

Environmental Performance of Clustered Firms

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ABSTRACT

There has been substantial research in recent years on the development dynamics of agglomeration economies - the industrial cluster perspective. However, the industrial cluster literature has tended to neglect the environmental impacts of clustering. Meanwhile, industrial ecology has tackled environmental concerns by promoting a new type of eco-friendly industrial system, eco-industrial park (EIP), that encourage circular flows of materials, energy and by-product exchange between neighbouring firms. Given that these two theories can potentially supplement each other, this doctoral study seeks to build bridges between the industrial cluster literature and the industrial ecology literature in order to address the research question: “how do clustered producers draw on inter-firm collaboration and institutional linkages to undertake holistic environmental upgrading strategies?” This study draws on comparative empirical evidence from the Banwol-Sihwa textiles dyeing cluster and the Yeosu petrochemical cluster in South Korea. Both the industrial clusters show a pattern of gradual environmental upgrading that is termed as ‘collective eco-efficiency’, although specific types of such collective behaviours have become differentiated due to their structural differences. The findings provide three key contributions to industrial ecology: (1) Intra-sectoral inter-firm relationships and regional firm-institutional relationships are much more influential in establishing an EIP than inter-sectoral inter-firm relationships on which industrial ecology has conventionally emphasised. (2) Although industrial ecology has mainly concerned of sectoral heterogeneity within an area, the multiplicity of production stages within an industrial cluster is also an important physical condition in establishing an EIP. (3) The notions of institutional setting and planning that have used in very ambiguous manners in industrial ecology are in essence a type of learning-by-interaction dynamics between local firms and other actors based on regional innovation systems. As for the industrial cluster literature, the findings in this study also suggests three conceptual implications: (1) Most studies addressing environmental issues in the industrial cluster literature have largely ignored the inter-sectoral dimension, the dynamics of collective efficiency is not necessarily limited within a sectoral boundary at least with regard to environmental upgrading. (2) Given that value chains do not necessarily match material flows, anchor tenant’s coordination power over material flows should be highlighted in addition to lead firm’s coordination power over value chains. (3) Regional innovation systems function as institutional ability to balance private benefits and social benefits.

DECLARATION

I, **Suk-Jin Yoon**, hereby, declare that no portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABBREVIATIONS

AGEC: Ansan Green Environment Centre
BDEC: Banwol Dyeing Enterprise Cooperative
CEO: Chief Executive Officer
CSR: Corporate Social Responsibility
EFC: Electric Fume Collector
EIP: Eco-Industrial Park
ISO: International Organisation for Standardisation
KAIST: Korea Advanced Institute of Science and Technology
Kbiz: Korea Federation of Small and Medium Business
KICOX: Korea Industrial Complex Corporation
KITECH: Korea Institution of Industrial Technology
KNCPC: Korea National Cleaner Production Centre
KoFC: Korea Finance Corporation
KPIA: Korea Petrochemical Industry Association
KPU: Korea Polytechnic University
KTL: Korea Test Laboratory
LCA: Life Cycle Assessment
MOTIE: The Ministry of Trade, Industry and Energy
NGO: Non-governmental Organisation
NISP: National Industrial Symbiosis Programme
ODM: Original Design Manufacturing
OEM: Original Equipment Manufacturing
OHSAS: Occupational Health & Safety Management System
PCRD: Presidential Committee on Regional Development
POSTEC: Pohang University of Science and Technology
RIS: Regional Innovation System
SCDEC: Seoul and Central Regional Dyeing Enterprise Cooperative
SDEC: Sihwa Dyeing Enterprise Cooperative
SHGEC: Siheung Green Environment Centre
SMEs: Small and Medium-sized Enterprises
YIEA: Yeosu Industry Environment Association

DEDICATION

To my beloved mother,

Suk-Hee Kim

For her love and support

&

With heartfelt thanks to
my sisters and brothers-in-law

ACKNOWLEDGEMENT

In my early 20s, I visited a small industrial town where local residents were waging a solitary struggle against an industrial waste incinerator construction. An industrial waste disposal field was already located in the area, causing damage to neighbouring farms. Local farmers had occupied the construction site in order to stop the building work, while the construction company tried to forcibly drive the local people out of the construction site. I stayed there and helped the local residents for three months. This environmental dispute posed a question about an alternative business model to minimise environmental damage to nature and residential communities for me. This thesis is an answer that I have found after many years of searching.

Throughout my PhD study, I have received warm hearted encouragement and support. Above all, I would like to give my utmost thanks to my supervisor, Dr. Khalid Nadvi, who has given me guidance in the whole process of this study as well as mental support during the PhD programme. The most invaluable insights and his insightful comments and instructions have always been sufficient to quench my thirst for knowledge. I also appreciate Professor Philip Woodhouse who continuously stimulated my intellectual curiosity and facilitated my thinking process.

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I. INTRODUCTION

1.1. Objectives and Justification of the Study

What is your image of industrial clusters? To this question, some would imagine a vibrant manufacturing site full of workers and production equipment. Simultaneously, others might picture a pollution haven filled with odour and unclean water. These two different images reflect the positive and negative aspects of industrial clusters. The negative aspect of agglomerated industrial activities is being increasingly highlighted. We frequently hear news about environmental degradation and health problems directly related to pollution crises caused by intensive manufacturing activities in industrial regions.

This doctoral study addresses the dark side of industrial clusters. As environmental concerns are being amplified across the world, it is now commonly recognised that environmental sustainability is one of the key areas for industrial competitiveness. More importantly, environmental issues generated from clustered firms are a matter of survival not only for specific firms, but for the wider population that resides within and near industrial regions. For these reasons, the environmental sustainability of industrial clusters can no longer be ignored. Unless environmental damages from industrial clusters are mitigated, clustering cannot be regarded as a sustainable business strategy. This study aims to make a contribution towards this agenda by investigating the connections between the competitiveness aims of industrial clusters and the sustainability goals of industrial ecology.

South Korea presents a particularly relevant case to study this agenda. The South Korean government has initiated an eco-industrial park programme (EIP), operating in eight industrial regions of the country, to improve the environmental sustainability of local industrial clusters. EIP is a territorial industrial system to facilitate by-product exchanges and energy cascading between neighbouring firms. EIP is basically a technical engineering solution to minimise industrial wastes and maximise resource productivity. A major concern in implementing an EIP is that two or more firms should be involved due to its character as inter-firm by-product exchanges. In other words, a group of firms have to communicate and collaborate with each other. For this reason, an EIP tend to be established through complicated interactions and is affected by various social factors.

Taking note of this social dimension of the new industrial system, this doctoral study raises the core question: “how do clustered producers draw on inter-firm collaboration and institutional linkages to undertake holistic environmental upgrading strategies?” In order to address the core research question, I draw on evidence from the Banwol-Sihwa textile dyeing cluster and the Yeosu petrochemical cluster in South Korea. The two industrial clusters are part of the industrial regions that were designated as EIPs by the Korean government. While Banwol-Sihwa is a typical industrial cluster dominated by small and medium sized firms, vertical production systems led by large firms are common in Yeosu. This difference points to potentially differentiated pathways towards EIP development, thereby introducing a critical comparative dimension to this study.

1.2. Potential Theoretical Contribution

Inspired by the lesson from a small industrial town, Kalundborg in Denmark, the industrial ecology literature insists that linear material flows in the conventional industrial system can be converted into material circulation systems (Graedel, 1994; Lifset and Graedel 2002). Firms located in Kalundborg have developed this type of material circulation system over the last 40 years. Since the emergence of industrial ecology, an increasing number of industrial areas have employed industrial ecology principles. Some industrial areas that have already developed material circulation systems have been uncovered and labelled as following industrial ecology practices (Chertow, 2007; Van Berkel, 2009). One of the main arguments in the industrial ecology literature is that by-products generated by a producer can be reused by neighbouring producers as raw materials. As practical models, industrial ecologists suggest the possibility of environmental management practices based on synergy effects arising from geographically agglomerated firms. These are often termed ‘eco-industrial parks’ (EIP) or ‘industrial symbiosis’ (Lowe, 1997; Ayres and Ayres, 2002; Chertow, 2004; Lambert and Boons, 2002).

This line of thinking is relevant to another school of thought that has intensively investigated agglomeration economies, the industrial cluster literature. Industrial cluster theory has its roots in Alfred Marshall’s classical work on the early European and especially British industrial districts of the late 19th Century. This viewpoint was more recently resurrected by Italian researchers in the 1970s and 1980s and termed industrial

districts (see for example, Becattini, 1990; Brusco, 1990; Markusen, 1996) This phenomena, of firm agglomeration, has been significantly developed within economic geography, business studies and development economics under the more generally accepted terminology of industrial clusters. The main concern of the industrial cluster literature is how clustered firms maintain and improve their industrial competitiveness. Especially, the industrial cluster perspective places a great deal of emphasis on the importance of social factors and inter-firm networks on economic ties within a regional territory.

Both the industrial ecology and the industrial cluster literatures have notable gaps with respect to the attainment of environmental sustainability. The industrial ecology literature, which has its origins in the natural science and industrial engineering disciplines, is weighted towards technical solutions (Boons and Roome, 2001; Hoffman, 2003; Korhonen *et al.*,2004). Concentrating on physical and technical approaches is still the overwhelming tendency within the field resulting in a huge weakness in industrial ecology theory. In this regard, an increasing number of studies have begun to investigate social factors of industrial ecology (Lowe, 1997; Schlarb, 2001; Lambert and Boons, 2002; Cohen-Rosenthal, 2003; Baas and Boons, 2004; Deutz and Gibbs, 2004; Deutz and Gibbs, 2008; Gibbs, 2009). However, most social science based studies in the field of industrial ecology have focused on exploring social factors affecting firms' behaviours in establishing networks of by-product exchanges and energy cascading, rather than investigating more fundamental dynamics. One of the weaknesses in the industrial cluster literature is its limited attention to environmental concerns caused by the economic activities of clustered firms. An intensive agglomeration of manufacturing activities within a limited area is more than likely to cause environmental damage, including various types of pollution. In response to this criticism, some authors in the field of industrial cluster have begun to study environmental issues (Kennedy, 1999; Tewari and Pillai, 2005; Crow and Batz, 2006; Almeida, 2008; Konstadakopulos, 2008; Mazzanti and Zoboli, 2009; Lund-Thomsen and Nadvi, 2010). However, most studies addressing environmental joint actions of clustered firms in the industrial cluster literature have paid limited attention to end-of-pipe solutions. Therefore, in both the industrial cluster literature and the industrial ecology literature, it is still unclear what dynamics underlie the environmental performance of clustered firms.

It is this gap that this dissertation aims to fill. The industrial ecology literature provides practical models of inter-firm cooperation to solve environmental problems, raising

questions about economic, political and social dynamics underlying inter-firm synergy effects. The industrial cluster literature provides substantial explanations about economic, political and social dynamics of inter-firm cooperation within an industrial area, manifesting interest in environmental issues. Therefore, the two theories can potentially supplement each other and fill gaps in a complementary manner. This doctoral study seeks to build bridges between the industrial ecology literature and the industrial cluster literature and thereby address gaps in both theories.

1.3. Research Questions

There are four propositions put forward in this doctoral study. First, environmental performance of clustered firms is driven by external pressures. A reading of the case studies on environmental upgrading of industrial clusters illuminates that some external impacts like government regulations, community petitions and international environmental standards urge clustered firms to undertake joint actions for environmental performance. The second proposition is that the characteristics of the local production system influence environmental joint actions of clustered firms. Cluster upgrading normally reflects the nature of the local production system. Accordingly, it can be supposed that the environmental performance of clustered firms is differentiated by the nature of the local production system. The third proposition put forward is that local non-firm institutions support clustered firms to improve their environmental performance. The industrial cluster literature, especially when drawing on the regional innovation system approach, has highlighted the roles of institutional support system surrounding an industrial cluster. Therefore, it can be proposed that non-firm institutions contribute to environmental performance of clustered firms. The final proposition is that different types of industrial clusters take differentiated pathways towards an EIP. These four propositions are suggested to explore an industrial cluster's holistic environmental upgrading strategies toward EIP development. In parallel with the four propositions, I postulate four sub-questions as follows;

- (1) What sort of environmental problems arise from an industrial cluster?
- (2) How does the nature of the local production system affect the EIP development of clustered firms?

- (3) In what way do institutional support systems facilitate the collective actions of clustered firms to promote EIP development?
- (4) What are the comparative lessons from the different environmental upgrading strategies between the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster?

1.4. Introduction to the Case Studies

This research adopts a case study methodology. Empirical evidence from two industrial clusters, the Banwol-Sihwa textiles dyeing cluster and the Yeosu petrochemical cluster is used to address the four research questions. The two industrial clusters have been developed towards EIP under a government scheme, the EIP programme. Therefore, it might be useful to introduce the Korean EIP model briefly.

1.4.1. Korean EIP Model

The Korean EIP model partly stems from a research project by the Korea National Cleaner Production Centre (KNCPC) of Korea Institution of Industrial Technology (KITECH) in 2002. The Ministry of Industry and Resource (currently the Ministry of Trade, Industry and Energy: MOTIE) accepted the policy suggestion from the research and formally launched the EIP programme in 2005. The national EIP plan consists of three five-year phases. The first phase between 2005 and 2010 sought to establish groundwork and networking. The second phase between 2010 and 2014 aims to widen EIP networks from the industrial complex level to the province level. The last phase from 2015 is plan to construct EIP networks at the national scale. The government has allocated some parts of the national R&D budget for this programme and designated five industrial regions as the EIP areas at the initial phase: Banwol-Sihwa, Yeosu, Ulsan, Cheongju and Pohang. Three more industrial regions were added at the beginning of the second five-year phase.

The Korean EIP initiative is formally called an ‘ecological industrial complex.’ This legal concept was introduced with the enactment of the Act on Promotion of the Conversion into Environment-friendly Industrial Structure in 1995. This law is a remarkable turning point

in driving the Korean industrial structure in an environment-friendly manner by regulating the government's roles to facilitate not only EIP but also other environmental management practices such as cleaner production processes, green management, and the adoption of international environmental standards. According to the act, an ecological industrial complex is described as “the industrial complex designated... in order to minimize the burden to environment and to maximize the efficiency of resources by regenerating the remnants, such as by-products, etc. generated in the course of manufacture of products, and wastes into raw materials or energy” (Act No. 10615, Article 4-2). MOTIE is in charge of designating and managing the national EIP programme. The Act on Promotion of the Conversion into Environment-friendly Industrial Structure specifies five main undertakings for which the government can provide financial assistance and other supports as follows;

- The development and propagation of technology for the connected utilization of resources and energy among enterprises within the ecological industrial complex;
- The construction of comprehensive management system of resources and energy within the ecological industrial complex;
- The cultivation and education of specialists related with the construction of ecological industrial complexes;
- Cooperation with local communities for construction of ecological industrial complexes;
- Other projects prescribed by Presidential Decree for construction of ecological industrial complexes (Act No. 10615, Article 21; Amended on 24 May 2011).

The government plays the role of disseminating recycling technology, providing administrative services, managing expert pools and networking local stakeholders. In practice, the central government bureaucracy alone cannot assume full charge of the EIP implementation because the EIP is basically formulated, and implemented, at the local level. For this reason, MOTIE delegates authority to an agency which can be specialised for the EIP programme (Act No. 10615, Article 21-3; Amended on 24 May 2011). Korea Industrial Complex Corporation (KICOX) is the lead agency of the EIP programme. KICOX defines the term of EIP in the Korean context as follows:

“...an industrial complex utilizing industrial ecology, which deals with the laws of natural ecosystem to be applied to industry. In eco-industrial park, by-products, wastes, wasted energy produced within eco-industrial park are recycled as material and energy source for other companies and factories, aiming for zero emission” (the Korea EIP website, www.eip.or.kr).

Clearly, the expressions of “the laws of natural ecosystem” and “zero emission” in this definition exhibit the normative and state-directed character of the Korean EIP model. The industrial symbiosis models in East Asia tend to be developed via policy instruments (Behera *et al.*, 2012) and the Korean EIP is one of the examples.

1.4.2. Banwol-Sihwa Textile Dyeing Cluster and Yeosu Petrochemical Cluster

The case studies of this research were implemented in the Banwol-Sihwa textile dyeing cluster and the Yeosu petrochemical cluster. The textile dyeing cluster is located in the Banwol-Sihwa region that is notorious for its nickname of “industrial district for polluters” (Park and Markusen 1995, p. 90). The Banwol-Sihwa region was established in order to accommodate pollution-emitting small and medium sized firms (Jung, 2006). Accordingly, the Banwol-Sihwa industrial complex was predestined to be a polluted (and polluting) region. The dyeing cluster is one of the groups that were singled out as pollution-emitting industries by the government and transplanted from the Seoul capital region to Banwol-Sihwa. As the Banwol-Sihwa region was designated as an EIP by the government in 2006, the textile dyeing cluster began to participate in the EIP programme. The dyeing cluster is a typical agglomeration of small and medium sized firms and a part of the global apparel value chains. The case study on the Banwol-Sihwa textile dyeing cluster shows an interesting story on how the SME cluster has achieved EIP development.

The Yeosu industrial complex is a single-industry region. Vertically integrated production systems led by large petrochemical and chemical firms are common in Yeosu. Yeosu is a historical harbour city located on the southern coast of the Korean peninsula. During the war with Japan between 1592 and 1598, Yeosu was one of the major naval bases. In the modernisation period, Yeosu experienced a series of bitter historical events: the invasion of the English fleet in 1885, the peasants’ war against Japanese imperialism in 1894 and the military rebellion caused by the ideological struggle in 1948. After being developed as an

industrial site, the Yeosu region had undergone a series of environmental disputes and disasters from the mid-1990s to the early 2000s. The central government designated the Yeosu region as an EIP area in 2005. The case study on the Yeosu petrochemical cluster shows how the large firm cluster has confronted these serious environmental disputes and finally attained EIP development.

1.5. Thesis Structure

The thesis is structured as follows: **Chapter 2** is dedicated to the literature review on industrial ecology and industrial clusters. The literature review on industrial ecology is mainly concerned with the social dimension of EIP developments. The existing studies on the social dimension of industrial ecology suggest four social factors: mental distance, roles of champion, institutional setting and planning. In terms of the industrial cluster literature, this chapter is focused on the discussions on the three main dynamics of industrial cluster upgrading: collective efficiency, value chain governance and regional systems of innovation. Integrating the four social factors of industrial ecology and the three dynamics of industrial clusters respectively provides the basis for developing the analytical framework for this study. Therefore, chapter 2 suggests the conceptual foundations with which the industrial ecology literature and the industrial cluster literature can be bridged. Based on the discussion on building bridges between the two literatures, I suggest the key theoretical notion of this study, collective eco-efficiency.

Chapter 3 is an overview of the research methodology employed in this doctoral study. Case study methodology is the main research strategy to understand the dynamics underlying the EIP phenomena in the two industrial cluster case studies. This chapter begins with discussing the philosophical foundation of this study, social constructivism. In sequence, the research design, the case selection criteria and the research procedure, data collection and analysis process are introduced and detailed. Finally, this chapter elucidates the validity, the reliability and the ethical issues of this study.

Chapter 4 addresses the first research question: “What sort of environmental problems arise from industrial cluster?” This chapter begins with the introduction to the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster and their environmental concerns. The environmental concerns have triggered a series of societal interactions in the

Banwol-Sihwa region and the Yeosu region. The investigation on these societal interactions identifies the drivers that have encouraged environmental upgrading towards EIP development in the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster. Accordingly, this chapter is mainly devoted to the narrative on the societal reactions surrounding the environmental concerns in the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster. The narrative from the two industrial clusters demonstrates how environmental collective failures can be redirected towards collective eco-efficiency.

Chapter 5 and **Chapter 6** seek to analyse the dynamics underlying the EIP developments drawing on empirical evidence from the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster. A cluster's environmental upgrading reflects the nature of local production system and institutional support system. In accordance with this proposition, these two chapters address the second research questions: "how does the nature of local production system affect the EIP development of clustered firms?" and the third research question: "in what ways does institutional support system facilitate collective actions of clustered firms to promote EIP development?" The empirical evidence from the two industrial clusters are analysed with the four social factors of industrial ecology and the three dynamics of industrial clusters. Chapter 5 investigates the EIP development in the Banwol-Sihwa dyeing cluster and chapter 6 analyses the EIP development in the Yeosu petrochemical cluster.

Chapter 7 addresses the last research question: "what are the comparative lessons from the different environmental upgrading strategies between the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster?" The Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster have very different characteristics of local production system and institutional support systems. First, while the Banwol-Sihwa dyeing cluster is an agglomeration of small and medium sized firms, the Yeosu petrochemical cluster is a large firm agglomeration. Second, while the Banwol-Sihwa dyeing cluster is a part of globalised value chains, the production system of the Yeosu petrochemical cluster consists of localised value chains. Third, the Banwol-Sihwa dyeing cluster is engaged in buyer-driven value chains, the Yeosu petrochemical cluster can be seen as producer-driven value chains. Last, the Banwol-Sihwa dyeing cluster is surrounded by a typical regional innovation system consisting of innovation support organisations, the petrochemical and chemical firms lack such an innovation support environment but do work in cooperation with civil society organisations. Chapter 7 analyses the finding from the case studies in accordance

with these four different dimensions and, thereby, provides comparative lessons on different pathways towards environmental performance of clustered firms.

Chapter 8 summarises the theoretical discussions of this research and the findings from the case studies on the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical clusters. In addition, this chapter identifies the limitations of this study and suggests the recommendations for further research.

II. THEORETICAL FRAMEWORKS: BUILDING BRIDGES BETWEEN INDUSTRIAL ECOLOGY AND INDUSTRIAL CLUSTER

2.1. Introduction

This chapter reviews the existing literature on eco-industrial parks and industrial clusters. Industrial ecology has dramatically developed with its rigid technical base and various engineering models over the past two decades. One of the noticeable advances in industrial ecology is developing by-product exchange and energy cascading practices between co-located firms within an industrial area. However, the social dimension still remains relatively under-studied in the industrial ecology literature, despite the widespread awareness of the necessity to understand the economic, political and social dimensions of practical industrial ecology models. At the same time, there has been substantial research on the development dynamics of industrial regions - the industrial cluster perspective, and its socio-economic underpinnings. However, there has been a relatively limited attention on environmental concerns in the industrial cluster literature. Potentially, the two perspectives could throw light on different aspects of industrial landscape which are a theoretical gap for each other. Together these gaps constitute the core research question for this study: “how do clustered producers draw on inter-firm collaboration and institutional linkages to undertake holistic environmental upgrading strategies?”

This chapter aims to build bridges between the two overlapping academic perspectives to set up a theoretical framework in order to answer the core research question. The second section of this chapter is dedicated to reviewing the basic ideas of industrial ecology, and to considering the social dimension within the industrial ecology framework, and the possible linkages that arise with the industrial cluster perspective. The third section is devoted to a critical review of the industrial cluster literature, raising questions on how the industrial cluster literature can deal with environmental concerns. The last section of this chapter provides a discussion on how to build theoretical bridges between the industrial ecology literature and the industrial cluster literature. This suggests a potentially important conceptual contribution by this doctoral study to fill gaps in existing theoretical bodies.

