copy of these.

As Curtin University has an ethical process for research which requires that I advise you of the purpose of the research and what the anticipated outcomes will be, I am also attaching an information sheet and consent form which I will collect from you at the time of the interview.

Thank you in anticipation of your support and your time for this project. I will be contacting you in the next few days to make the arrangements. In the meantime, my contact details can be found below.

Yours sincerely

Biji Kurup

Biji Kurup
PhD Candidate
Centre of Excellence in Cleaner Production
Email: b.kurup@curtin.edu.au
Phone: +61 8 9266 3130

The Centre of Excellence in Cleaner Production acknowledges the ARC Linkage Program and the Industry Partners (Alcoa World Alumina Australia (WA), BP Refinery (Kwinana), CSBP and KIC) for their funding of this project.

"QUESTIONNAIRE" CONSENT FORM

I ____________________________________ have been nominated by the _______________________________________ (organisation) operating in the ________________________________ (industrial area) as the primary contact for my organisation, and have received and read the introductory letter attached to this consent form. My organisation agrees to take part in the research on ***Methodology for capturing environmental, social and economic implications of industrial symbiosis in heavy industrial areas***, conducted by the Centre of Excellence in Cleaner Production, Curtin University of Technology. I know that my organisation has the right to withdraw from the research at any time without explanation, and in the event of such withdrawal, I will request you to destroy or return all material supplied to the research team to my organisation

My organisation understands that identity of the person and all the information provided is treated as confidential and will not be released to the public by the research team or the University. However the analysis of the results can be used as the research outcome.

Name & signature

____

Position

____

Organisation:

____

Date

____

Principal Investigator

____

The Centre of Excellence in Cleaner Production acknowledges the ARC Linkage Program and the Industry Partners (Alcoa World Alumina Australia (WA), BP Refinery (Kwinana), CSBP and KIC) for their funding of this project.

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No	Questions		Scales					Scores (%)			
	Kwinana Water Reclamation Plant (KWRP) and its industrial symbiosis outcomes	***Yes/No***	***Strongly disagree***	***Disagree***	***Neutral***	***Agree***	***Strongly agree***	***0-25***	***25-50***	***50-75***	***75-100***
1	KWRP project has increased water conservation										
2	KWRP project has increased water security										
3	KWRP project has reduced air emissions										
4	KWRP project has reduced water contamination										
5	KWRP project has reduced dust emissions										
6	KWRP project has reduced noise problems										
7	KWRP project has increased productivity of business										
8	KWRP project has improved retention of										

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No	Questions		Scales					Scores (%)			
	Kwinana Water Reclamation Plant (KWRP) and its industrial symbiosis outcomes	***Yes/No***	***Strongly disagree***	***Disagree***	***Neutral***	***Agree***	***Strongly agree***	***0-25***	***25-50***	***50-75***	***75-100***
	employees										
9	KWRP project has increased job security										
10	KWRP project has improved shared occupational health and safety programs										
11	KWRP project has increased investment in research and development										
12	KWRP project has increased sharing opportunities of infrastructure/technology										
13	KWRP project has increased information sharing between companies										

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No	Questions		Scales					Scores (%)			
	Kwinana Water Reclamation Plant (KWRP) and its industrial symbiosis outcomes	***Yes/No***	***Strongly disagree***	***Disagree***	***Neutral***	***Agree***	***Strongly agree***	***0-25***	***25-50***	***50-75***	***75-100***
14	KWRP project increased sharing of human resources between companies										
15	KWRP project has increased employee management relations										
16	KWRP project has decreased number of complaints from communities										
17	KWRP project has increased sharing of information between communities and industries										
18	KWRP project has increased level of understanding about the industrial symbiosis projects										

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No	Questions		Scales					Scores (%)			
	Kwinana Water Reclamation Plant (KWRP) and its industrial symbiosis outcomes	***Yes/No***	***Strongly disagree***	***Disagree***	***Neutral***	***Agree***	***Strongly agree***	***0-25***	***25-50***	***50-75***	***75-100***
19	KWRP project has increased networking between industries and communities										
20	KWRP project has increased the perception of communities in regards to environmental health										
21	KWRP project has increased public relation officer's opportunity to visit community groups										
22	KWRP project has increased publicity about the project in the community										
23	KWRP project has increased more opportunities of educational partnership										

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No	Questions		Scales					Scores (%)			
	Kwinana Water Reclamation Plant (KWRP) and its industrial symbiosis outcomes	***Yes/No***	***Strongly disagree***	***Disagree***	***Neutral***	***Agree***	***Strongly agree***	***0-25***	***25-50***	***50-75***	***75-100***
	for school children										
24	KWRP project has increased employment opportunities										
25	KWRP project has increased business opportunities										
26	KWRP project has increased infrastructure facilities for industries										
27	KWRP project has increased public infrastructure like efficient sewage treatment system, roads, and rails.										

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No	Questions		Scales					Scores (%)			
	Kwinana Water Reclamation Plant (KWRP) and its industrial symbiosis outcomes	*Yes/No*	*Strongly disagree*	*Disagree*	*Neutral*	*Agree*	*Strongly agree*	*0-25*	*25-50*	*50-75*	*75-100*
28	KWRP project has reduced direct or usual expenditure (labour, equipment, and raw materials)										
28	Labour										
29	Equipment										
30	Raw materials										
	KWRP project has reduced hidden costs (compliance, permit costs)										
31	Compliance costs										
32	Permit costs										
	KWRP project liabilities costs has reduced (penalties/fines, future liabilities)										
33	Penalties/fines										

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No	Questions		Scales					Scores (%)			
	Kwinana Water Reclamation Plant (KWRP) and its industrial symbiosis outcomes	***Yes/No***	***Strongly disagree***	***Disagree***	***Neutral***	***Agree***	***Strongly agree***	***0-25***	***25-50***	***50-75***	***75-100***
34	Future liabilities										
35	KWRP project has increased site visit opportunities of communities to industries										
36	KWRP project has improved collaboration of government bodies										
37	KWRP project has improved collaboration of communities										
38	KWRP has improved industry's stand towards community and Government										

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(Alcoa World Alumina Australia (WA), BP Refinery (Kwinana), CSBP and KIC) for their funding of this project.