2.2. Industrial Ecology

Industrial ecology, a newly emerging field of study, is one of main theoretical bodies in this research. In accordance with the increasing concern about environmental issues across the world, a variety of approaches have been introduced to decrease the negative impacts of industrialisation on the environment. In the same context, industrial ecology aims to explore the co-existence of industrialisation and nature. This perspective tackles the conventional thinking that industries necessarily cause environmental concerns and insists that the human industrial system can be harmonized with nature by imitating the biological ecosystem.

2.2.1. The Conceptualisation of Industrial Ecology

Identification of Industrial Ecology

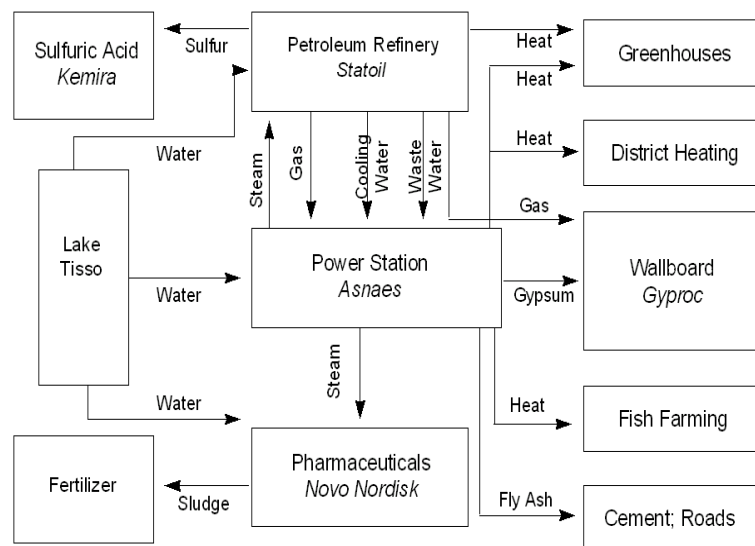
Many studies on industrial ecology have indicated that there are two origins of the new approach. The first is the concept of industrial metabolism developed by Robert Ayres in 1989. Ayres uses the term ‘industrial metabolism’ because the industrial economy resembles the biosphere in that both imply a transformation of materials. In addition, he insists that we have to learn from the biosphere to increase sustainability and efficiency in production and the use of by-products (Ayres, 1989). The second origin appeared in the article by Robert Frosch and Nicholas Gallopoulos. While pointing out the circulation of resources and energy in biological systems, they maintain that the traditional model of industrial activities should be transformed into a more integrated model, an industrial ecosystem, which copies the advantages of the biological system. (Forsch and Gallopoulos, 1989).

In succession to this line of the literature, industrial ecology acknowledges that our economic system is “always only a subsystem of the larger ecosystem and dependent on it” (Korhonen, 2001, p. 258). This suggests that industrial ecology argues for a switch-over to an integrated holistic point of view regarding the central relationship between human beings and nature. The epistemological position of industrial ecology is based on the combination of the two potential contradictions between industry and ecology (Erkman, 1997). Economic systems are functioning within the biosphere, instead of regarded as an

isolated space from ecological systems (Socolow, 1994; Graedel and Allenby, 1995; Green and Randles, 2006). In the industrial ecology perspective, nature is not the objective, which is the target of management and control against the subjective human beings. If this perception is accepted, industrialisation might be not in conflict with nature at least in terminological meanings any more.

The practical origin of industrial ecology is the fascinating success story of an industrial town, Kalundborg, in Denmark. Since 1960s, Kalundborg has formed its distinctive circulation system of energy and by-products. The system consists of about 18 linkages and 6 key actors; Asnaes Power Station, SK Power's 1350-megawatt power plant; Statoil A/S, a large oil refinery; Nova Nordisk, a multinational biotechnology company; Gyproc, a Swedish company producing plasterboard; Bioteknisk Jordrens, a soil remediation company; and the town of Kalundborg (Erkman and Ramaswamy, 2006, p.37). A network of wastes, by-products and energy flows operates between these key players and other participants like residents and farmers. Since the Kalundborg model has been labelled with ecological metaphors as the prototypical industrial ecology practice, a growing number of symbiosis-like networks have been promoted, recognised and uncovered across the world (Chertow, 2007).

[Figure 2-1] Schematic Diagram of the Industrial Symbiosis in Kalundborg, Denmark



*Source: Allenby and Graedel (1999, p. 49)

With the development of the new perspective, industrial ecology has widened its scope of research. There is, as yet, no standard definition of industrial ecology. Nevertheless, one of the commonly accepted definitions of industrial ecology is suggested by Graedel and Allenby. In the first textbook on industrial ecology, published in 1995, they said,

Industrial ecology is the means by which humanity can deliberately and rationally approach and maintain a desirable carrying capacity, given continued economic, cultural, and technological evolution. The concept requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them. It is a systems view in which one seeks to optimize the total materials cycle from virgin material, to finished material, to component, to product, to obsolete product, and to ultimate disposal. Factors to be optimized include resources, energy, and capital (Graedel and Allenby, 1995, p. 9).

This definition demonstrates three basic characters of industrial ecology. First of all, industrial ecology definitely pursues technical changes. A majority of authors in the field of industrial ecology see technical innovation as one of main research themes and measures of solution to environmental concerns (Lifset and Graedel, 2002). Second, industrial ecology aims at changing existing industrial systems deliberately into a desirable condition, as disclosed in the definition. This normative and policy-driven feature of industrial ecology provokes the necessity of understanding economic, political, and social factors which have an influence on the flow of resources (White, 1994). Last but not least, industrial ecology suggests a system perspective to cover a whole circulation of materials and energy, rather than focusing on individual manufacturing processes. This characteristic is the key driver for the development of two research strands of industrial ecology; the debates on material flow analysis in value chains (Searing 2004; Koponen, 2009; Seuring *et al.*, 2009), and the discussions on the geographical boundary (Baas and Boons, 2004; Jensen *et al.*, 2011; Lombardi and Laybourn, 2012).

From Linear flow to Closed Loop

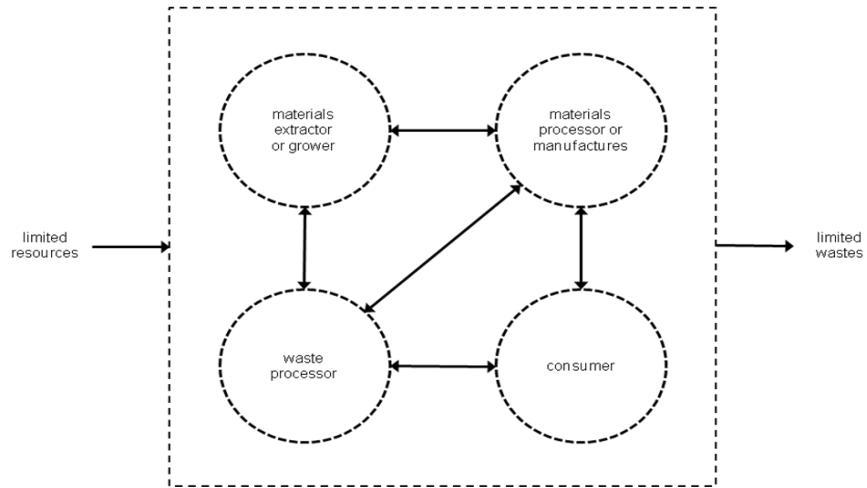
Most studies in the field of industrial ecology have their common features. The most prominent one is the argument that existing industrial systems should be renewed like an ecosystem (Frosch, 1992; Erkman, 1997; Fleig, 2001; Gibbs, 2003). While natural ecosystems are a cyclic system in which every waste and by-product from some animals

and plants can be reused by other species, the current human industrial system is a collection of linear flows. In the process of creating economic values humans just extract materials and fossil energy from nature and dump wastes into nature (Tibbs, 1993). Industrial ecologists think that the current linear system is not sustainable (Jelinski *et al.*, 1992; Socolow *et al.*, 1994; Fleig, 2001; Korhonen, 2003). Therefore, the fundamental solution suggested by industrial ecology in order to solve environmental problems is reforming the traditional industrial systems as a circulating process of materials and energy by imitating the biospheres. So-called 'closed-loop' system as a symbolised expression of industrial ecology, means facilitating flows of materials and energy between product units within an industrial system. The following diagrams show the differences between conventional industrial models and models of industrial ecology.

[Figure 2-2] Shift from Linear Materials Flows to Closed Loop



(a) Linear material flows in the conventional industrial system



(b) The practical model of industrial ecology

*Source: Modified from Socolow et al (1994: 25~27) and Lifset and Graedel (2002: 5)

While Model (a) shows a typical linear process, Model (b) reflects the ideal material flows of industrial ecology. At each stage from the processing of raw materials to the consumption, the flows of recycled materials can be noticed. Not only that, at all stages in the material flows, actors exchange their by-products and extra energy. As a result, inputs as virgin resources and outputs as wastes are limited.

Superset of environmental management practices

Industrial ecology has the characteristic as an integrated approach of various environmental management practices. Industrial ecology is the most highly evolved of these stages, embracing all the other environmental management approaches as its subsets (Hamner, 1996).

This doctoral study simplifies various environmental management practices into three major approach; pollution control, cleaner production and industrial ecology. Pollution control is an approach to capture and treat pollutants whereby their impacts to the nature can be reduced (Glavič and Lukman, 2007, p 1879). Considering that this approach is

focused on how to restrain pollutants already generated from spreading in unexpected ways, pollution control can be distinguished from cleaner production and industrial ecology. Cleaner production refers to the improvement of industrial processes and products that prevent pollution and reduce resource use and then minimise risks to the environment (Van Berkel *et al.*, 1997; Glavič and Lukman, 2007). In other word, the main concern of cleaner production is applying environmental improvement methods to production processes to ensure that pollutants are not generated or at the very least minimized. Cleaner production includes pollution prevention methods such as product modification, input substitution, technical modification and on-site recycling, toxic use reduction and eco-design (Van Berkel *et al.*, 1997). Accordingly, cleaner production can be distinguished from pollution control as a set of *ex ante* environmental management practices.

The authors in industrial ecology believe that redesigning the existing industrial systems is the most effective solution to the ecological problems caused by industrialisation. Such *redesigning* requires firms to be involved in inter-firm by-product exchange and energy cascading networks and thereby give rise to changes and rearrangement of other environmental management approaches like pollution control and cleaner production that are adopted into production. Therefore, in order to implement industrial ecology practices, it is necessary to understand the interrelation between pollution control, cleaner production and industrial ecology.

2.2.2. Industrial Symbiosis: The Regional Approach of Industrial Ecology

Research Areas of Industrial Ecology

Industrial ecology is an interdisciplinary approach and thus encompasses a variety of research strands and methods. Van Berkel and his colleagues suggest that industrial ecology has four subfields: material-focused approach, commodity-focused approach, region-focused approach and actor-focused approach (Van Berkel *et al.*, 1997). The material-focused approach is the area where the flows of specific materials through an industrial society is analysed via particular methods like substance flow analysis. The commodity-focused approach is similar to the material-focused approach but has a wider sense. The analysis focuses tracking component materials of selected products and optimising product-environment interaction. The representative method used in this

approach is life cycle assessment (LCA). Yet another approach, the most well-known, is industrial symbiosis or eco-industrial park. This regional-focused approach can be understood as the optimisation of material flows at the spatially defined local level. Finally, the actor-focused approach is the social dimension of industrial ecology that leads to an alternative form of industrial policy, namely eco-industrial development. It is a system that delivers sustainable environmental development alongside social and economic dimensions of such development (Chiu and Yong, 2004).

The first two approaches and the latter two approaches tend to be integrated respectively in more recent literature of industrial ecology. Boons and Howard-Grenville (2009) classify the research areas of industrial ecology into two lines: production chain approach and regional approach. The production chain approach involves analysis of material life cycles along with a set of productions. This embraces the material-focused approach and the product-focused approach. On the other hand, research on geographically bounded networks like industrial symbiosis, eco-industrial park and eco-industrial development are labelled with the regional approach.

The theoretical boundary of this study is limited to the regional approach of industrial ecology because it has many commonalities with the industrial cluster literature.¹ In this context, some industrial ecologists take the view that eco-industrial development is a policy can foster local and regional development (Lowe, 1997; Schlarb, 2001; Deutz and Gibbs, 2008). Deutz and Gibbs (2008) in particular interpret eco-industrial development as a variant of industrial cluster policy.

Industrial Symbiosis

The regional approach of industrial ecology is better known as industrial symbiosis in academia. The term ‘industrial symbiosis’ first emerged to express organic relationships between different industries by George T. Renner in 1947 (Yang and Feng, 2008). This

¹Although the production chain approach of industrial ecology is beyond my doctoral study, this research tendency suggests a very interesting research agenda. In similar fashion that the industrial district and industrial cluster literature has developed with the global value chain and production network literature, industrial ecology is evolving toward its vertical dimension in a form of production chain approaches. A few nascent studies aiming at building bridges between the industrial ecology literature and the value chain literature has already been implemented by a group of industrial ecologists (for example, Koponen 2009; Seuring 2004; Seuring et al 2009).

concept was reintroduced in Lowe and Evans' research in 1995 on industrial complexes in which dissimilar industries exchanged materials on a large scale (Lambert and Boons, 2002). According to Chertow (2004), industrial symbiosis can be defined as place-based resource flow management and exchanges among firms engaged in traditionally separate industries. By importing a biological term, symbiosis, which is defined as a close sustained living together of two species or kinds of organisms (Ehrenfeld and Chertow, 2002, p. 335), the concept of industrial symbiosis is used to build reciprocal exchanges of resources in a diverse business community. There are three synergies that can be seen as industrial symbiosis (Chertow and Ashton, 2009, p. 129):

- By-product exchanges: use of traditionally discarded materials or wastes as substitutes for commercial products or raw materials;
- Utility sharing: pooled use and shared management of commonly used resources such as steam, electricity, water and wastewater;
- Shared services: collective provision of services by a third party to satisfy ancillary needs, such as waste management or fire suppression.

There is one more practical model, eco-industrial park, which is used in somewhat indiscriminate manner with the term industrial symbiosis in the industrial ecology literature. The concept of eco-industrial park has been employed as a term for fostering a specific policy agenda and was first formally used in a project initiated by the Environmental Protection Agency of the US government. In a 1996 workshop, two definitions about eco-park were selected (Lambert and Boons, 2002). Each definition has its own focus; while the former stresses 'community' and 'cooperation' in an industrial area, the latter seems to value 'system' and 'efficient resource usage'.

- (1) A community of businesses that collaborate with each other 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 local community.
- (2) An industrial system of planned materials and energy exchanges that seeks to minimise energy and raw materials use, minimise waste, and build sustainable economic, ecological and social relationships (Lambert and Boons, 2002, p. 472).

It is possible to notice two differences between industrial symbiosis and EIP. The first difference between the two concepts is, while industrial symbiosis is not strictly bound to a geographical area, EIP refers to the industrial ecology initiative within an industrial estate (Chertow and Ashton, 2009). The other difference is the focus on relationships. While industrial symbiosis focuses on inter-firm relationships, industrial eco-park is based more on community notions. Although the two concepts are synonymous with each other, this research use the term of EIP to indicate the policy initiative through which industrial ecology practices are implemented in South Korea. As for the term of industrial symbiosis, I use it to call inter-firm synergy networks as local projects, reflecting the definition provided by Chertow and her colleagues.

Companies in an EIP are not linked to each other in nature because EIP-oriented synergy networks are not a part of traditional sector-based production networks. Such “unexpected connections between heterogeneous classes of industries” (Heeres *et al.*, 2004, p. 987) can be generated with two physical conditions. The most basic condition is, as repeatedly documented in the industrial ecology literature, geographical proximity. The other condition is the presence of an anchor tenant. Anchor tenant refers to a firm whose by-products can be used as main resources for other neighbouring firms; for instance, a power plant that generates steam for other local firms. Thus an anchor tenant can serve to identify potential resource exchange networks and attract other firms into an EIP (Lowe, 1997; Chertow, 2000; Gibbs and Deutz, 2005; Gibbs, 2008). The effect of geographical proximity and the presence of an anchor tenant are a decisive physical condition for an EIP, However, such favourable physical conditions do not necessarily promise industrial symbiosis and EIP developments. Although it can be assumed that an industrial ecology practice is technically applicable if the effect of geographical proximity and the presence of anchor tenant are given in the industrial landscape, the task to establish it must be carried out through complicated economic, political and social processes. Therefore, the question of how the physical conditions that could potentially generate industrial symbiosis networks actually lead firms to taking steps toward EIP initiatives is a critical issue in the field of industrial ecology.

2.2.3. Industrial Ecology and Its Social Dimensions

One of the hottest controversies in the field of industrial ecology is how to make industrial symbiosis feasible in a real industrial landscape. Lifset and Graedel (2002) state that this ‘how’ question is located in the intellectual boundary where industrial ecology overlaps with the social science field. Considering that “the very core subject of industrial ecology is the redesign of society” (Vermeulen 2006, p. 575), increasing number of studies on industrial ecology have imported various approaches from social science (Ehrenfeld and Gertler, 1997; Esty and Porter, 1998; Andrews, 2001; Vermeulen, 2006; Salmi and Toppinen, 2007; Chertow, 2008; Ashton, 2009). Yet, concentrating on physical and technical approaches is still the overwhelming tendency within the field, resulting in a weakness when the principles of industrial ecology are applied to real industrial societies.

Lesson from Empirical Studies

If the consideration of economic, political and social factors is truly indispensable in practice when one puts the industrial ecology concept into operation, it might be instrumental to review empirical case studies so as to learn lessons. The first and most important case study in the field of industrial ecology is, beyond doubt, the Kalundborg model which is the most well-known example of industrial symbiosis in the world. Grann (1997) summarizes 9 characteristics of Kalundborg: (1) The different but mutually beneficial participating industries; (2) The commercially sound individual industry agreements; (3) Environmental improvements, resource conservation, and economic incentives; (4) Short physical distances between participants; (5) Equal importance of short mental distances; (6) Voluntary participation but close cooperation with governments; (7) Mutual management understanding and cooperative commitment; (8) Effective communication between participants; (9) Significant side benefits such as safety and training. By reviewing this list, it is obviously noticeable that a majority of the features are related to cooperative mutual relationships between participants of the Kalundborg industrial symbiosis. In fact, many authors in the field of industrial ecology point out what makes Kalundborg a successful model is not a particular high-technology. The key to its success is that the participants are allowed and continue to encourage interactions (Grann, 1997; Ehrenfeld and Chertow, 2002; Jacobsen, 2003; Erkman and Ramswamy, 2006). In

short, the lesson from Kalundborg is that the trustful and cooperative culture of the local industrial area is of great importance.

Beyond the iconic case of Kalundborg, industrial ecologists have been collecting empirical evidence from across the world to make their theoretical argument more robust and their models more feasible. Heeres *et al.* (2004) compare three US EIP initiatives and three Dutch cases, embracing the question of how to encourage collaboration among stakeholders. This comparative case study makes a conclusion that the Dutch EIP projects are more successful than the US cases because of the active involvement of firms, the presence of business association and the existence of cluster-based communication platform. Drawing on the evidence from the Bussi chemical site in Italy, Taddeo and his colleagues point out that the climate of trust and cooperation among companies, the coordination of public agency and the support of local government in addition to the physical and industrial conditions are key drivers to the successful EIP (Taddeo *et al.*, 2012). The Kwinana case in Australia, another well-known case of industrial symbioses, shows the importance of the economic motivation of local firms, the coordinative function of local industries council and the expectation from local community (van Beers *et al.*, 2007). Furthermore, the Swedish case study carried out by von Malmborg (2004) emphasises the role of local authorities in knowledge spill-over in the public-private partnership for regional sustainable development.

The empirical case studies on industrial ecology practices in the non-western regions have distinctively paid much attention to the role of public agencies in establishing eco-industrial parks. Elabras Veiga and Magrini (2009) investigate the EIP initiative in Rio de Janeiro, Brazil. Their finding is that the physical exchange of resources is a long-term process and the cooperative relations between governments, public agencies, private institutions, industries, academia, and communities are pivotal to EIP development. In the East Asian region, the Japanese Eco-Town model has achieved significant success with strong government support (Van Berkel *et al.*, 2009). Similarly, Behera *et al.* (2012)' case study on the EIP project in Ulsan, one of the biggest industrial areas in South Korea, illuminates how EIP can be planned and driven by government policy.

Regardless of regions, most case studies put a priority on industrial structures, spatial infrastructures and technical elements. What is also obvious, and essential, is that most empirical case studies on industrial symbiosis and EIP commonly point out a variety of elements normally being investigated in the social sciences as the key to success. Thus the

next step is to review the social science track within industrial ecology in order to erect a pillar for building a bridge with the industrial cluster literature.

Social Dimension of Industrial Ecology

The empirical evidence reviewed above gives the sense that social factors are a critical element in most EIP initiatives, although investigating such elements is often located in the peripheral area of industrial ecology. Noticeably the theoretical discussion of industrial ecology tends to “focus primarily on technical processes and quantitative, material-oriented analysis” (Hoffman 2003, p. 66), as its development has primarily stemmed from natural science and technical engineering (Korhonen *et al.*, 2004). However, it must be remembered that an industrial symbiosis or EIP is a social system (Boons and Roome, 2001). In this regard, some authors in the field of industrial ecology contend the necessity of considering the social dimension that is involved in the physical flows of resources and energy (Cohen-Rosenthal, 2000; Ehrenfeld, 2000; Boons and Roome, 2001). This line of argument has developed the social science strand of industrial ecology, generating four technical terms that represent social factors of industrial symbiosis; mental distance, champion, institutional setting and planning.

Mental distance literally means the degree of psychological intimacy between firms involved with an industrial symbiosis. As emphasised on the geographical proximity, the industrial ecology literature has also highlighted the importance of short mental distance which is expressed as trust, openness and communication (Ehrenfeld and Gertler, 1997; Chertow, 2000; Ashton and Bain, 2012). The emphasis on mental distance is to deal with the role of trust and collaboration in forming an industrial symbiosis. This is arguably reasonable because trust, openness and reciprocal cooperation can alleviate defensive attitude between possible symbiosis partners and restrain opportunism in forming a new business relation. Many analyses in industrial ecology insist and prove that cooperative business culture and existing social networks can contribute to facilitating a potential industrial symbiosis network (Lowe and Evans 1995; Ehrenfeld and Gertler, 1997; Gibbs *et al.*, 2004; Gibbs and Deutz, 2007; Ashton, 2008; Chertow and Ashton, 2009; Paquin and Howard-Greville, 2009). For instance, through the analysis on the UK NISP model, Lombardi and Laybourn (2012) argue that member firms of a network tend to show more

cooperative attitude and thus engage in industrial symbiosis exchanges in the same manner as with any other transactions within the network.

However, it cannot be said that a proper level of social ties for industrial symbiosis is everywhere. Kalundborg, the self-organising industrial symbiosis based on endogenous social networks, is actually exceptional. Facilitating networking for symbiotic relationships demands time and efforts (Gibbs and Deutz, 2007). Therefore, the industrial ecology literature focuses on the role of network brokers who can coordinate the relationship between firms, so-called 'champions'. Champion can be defined as organisations or persons "who are able to bring group of actors together and motivate them to become personally involved in the construction of an EIP" (Hewes and Lyons, 2008). The coordination bodies play the role in discovering key actors at the local level, circulating knowledge about industrial symbiosis and facilitating communication between stakeholders (Mirata, 2004). The essential qualification for a champion is deep understanding of regional business culture and local communities (Behera *et al.*, 2012). In other words, champions should be embedded in local business society (Hewes and Lyons, 2008) so that the coordination activities of champions can be influential and effective.

The ultimate goal of coordinating activities carried out by champions is to establish platforms through which firms and other actors can have effective communication channels, share common purposes and undertake collaborative interactions. This implies the importance of "having the right institutional setting in a region" (Mirata, 2004). In this context, the right institutional setting has two meanings; the explicit involvement of non-industrial actors like business associations, financial bodies, research institutes, universities, local communities, public agencies and local governments (Heeres, 2004; Deutz and Gibbs, 2008; Lombardi and Laybourn, 2012) and the systems of sharing information, decision-making process, infrastructure and regulatory framework (von Malmberg, 2004).

The last factor of the social dimension which has been stressed in the industrial ecology literature is planning. Based on the empirical evidence collected by industrial ecologists, this refers to the public intervention in EIP practice. Most existing industrial symbiosis networks and EIP models, including Kalundborg, have been implemented with direct and/or indirect public interventions. There is a strong emphasis on the role of public agencies like government in the industrial ecology literature. Weinburg *et al.* (1994) argue that the central government is a key player in encouraging industrial ecology practices. Central and local governments ensure favourable regulations, provide research funding

(Gibbs, 2003), facilitate knowledge transfer (von Malmborg, 2004) and identify champions (Behera *et al.*, 2012). EIPs are likely to be established as a result of target programmes (Ronch *et al.*, 2013). Considering complicating and conflicting interests of various stakeholders involved in the eco-industrial development, the convincing power of public authorities takes a pivotal position (Behera *et al.*, 2012; Lombardi and Laybourn, 2012).

2.3. The Industrial cluster Perspective

From village markets to national-scale industrial complexes there is a strong tendency for economic actors in a same and/or similar sector to gather in a specific area and interact with each other. Over the last 30 years this common and stylized phenomenon, often termed industrial clusters or industrial districts, has been an intensively debated issue among economists and other academics, development agencies and planners, and political decision-makers (Porter, 1990; Pyke *et al.*, 1990; Krugman, 1991; Schmitz and Nadvi, 1999). Most references to industrial clusters have indicated that Alfred Marshall's work, *Principles of Economics*, is the original source investigating the phenomenon of agglomeration economies (Brusco 1986; Goodman, 1989; Becattini, 1990; Asheim, 2000). After *Principles of Economics* was published in 1890, the notion of industrial district was revitalized by a group of Italian researchers who were eager to explain the exceptional industrial success carried out by small and medium sized firms in the Emilia-Romagna region of Italy. Combining with analysing the crisis of the Fordist mass production system and focusing on the flexible specialization system (Piore and Sabel, 1984; Storper and Scott, 1989; Best, 1990), their research led to the theoretical development of a family of perspectives on agglomeration economies; new industrial district, industrial cluster, learning region, innovative milieu and regional innovation system. It is not necessary to review all strands of the industrial cluster literature here. Rather, this section aims to decompose the components of an industrial cluster and recombine a theoretical framework suitable for explaining the contextual causality of environmental performance carried out by clustered firms.

2.3.1. Conceptualisation of Industrial Clusters

At the first glance, an industrial cluster looks like a crowd of companies, stores, or farms. However, as can be seen through the theoretical and historical origin, industrial cluster is not such a naive concept. A lot of explanations on what constitutes an industrial district or industrial cluster have been suggested since two pioneering works by Becattini and Porter in 1990. In order to embrace environmental issues in the industrial cluster framework, I intentionally review three components of which an industrial cluster consists; firm agglomeration, tier of non-firm institutions and actors in external linkages.

Component 1: Firm Agglomeration

Industrial cluster theory defines an industrial cluster with the focus on spatial production systems. The simplest way to define a cluster is regarding it as local concentrations of certain economic activities (Altenburg and Meyer-Stamer, 1999) or sectoral and spatial concentrations of firms (Schmitz and Nadvi, 1999, p. 1503). More specifically, a cluster can be defined as “a geographical and sectoral concentration of numerous producers and ancillary agents, engaged in production, supply or trade activities which are directly associated with the manufacture of a specific product or set of products” (Nadvi 1996, p. 4).

As a production system consisting of firms at different stages of production (Pyke and Sengenberger, 1990), the simplest rationale of spatial clustering is mitigating the concern about transaction costs within input-output linkage (McCann, 1995). The best example is petrochemical industrial complexes in which suppliers and buyers are physically connected with each other along with input-output relations. In addition, Garofoli (1991) summarizes four benefits of spatial agglomeration in an analytic way:(1) an extensive division of labour between firms in the local production system, (2) A strong product specialization at the firm and company level, (3) The existence of an effective information network at the district level, (4) The high competence level of the work force. Clustering helps SMEs achieve flexible specialisation and enjoy the benefits from co-locating with related industries, business supporting services and labour pool in a form of public goods.

Porter provides a useful analytical insight on industrial clusters by modifying his well-known framework, competitive diamond (Porter, 1990), in the local context. His view is that a competitive local business cluster consists of local firm strategy and rivalry, demand conditions, related and supporting industries and factor input conditions. These static

elements can be reinterpreted by focusing relations within an industrial cluster. Local firm strategy and rivalry is materialised through competition and cooperation which generate horizontal ties among local producers, the most distinctive feature of industrial clusters. Demand conditions are unveiled in the relations between local producers and buyers, in other word, forward vertical linkages. Forward vertical linkage can be structured within an industrial cluster that takes a form of hub-and-spoke (Markusen, 1996) as well as extended to the outside world in global value chains (Humphrey and Schmitz, 2004). Related and supporting industries are captured in the relations between local producers and their capital goods suppliers or raw material suppliers. These relations can be represented by the term of backward vertical linkages. In summary, an industrial cluster has firm agglomeration that is structured through horizontal linkages, forward vertical linkages and backward vertical linkages as its centre.

Component 2: Institutional Infrastructure

An industrial cluster accommodates not only firms but also a variety of non-firm institutions which interact with clustered firms and provide business supporting services. Asheim and Isaksen (2002) notice that two main types of actors interact with each other in order to develop an industrial cluster towards a more innovative space. They are clustered firms and, so-called, institutional infrastructure composed of various non-firm business supporting organisations. Porter includes such local institutions into one of his cluster diamond categories and explicitly identifies them as a major part of industrial cluster into his most frequently cited definition, stating “a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities” (Porter, 2003, p. 254). The non-firm institutions include business consultative bodies like local chamber of commerce and industry, public authorities like local governments, knowledge production units like universities and research laboratories and financial bodies like banks.

These actors together build a tier of non-firm institutions that are distinguished from firm agglomerations within an industrial cluster. This tier has been named in various manners, for instance, knowledge generation and diffusion subsystem (Autio, 1998), soft infrastructure (Cooke, 2001), local establishment (Dei Ottaiti, 2003), knowledge infrastructure (Lundvall, 2007) and institutional infrastructure (Asheim and Isaksen, 2002).

Regardless of its name, the industrial cluster literature, especially more policy-driven research strands like regional innovation system and innovative milieus, has paid much attention to the existence of this tier because of its specific functions. The non-firm institutions of industrial cluster functions to support the innovation capacity of local firms, coordinate the inter-firm relations and, ultimately, supply public goods to improve local industrial competitiveness. The knowledge dissemination and education of research institutes and universities are public benefits in essence. In addition, the emergence of social upgrading issues in the industrial cluster literature (Porter and Kramer, 2006; Puppim-de-Oliveira, 2008; Battaglia *et al.*, 2010, Lund-Thomsen and Nadvi, 2010; Lund-Thomsen and Pillay, 2012) leads to spotlighting the local stakeholders such as residential communities and NGOs who have not been regarded as in favour of industrial cluster. Such actors who can be categorised as local civil society also interact with clustered firms in direct and indirect ways. Residential communities can function to reproduce labour power by providing some subsidiary resource like accommodation and NGOs function as a pressure group to correct inappropriate behaviours of firms. I deliberately identify local civil society as one of main local institutions with a view to tracking societal interactions surrounding environmental issues at the local level.

Component 3: External Linkages

It is very obvious that industrial clusters are not a lonely island. The actors located in an industrial cluster are linked with various external actors. Therefore, external linkages should be deemed as a main component when probing the structure of an industrial cluster. There are two main external linkages which significantly influence industrial clusters; global value chain and state regulatory framework.

An industrial cluster's external linkages at the global level are the most intensively studied area over the last one decade under the label of global value chain (Gereffi, 1994; Sturgeon, 2001; Humphrey and Schmitz, 2002; Humphrey and Schmitz, 2004; Gereffi *et al.*, 2005; Gibbon *et al.*, 2008; Nadvi, 2008; Pietrobelli and Rabellotti, 2011). Value chain can be defined as "the sequence of productive and value-added activities leading to and supporting end use" (Sturgeon, 2001). In accordance with the decentralisation of production activities across national boundaries, each value added stage from manufacturing to marketing has been dispersed into different geographical locations in

many industrial sectors. Global value chain is a framework aiming at explaining this global-scale division of labour. Industrial clusters, in many cases, function to provide specific components or services as a part of value-added process organised along with global value chains. More importantly, local relationships are significantly affected by powerful global players like branded buyers and retailers through the global value chain governance structure and thus local upgrading strategy and innovation activities are influenced. For instance, certain types of technical changes in product or process demanded by lead firms not only trigger upgrading (or downgrading) of local firms directly engaged in global value chain but also affect related industries like raw material suppliers and capital goods suppliers because all parts of a product are normally interconnected. This implies, although the global value chain literature has been largely ignored the relations between local producers, raw material suppliers and capital goods suppliers, that the external linkages can have a crucial impact on local backward linkages as well as on forward vertical linkages and horizontal linkages.

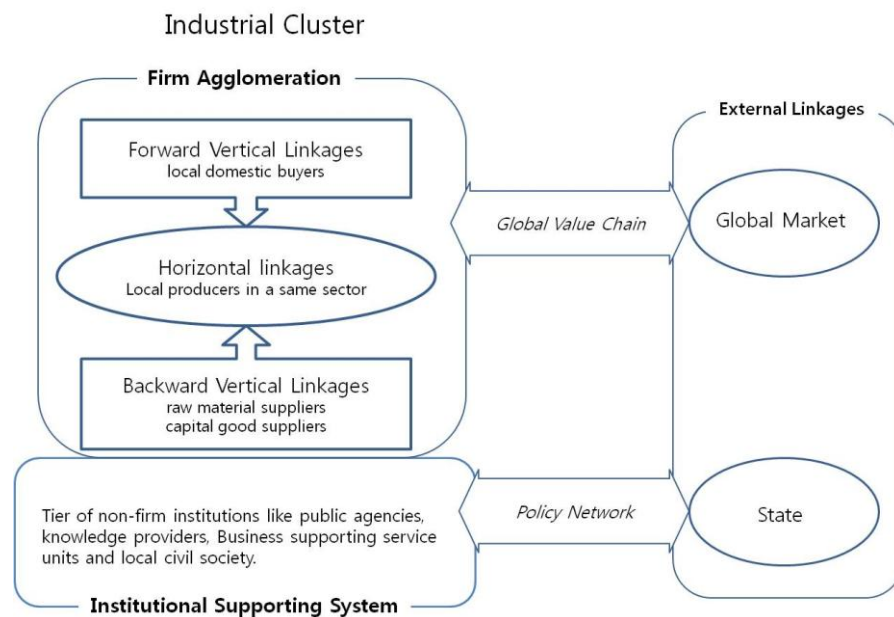
The other major player external to industrial clusters is without doubt states. The state's role to develop industrial clusters and promote local industrial competitiveness is especially outstanding in the East Asian region (Fan and Scott, 2003; Arıkan and Schilling, 2011). These various roles played by the state are materialised as regulatory framework to manage, support and guide the development of industrial clusters. As a case study on Korean industrial clusters, this doctoral research explicitly scrutinizes how the state intervenes in the dynamics of industrial clusters.

A Framework to Analyse an Industrial Cluster

Based on many empirical studies, various types of industrial cluster have been indicated (Storper and Harrison, 1991; Humphrey, 1995; Rabellotti, 1995; Markusen, 1996; Knorringa and Meyer-Stamer, 1998; Altenburg and Meyer-Stamer, 1999; Gordon and McCann, 2000; Paniccina, 2006; Okamoto, 2009). Despite this great diversity of industrial clusters, there are three compositions of an industrial cluster that are commonly noted in the industrial cluster literature. The core of an industrial cluster is firm agglomeration through which production networks are established and operated. Clustered firms tend to form three types of inter-firm relations through which they compete and cooperate with each other; forward vertical linkages, horizontal linkages and backward (or inter-sector)

vertical linkages. This economic territory is equipped with a tier of non-firm organisations functioning to support and constrain firms' economic activities, namely institutional support system. The combination of these two groups of actors is the base structure of an industrial cluster. In addition to these two basic components, an industrial cluster as an open system has two external linkages, global value chain and regulatory framework, with the global market and the state. A simplification of this structure is as in figure 2-3.

[Figure 2-3] The Simplified Structure of Industrial Cluster



*Source: Author

2.3.2. Dynamics in Development of Industrial Cluster

The key question in the industrial cluster literature is the dynamics via which competition and cooperation are simultaneously activated (Nadvi, 1999). Competition and cooperation of course lie with relations within an industrial cluster. As illuminated in the previous section, the static components of an industrial contain various relational dimensions. Firm agglomeration is comprised of horizontal linkages, forward vertical linkages and backward vertical linkages. Non-firm actors that constitute institutional infrastructure are linked with each other as well as connected to clustered firms, forming cluster-wide institutional linkages. Furthermore, an industrial cluster interplays with external actors through its

external linkages. Such relational dimensions are the channels through which the dynamics of industrial cluster are activated. If so, what are the dynamics in the relations among clustered firms as well as between firms and other non-firm actors? A variety of theoretical explanations that have been suggested in the field of industrial cluster research can be summarised into three dynamics.

Collective Efficiency in Industrial Clusters

Why firms agglomerate in an area is the initial inquiry to investigate the features of industrial cluster. The Marshallian approach has pointed out the benefits such as the accessibility to common labour pool and knowledge spill-over from the concentration of firms. Secondly, the simplest understanding about the agglomeration of firms, called 'industrial complex analysis', is suggested by the neo-classical economics group. According to this perspective, the only reason of agglomeration economy is that firms tend to determine their locations close to other firms involved in an input-output and consumption hierarchy to minimise spatial transaction costs like transport costs (McCann, 1995; Gordon and McCann, 2000). In contrast, the neo-institutional approach pays attention to invisible costs, 'transaction costs' originally regarded as a negative side effect (Dahlman, 1979). Neo-institutionalism perceives an industrial cluster as a stable community of firms and support organizations (Staber, 1998). Therefore, the strong relationships between members of the community have an effect on decreasing transaction costs caused by free-riding and opportunism.

The common focus of these three perspectives is 'externality'. Externality can be defined as unintended benefits or damages arising from an economic activity. The cause of externalities is that private costs or benefits is not balanced with social costs or benefits (Schmitz, 1999). In other words, Externalities are generated when the price signal in market mechanism cannot represent the whole costs of a transaction (Nadvi, 1996). Externality can be either positive or negative to interrelated firms or the whole society. Generally, the positive externality is named as 'external economy' and the negative externality is called as 'external diseconomy'. Interestingly, while the mainstream economics has used the term of externality with a negative nuance, the industrial district literature employs it in a positive way. The authors in the strand of the industrial cluster

perspective have observed that actors in industrial clusters are contributors as well as beneficiaries of external economics rather than free-riders (Schmitz,1995, p.1999).

The notion of external economies is a central theme in understanding industrial cluster (Goodman, 1989). Nadvi (1996) describes four pecuniary external economies which are static and passive in nature; (1) specialised labour market, (2) specialised machinery, (3) supply and subsidiary units, and (4) trade related information services (Nadvi, 1996). Furthermore, he points out three more external economy gains from firms-clustering and classifies them with three categories; real or pecuniary, dynamic or static, and passive and active. This work suggests a knot between the given externalities in an industrial cluster and the possibility to create other externalities by clustered firms.

Focused on externalities, firms look like the passive beneficiaries. However, the actors within an industrial cluster are not fatalists. In a given circumstance, they try to improve their competitiveness and carry out innovation. This is joint action which “involves active and consciously pursued inter-firm relations that go beyond anonymous market driven contracts” (Nadvi, 1996, p. 28). Joint action is the key to understand the competitiveness of an industrial cluster because the fundamental theoretic framework for industrial districts relies on the creation of external economies (Asheim, 2000).

According to Nadvi (1996), there are three dimensions of joint action; in horizontal ties, vertical ties and through cluster-wide institutions. Firstly, horizontal ties, the cooperative behaviours between two or more firms can be carried out for marketing, investment, common usage of specialized facilities and information-sharing. In terms of vertical ties, which mean the relations between suppliers and sub-contractors or traders and buyers, there are a variety of cooperation to improve products and share information via the communication between users and producers. The last case is about cooperation among a lot of local firms to establish and operate local trade associations, trade fairs and research institutes. Combined with external economies, joint action results in ‘collective efficiency’ of an industrial district (Schmitz, 1999). Collective efficiency is the primary benefit from clustering of firms and the heart to make an industrial cluster alive.

Local firms tend to be engaged in various social and institutional linkages for arrangement of actors, activities and resources (Powell, 1990; Hakansson and Johanson, 1993; Nadvi, 1996) and thereby do joint actions that can give rise to public goods or club goods. This leads to the inquiry on the channels that enable inter-firm relations to be coordinated in

reciprocal manners and non-market-based issues like power asymmetry or opportunism to be managed in appropriate ways, so-called governance. The pattern of joint actions relies on the structure of an industrial district. Although the prototype industrial district investigated in the initial literatures in the 1980s is based on the Emilia-Romagna model in Italy, it has been identified there exist various types of industrial clusters and industrial districts across the world (Storper and Harrison, 1991; Rabellotti, 1995; Markusen, 1996; Park, 1996; Altenburg and Meyer-Stamer, 1999; Gordon and McCann, 2000).

Upgrading through Value Chains

Another dynamic underlying the industrial cluster development is upgrading through value chain governance. Although the industrial cluster literature has paid relatively less attention on the importance of external linkages (Humphrey and Schmitz, 2002; Giuliani *et al.*, 2005), globalisation has driven industrial clusters to be engaged in global-scale production and distribution systems. This raises the question on “authority and power relationships that determine how financial, material and human resources are allocated and flow within a chain” (Gereffi 1994, p. 97), namely global value chain governance.

Gereffi *et al* (2005) provides three core factors by which the types of global value chains can be determined; complexity of transactions, codifiability of information and capability of suppliers. Branded companies tend to seek to outsource their non-core activities and procure components from specialised suppliers. Retailers continue to widen their distribution channels cross borders. This strategy of global-scale large firms, normally called as lead firms in the global value chain literature, increase transaction costs due to the complexity of transactions. If the complexity of transactions is high, the value chain governance tends to be more hierarchical due to the increasing necessity of monitoring and control. In order to reduce the complexity of transactions to the extent transaction cost is affordable, firms can codify information and technology and thereby avoid certain deficiency in manufacturing and trading with their suppliers. In this regard, when the codifiability of information is high, firms governing value chains can gain the advantages to save the costs for monitoring and control. However, the codifiability advantages are likely to be limited to the extent that the suppliers are capable of adopting codified information and technology. Accordingly, the capability of suppliers is the other

determinant that influences the degree of control and monitoring by the firms governing value chains.

The global value chain literature especially places a great deal of emphases on upgrading effects that local producers can enjoy via being engaged in global value chains. Lead firms transfer knowledge and information to their suppliers along the chains and thus local producers who newly enter into the chains can learn a lot about quality management, just-in-time delivery, production practices to protect workers and environment and even other functions like marketing (Gereffi, 1999; Schmitz and Knorrinda, 2000; Humphrey and Schmitz, 2004; Giuliani *et al.*, 2005; Nadvi 2008;). Humphrey and Schmitz categorize four types of upgrading as follows;

- Process upgrading: transferring inputs into outputs more efficiently by reorganising the production system or introducing superior technology
- Product upgrading: moving into more sophisticated product lines (which can be defined in terms of increased unit values)
- Functional upgrading: acquiring new functions (or abandoning existing functions) to increase the overall skill content of activities
- Inter-sectoral upgrading: firms of clusters move into new productive activities (Humphrey and Schmitz, 2002, p. 1020).

The patterns of upgrading vary according to the types of chain governance. Humphrey and Schmitz (2002) argues that more hierarchical governance is favourable for process and product upgrading while more market-based governance provide often chances for functional upgrading. Global value chain analysis casts light on the governance structures of external linkages through which clustered firms can achieve upgrading, especially in export-oriented industrial clusters.

However, being engaged in value chains is, in a sense, a passive gain favourable for local producers. This leads to the need for explaining local producers' intentional efforts to absorb the knowledge transferred from lead firms, meet global standards and thus maintain or promote their position in value chains. In the point of view of the industrial cluster literature, this task demands to bring the dynamic of innovation system together with collective efficiency and value chain.

Regional System of Innovation

Innovation capacity is undoubtedly one of the keys to industrial success. Innovation activities basically aim to improve and commercialise technology, thereby firms gain competitive advantages and create extraordinary profits. If such a change is a just one-off event, innovation is not meaningful to maintaining competitiveness. In this regard, technical change alone cannot guarantee long-term advantages (Hekkert *et al.*, 2007). Accordingly, innovation is more than technical changes. Innovation also refers to changes in organisational structure, attitudes of actors relational practices, etc (Cooke *et al.*, 1997).

The industrial cluster literature has the strong tradition that the territorial dimension is regarded as a space for innovation. Marshall's idea of the industrial atmosphere is a portrait of the scene that new ideas are created and circulated through an industrial district (Iammarino, 2005). The substantial literature on industrial clusters has interpreted it in the more modern term, innovation process. Furthermore, the industrial cluster perspective has been spun off into some academic streams concentrating on innovation process; innovative milieus (Crevoisier, 2004), learning regions (Asheim, 1995; Morgan, 1997; Hassink, 1999) and regional innovation system (Cooke, 1992; Cooke and Braczyk, 1998).

RIS can be defined as "a set of interacting private and public interests, formal institutions, and other organisation that function according to organisational and institutional arrangements and relationships conducive to the generation, use and dissemination of knowledge" (Doloreux and Parto, 2005, pp. 134-135). In order to sketch the RIS framework, it might be useful to review three dimensions of RIS: the territorial dimension, the organisational dimension and the cultural dimension. First, RIS is definitely the notion of geographical space. It is generally imagined that RIS has wider boundary than an industrial cluster (Tödtling and Trippel, 2005) because it has various connections to national and global actors as well as include various local actors. This leads to the second dimension of RIS. The organisational tenants of RIS are not only firms but also non-industrial actors such as public laboratories, universities, technology transfer organisations, incubators, investors, trainers and other intermediaries (Cooke and Braczyk, 1998; Asheim and Isaksen, 2002). These organisations are the actors located and working in the institutional infrastructure of an industrial cluster. As learning denotes interaction plus knowledge development in the RIS literature (Hassink and Lagendijk, 2001), the core of organisational dimension is interaction rather than individual behaviours. Therefore, the

innovation literature places a great deal of emphases on learning-by-interaction which demands high degree of communication and collaboration between different actors (Edquist, 2005). Such intensive interaction between geographically co-located institutions can be regarded as a cultural phenomenon. In this line of thinking, Cooke et al (1997) argues RIS needs the regional culture favourable for innovation. The interaction among the actors who constitute an institutional milieu is based on embeddedness (Cooke and Braczyk, 1998).

Yet another critical dimension is the strong connectivity to roles of state. The nascent innovation system literature was deeply rooted in the analysis on national science and technology development frameworks (Lundvall, 2007) and the RIS framework was emerged from the concept of national innovation system. The theoretical characteristics of RIS as a policy-oriented study attributes to this tradition. In realities, the national system exerts substantial authority because funding and organizing activities in RIS largely relies on public resources and policy decisions (Doloreux, 2002).

The scale of state involvement can be clarified by reviewing three modes of RIS: grassroots, network and dirigiste (Asheim and Isaksen, 2002; Cooke, 2004; Hassink, 2004). Grassroots RIS refers to the pattern that innovation activities are endogenously initiated and implemented at the local level without significant involvement of external actors like the state. The main stimulus of interaction is spatial, social and cultural proximity. Non-firm organisations are locally embedded but few and not well-structured. In the second mode, network RIS, firms and other organisations are involved in high interactive learning. The resources to support innovation activities come from various levels from local to even supranational. System coordination is high and consequently is likely to form institutional infrastructure. The third type, dirigiste RIS, refers to an exogenous development model. The systems in this mode are largely organised by central government policies and/or international programmes. Accordingly, innovation activities in dirigiste RIS tend to be implemented in the cooperation with external actors, relying on the supra-regional level resources.

[Table 2-1] Three main RIS types

	Initiative	Main Stimulus of Cooperation	Innovation resources	Innovation support organisation	Knowledge flow
Grassroots RIS	Endogenous	spatial, social and cultural proximity	Local level	Locally, however, few relevant knowledge organisation	Interactive
Network RIS	Mixed	Planned, systemic networking	Multi level	Locally, forming institutional infrastructure	Highly interactive
Dirigiste RIS	Exogenous	Central government policies and/or international programme	External	Mainly outside	More linear

*Source: modified from Asheim and Isaksen (2002) and Cooke (2004)

Innovation system is the dynamic that underlies the institutional infrastructure of an industrial cluster. This dynamic is emerged in the relations between clustered firms and non-firm business supporting organisations, namely cluster-wide institutional linkages. As intensively discussed in the innovation system literature, these linkages have the nature of public intervention and thereby can be interpreted as policy networks (Helmsing, 2001; Humphrey and Schmitz, 2002). Therefore, it is arguable that RIS is a channel through which state and local actors in an industrial cluster interplay with each other.

Embeddedness

It is possible to imagine that individual firms have little concern about the relationships with other firms or other actors at the very early stage of clustering. However, through balance between co-operation and competition which is a significant character of industrial district (Brusco, 1990), complicated networks are continuously formulated (Piore and Sabel, 1984). Furthermore, firms begin to be embedded in the relationships within industrial districts. In reality, frequent contacts within an area generally increase trust between individuals or firms. There is the need to refine the concept of embeddedness to

use it in an appropriate way. The concept of embeddedness dates back to Karl Polanyi's masterwork, *The Great Transformation*. He said as the following;

Acts of barter are here usually embedded in long-range relations implying trust and confidence, a situation which tends to obliterate the bilateral character of the transaction. The limiting factors arise from all points of the sociological compass: custom and law, religion and magic equally contribute to the result, which is to restrict acts of exchange in respect to persons and objects, time and occasion (Polanyi,2001,p. 64).

Here, Polanyi indicates that market or price signal is not the only factor affecting people's transaction behaviours. Granovetter inherits Polanyi's idea and establishes the concept of embeddedness. Embeddedness is a state that behaviour and institutions are so constrained by ongoing social relations that they cannot be understood as an independent existence (Granovetter, 1985). The emerging question about this definition is "who or what the socially embedded actors are, and in what these actors are actually embedded" (Hess 2004,p. 166).

In order to make the concept of embeddedness instrumental in the analysis on industrial districts, arguably, adapting two typologies on embeddedness is useful. The first typology is dividing the concept into relational embeddedness and structural embeddedness. While relational embeddedness is direct cohesive ties in which actors are connected with each other directly for gaining fine-grained information, structural embeddedness means that actors occupy their structural positions and can expect to collect information through the network structure (Gulati, 1998). To put it another way, an actor's behaviour is constrained not only by the direct interaction with other actors but also by structural position. The other typology is related to spatiality; local embeddedness and global embeddedness. Most initial literatures on industrial districts focus on the relationships and interactions between geographical proximate firms. If firms and the other actors are constrained by localised networks within an industrial district, this condition can be called as local embeddedness. On the other hand, nonlocal embeddedness, long-distance interactions and trust-building across local boundaries, is also important (Park, 1996).

Embeddedness plays the role of catalyst for dynamics of industrial clusters. The emphasis of this research is placed on local and structural embeddedness; firms and the other actors

take a position in accordance with the configuration of industrial district and play their role as a part of the socio-economic entity.

Three facets of Cluster Upgrading Dynamics

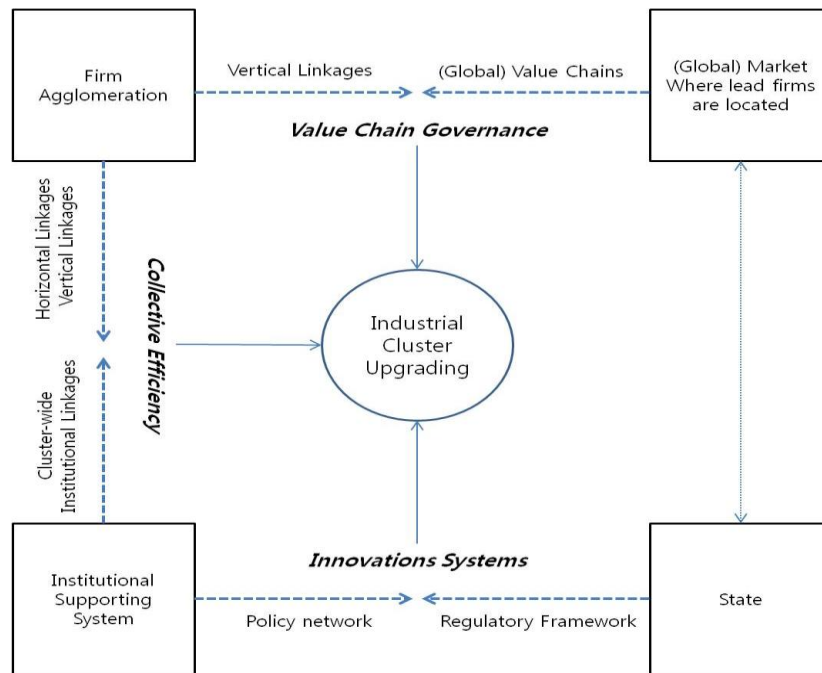
An industrial cluster is composed of three components; firm agglomeration, institutional infrastructure and external linkages. Focusing on firm agglomeration, it is noticed that forward vertical linkages, horizontal linkages and backward vertical linkages constitute the basic structure of local production system. The essential dynamics emerged from these inter-firm linkages is collective efficiency. The collective efficiency framework especially addresses horizontal linkages because this relational dimension is the channel through which competition and cooperation simultaneously occur. Forward vertical linkages are connected to or embraced by value chain external to industrial clusters. By focusing on the role of lead firms, the global value chain literature demonstrates that local producers can be upgraded through the dynamic of chain governance. One thing that should be pointed out is the location of lead firms. In fact, lead firms do not necessarily locate outside an industrial cluster or in a certain foreign country. In hub-and-spoke clusters, lead firms are situated within the boundary of industrial cluster. Accordingly, forward vertical linkages here are similar to value chain ties. On the other hand, backward vertical linkages have been less investigated than forward linkages. Backward vertical linkages, which are normally expressed with somewhat vague term, related industries, in the industrial cluster literature, is the relations between a main industrial sector and its capital goods suppliers, raw material suppliers and utility providers. In this sense, backward linkages can be reinterpreted as inter-sector linkages.

An industrial cluster not only accommodates firms but also embraces various non-firm organisations. Local actors like private interests, public agencies, research institutions and local civil society constitute the tier of non-firm organisation, namely institutional support system, to produce public goods, support business activities of clustered firms and sometimes regulate undesirable behaviours of local firms. These functions are initiated and implemented in the locally embedded relations. The existence and function of this relational dimension have been intensively scrutinized in the innovation literature and explained by the RIS framework. RIS analysis sheds light on the state's roles in promoting

and developing industrial clusters and identifies the characteristics of institutional support system.

Collective efficiency, chain governance and innovation systems are respectively focused on different aspects of industrial clusters, but all of them aim to elucidate the dynamics of cluster upgrading. The other dynamic which might influence cluster upgrading lies in the relation between market and state. I exclude a detailed discussion on this fourth dynamic of industrial cluster upgrading because its influence is likely to be reflected in value chain or regulatory framework. As a whole, the three-faceted cluster upgrading dynamics can be seen in figure 2-4.

[Figure 2-4] Three facets of Cluster Upgrading Dynamics



*Source: Author

2.3.3. Introducing Environmental Issues into Industrial Clusters

As Schumacher argues, “far larger is the capital provided by nature and not by man” (Schumacher, 1973, p. 12). In this sense, the damage to the natural conditions of production can cause the increase of production costs and other social costs affecting firms. This issue is not only globalizing but also localizing because the problems tend to directly

damage nature and people near a source of environmental problems. In this sense, it is not strange at all that industrial clusters can be described as a pollution haven. Hence, rising environmental issues related to agglomeration economies is one of urgent challenges for the industrial cluster literature.

External Diseconomies

The industrial cluster perspective is, however, relatively negligent in studying diseconomies of clustering (Kennedy, 1999). Most studies investigating industrial clusters mainly focus on the positive effects of externalities. However, clusters of firms can cause external diseconomies like increasing price of scarce resources and generating pollution costs (Nadvi, 1996). Environmental damage, which this research aims to introduce into the industrial cluster perspective, is a typical external diseconomy. Therefore, it is a basic step to elaborate the concept of external diseconomies as a foundation stone to rebuild the theoretical framework.

Externality can result in separation between private profit and social benefit (Scitovsky, 1954). When considering the ethical issue in economic and business activities is becoming an essential factor to maintain or improve firm's competitiveness, it is important to pay more attention to external diseconomies in an industrial cluster. Moreover, an industrial cluster is the space within which economic activities are embedded in complicated networks including many social actors. This leads to the inconsistency between private profit and social benefit and can be a big barrier to the economic performance of clustered firms.

However, in the long term, it can be expected that the characters of external diseconomies change because actors generally tend to try to adjust their common issues. For central and local governments, there is no fundamental difference in the characters of external diseconomies because of their consensual roles in a society.² On the other hand, there is a possibility that firms and other actors will accept the meaning of the external diseconomies from the environmental issues in a long term differently from a short term. According to the development of the industrial cluster, embeddedness evolves from relational to structural embeddedness. This means that the matter of who is responsible for a common

²There might be three basic roles; regulation, coordination, and redistribution.

issue becomes clear because of socially expected roles of each actor in structural embeddedness. As a result, a sum of anonymous people who are damaged become the set of various institutionalized actors. The actors damaged by the ecological problems can be motivated to design a variety of autonomous measures and organize collective behaviours to constrain the negative environmental effect from clustered economic activities. If the pressure is enhanced by the social sanctions, formal regulations, the public opinion in local civil society or the ethical code pursuing in international market, local firms would need to respond, either through compensation, technical improvement or at least making excuse.

A Review of Environmental Issues Observed in Cluster Research

The dark side of agglomeration economies has recently become an emerging theme in this age of environmental crisis in the industrial cluster literature. Kennedy (1999) provides the pioneering case study to investigate the environmental externalities in an industrial cluster context. She drew on empirical evidence from the Palar Valley tannery cluster, India to show how clustered firms could respond to government regulations on effluents through collective action to set up common effluent treatment plants. In a similar case, Crow and Batz (2006) demonstrate that the small bleachers and dyers in Tirupur, India could manage the water pollution crisis via joint actions without negative impacts of regulatory enforcement.³ Meanwhile, a few case studies on environmental issues of industrial clusters under the framework of global standards and corporate social responsibility have been carried out (for example, Tewari and Pillai, 2005; Lund-Thomsen and Nadvi, 2010). The common findings in these studies are the importance of joint actions based on local social ties and led by industrial associations in order to cope with common environmental issues among clustered firms, clearly showing that such environmental performances are underpinned by collective efficiency.

The other lesson from the case studies on environmental externalities of industrial clusters is the role of public involvement to provide technical and institutional subsidies. For example, a series of recent studies based in the Italian industrial district context are more focused on policy-related effects and the importance of public environmental management programmes (Montini and Zoboli, 2004; Mazzanti and Zoboli, 2009; Battaglia *et al.*, 2010;

³ Lund-Thomsen (2009) illustrates a somewhat less successful case of a response to environmental pressures in the tannery cluster of Kasur, Pakistan.

Daddi *et al.*, 2012). This tendency can also be found in the literature in the developing country context. Konstadakopulos (2008) argues that the necessity of the government roles in supporting new technologies and environmental management practices with the empirical evidence from the Red River Delta's handicraft cluster in Vietnam. The case study on the jeans laundries in Toritama, Brazil, reported by Almeida (2008) shows how public and non-public institutions could cooperate in enforcing the environmental regulation and helping local firms to environmentally upgrade. The common point in all these studies is an emphasis on the public intervention to communicate with, and support, local firms rather than simple command-and-control approach. Due to the limited financial and technical capacity of SMEs, public involvement is a critical factor to environmental upgrading of industrial clusters.

Environmental concerns are in many cases a common issue for clustered firms because they engage in similar activities with similar resources and emit wastes into the same place (Daddi *et al.*, 2012). If they take an action collectively to solve environmental problems, negative environmental externalities can be transformed into localised agglomeration advantages (Montini and Zoboli, 2004). All the previous studies on environmental issues in the industrial cluster literature provide positive evidence on this argument.

2.4. Conclusion: Building Bridges

The industrial ecology perspective suggests that industrial clusters can be potentially liberated from the stigma of being pollution havens. This hope is already in practice in many industrial areas across the world. One of the major challenges that industrial ecology has faced is understanding the economic, political and social dimensions to applying industrial ecology practices. What has been of concern for industrial ecologists in terms of the social dimension are actually the subjects that the industrial cluster literature has agonised over a long time. A growing number of authors in the field of industrial ecology have begun to assert that EIP initiatives are a type of industrial cluster policy or ask the question of whether EIP can be seen as a variant of industrial cluster policy (Lowe, 1997; Schlarb, 2001; Lambert and Boons, 2002; Cohen-Rosenthal *et al.*, 2003; Baas and Boons, 2004; Deutz and Gibbs, 2004; Deutz and Gibbs, 2008; Gibbs, 2009). However, the industrial cluster literature has provided little response yet. This section discusses how this

gap can be filled by building theoretical bridges between the industrial ecology literature and the industrial cluster literature. This provides a conceptual framework for this study to analyse empirical evidence from the EIP initiatives in South Korea.

2.4.1. Commonness and Differences of Two Theories

In order to build a synthetic theoretical framework, it should be figured out what commonalities and differences the industrial ecology theory and the industrial cluster theory have. The most noticeable similarity is their analytic focus on local production systems. The industrial cluster literature obviously defines its research area as geographical spaces. Geographical influences are also essential for industrial ecologists (Andrews, 2001) and, especially in terms of eco-industrial park model, locality is a main research theme in industrial ecology. Accordingly, the first step toward building a theoretical bridge is how to understand EIP in local production systems. The other common feature is that both academic fields concern inter-firm relations. The main argument for the industrial cluster literature is that clustered firms obtain competitive advantages via various economic and social inter-firm relationships. Industrial ecology also asserts that firms can enjoy synergy effects through reciprocal inter-firm exchanges.

However, more detailed review on two theoretical bodies shows several differences. The first difference is about their research interests. While the industrial cluster literature probes economic value-added activities, the research interest of industrial ecology is material flows. In fact, tracking material flows gives the advantages to broaden one's horizons from main production lines to what have been little considered in the industrial cluster literature like water and energy utilities, raw material providers and subsidiary input suppliers. This first difference results in their distinguishable viewpoints on the sectoral dimension. The industrial cluster literature is mainly focused on intra-sector dynamics. In contrast, the industrial ecology literature tends to pay much attention to inter-sector dimensions. Besides, industrial ecology has a practical reason to deliberate the inter-sector dimension carefully. As the firms in the same industrial sector generate similar types of by-products, by-products are more useful in inter-sector exchanges. In this regard, Chertow (2004) points out that industrial symbiosis is the exchange between traditionally separated industries. The last difference between two perspectives is the scale of firms. The industrial cluster literature mainly considers SMEs. In the case of industrial ecology, although there

has been little mention about the scale of firms, it seems that most case studies are dedicated to investigating large firms. This does not imply that industrial ecology fails to include SMEs into its practical models. Rather, it is because large firms normally generate sufficient volume of by-products that can assure the scale of economy in industrial symbiosis.

When considering the environmental management issue, it can be also recognised that both literature have something in common. The literature review on the environmental issues in industrial clusters shows that the industrial cluster literature is focused on the pollution control approach (Kennedy, 1999; Crow and Batz, 2006; Lund-Thomsen, 2009). The other studies combined with the global value chain framework (Tewari and Pillai, 2005; Lund-Thomsen and Nadvi, 2010) tend to employ the cleaner production approach based on global standards or corporate social responsibility.

Industrial ecology is a systemic approach embracing pollution control and cleaner production as its subsets. Industrial ecology, especially the region-focused approach, overlaps with the industrial cluster literature in terms of pollution control and cleaner production. For example, the industrial ecology project in the Rotterdam industrial area shows its gradual development from sharing common effluent treatment plants to exchanging by-products (Baas and Boons, 2004). This Dutch case implies that the environmental management strategy can go well beyond pollution control and cleaner production. Chertow's definition on industrial symbiosis, one of the most frequently cited in the field of industrial ecology, includes utility-sharing and shared service as well as by-product exchange (Chertow *et al.*, 2008). As most case studies on environmental issues in the field of industrial cluster have investigated utility sharing and shared service as the environmental joint action of clustered firms, it can be argued that the two literatures have common interests at least with regard to pollution control and cleaner production.

[Table 2-2] Comparison of Industrial Cluster and Industrial Ecology

	Industrial Cluster	Industrial Ecology (region-focused approach)
Research focus	Value-added activities within a limited geographical area	Material flows within a limited geographical area

Organisational dimension	Inter-firm relations	Inter-firm relations
Sector dimension	Mainly same industrial sector	Different industrial sectors
Scale of firm	Small and medium sized firms	Not clearly mentioned, however, by-products' scale of economy matters.
Main environmental management strategies	Pollution control and cleaner production	Pollution control, cleaner production and industrial symbiosis or EIP

*Source: Author

Understanding EIP as a Set of Supply Chains

How can EIP be understood with the industrial cluster framework? EIP, one of the practical models driven from industrial ecology, aims at establishing networks for by-product exchange and energy cascading among contiguous firms. EIP is a set of supply chains in the way that it is a trade of resources. The only difference with normal supply chains is that the objects of trade are by-products, wastes and extra energy. The function of this network is to change some types of negative externality to positive externality. Concretely, EIP is activated in order to decrease the environmental damages and social costs resulting from economic activities within an industrial area and improve resource productivity of clustered firms. Accordingly, it can be argued that EIP aims at establishing a set of inter-firm networks specialized in recycling by-products and cascading energy for the sustainable development of local industrial area. Its fundamental function is converting local external diseconomies into local external economies.

2.4.2. Integrated Conceptual Framework

Creating a set of supply chains for by-product exchanges and energy cascading needs careful consideration of economic, political and social elements. In this regard, industrial ecology has identified four key concepts; mental distance, roles of champion, institutional setting and planning, as reviewed in the second section of this chapter. These four elements form the social dimension of industrial ecology and provide critical clues to build theoretical bridges between the industrial ecology literature and the industrial cluster

literature. If so, how are the four elements interpreted with the theoretical lens of the industrial cluster literature?

The application of industrial ecology practices to an industrial cluster is of course upgrading. It can be supposed that, as usual in the other types of cluster upgrading, the three dynamics of industrial cluster (collective efficiency, value chain governance and RIS), arguably, are activated in the environmental upgrading process in mutually integrated ways. Therefore, one can postulate that the four key elements from the social dimension of industrial ecology stem from the three industrial cluster dynamics.

Mental Distance and Role of Champion for EIP in Local Production System

Baas and Boons (1997) analyse various industrial ecology practices with five types of production system: product life cycle type, material life cycle type, geographical area type, sectoral type and miscellaneous type. Product life cycle is the industrial ecology practice in the producer-user relations, while material life cycle emerges along the relations between actors dealing with specific materials like the steel industry. The geographical area type refers to the industrial ecology practices in an industrial site with heterogeneous industrial sectors. This is actually the typical model like Kalundborg in Denmark and Rotterdam in the Netherlands. The sectoral type is composed of clustered firms engaged in same or similar sectors. Baas and Boons points out that, although firms in this industrial setting are less likely to adapt industrial ecology practices, sectoral organisation can develop certain environmental policies relevant to industrial ecology. The last type, miscellaneous, refers to by-product exchanges regardless of any specific boundary. This type is normally developed in ad hoc bilateral relations.

One would be reminded of vertical production linkages with the first two categories of product life cycle and material life cycle. Vertical production linkages are underpinned by value chain governance and role of lead firms is critical in value chain governance. In this regard, the industrial cluster literature normally postulates lead firms as champion. The empirical studies in industrial ecology also show that the role of champions tend to be taken by company managers and business associations. The other three types, geographical area, sectoral and miscellaneous, are relevant to horizontal linkages. The argument from industrial ecology is that mental distance like trust, openness, and embeddedness facilitates inter-firm cooperation and thus contribute to enhancing synergy effects toward industrial

symbiosis. The theoretical explanation on this sort of horizontal inter-firm interaction in the industrial cluster literature is collective efficiency.

Institutional Setting and Planning for EIP in Institutional Support System

Some studies in industrial ecology highlight that public agencies and/or local academic experts also play integral roles (Mirata, 2004; von Malmborg, 2004; Behera *et al.*, 2012). This gives rise to the importance of institutional setting and planning. The concepts of institutional setting and planning from industrial ecology correspond to institutional infrastructure of an industrial cluster and external linkages to state, in other word, policy networks. As discussed before, the underlying dynamics in institutional infrastructure and policy network of industrial cluster is RIS.

The industrial ecology literature also sees applying industrial ecology practices as innovation (Roberts, 2004; von Malmborg, 2004). By importing the theoretical lens from the regional economies literature, Baas and Boons (2004) frame three stages of the industrial symbiosis development as follows:

- Regional efficiency: autonomous decision-making by firms; co-ordination with local firms to decrease inefficiencies (i.e. utility sharing). Such activities may be facilitated by local government authorities, existing co-operative arrangements between entrepreneurs, in short; local social networks. This phase is characterised by identifying and make use of exiting win-win situations;
- Regional learning: based on mutual recognition and trust, firms and other partners exchange knowledge, and broaden the definition of sustainability on which they act. In this phase, other stakeholders (local citizens, grass roots movements) may become involved as well. Thus, both goal and range of membership broaden;
- Sustainable industrial district: actors develop an – evolving – strategic vision on sustainability and base their activities on this vision. (Baas and Boons, 2004, p. 1077).

Clearly, these three stages of industrial symbiosis development are addressed by learning-by-interaction. Such interactive learning is the RIS dynamics that normally occurs in the institutional support system of an industrial cluster.

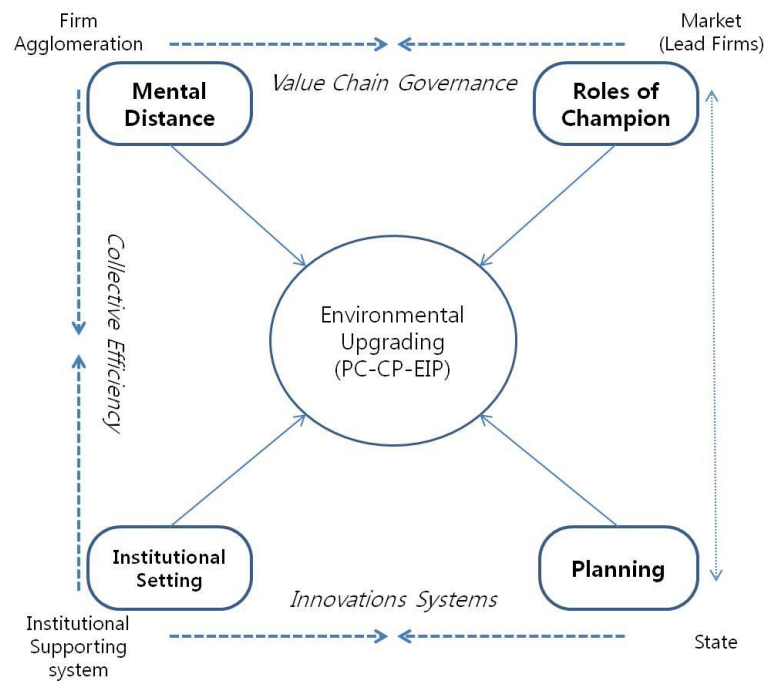
Ways to Environmental Upgrading of Industrial Clusters

As for industrial symbiosis, it is supposed that firms more rely on interactions in order to acquire knowledge and information because it basically emerges from inter-firm cooperation. Therefore, non-material-based linkages may be a precursor to waste and energy interchanges (Chertow, 2000). An industrial cluster has three types of non-material-based linkages; vertical production linkage, horizontal inter-firm linkage and cluster-wide linkage. These three linkages are respectively addressed by three industrial cluster dynamics of value chain governance, collective efficiency and regional innovation system.

One possible path through which the knowledge and information on new environmental management strategies can be transferred is the linkages between local producers and lead firms. In this case, value chain governance matters for environmental upgrading. As lead firms are commonly regarded as a pivot of value chains, the element of role of champion proposed by industrial ecology fits into this pathway. Second, local firms working in the same or similar sectors can take to improve their environmental performance. Joint action of clustered firms can be another pathway toward environmental upgrading. As shown in Kalundborg symbiosis, environmental joint action can have self-organising nature according to firms' strategic choices and self-regulatory behaviours. The critical issue in this type of environmental joint action is the questions of trust and consensus within firm interactions. Accordingly, the element of mental distance should be considered in the horizontal dimension. However, it is not easy to create or organize such 'relational assets' or 'soft infrastructures' (Gibbs, 2003). Hence, in many cases, joint action should be coordinated to build the industrial symbiosis relations among cluster firms. This brings about the third pathway toward EIPs. Empirical researches in the field of industrial ecology demonstrate that the non-industrial organisations such as public laboratories, universities, technology transfer organisations, incubators, investors which compose the organisational dimension of RIS are often involved with the EIP initiatives. Considering many EIPs or industrial symbioses have been initiated by the government – for instance, NISP in the UK (Mirata, 2004; Mirata and Pearce, 2004), Eco-Town in Japan (Van Berkel *et al.*, 2009), Circular Economy in China (Geng *et al.*, 2009) EIP in South Korea (Kim, 2007; Behera *et al.*, 2012) and EIE in Thailand (Panyathanakun *et al.*, 2013), the institutional support system to promote industrial ecology practices can be deemed as key policy networks. Therefore, it can be supposed that the elements of institutional setting and planning are understood in the RIS dimension.

To encourage firms to participate in environmental joint actions, there must be gains which are attractive enough to firms. These gains include resource productivity, secure supplement of materials and energy, cost saving, good reputation, social responsibility, etc. In summary, the gain is eco-efficiency. This eco-efficiency can be achieved through internalising external diseconomies by joint action. Using a simile with the notion of collective efficiency in the industrial cluster literature, it can be named as ‘collective eco-efficiency’.

[Figure 2-5] Configuration of Four Social Factors of IE in Cluster Upgrading Dynamics



*Source: Author

2.4.3. Research Questions Pursuing Empirical Evidence

EIP is a set of specialized networks between firms and other actors located in an industrial cluster for sharing environmental treatment facilities, environmental management services and resource exchanges. This is an effective option for firms to change external diseconomies to external economies. The main requirement to build bridges between the industrial ecology perspective and the industrial cluster perspective is to explore the

economic, political and social dynamics of an industrial symbiosis. Through the literature review in this chapter, the industrial cluster dynamics for environmental upgrading is roughly sketched. This doctoral study seeks to address this environmental upgrading dynamics by drawing on evidence from their initiatives in the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster.

The core research question, “how do clustered firms draw on inter-firm collaboration and institutional linkages to undertake holistic environmental upgrading strategies?” is segmented into four sub-questions as follows;

- (1) What sort of environmental problems arise from an industrial cluster?

This question identifies the drivers that urge clustered firms to take joint actions for environmental performance and furthermore encourage them to establish an EIP. Environmental problems tend to be materialised in the form of public concerns. Accordingly, one of the most effective ways to figure out the environmental problems that clustered firms encounter is describing the societal interactions between firms and other stakeholders in response to environmental problems. Chapter 4 addresses the first question by investigating a series of interactions surrounding environmental issues in Banwol-Sihwa and Yeosu.

- (2) How does the nature of the local production system affect the EIP development of clustered firms?

The second question analyses the dynamics of environmental cluster upgrading toward EIPs, focusing on the local production system dimension. As a local production system is composed of vertical and horizontal linkages of firm agglomeration, it is supposed that its main dynamics are value chain governance and collective efficiency. Therefore, the influence of value chain governance and collective efficiency on EIPs is analysed drawing on the empirical evidence collected from the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster.

- (3) In what way do the institutional support systems facilitate the collective actions of clustered firms to promote EIP development?

The third question aims to analyse the institutional support system dimension in which EIPs are coordinated and designed by the involvement of non-firm actors. The proposition here is that institutional support systems facilitate the environmental cluster upgrading toward EIPs. This proposition is examined by investigating the characteristics of institutional support systems of the Banwol-Sihwa region and the Yeosu region and their mechanism to implement the EIP programme.

- (4) What are the comparative lessons from the different environmental upgrading strategies between the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster?

The last research question seeks to compare the evidence from the Banwol-Sihwa case and the Yeosu case. Although the Banwol-Sihwa textile dyeing cluster and the Yeosu petrochemical cluster are very different from each other in terms of their production systems and institutional support systems, they have commonly attained significant environmental upgrading. Accordingly, this research question aims to investigate the two different pathways to EIP development. Chapter 7 is dedicated to this discussion.

III. RESEARCH DESIGN AND METHODOLOGY

3.1. Introduction

The primary aim of this chapter is to elucidate the research methodology of this doctoral study. I employ the case study research methodology to understand the dynamics underlying the EIP phenomena in two case industrial clusters which have some similarities and sharp differences with each other. One aim of the dissertation is to provide a comparative analysis of EIP, according to distinctive types of clusters. The empirical evidence is collected through contacting and meeting various actors involved in the EIP initiatives like local firms, research institutes, government agencies and NGOs.

This chapter is organised in four main sections. The next section provides a brief discussion on the philosophical foundation of this study, namely, social constructivism. The third section is dedicated to the explanation of how the case study research is designed. The research design, the case selection criteria and the research procedure are introduced in detailed ways. The fourth section is the focused description of the data collection and analysis process. The validity, the reliability and the ethical issues of this study are discussed in the last section.

3.2. Philosophical Underpinning: Social Constructivism

Before discussing the case study research design, it might be useful to identify the ontological and epistemological foundations of this study. This does not necessarily mean that this chapter is drenched with a philosophical discussion. An understanding of philosophical stances is involved in the types of evidence, the methods to collect evidence, the ideas to interpret evidence and, ultimately, the way to answer the research questions (Easterby-Smith *et al.*, 2002). Accordingly, the introduction to the philosophical underpinning here is functional to invite readers into a more substantial understanding of the methodological viewpoint in this study.

The research design and the methodology are based on the constructivist world view. It is commonly recognised that the positivist philosophy has overwhelmed the scientific

research field during most of the twentieth century. Briefly speaking, positivism believes that the objective truth on the external world can be generalised via value-free observation and testing. The positivist tradition has been challenged by critics for a long time and Tomas Kuhn's remarkable work in 1970, *The Structures of Scientific Revolutions*, triggered the full-scale emergence of other rival paradigms.

Constructivism is one of these philosophical paradigms. Guba and Lincoln (1994, pp. 110-111) summarise the ontology, epistemology and methodology of constructivism. First, the constructivist ontology is that realities are socially and experientially based and can be understood in the form of mental constructions which are not an absolute true. Second, constructivists assume that researchers and their research objects are in an interactive relationship in that findings are produced in the process of investigation. Third, the constructivist methodology is driven from the belief that individual constructions can be refined through a dialectical interchange so that a consensus construction is informed and sophisticated.

The constructivist worldview is contrary to the modern objectivist belief to which positivism is strongly committed. The basic ontology of positivism is that the world is externally and independently existing (Crotty, 1998). Accordingly, an investigator also exists independently from the world and thereby the objective and value-free observation is possible without any intervention from the world. Disagreeing with the positivist stance, constructivists pull down the dichotomy between an investigator and the world (Guba and Lincoln, 1994). Knowledge associated with realities is "being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context" (Crotty, 1998, p. 42). The notion of knowledge construction is followed by three reasoning. First, individual human beings perceive the world through their experience and interpret it. Accordingly, constructivists acknowledge the importance of subjectivity. In this regard, constructivists overlap the interpretivist stance focusing on social actors' experience (Schwandt, 1998). Second, realities, especially human practices, are being constructed. In other words, the constructivist position is premised on a social construction of reality (Searle, 1995). Last, knowledge or the terms to interpret the world are the artificial products from social processes (Gergen, 1985). This line of reasoning is named social constructivism.

While the social constructivist approach is not novel in the industrial cluster literature, the development of industrial ecology can be an interesting example for social constructivists.

Industrial ecology is an emerging academic field and it can be argued that the social dimension of industrial ecology is not firmly theorised yet. This implies, in the social constructivist viewpoint, that the knowledge upon the specific reality, called EIPs, is being constructed. The metaphorical language use and the practical models in industrial ecology are, arguably, the evidence of how researchers from different academic backgrounds communicate interactively, how knowledge is formed and how they can construct their social reality.⁴ In addition, industrial ecologists tend to think that the research on the economic, social, political and cultural contexts within an industrial symbiosis is situated in the social science field (Lifset and Graedal, 2002). This is reasonable because, no matter what technical solution is suggested, its acceptance and application relies on the various human contexts. In this regard, the social constructivist argument that reality is the result through the generally accepted social process in a specific context (Fish, 1989) resonates with this study which is intended to make a contribution to the social science field of industrial ecology. As discussed in the empirical chapters, EIP cannot be explained without its contextual understanding.

Taking note of more epistemological aspects, the EIP initiatives in Banwol-Sihwa and Yeosu can be addressed within the social constructivist viewpoint. EIP is a relatively new phenomenon, especially, in the Korean context. Accordingly, inquiries on the Korean EIP are situated in a continuously evolving process. This research circumstance clearly means that most information are scattered and often held by individual people involved in EIP as a form of experience and personal interpretation. A social science research to study dynamic changes cannot be implemented unless the investigator actually interacts with the people being investigated (Tacconi, 1998). As social constructivism places its emphasis on the collective generation of meaning (Schwandt, 1998), my role is information-weaving to

⁴ Furthermore, considering the origin of industrial ecology, it might be inevitable to have a doubt about the philosophical underpinning of industrial ecology. Why does industrial ecology which has its strong root in the natural and engineering sciences call for a social scientist research paradigm? The character of industrial ecology as multidisciplinary discourse ranging from natural science, technology to social science and dealing with complex integrated human/natural systems poses the ineluctable ontological issue; objective versus normative (Allenby, 2006). As Allenby points out, the philosophical paradigm issue of ontology, epistemology and methodology is not only for industrial ecology but also for all research fields of sustainability science family; ecological economics, life cycle assessment and sustainable engineering.

contribute to the knowledge construction by listening to people's experience and sharing ideas with the informants in an interactive manner.⁵

3.3. Research Design

The case study research design employed in this study has been gradually clarified in accordance with the progress in literature reviews and data gathering. This section illuminates each step of the case study research design. Through this procedure, the validity of this study can be scrutinised.

3.3.1. Case Study Strategy

The core research question of this study is “In what ways do the economic, political and social dynamics of industrial clusters promote or impede collective actions of clustered firms for the formulation of an eco-industrial park?” To answer the research question, empirical evidence is collected from two industrial clusters where local firms have achieved a relatively high degree of environmental performance, especially in terms of EIP initiatives.

Yin defines a case study as a research strategy that “investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (Yin 2009, p. 18). As a research object in the social sciences, case studies are a unit of human activities which can be investigated in the real world context (Gillham, 2000). A case can be an individual person,

⁵Any further discussion on the philosophical stance is beyond the boundary of this study. However, it might be useful to identify my personal preference to social constructivism for a possible future study. The interactive and interpretative stance of social constructivism makes me more comfortable than the individualistic and objective positioning of positivism. Clearly, it is because of my Korean and East Asian cultural background. While the western culture seems to be based in the worldview of “I and the others” stance, the East Asian stance is deeply embedded in the worldview of “I among us”. This difference is easily figured out by observing the language uses in two cultures. The East Asian philosophical tradition is likely to be characterised with its basic ontology and epistemology; Realities exist in the relations between the world and us. Although the Korean philosophical tradition is totally excluded in the process to accept the modern social sciences from the Western academia and marginalised as a moral philosophy, I reckon that it has the valuable potentiality to be developed as a social science paradigm in the future.

a group of people, organisation, site, situation, public programme etc. (Merriam, 2002; Yin, 2009; Robson, 2011). The fundamental goals of case studies are providing the detailed description of the contexts surrounding a phenomenon and understanding the dynamics of social behaviour underlying the phenomenon (Dyer and Wilkins, 1991). Case study is often expressed as a research strategy (Yin, 2009; Robson, 2011). The preference to the expression of strategy is because a case study is more than a specific skill and can be better understood if they are seen as a stance or approach.

In the viewpoint of case study strategy, my concern is investigating EIP as a phenomenon within two spaces of real industrial activities. The case study strategy was, perhaps understandably, not predetermined as a suitable methodology at the initial stage of this study. Before the fieldwork and even during the fieldwork, I have continued to sharpen and re-sharpen the research methodology. The methodological decision was made when I could sketch the given research circumstance surrounding the EIP initiatives in Banwol-Sihwa and Yeosu. There are several research conditions or circumstance in which a case study can be an effective methodological option. I introduce three research circumstances that fit into my study.

Theoretical Sampling

The first circumstance is so-called theoretical sampling (Eisenhardt, 1989). This is the condition that case study researches can provide empirical evidence to support and extend an emergent theory (Glaser and Strauss, 1967; Eisenhardt, 1989; Stake, 1995). As I review in chapter two, industrial ecology is an emerging theory and there might be a lot of industrial symbioses and EIPs across the world that are not fully investigated or even not discovered yet (Chertow, 2007). The more case studies are carried out, the better theory-building will be done. With regard to the Korean EIP model, there has not been a study based on the industrial district perspective. Accordingly, my case selection of the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster belongs to the theoretical sampling circumstance.

Ambiguous Boundary between Phenomenon and Contexts

The second circumstance is that a clear boundary between a phenomenon and its contexts cannot be figured out or a research aims to study contextual conditions of a phenomenon

(Stake, 1995; Gillham, 2000; Yin, 2009). The former is the case about which knowledge is not substantially accumulated and the latter is the case about which a research intends to adapt a new approach or to find out a less revealed causality. A majority of previous studies on EIP are based on the technical engineering approach. This research tendency is also true in the Korean academic context. I became aware that there has been little involvement of social scientists in the Korean EIP initiatives so far during my fieldwork. Moreover, it is also difficult to identify industrial district literature investigating the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster.⁶ Thus I have had to rely on my primary evidence to investigate the economic, social, political and cultural contexts of two industrial clusters.

Shortage of Secondary Data

The third circumstance is that there are not enough secondary data with which the features of the EIP can be expressed and measured in numerical terms. Although I have some statistical data sources on EIP like the government archives and the pamphlets published by Korea Industrial Complex Corporation (KICOX), the data is too basic to be used for any inferential analysis. This is because EIP is a newly introduced policy, hence the assessment tool is not fully developed and statistical data is not sufficiently accumulated as yet. Given that the secondary data on the EIP programme are unavailable, puzzling over raw data collected from a qualitative case study strategy is the appropriate and necessary methodological decision in my research designing.

3.3.2. Case Selection

Case Selection Criteria

A case study is fundamentally different from the positivist sampling. A case study is literally a research strategy to understand one or more cases in an in-depth manner.

⁶ While there are some previous studies on the Banwol-Sihwa national industrial complex (for example, Markusen and Park, 1995; Markusen, 1996; Jung et al, 2005; Jung et al, 2006), it seems that academic papers focused on the dyeing cluster have rarely published. As for the Yeosu national industrial complex, most papers are based in the environmental engineering discipline, concerning with its environmental issues rather than its economic, political and social structure.

Investigators select their cases intentionally and purposefully (Stake, 1995). The two cases in this study, the Banwol-Sihwa industrial complex and the Yeosu industrial complex, are also selected in a deliberate fashion, considering their common and different characters.

The case selection aims to investigate similar industrial ecology phenomenon in two different types of industrial cluster. Examples of polar types are chosen to extend emergent theory (Eisenhardt, 1989). In this regard, two main criteria were considered in selecting the cases. First, I observed that most case studies in the field of industrial ecology, perhaps involuntarily, have paid most attention to large firm clusters. It is partly because symbiotic networks between large firms are easier to spot and thus are first reported. Given that SMEs' industrial ecology practices are less documented in the field of industrial ecology, I opted for an EIP based in a SME agglomeration for one case study.

In contrast with this tendency in the industrial ecology literature, the industrial cluster literature has a substantial number of case studies on SME clusters. However, the industrial cluster literature has been relatively indifferent in large firm clusters or resource extraction industries such as the petrochemical and chemical sector that are the main research area in the field of industrial ecology. Accordingly, I intend to explore a typical example of large firm clusters working in a resource extraction sector and its EIP phenomenon as the other case study.⁷

Selection of Two Comparable Cases

Most of all, the cases are selected because EIP initiatives operate in both industrial complexes. The Banwol-Sihwa industrial complex is the sole SME agglomeration where the EIP programme has been implemented among the five regions designated as EIPs by the government when I carried out the fieldwork. Accordingly, in order to investigate EIP development by SMEs, the Banwol-Sihwa region is the inevitable choice. As for EIP development by large firms, I intended to investigate a petrochemical and chemical site. The reason of why I wanted to select a petrochemical and chemical site is that the petrochemical and chemical industry has an inherent nature as a material circulation

⁷ In addition, it is advantageous that two cases are selected in South Korea. Although the case study in my home country is an inevitable choice for the self-funded PhD student, there have been a small number of case studies on EIPs based in the non-western world so far.

system. There were two candidate industrial regions, Yeosu and Ulsan. Due to the better accessibility to Yeosu, I carried out the fieldwork in the Yeosu petrochemical cluster.

Secondly, the two industrial areas experienced a tremendous environmental disaster respectively over a similar period and have suffered from various environmental issues. Third, firms in both areas have their own business ties specialised for the environmental management. The fourth common feature is that both industrial clusters are part of a national industrial complex located in the coastal regions of South Korea.

At the firm agglomeration level, the two industrial clusters have several differences which can provide the useful frames to compare each other as portrayed in chapter 4. The Banwol-Sihwa textiles dyeing cluster is an agglomeration of single-plant SMEs, the Yeosu petrochemical cluster is an agglomeration of large firms. While most headquarters of the dyeing and printing units in Banwol-Sihwa are located at the local level, the petrochemical and chemical firms in the Yeosu petrochemical cluster are the localised production units of huge conglomerations or multinational companies. In terms of the value chain framework, while the dyeing cluster is a part of the globalised buyer-driven value chain, the petrochemical cluster is a localised producer-driven value chain.

There are some different features as to the non-firm organisation tiers of each industrial cluster. In Banwol-Sihwa, there are many institutions that function to support industrial activities. Public research institutes and local universities form their own 'cluster' within the area. Public agencies specialising in environmental management are also concentrated in Banwol-Sihwa. In contrast, the Yeosu industrial complex has much less number of institutions.

Selection of Six Representative EIP Projects

Multi-level case selection is demanded in an embedded case study by which an investigator focuses on subunits of a single case (Yin, 2009). This case study adapts multi-level case selection because an EIP is comprised of several industrial symbioses. The EIP initiatives in Banwol-Sihwa and Yeosu also consist of various local industrial symbiosis projects. In order to scrutinise how the local projects are operated, the research design also include three local industrial symbioses within each case industrial cluster.

Three industrial symbioses are in operation in the Banwol-Sihwa dyeing cluster. The most representative industrial symbiosis in which the dyeing cluster is involved is the

wastewater heat exchange with its neighbouring cogeneration plant. In addition, the dyeing cluster provides its effluent sludge to a cement manufacturing plant as a substitute. The project to recycle oil ingredient in the air pollutant emitted from a dyeing unit is on test. All these three industrial symbioses are investigated in this study.

Case 1: Wastewater Heat Exchange between effluent Treatment Plant and Cogeneration Plant

The first EIP project is the wastewater heat exchange between SDEC's effluent treatment plant and its neighbouring cogeneration plant (steam heat supplying unit), KG Energy, which has been operating since November 2011 in the Sihwa area. The basic principle of this industrial symbiosis is supplying the heat from textile dyeing effluent to the cogeneration plant as an energy source. The temperature of textile dyeing effluent is about 40 to 50 degrees Celsius. Accordingly, if the effluent is heated through the heating system, called heat pump, the wastewater heat can be reused as an economically valuable energy source (Interviews AN-I1, AN-I2, AN-I7). The exchange network in Sihwa has been operating since November 2011 while the network in Banwol is still under the negotiation.

Case 2: Effluent Sludge Recycling between Dyeing Cluster and Cement Manufacturing Plant

The dyeing cluster's second industrial ecology practice is the exchange of textile effluent sludge between the dyeing cluster and a cement manufacturer since 2007. Cement is made with 90 percent of limestone and 10 percent of the other resources such as ferric material and clay. The textile dyeing effluent sludge can be used as a substitute for clay (Interviews AN-I1, AN-F8). As for the textile dyeing businesses, supplying effluent sludge to the cement manufacturing industry is the easiest way to cope with the sludge problem because cement furnace burns sludge at 1,450 degrees Celsius. This means that the dyeing and printing firms do not need to be concerned about secondary pollution, intermediate treatment and the percentage of water content in sludge (Interview AN-I4).

Case 3: Electric Fume Collection System to Recycle Oil Ingredients from Odour

The last EIP project which is carried out in the Banwol-Sihwa dyeing cluster is the collection and reuse of oil in the white smoke emitted from textile dyeing mills. The basic principle applied for this EIP project is collecting oil ingredient which is contained in the air pollutant generated from the tentering process through the odour control system, called electric fume collector. One dyeing firm, one used oil refinery and one university-based research group have been involved in this project.

As for Yeosu, eleven industrial symbioses are in operation (Internal data provided from Jeonnam EIP Centre). Because of their big scale and sufficient financial capacity, the firms located in the Yeosu petrochemical cluster have relatively rich opportunities to establish industrial symbiosis networks. I investigate three industrial symbioses in Yeosu selectively. The first case is the largest industrial symbiosis in the Yeosu petrochemical cluster, the hydrogen recycling network, in which 22 firms are participate. I selected this industrial symbiosis as a case because the hydrogen recycling network is the representative EIP project in which most large firms are involved. Another industrial symbiosis being investigated in this research is the network to recycle waste catalysts. This network is highly profitable because the catalysts used in the petrochemical industry are mostly precious metals. The last case network is effluent sludge recycling. A group of affiliate firms have succeeded in minimising their effluent sludge by establishing a recycling network between their production units and cogeneration plant unit. I selected these two industrial symbioses in accordance with the advice from Jeonnam EIP Centre.

Case 4: Hydrogen Recycling Network

The hydrogen recycling network is the biggest by-product exchange network in which 22 firms are involved. This network aims to reuse hydrogen generated from the naphtha cracking centres in a more economically profitable way. Before this industrial symbiosis was introduced, hydrogen was used as fuel gas in naphtha cracking units or just emitted to the atmosphere (Interview YO-F2, YO-I2). In fact, the inter-firm exchange of hydrogen was already envisaged endogenously at the local level before the government launched the EIP programme (Interview YO-I3). Public intervention helped firms to expand across the cluster and thus this network is now evaluated as the most successful EIP case in Yeosu.

Case 5: Network to Recycle Waste Platinum Catalyst

The second case is the network to optimise waste catalyst recycling. Catalyst is a material to quicken chemical reactions in petrochemical processes. Catalysts are discarded because they cannot function properly after a certain operation time. In many cases, the materials used as catalysts in the petrochemical industry are precious metals (Interview YO-F3). To reuse the precious metal catalysts, a group of firms located in the Yeosu petrochemical cluster has tested a new metal refining technology and several firms are currently participating in this new business.

Case 6: Effluent Sludge Recycling as Energy Source

The final industrial symbiosis investigated in this study is the network to reuse effluent sludge as an energy source. Effluent sludge accounts for 65 percent of the total amount of sludge, 83,470 tons, generated from the Yeosu industrial district (Ministry of Knowledge Economy and Korea Industrial Complex Corporation, 2011). As the ocean disposal of sludge will be prohibited shortly, the petrochemical firms must find other ways to treat their sludge on land. The affiliate firms of Kumho Group in the Yeosu industrial district have succeeded in using sludge as an auxiliary fuel for their affiliate cogeneration plant. Kumho petrochemical, Kumho P&B Chemical and Kumho Polychem generate organic sludge, while Kumho Cogeneration Plant emits inorganic sludge. The cogeneration plant is equipped with fluidized incinerators that use sand as the material to improve thermal efficiency.

These subunits are selected in two different ways in each case industrial cluster. In Banwol-Sihwa, all three EIP projects in which the dyeing cluster is involved are investigated. However, the number of EIP projects in Yeosu is quite large; hence the investigation focuses on three representative projects. The representativeness is based on three criteria; whether core large firms of the petrochemical cluster are participating or not; how many firms are involved; and whether the local EIP centre can confirm its representativeness. The point in this lower-level case selection is that the subunits are not specific actors like local firms, research groups and public agents but specific projects for which the actors collaborate with each other. The case selection criteria and the characters of each case and subunits are illuminated in table 3-1.

[Table 3-1] Multi-level Case Selection

	Case 1: Banwol-Sihwa Industrial District	Case 2: Yeosu Industrial District
Common Features	<ul style="list-style-type: none"> - National industrial complex managed by the central government - Experienced environmental disasters in the mid-1990s - EIP in process since the late 2000s - Local governance existing and active local NGO movement 	
Different Features	<ul style="list-style-type: none"> - Dyeing and printing sector - Dominated by small, locally owned firms - A part of globalised buyer-driven value chain - High availability of technical expertise and business supporting services in the region 	<ul style="list-style-type: none"> - Petroleum, petrochemical, and chemical sector - Dominated by large, externally owned firms - Localised producer-driven value chain - Low availability of technical expertise and business supporting services in the region
Subunit EIP Projects	<ul style="list-style-type: none"> Three industrial symbioses - Wastewater heat exchange network - Sludge treatment network - Collection and Reuse of oil ingredient via EFC 	<ul style="list-style-type: none"> Three industrial symbioses - Hydrogen recycling network - Waste catalyst recycling network - Effluent sludge recycling network

*Source: Author

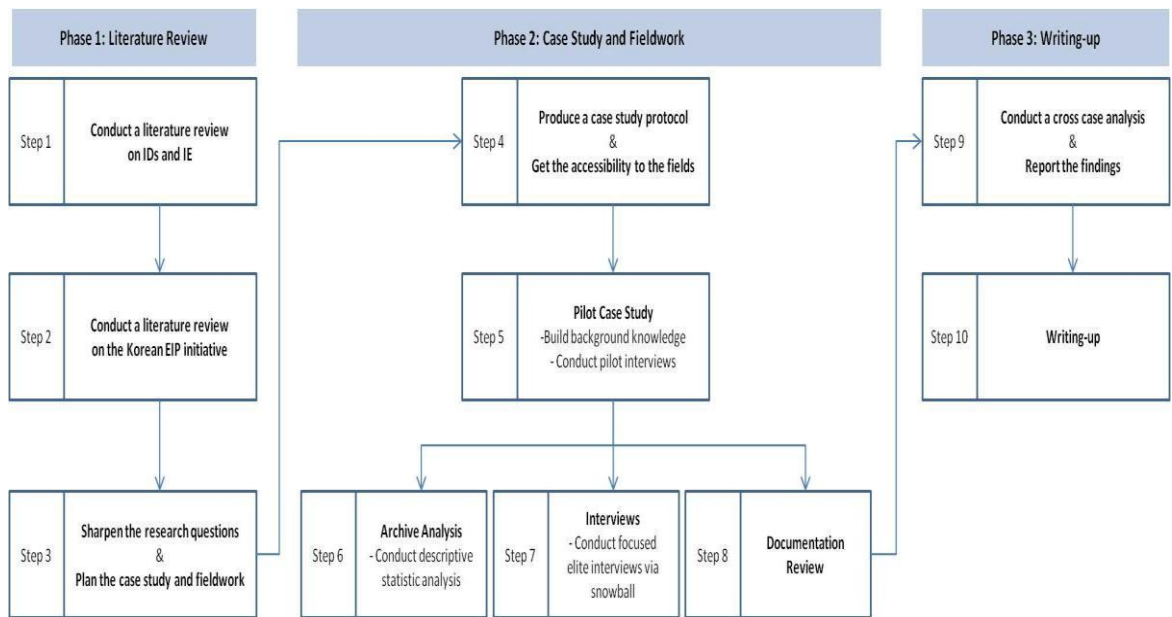
3.3.3. Research Process

The research process was made up of three phases; (1) the literature review to establish the theoretical framework, (2) detailed and in-depth empirical case studies of the two case industrial clusters and (3) data analysis and writing-up. The case study phase started with setting-up a case study protocol and planning the fieldwork. Yin (2009, p. 81) proposes that a case study protocol has an overview of the case study project, field procedures, case study questions and a guide for the case study report. Referring to Yin's suggestion, the initial case study protocol was designed with the focus on the fieldwork plan and the interview questionnaire. However, the initial protocol was amended in many aspects in accordance with the realities in the field.

The fieldwork was initially planned to be implemented in 2010, but due to personal reasons, it was effectively carried out during ten months in 2011. At the start of the fieldwork, the first challenge was sketching the characteristics of two industrial sectors and learning the technical aspects of industrial ecology practices. It was necessary to build some background knowledge to communicate with the informants so that various documents and literature were reviewed. The search was implemented on the internet and local libraries and the sources are mainly formal reports published by the government agencies and the national-level business associations. In the meantime, a few interviews were carried out. Due to the lack of background knowledge, most interviews in this step were devoted to learning the technical features of the dyeing industry and the petrochemical industry. Therefore, this learning process can be regarded as the pilot case study.

The next step is the full-scale case study fieldwork. The investigation began in the Banwol-Sihwa industrial complex and then moved into the Yeosu industrial complex. Three pathways to the data collection were employed. The first was the investigation and analysis of archival records. The descriptive statistic analysis has been carried out to illuminate the measured phenomenon and compare with the qualitative data collected from the interviews. The second was interviews with local informants. The dialogues with the informants are the major data source in this study. The third was documentation review. The data collected from the full-scale fieldwork has continuously been interpreted and analysed. The intermediate results from the interpretation and the analysis have been recorded in a series of research notes. At the final stage of the fieldwork, the cross case analysis was implemented with the results and data gained from two industrial areas. The whole research process can be diagrammed as in figure 3-1.

[Figure 3-1] The Flow of Research Processes



*Source: Author

3.4. Data Collection and Analysis

3.4.1. Principle: Data Triangulation and Constructivist Interpretation

The question of “in what ways data is collected” is a crucial issue to evaluate validity and reliability of a study. Therefore, it is useful to identify two principles that I followed in the data collection process. These are data triangulation and constructivist interpretation.

Triangulation can be defined as “the combination of methodologies in the study of the same phenomenon” (Denzin, 1978, p. 291). Denzin suggests four categories of triangulation; data triangulation, investigator triangulation, theory triangulation and methodological triangulation. Among these four types, data triangulation is applied to this research. Data triangulation refers to drawing on empirical evidence from a variety of data sources (Mathison, 1988). Given that the case study strategy has the advantage of multiple data sources (Chetty, 1996; Stake, 1995; Yin, 2009), I collected data from various sources like government reports, archival records, newspaper articles and internal documents provided by informants. Such raw data were constantly compared with data collected from

interviews. I processed information by synthesizing all data and only refined information was accepted as evidence.

In parallel, constructivist interpretation underlies the data collection process, especially with regard to the interviews. As described before, most data useful in this research are engraved in the local informants' minds as the form of experiences, memories and ideas rather than in a form of texts or numerical figures. This implies that information is personally interpreted and knowledge is individually constructed. Therefore, the interview is the process to collect individual constructions and continue to sharpen them into knowledge.

3.4.2. Archival Records and Documentation Reviews

The data collection methods have been arranged in response to the four subordinate research questions; (1) What sort of environmental problems arise from an industrial district? (2) How does the nature of the local production system affect the EIP development of clustered firms? (3) In what way do institutional support systems facilitate the collective actions of clustered firms to promote EIP development? (4) What are the comparative lessons from the different environmental upgrading strategies between the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster?

Environmental issues are a momentum and driver for eco-industrial development. This shows the political dynamics toward the EIP development. The two others, local production system and institutional support system, which represent the economic dynamics and the institutional dynamics underlying the EIP phenomenon in this research design, are postulated as causal elements or situational factors.

Environmental Problems

The government archives were firstly investigated due to its public accessibility and convenience in sketching realities with numerical and graphical data. The sources are the environmental white papers published by the central government and the provincial governments, the environmental statistics yearbooks reported by the Ministry of

Environment, and the other statistics records on effluent, air pollution and industrial wastes published by a few specialised public bodies on an annual basis.

A variety of documents are another data source. Reading newspaper articles were the easiest way to gain the basic information. In addition, a large number of academic studies and public research reports on environmental issues have been reviewed. In order to generate more contextual understanding, the minutes of meetings of three city assemblies and two regional consultation committees were also reviewed. The last source for the documentation reviews is the CSR reports that are available only for the large firms located in the Yeosu petrochemical cluster.

Societal Interaction

Environmental concerns are obviously one of the representative public agenda with various stakeholders involved in solving the issues. I reviewed the societal interaction surrounding the environmental issues generated from clustered firms in Banwol-Sihwa and Yeosu as the background knowledge and context-setting at the initial stage of my fieldwork. However, it did not take much time to realise this is a very important dynamic driving the local production systems toward EIPs because most informants pointed out that such societal interaction offers triggered collective actions by clustered firms for improved environmental performance.

The societal interactions in which clustered firms are involved are not easily exposed by quantitative sources. Accordingly, I had to heavily rely on the narratives provided by interviewees. The problem in listening to the stories from people is the accuracy of their memory. Thus I did not solely rely on the interviews but also searched and reviewed all available records and news reports. A series of events related to environmental issues in Banwol-Sihwa and Yeosu were chronicled in the interim reports and fieldwork research notes and the actors involved in each event were identified. This work was useful to identify whom I had to meet and interview during the fieldwork.

Local Production System

In retrospect, uncovering the current status and character of local production systems in the two industrial clusters was the most challenging task in the data collection process. There

are a surprisingly small number of previous studies on the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster in the industrial cluster literature and even in the Korean academia. To solve this puzzle I began with the industrial complex statistics yearbook published by KICOX in order to collect general and superficial information on two industrial clusters. Some maps demonstrating the geographical features of the industrial districts were one of the data sources. Two comprehensive directories of companies published respectively by the Korea Chamber of Commerce and Industry and *Maeil* Business Newspaper on an annual basis provided some basic information about individual firms located in Banwol-Sihwa and Yeosu. However, the two directories often gave different information about the same firms. Hence, this archival record can only be used as a complementary data source.

Together with the interviews, the documentation reviews were the main data collection technique in terms of production networks. The internal documents like list of member firms provided by the local business associations are the most essential source in gathering the information on individual firms and identifying the character of local production networks. A few missing information on individual firms were collected via reviewing credit reports or company websites. Combined with the archive data, I have produced a database on individual dyeing firms and petrochemical firms which contain company name, owner, year of establishment, main production line, main product, number of employers, annual sales and so forth. In addition, a few public research reports on the dyeing industry or the petrochemical industry were reviewed.

Institutional Support System

Based on the conceptual framework suggested in Chapter 2, I postulate there are three dimensions that should be probed in order to understand the influence of institutional support system on the environmental performance of clustered firms; the structure of institutional infrastructure at the local level, the regulatory framework of the state at the national level and the cluster-wide institutional linkages retaining the characteristics of policy networks.

The basic data sources relevant to the institutional support system are documents. There are a substantial number of formal documents published by public agencies and research institutes like proposals, interim reports, project case studies, and pamphlets available at

the local level. Besides, the higher-level documents like agendas, assessment reports and meeting minutes at the central government level are also accessible as a form of public files. Reviewing these documents provided me with the knowledge about the types and roles of local institutions. In addition, I studied the state acts relevant to industrial location, environmental management and technology and science promotion as well as analysed some budgetary documents illuminating how much resource has been allocated to a specific public programme. This data collection work aimed to understand the regulatory framework.

Due to the specific character of South Korea as a government-led developmental state, reviewing documents is an effective method to figure out the hierarchical policy structures. However, mapping cluster-wide institutional linkages is a different task because such linkages often pertain to invisible social dimensions. Therefore, the qualitative data collected from the interviews during the fieldwork is the main source with which I demonstrate the cognitive maps on the cluster-wide institutional linkages of the two industrial areas.

[Table 3-2] The data sources from archival records and documents

	Archival Records	Documentation Reviews
Environmental issues	<ul style="list-style-type: none"> -Environmental white papers - Environment statistics yearbook - Other statistical records on pollutants 	<ul style="list-style-type: none"> - Newspaper articles - Public research project reports - Academic papers - CRS reports - Meeting minutes
Production networks	<ul style="list-style-type: none"> - Industrial complex statistics yearbook - Comprehensive bibliography of companies 	<ul style="list-style-type: none"> - Internal documents - Credit reports - Company websites - pamphlets
Social networks		<ul style="list-style-type: none"> - Business community newspapers - Chronicles
Government intervention	<ul style="list-style-type: none"> -Budgetary documents 	<ul style="list-style-type: none"> - Agendas and announcements - Policy assessment reports

- proposals
- Interim reports
- Project case studies
- meeting minutes

*Source: Author

3.4.3. Interviews

Interview Setting

In accordance with the conceptual structure of industrial district identified in Chapter 2, the interviews were implemented with actors from the three main components of each case industrial cluster: the firm agglomeration, the institutional infrastructure and the external linkages. By making the three conceptual spaces, I intend to triangulate the phenomenon with three distinguishable opinions from the three sectors.⁸

44 formal interviews and many informal conversations were carried out with 38 respondents from 32 organisations. All interviews and discussions have been transcribed, summarised and translated. The final interview transcriptions are converted into a form of database as in table 3-3.

[Table 3-3] Interview database

Code	Case Area	Conceptual Space	Character of Organisation
CE-I1	Central	External	Quasi-public business supporting agency: Korea Federation of Small and Medium Business (Kbiz)
CE-I2	Central	External	Quasi-public business supporting agency: Technopark
CE-I3	Central	External	University: Pohang University of Science and Technology (POSTEC)

⁸ I do not argue that this interview setting is designed as within-method triangulation. However, it was practically effective to adjust some distorted memories of the informants and figure out the difference of opinions come from each sector.

CE-I4	Central	External	Public agency: Presidential Committee on Regional Development (PCRD)
CE-I5	Central	External	Public agency: Korea Industrial Complex Corporation (KICOX), Cluster Promotion Department
CE-I6	Central	External	Public research institute: Korea Institute of Industrial Technology (KITECH), Green Manufacturing System Division
CE-I7	Central	External	Public agency: Korea Finance Corporation (KoFC)
AN-F1	Banwol-Sihwa	Firm Agglomeration	Firm: dyeing unit
AN-F2	Banwol-Sihwa	Firm Agglomeration	Firm: dyeing unit
AN-F3	Banwol-Sihwa	Firm Agglomeration	Firm: dyeing unit
AN-F4	Banwol-Sihwa	Firm Agglomeration	Firm: printing unit
AN-F5	Banwol-Sihwa	Firm Agglomeration	Firm: printing unit
AN-F6	Banwol-Sihwa	Firm Agglomeration (external to the cluster)	Firm: global buyer
AN-F7	Banwol-Sihwa	Firm Agglomeration (external to the cluster)	Firm: global buyer
AN-F8	Banwol-Sihwa	Firm Agglomeration	Firm: EIP partner
AN-I1	Banwol-Sihwa	Firm Agglomeration	Local trade association: Sihwa Dyeing Enterprise Cooperative (SDEC)
AN-I2	Banwol-Sihwa	Firm Agglomeration	Local trade association: Banwol Dyeing Enterprise Cooperative (BDEC)
AN-I3	Banwol-Sihwa	Institutional Infrastructure	Public agency: Gyeonggi Eco-Industrial Park Development Division(Gyeonggi EIP Centre)
AN-I4	Banwol-Sihwa	Institutional Infrastructure	Public research institute: Korea Test Laboratory (KTL)
AN-I5	Banwol-Sihwa	Institutional Infrastructure	Public research institute: Korea Institute of Industrial Technology (KITECH), Gyeonggi Regional Division
AN-I6	Banwol-Sihwa	Institutional Infrastructure	Public research institute: Korea Institute of Industrial Technology (KITECH), Dyeing & Finishing Technology Centre

AN-I7	Banwol-Sihwa	Institutional Infrastructure	Public research institute: Korea Institute of Industrial Technology (KITECH), Green Energy Technology Centre
AN-I8	Banwol-Sihwa	Institutional Infrastructure	Public agency: Korea Industrial Complex Corporation (KICOX), Gyeonggi Regional Headquarter
AN-R1	Banwol-Sihwa	Institutional Infrastructure	Regional committee: Sihwa Regional Committee for Sustainable Development
AN-R2	Banwol-Sihwa	Institutional Infrastructure	Local NGO: Ending Odour in Ansan
YO-F1	Yeosu	Firm Agglomeration	Firm: oil refinery unit
YO-F2	Yeosu	Firm Agglomeration	Firm: naphtha cracking unit
YO-F3	Yeosu	Firm Agglomeration	Firm: chemical manufacturing unit
YO-I1	Yeosu	Firm Agglomeration	Local trade association: Yeosu Industry Environment Association (YIEA)
YO-I2	Yeosu	Institutional Infrastructure	Public agency: Jeonnam Eco-Industrial Park Development Division(Jeonnam EIP Centre)
YO-I3	Yeosu	Institutional Infrastructure (external to the cluster)	University: Korea Advanced Institute of Science and Technology(KAIST)
YO-R1	Yeosu	Institutional Infrastructure	Regional committee: Yeosu Committee for Co-development
YO-R2	Yeosu	Institutional Infrastructure	NGO: Yeosu Agenda 21
YO-R3	Yeosu	Institutional Infrastructure	NGO: Yeosu YMCA

Interviews in Banwol-Sihwa

The interview process started in the Banwol-Sihwa dyeing cluster. I tried to contact individual firms at the very first stage and, naturally enough, failed to obtain interview opportunities from dyeing and printing firms several times due to an initial of rapport formed with dyers. Accordingly, it was necessary to access the gatekeepers of the Banwol-Sihwa dyeing cluster, Banwol Dyeing Enterprise Cooperative (BDEC) and Sihwa Dyeing Enterprise Cooperative (SDEC). The full-scale investigation in Banwol-Sihwa was begun

from the interviews with the two dyeing business cooperatives, BDEC and SDEC. Because they are the representative of the dyeing sector and one of key actors in the EIP initiative in Banwol-Sihwa, my visits to SDEC and BDEC became the opportunity to sketch a cognitive map on the environmental management system.⁹

The first thing that greeted me in Sihwa was bad smell. Although the odour does not come from SDEC's effluent treatment plant, there was a powerful stench and I could understand immediately why the odour is a controversial environmental issue in Banwol-Sihwa. The head manager of environmental management department (who is now promoted to the executive director) of SDEC provided detailed answers to my questions and kindly guided me around the effluent treatment plant and the heat pump facility that is operated for the wastewater heat exchange network. As for BDEC, the most impressive scene was a big banner hung on the effluent treatment plant showing their slogan, so-called 3R Innovation "Reduction, Recycling, Reusing" The interviews with BDEC and SDEC revealed that the EIP initiative has been implemented in the cooperation with non-firm local institutions and that individual dyeing and printing firms were seldom engaged in EIP projects. This led to the necessity that subsequent interviews should be more focused on local institutions participating in the Banwol-Sihwa EIP initiative.

As for individual firms, I interviewed five dyeing and printing units in order to inquire into the business structure in the Banwol-Sihwa dyeing cluster and, more importantly, the contributions to the EIP programme of individual firms. I had been in trouble at the initial stage of firm interviews due to the lack of my background knowledge on the dyeing and printing process. For example, a company manager had to spend most of this interview time to teach me about the manufacturing process and technical aspects of dyeing and printing. I had a chance to look around the workplaces of two firms. One of the facilities I visited was particularly impressive because three silk printing firms share one factory to save on cost and generate synergy effects.

A series of interviews with individual dyeing and printing firms significantly affected my initial research design in two ways. First, I realised that the business people working in the Banwol-Sihwa dyeing cluster are proud technicians and engineers and thus I should be a *humble listener*. Accordingly, the interview questionnaires prepared before the fieldwork

⁹ In addition to the dialogues with the informants from the two business cooperative, I also directly observed the essential facilities in their EIP initiative like the common effluent treatment plants and the heat pumps with their guidance.

were sharply changed into more open-ended styles. Second, it turned out that the dyeing cluster is highly linked with the apparel value chain in the global context. Hereupon, I interviewed two branded clothing companies that are global buyers who have business relations with the Banwol-Sihwa dyeing cluster.

To investigate the global apparel value chain in which the Banwol-Sihwa dyeing cluster is engaged, I interviewed three people from two top-branded apparel companies that are based in the US and European respectively. The US-based buyer has a strong linkage with several firms located in Banwol-Sihwa so that most information on the global value chain was collected from it. They explained their business strategy to govern the global value chain in detailed ways and their compliance programme related to environment and labour issues. I also tried to contact and meet a few firms in other sectors that were in the partnership with SDEC and BDEC for the EIP initiative. It was much harder to gain access to the EIP partner firms because I could not find a contact person between the different industrial sectors. Fortunately, one firm consented to being interviewed and provided sufficient information on its by-product exchange practice with the dyeing and printing sector.

The more I investigated the Banwol-Sihwa dyeing cluster, the more obvious the engagement of non-firm institutions in implementing the EIP initiative in the Banwol-Sihwa dyeing cluster is much more extensive than I expected before the fieldwork. This drove my interview focus to identifying the institutional structure of the Banwol-Sihwa industrial complex and investigating the roles of non-firm organisations. I visited EIP practitioners and researchers from the local institutions directly involved in the EIP projects of the Banwol-Sihwa dyeing cluster: Gyeonggi EIP Centre; Korea Test Laboratory (KTL); and, Korea Institute of Industrial Technology (KITECH). These interviews resulted in two essential findings: (1) The EIP initiative has developed together with another national-level industrial policy, called Industrial Cluster Programme, whose purpose is to build and promote regional innovation system. (2) Many efforts to improve the environmental performance of the dyeing sector had been made through the cooperation between the Banwol-Sihwa dyeing cluster and other local institutions, especially KITECH, already before the EIP programme.

Stakeholders like residential communities and NGOs are considered as one of main actors from the beginning of this doctoral study because environmental problems generated from industrial activities in an industrial area is a public issue by which everyone can be affected.

I interviewed an expert involved in Sihwa Regional Committee for Sustainable Development, a local university-based researcher working with civil society bodies in Ansan and a former representative of Ending Odour in Ansan, one of local environmental movement organisations.

Interviews in Yeosu

The Yeosu petrochemical cluster is composed of one petroleum refinery, three naphtha cracking units and other chemical firms. Accordingly, I selectively interviewed the petroleum refinery, one naphtha cracking centre and one of the chemical firms. All the firms interviewed in the Yeosu petrochemical cluster have participated in at least one industrial symbiosis network.

The first firm interview was a very luck case. One of my friends worked for one of the three naphtha cracking centres in Yeosu. She called one of her previous colleagues and the staff introduced me to the head of environment and safety management team. The high-level manager kindly answered all my questions and provided me very detailed explanation on the petrochemical production system, drawing many chemical formulas and diagrams. The second firm interview was carried out with the sole petroleum refinery in the Yeosu industrial site. As the petroleum refinery is a huge multinational company, I was somewhat sceptical about a chance to interview the firm. After long agonizing I emailed its customer counselling system on the firm's website and, surprisingly, the customer service team called me to inform that an interview is arranged, saying "apologies about the delayed response." The general manager of corporate social responsibility team who I met explained a lot about their CSR activities, political involvement and corporate governance as well as environmental issues. The last firm interview was mediated by Gyeonggi EIP Centre. It was also productive meeting because I could make an interesting point with regard to the corporate governance thanks to the informant's explanation on the interaction between affiliate firms.

To investigate environmental joint actions and horizontal linkages in the Yeosu petrochemical cluster in greater depth, I contacted YIEA, a local industrial association specialised in managing environmental concerns. This interview furnished me with crucial raw data on the cluster governance structure and relations between large firms and non-

firm institutions at the local level. This raised the necessity of a close probe into the roles of non-firm actors for the EIP initiative in Yeosu.

While interviewing individual firms, I also contacted and visited Jeonnam EIP Centre, Yeosu Committee for Co-Development, Yeosu Agenda 21 and Yeosu YMCA. Jeonnam EIP Centre elucidated current networks in which industrial symbioses are embedded. Particularly, Jeonnam EIP Centre played a gatekeeper role by introducing other interviewees and providing a guide to the industrial site. Different from Banwol-Sihwa, Yeosu does not have quantitatively thick and spatially intensive institutional infrastructure. Instead of business supporting function, political institutions have high influential power in Yeosu. Eleven large firms represent the industrial community by participating in the regional consultative committee, Co-Development Committee. The other reason is that, different from the Banwol-Sihwa case, Yeosu-based NGOs have actively participated and, in a sense, took the lead in establishing the EIP in Yeosu. Therefore, I needed to scrutinise the influence of these actors. In addition, I selectively interviewed an external researcher who was a member of the EIP promotion team at the initial stage of the EIP programme in Yeosu and Jeonnam EIP Centre. As I expected, the researcher, as a founding member, explained cooperative relationships when the EIP programme was started in Yeosu.

Interviews at the National Level

Several interviews beyond the geographical boundaries of Banwol-Sihwa and Yeosu were carried out during the fieldwork. First, I visited key informants from the headquarters of KICOX and KITECH in order to understand the national-level plan and management system on the EIP programme. Besides, I had discussions with a former practitioner worked for Technopark, one of the regional innovation system projects in South Korea, a former policy maker worked for the Presidential Committee for Regional Development, the organisation that has developed the Industrial Cluster Programme since 2003, and a researcher specialised in industry-academy cooperation. All these three interviews aimed to study policy network frameworks in which the EIP programme are situated and implemented. Furthermore, I contacted Korea Finance Corporation in order to understand public funding systems to support firms' environmental upgrading.

Interview Methods

The most elementary aim postulated in the interview process is cross-checking the facts which I have found via the archival record analysis and the documentation reviews. This is the screening to single out any mistaken information. However, this is not the ultimate goal of the interviews. The fundamental purpose is to collect qualitative data with which the sequence and consequence of events within the local EIP initiatives can be constructed and the causes and effects underlying the EIP phenomenon can be interpreted.

Based on the industrial cluster perspective, the main data source is definitely the interviews with firm owners or high-level managers. The interview is an effective tool in gathering important local knowledge about what make the cluster works (Austrian, 2000). I also met experienced experts and mature researchers who play a role to support or encourage the local firms to improve their environmental performance. In order to derive their stories, the interviews were designed as a type of focused interview. Focused interview can be featured that a researcher focuses on the experience and opinions of the interviewees who have been involved in a situation (Merton *et al.*, 1990). I supposed that the most effective interview technique to elicit stories, experience and opinions from the proud elites is making the questionnaire an open-ended style. Thus, the interviews took a form of guided conversation. This type of qualitative interviewing method is preferable to the constructivist epistemology (Warren, 1994).

Furthermore, it should be noticed that some interviews were a sort of interdisciplinary discussion. Some interviewees were with the researchers trained in the natural science or the technical engineering discipline. Naturally, the interviews with them became a chance to communicate with industrial ecologists. As normal for any researcher, the industrial ecologists who I met during the fieldwork have their own propositions, analyses and interpretation on the phenomenon. This interview atmosphere was advantageous that I can share their opinions, reinterpret their understanding and construct the knowledge on the environmental performance of clustered firms in two industrial districts.

3.4.4. Data Analysis Framework

The data analysis framework to address the four research questions is as follows;

What sort of environmental problems arise from an industrial cluster?

- Introducing the two case studies; the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster;
- Identifying the environmental issues generated from the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster;
- Analysing the narrative on societal interactions surrounding the environmental issues in two case areas in chronological order.

How does the nature of the local production system affect the EIP development of clustered firms?

- Identifying the characteristics of local production systems in the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster and mapping the cluster structures;
- Investigating the six subunit case studies of industrial symbioses and mapping the environmental management systems of the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster;
- Analysing the EIP developments in the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster with the four social factors of industrial ecology;
- Analysing the dynamics underlying the EIP development in the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster.

In what way do institutional support systems facilitate the collective actions of clustered firms to promote the EIP development?

- Identifying the characteristics of institutional support systems in the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster and mapping the cluster structures;
- Investigating the six subunit case studies of industrial symbioses and mapping the environmental management systems of the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster;
- Analysing the EIP developments in the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster with the four social factors of industrial ecology;
- Analysing the dynamics underlying the EIP development in the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster.

[Table 3-4] Data Analysis Framework

Analysis Area	Cluster Structure	Upgrading Dynamics	EIP	Industrial Ecology
Local Production System	Firm agglomeration - Vertical linkages - Horizontal linkages	Value chain governance Collective efficiency		Role of champion Mental Distance
Institutional Support System	Institutional infrastructure - Actors and their roles	Regional innovation		Institutional setting Planning

*Source: Author

What are the comparative lessons from the different environmental upgrading strategies between the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster?

- Comparing the differences between the two clusters in terms of the scales of firms, the structures of value chains and the characteristics of institutional support systems;
- Comparing the differences between the two clusters' EIP development in terms of mental distance, champion's role, institutional setting and planning;
- Synthesizing the lessons from the comparative analysis.

3.5. Trustworthiness, Ethical Issues and Research Limitations

All researchers must demonstrate the credibility of their studies. While the positivist and quantitative research tradition has its well established and codified rules to prove validity and reliability, how to establish validity and reliability in qualitative researches is still a debate. Nevertheless, "trustworthiness of a research report lies at the heart of issues conventionally discussed as validity and reliability." (Seale, 1999, p. 266) In a sense, demonstrating validity and reliability of this study is a repetitive explanation of methodology. Thus, in this concluding section I offer my arguments on the verification of validity and reliability of the primary and secondary evidence presented in this study. In addition, ethical issues pertaining to this study are also considered.

3.5.1. Trustworthiness

Validity

As introduced in chapter one, this doctoral study can be characterised as a qualitative exploratory case study. Maintaining the methodological position as a qualitative research, some quantitative data are used in a limited way in order to describe the background of the EIP phenomenon and supplement qualitative data.

To demonstrate validity, the main research design method, case study strategy, and the basic research nature, qualitative exploration, should be simultaneously considered. Yin summarises three types of validity which can be applicable to case studies as followed;

- Construct validity: identifying correct operational measures for the concepts being studied
- Internal validity (for explanatory or causal studies only and not for descriptive or exploratory studies): seeking to establish a causal relationship, whereby certain conditions are believed to lead to other conditions, as distinguished from spurious relationships;
- External validity: defining the domain to which a study's findings can be generalized (Yin, 2009, p. 40).

According to Yin's suggestion, internal validity is not relevant to the present research. In terms of construct validity, the first and most popular suggestion from qualitative researchers is triangulation (Denzin, 1978; Mathison, 1988; Creswell and Miller, 2000; Golafshani, 2003; Yin, 2009; Robson, 2011). Data triangulation is used in this study as the main tactic to attain validity. Another tactic is disconfirming evidence (Creswell and Miller, 2000), the constructivist version of falsification. Investigators intentionally search for negative evidence with which preliminary proposed themes or categories can be disconfirmed (Miles and Huberman, 1994). By applying the disconfirming evidence tactic, two major corrections have emerged. First, rejecting my initial idea that global buyers directly affect the EIP phenomenon, their influence works in a different way. Second, my biased understanding that the government is just a regulator has been disconfirmed through a series of interviews. The last but most decisive tactic to attain construct validity is self-correcting. Qualitative researchers normally continue to sharpen and re-sharpen their

research questions and methods. This aims to assure methodological coherence which means a proper combination between research questions and methods (Morse *et al.*, 2002). The self-correcting process has unfolded in two ways during the fieldwork. Firstly, the interview questionnaire has changed to an open-ended style because the initial questionnaire was much too structured without considering the character of informants and information. Secondly, while the initially planned case study protocol postulated firms and other organisations as subunits of analysis, the local EIP projects has been recognised as subunits as the investigation has been carried out in the real contexts. In short, triangulation, disconfirming evidence and self-correcting construct have added to the methodological rigour of this research and the quality of the data.

External validity is about generalisation of findings from case studies (Yin, 2009). It should be noticed that this exploratory study does not aim to provide theoretical generalisation. Rather, the findings are used to build some propositions which can be examined in further research. Accordingly, the issue on external validity is narrowed down into the question of whether the cases are properly selected or not. As explained in the third section of this chapter, the cases are selected in a purposive fashion. Two industrial clusters are deviant as well as typical. Although all industrial districts across the world are distinctive in a sense, the Banwol-Sihwa industrial cluster and the Yeosu industrial cluster are more unique in the way that they have been evolving toward EIPs. On the other hand, both cases are representative in the Korean context. The Banwol-Sihwa dyeing cluster is one of five dyeing clusters that have similar business structures with each other. The industrial ecology practices developed in the Banwol-Sihwa dyeing cluster are continuously disseminated and applied to the other dyeing clusters. The Yeosu petrochemical cluster is one of three representative petrochemical clusters in South Korea whose industrial structures are built in accordance with the standardised chemical engineering process. The industrial ecology practices are frequently shared between the Yeosu petrochemical cluster and the other matured petrochemical cluster in Ulsan due to their industrial and technical similarity. In summary, the two cases are purposefully selected considering the minimum degree of typicality.

Reliability

Reliability is linked to the validity of a study (Golafshani, 2003). While reliability in quantitative research or fixed research design is confirmed with the use of standardised research instruments (Robson, 2011), the issue in qualitative research is establishing consistency of research process. In a more practical manner, Yin defines reliability as “demonstrating that the operations of a study” (Yin 2009,p. 40). His suggestion is the use of case study protocol and development of case study database. In the same line of arguments, audit trail in the methodologist terminology is one of options for reliability in qualitative research (Miles and Huberman, 1984; Creswell and Miller, 2000; Robson, 2011). Audit trail refers to the documentation with which a researcher can illuminate all research decisions and activities (Creswell and Miller, 2000). It can be a research note or a database. The function of audit trail is help reviewers, the supervisory team in this doctoral study, to look over how a research is conducted.

Adapting the audit trail tactic, I have produced three sorts of documents during the fieldwork; raw data, fieldwork previews and research notes. The raw data, that take the form of computer files, are interview transcriptions and statistical data sets on environmental issues and firm information. The raw data have been analysed continuously and the interim findings have been recorded simultaneously in the fieldwork preview documents and research notes. The fieldwork previews are the document to summarise the collected information and show the primary ideas on data analysis. The fieldwork preview documents were reported sixteen times in total. The other documents, research notes, are the most crucial audit trail. The research notes contain the summarised data analyses, the interim findings and opinions. The research activities and even personal feelings in the fieldwork were also included in the research notes. Ten research notes have been produced and reported on a roughly monthly base during the course of the fieldwork(A sample fieldwork preview document and research note are provided in the appendix).

3.5.2. Ethical Issues

This study deals with environmental issues. Most informants who have been interviewed during the fieldwork are open-minded about their environmental concerns, but it is obvious

that environmental problems are still sensitive for firms and other stakeholders. To prevent any possible ethical issues, all names of informants are expressed in anonymous ways.

The most sensitive research step in reference to personal privacy is the interviews. All interviews have been permitted by the interviewees via email contacts or telephone communication. I normally provided a document to introduce my study and list of interview questions in advance unless an informant stated that she or he did not need it. Most interviews have been recorded with the interviewees' agreement. I asked the interviewees if there was any sensitive content in dialogues at the end of interviews. A few comments were deleted in accordance with my own judgement to protect their privacy. No informants were paid in any way for their participation in the interviews although I provided small gifts in the customary manner in South Korea.

Lastly, the ethical issues and the risk assessment were scrutinised and the research process approved by the ethics committee of the School of Environment and Development at the University of Manchester.

3.5.3. Research Challenges and Limitations

I faced some difficulties during the fieldwork. First of all, several interviews were refused. In the case of the Banwol-Sihwa dyeing cluster, I failed to gain access to a first tier supplier that has trade relations in between the dyeing and printing firms and global buyers. In order to make up for any potential deficiency in information related to first tier suppliers' contribution to the textiles dyeing cluster's environmental upgrading, I asked questions about the roles of first tier suppliers while interviewing two local business cooperatives, five dyeing and printing units and two global buyers. However, there might be some unexplored information about the roles of first tier suppliers. In addition, I could not interview two research teams that respectively carried out the project to collect and reuse oil ingredients from air pollution in the Banwol-Sihwa dyeing cluster and the project to recycle hydrogen in the Yeosu petrochemical cluster. However, I interviewed all the other actors who were involved in these two projects and thus obtained detailed information on how the feasibility studies of the two projects were implemented.

The second difficulty in conducting interviews was that most informants working for the large firms had less information than I expected. Due to the internal division of labour

within multinational clothing companies and petrochemical firms, an individual interview could not represent a large firm. As the interviewees working for the large firms normally had limited information pertaining to their own narrow work areas, it was necessary to carry out multiple interviews with different departments of a firm and follow-up interviews in order to explore more contextual knowledge. In the case of a global branded company in a trade relationship with the Banwol-Sihwa textiles dyeing cluster, I conducted interviews with two managers, working respectively for the marketing team and the material procurement team. In addition, I conducted an email interview with the firm's compliance team on the condition of anonymity. When interviewing a CSR manager working for a petrochemical firm, he mediated a telephone interview with his colleague from the production management department so that I could collect information on technical aspects of the firm's EIP projects. As for another petrochemical firm, the interviewee called a junior staff member who could give more working-level information. These data collection activities were effective to avoid a possible lack of information and data on large firms' involvement in the EIP development.

Third, I experienced two sorts of problems related to language use while communicating with informants. The firm managers and engineers interviewed during the fieldwork used a great number of technical and scientific terms specific to the textile dyeing process or the petrochemical process. This issue was solved as I acclimated myself to their language use by acquiring a degree of background knowledge on manufacturing technologies and environmental engineering. The other problem was that interviewees used two key expressions, *cluster* and *governance*, with localised meanings. These two loanwords that are widely used in South Korea have different meanings from their specific academic meanings in the industrial cluster literature. As the Korean government has implemented an industrial policy, called Industrial Complex Cluster Programme, across the nation and operated many academia-industry-research cooperation groups, called Mini-Clusters, at the local level, local informants understood and used the term 'cluster' to denote a particular policy framework. The other term, 'governance', normally refers to a political system through which various stakeholders can participate in inclusive decision-making. On this account, I had to carefully use the two words in talking with local informants and rephrase them with alternative English expressions in producing interview transcripts so as to prevent confusion between their practical use in the Korean context and their academic use in this thesis.

Finally, the most significant issue is that accurate data on financial profits and costs generated from the EIP programme was not obtained, especially in the case of the Yeosu petrochemical cluster. This is because informants were hesitant in disclosing financial data on benefits and costs. Price-setting is a very sensitive issue in by-product exchange networks. Respondents were concerned that such sensitive information might be published and thus provided to potential market competitors. The public agencies that have managed or were involved in the EIP programme provided only information on estimated benefits and costs. They also refused to provide accurate data on individual industrial symbioses, because disclosing such information could directly damage individual firms that were participating in the EIP programme. Accordingly, I only use the information on financial profits and costs that are reported in some formally published documents by the government.

IV. ENVIRONMENTAL PROBLEMS IN INDUSTRIAL CLUSTER

4.1. Introduction

Industrial ecology aims to change environmental management practices of a whole production system. Such system-wide change cannot come overnight; it requires the intrinsic attribute of long-term transition. This implies that certain continuous changes in circumstance surrounding a production system act as an incentive to bring about a change in the production system and the governing mechanism of production system is induced to adapt to such changes.

This chapter identifies the nature of the environmental problems that have led to industrial ecology practices evolving within the local production systems of the two cluster case studies. Accordingly, this chapter provides answers to the first research question: “What sort of environmental problems arise from an industrial cluster?” The seriousness of environmental problems generated from intensive economic activities within a limited area can result in a series of interaction among local actors; for example, as in the case of the Palar Valley in India (Kennedy, 1999), or Toritama in Brazil (Ameida, 2008). Thus, I focus on the societal interactions surrounding the environmental concerns in Banwol-Sihwa and Yeosu.

The next section introduces the core features of the two industrial cluster case studies, the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster. The third section and fourth section of this chapter describe the environmental challenges confronting the two clusters and outlines the societal reactions surrounding these environmental concerns in Banwol-Sihwa and Yeosu respectively. The narrative in these two sections demonstrates how environmental issues have triggered a series of interaction among clustered firms and the other actors and thus driven the two clusters toward EIP initiatives. The final section is a summary of the analyses in this chapter.

4.2. Introduction to Banwol-Sihwa and Yeosu

4.2.1. Banwol-Sihwa Dyeing Cluster

Spatial Features of Banwol-Sihwa Dyeing Cluster

The Banwol-Sihwa dyeing cluster is an agglomeration of dyeing and printing units in the Banwol-Sihwa national industrial complex. The Banwol-Sihwa national industrial complex is located in the middle-west coastal area of the Korean peninsula and is one of the biggest industrial districts in South Korea. The industrial district is divided into two areas, Banwol and Sihwa, along the jurisdictional boundary between the city of Ansan and the city of Siheung. The Banwol area belongs to the city of Ansan, while the Sihwa area is a part of the city of Siheung. There are two reasons why the Korean government built the Banwol-Sihwa industrial complex. Firstly, there was the need to spread the population and transfer pollution-emitting industrial facilities away from the capital city, Seoul, to the other area (Jung, 2006). Plus, Banwol-Sihwa is a suitable area in the geographical context. It is located within 70km from the centre of Seoul and is near other big cities, Suwon and Incheon, as well as next to the West Sea. Accordingly, the industrial district became a planned satellite city of Seoul and was set up as “an enclave for heavily polluting plants” (Park and Markusen, 1999, p. 147).

The Banwol-Sihwa national industrial complex is the nest for SMEs of several sectors which are mainly single-plant firms. According to the data recorded in September 2010 by Korea Industrial Complex Corporation (KICOX), 5,064 firms are located here, employing 122,499 workers in the Banwol area. The machinery and electronics sectors account for slightly over half of the total number of firms while garments and chemical processing are the other two main industrial sectors in the Banwol area. In the Sihwa area, there are 8,436 firms employing 88,749 workers. The machinery industry is the biggest sector in Sihwa, followed by the electronics, chemical processing and steel industry in sequence.

The dyeing and printing units were one of groups that moved from Seoul into the Banwol-Sihwa national industrial complex. There are two agglomerations of dyeing and printing firms in the Banwol area and Sihwa area respectively. The dyeing and printing firm agglomeration in Banwol was first formed in 1987, the agglomeration in Sihwa was

established in 1992. Although the two dyeing clusters are spatially separated, they share common features in terms of business structure and are strongly linked with each other through various relations including ownerships or business alliances. Therefore, the two dyeing clusters are regarded as one cluster unit in this study.

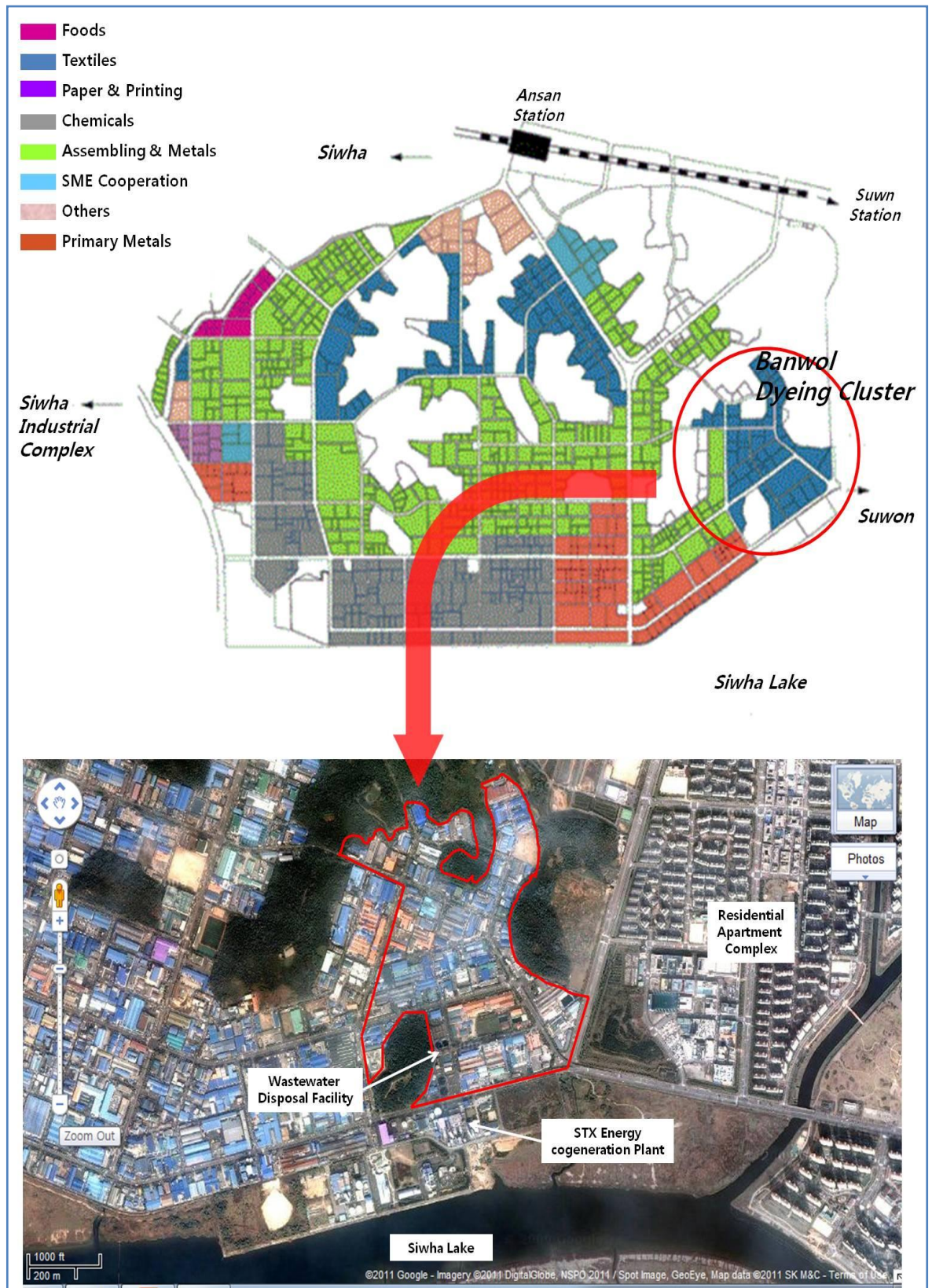
The dyeing cluster in the Banwol area is an agglomeration of 53 firms and their 60 dyeing and printing units¹⁰. All dyeing and printing firms in the Banwol area are members of the Banwol Dyeing Enterprise Cooperative (BDEC) which was established in December 1986 and began its economic activities in 1987 (Korea Association of Dyeing Enterprise Cooperatives, 2004). Their collective migration into the Banwol area was the result of long negotiation on water supply, cogeneration plant, and wastewater disposal facilities with the government. The dyeing and printing cluster in Banwol has formed in the southeast area of the complex, surrounded by low mountains and facing Sihwa Lake.¹¹ Figure 4-1 illustrates the spatial features of the dyeing and printing cluster in the Banwol area. The map on the upper side shows the location of each industrial sector in the Banwol national industrial complex. The red circle is the location of the dyeing and printing firm agglomeration, which is magnified the Google satellite picture.

The second wave of dyers' collective migration from Seoul settled in the southwest corner of the Sihwa National Industrial Complex surrounded by Sihwa Lake and the Yellow Sea. The cluster in Sihwa constitutes of 29 dyeing and printing units. Similar to the cluster in the Banwol area, all dyeing and printing firms in the Sihwa area are members of the Sihwa Dyeing Enterprise Cooperative (SDEC) which was established in 1993. Their production was activated in 1996 when the construction of the common effluent treatment plant in Sihwa was finished. Figure 4-2 illuminates the location of the agglomerated dyeing and printing firms.

¹⁰Banwol Dyeing Enterprise Cooperative includes 12 other firms that are working in the different industrial sectors but have the same membership with the dyers. But I do not count these 12 firms as the member of dyeing cluster because they, despite their formal membership, are not involved in the same production network with the dyeing and printing units.

¹¹ This geographical circumstance became an environmental burden to the dyeing and printing firms in the industrial district. As the Sihwa Lake began to be seriously polluted, the dyers had been regarded as a key suspect in the water pollution. This stigma is still remained.

[Figure 4-1] The location of the Clustered Dyeing and Printing Firms in the Banwol Area



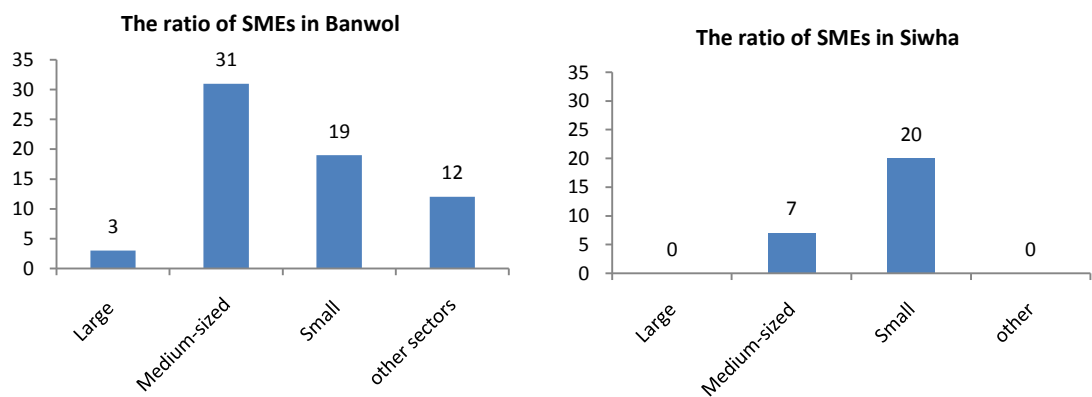
[Figure 4-2] The Location of the Clustered Dyeing and Printing Firms in the Sihwa Area



Single-plant SMEs Agglomeration

Most dyers located in the Banwol-Sihwa dyeing cluster are single-plant firms although a few have production facilities in other regions including Southeast Asia and South America. All of them have the dyeing process as their main production line. Basically, a firm cannot be established in the Banwol-Sihwa dyeing cluster unless it is equipped with a dyeing or printing process line because the collective treatment of dyeing effluent is the member firms' common purpose. This is the reason why they call themselves dyers.

[Figure 4-3] The ratio of SMEs in the Banwol-Sihwa dyeing cluster



*Source: author's survey in 2011

Specialisation Patterns

It is noticeable that the production line of each individual firms located in the textiles dyeing cluster is highly specialised. There are, roughly speaking, four main patterns of specialisation; material specialisation, technical specialisation, product specialisation and functional specialisation.

The first specialisation pattern is about the sort of textile materials with which the firms can carry out the manufacturing process. As shown in table 4-1, the main production lines of the firms in the dyeing cluster are differentiated according to what sort of textiles they deal with; synthetic fibre, cotton, knit, silk and so on. Moreover, these textiles are diversified in many detail sorts; for instance in the case of chemical fibre, acetate, rayon, poly nylon, polyester, and blended fabrics. Each textile material demands specific degree

of temperature and pressure as well as specialised dye stuffs and chemical additives in particular dyeing and printing processes (Interview AN-I2, AN-F1).

[Table 4-1] The main production line of the firms in the dyeing cluster

	Banwol	Sihwa
Syntheticfibredyeing	17	9
Cotton dyeing	7	2
Knit dyeing	12	6
silk fabric dyeing	3	-
yarn and thread dyeing	7	5
Printing	11	3
others	3	2
Total	60	27

*Source: author's survey in 2011

The second specialisation pattern can be termed as technical specialisation. One firm cannot cover a multitude of textile materials. Consequently, each firm in the dyeing cluster should choose main items and develop specialised manufacturing techniques in order to decrease financial risk and make effective investment. Basically, there are three dyeing methods; dip dyeing, printing, and yarn dyeing (Interview AN-I2). As illuminated in table 4-1, fourteen plants are specialised in printing and thirteen in yarn dyeing. In addition, individual firms are equipped with specifically differentiated dyeing technique and knowhow (Interview AN-F1, AN-F2).

The third specialisation pattern is based on the nature of their final products. As working in the middle stream of the garment industry, the main product produced in the dyeing cluster is garment textile. However, it should be considered there are many sorts of garment textile; lining, interlining, yarn, thread, fur, stocking, and even embroidery. Moreover, a few firms supply technical textiles to other industrial sectors like the automobile industry as well as garment textiles.

The individual firms in the Banwol-Sihwa dyeing cluster are specialised in narrow range of activities and thereby the local production system has, as a whole, fairly high complexity. It can be understood that this characteristic stems from the nature of the global garment market. The customer preference is ever-changing in the garment market being affected by seasons and trends. Therefore, the three specialisation patterns reflect the cluster's strategies to meet idiosyncratic and heterogeneous customer tastes.

The Competitiveness in the Global Market

In contrast to the common view that the Korean garment industry has been eclipsed by the competition from cheaper Chinese and Southeast Asian rivals, the dyeing and printing manufacturers in Banwol-Sihwa have maintained their competitiveness in the global market. The Banwol-Sihwa dyeing cluster is strongly connected to the global apparel value chain. The yarn and textile processed by the dyeing and printing firms in the cluster are primarily supplied to garment manufacturers in the form of intermediate inputs. The garment manufacturers are Korean garment vendors including the so-called 'Big Three', Han-Sea, Sea-A and Hansoll, who function as major suppliers to the US or EU based retailers (Interview AN-I5). These vendors purchase the dyed and printed textiles from the dyeing cluster, produce final goods in sewing units mainly located in South East Asia and export clothing to the US and European market under the global brands like GAP, Target, Wal-Mart, Kohl's and The Limited (Interviews AN-I1; AN-F1; AN-F2; AN-I8). These multinational branded companies or major retailers govern the whole production networks from distributing orders to marketing. Although the global apparel value chain can take a variety of business styles, this is a typical OEM business for the dyeing and printing firms.

The OEM manufacturers in the global apparel value chain are always in tough competition. Accordingly, a key question is how the dyeing and printing firms in the Banwol-Sihwa cluster maintained their relatively high competitiveness despite challenges from Chinese and other Asian rivals who have the advantage of lower wage cost. The informants interviewed during the fieldwork in the Banwol-Sihwa dyeing cluster point to three main reasons for their competitiveness. First, the dyeing and printing firms located in Banwol-Sihwa are equipped with relatively larger production capacity than other textiles dyeing clusters in South Korea. This feature becomes an advantage with which the dyeing and printing firms in Banwol-Sihwa can deal with the quantity demanded by vendors and

global retailers (Interviews AN-I1, AN-I5). However, the large production capacity alone cannot be the decisive element of their competitiveness because their competitors like Chinese dyeing mills often have much bigger production capacity. Accordingly, the technical superiority of the Banwol-Sihwa dyeing cluster based on the specialisation patterns is also critical. In this regard, an interviewee working for a global retailer makes a significant comment as follows:

They are textile mills, more like, and very small. By the way, the Chinese dyers are based on very huge mass production but less-advanced technology. Therefore, the sorts of item they can supply are limited. So, we prefer the Chinese textile mills for massive amount of cheap items. But there are some cases which demand various colours and complicating patterns like human face. These items should be produced through a sophisticated way. Besides, there are some colours which are very difficult to make. Dyeing in such colours has to be done here in South Korea (Interview AN-F6).

Although the technical gap between the Korean dyers and their international rivals is very small (Interview AN-I2), the dyeing and printing firms in the Banwol-Sihwa dyeing cluster are still a dependable business partner as regarding fabrics such as cotton, knit and silk (Interview AN-I5, AN-F4, AN-F6).

The last element of the cluster's competitiveness is the well-developed cluster-wide institutional resources. There are several formal and informal ties which function to facilitate the cooperative relations and the joint actions among the dyeing and printing firms within the cluster. For example, the two business cooperatives, BDEC and SDEC, play integral roles from improving the environmental performance of the clustered firms to maintaining the communication channel with the governmental agencies. Besides, various business supporting bodies and research institutes are located in the Banwol-Sihwa industrial complex. The dyeing cluster has been closely interacting with such non-firm organisations. This institutional infrastructure is the engine to propel the continuous upgrading of the Banwol-Sihwa dyeing cluster.

4.2.2. Yeosu Petrochemical Cluster

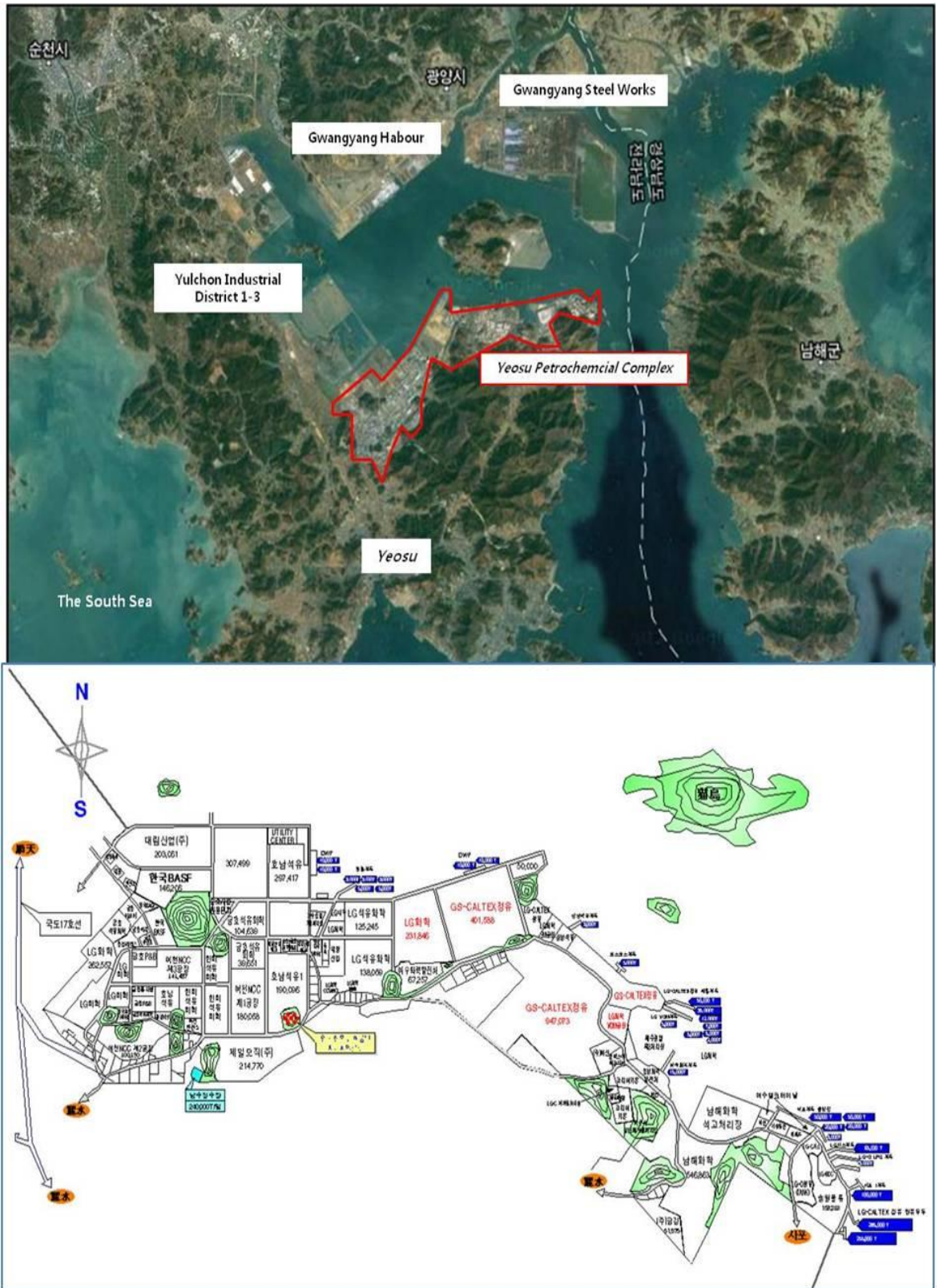
Spatial Features of Yeosu Petrochemical Cluster

Yeosu is on the southern coast of the Korean peninsula. The Yeosu petrochemical cluster, formally known as the Yeosu National Industrial Complex, is located nine kilometres north of Yeosu and is a part of the industrial region surrounding Gangyang Bay. In the late 1960s, the Korean government had strongly driven the development of the petrochemical industry despite doubts about its economic feasibility. The development of industries during the first Five-Year Economic Development Plan between 1962 and 1966 generated increasing demands for industrial materials for which Korea heavily relied on imports. This situation encouraged Korean economic bureaucrats to seek import substitution of petrochemicals (Korea Petrochemical Industry Association, 2009). The government plan to foster the refinery and chemical business sector was fully activated with the Second Five-Year Economic Development Plan. As Honam Oil Refinery (Currently, GS Caltex), the first private refiner in Korea, rammed pipes into Yeosu in 1968, the second petrochemical complex started to be formed in Yeosu, following the Ulsan petrochemical complex. Yeosu was formally designated as a national industrial complex in 1974. Accordingly, the Yeosu industrial complex is a typical example of government-sponsored industrial districts. Moreover, as South Korea is a non-oil nation, the central government has paid special attention to the petrochemical sector for national energy and industrial security. Now the Yeosu industrial complex is one of the three major petrochemical sites¹² and its production capacity of ethylene¹³ is the biggest in Korea (Korea Petrochemical Industry Association, 2009).

¹² Ulsan is the firstly developed and second largest petrochemical complex in Korea. The other is the Daesan petrochemical complex which is the most recently developed and its lead firm is Samsung.

¹³ Ethylene is the most basic and essential material generated from the oil refinery process. Therefore, its production amount is generally regarded as the index to measure the production capacity of petrochemical clusters.

[Figure 4-4] The Location of Yeosu Industrial Complex



Large Firm Agglomeration

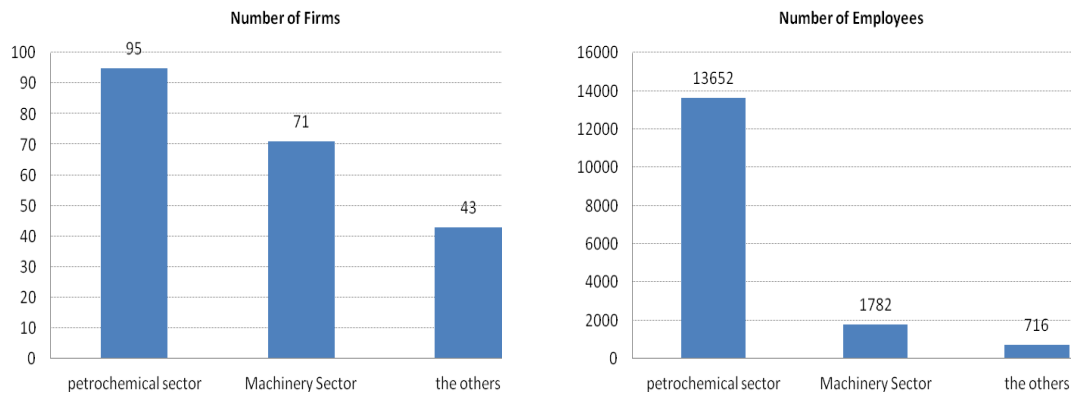
According to the data from September 2010 reported by KICOX (www.e-cluster.net), 209 firms operate in the Yeosu national industrial complex. The number of employees is 16,150 including 916 female workers. As shown in table 4-2 and figure 4-7, the number of firms operating in the petrochemical sector overwhelms the other industrial sectors. Although the number of petrochemical firms accounts for less than the half of the total number of firms, they hire 84.5 percent of the total number of employees working in the Yeosu industrial district. The second largest industrial sector in the Yeosu industrial district is the machinery industry. The machinery industry is co-located with the petrochemical sector to provide the subsidiary engineering services to the petrochemical firms. Thus, the Yeosu industrial region is in fact a single-industry petrochemical complex. The petrochemical sector is a highly capital-intensive industry equipped with automated giant-scale production facilities. Crude oil and its derivative products are processed at high temperature and high pressure. The production units are owned by multinational companies like Chevron and BASF or Korean *Chaebols* like LG and Samsung. In this regard, the Yeosu petrochemical cluster can be seen as a large firm agglomeration.

[Table 4-2] The Number of Firms and Employees in the Yeosu Industrial Complex

	total	Food	Timber & Paper	Petro- chemical	Base Metal	Steel	Machinery	Electricity & Electronics	Others	Non- manufacturing
Firms	209 (100.0)	2 (1.0)	1 (0.5)	95 (45.5)	12 (5.7)	1 (0.5)	71 (34.0)	3 (1.4)	6 (2.9)	18 (8.6)
Employees	16,150 (100.0)	19 (0.1)	32 (0.2)	13,652 (84.5)	226 (1.4)	43 (0.3)	1,782 (11.0)	154 (1.0)	26 (0.2)	216 (1.3)

*Source: KICOX (September 2010).

[Figure 4-5] Industry Ratio in the Yeosu Industrial Complex



*Source: Modified by author with the data from KICOX (September 2010).

Vertical Production Network

The petrochemical industry is an assemblage of value-chain activities from refining crude oil to producing specific chemical materials. To process and exchange raw materials and intermediate products in gas or liquid state, it is efficient for petrochemical plants to congregate within a specific area. All firms located in a petrochemical cluster are in input-output relations with their neighbouring firms. A petrochemical production network is established with at least one petroleum refinery as its centre and has physical pipe lines between production facilities. This industrial linkage is constituted in accordance with the formulaic chemical reaction process from a refinery to individual petrochemical and chemical plants (Interview YO-I3).

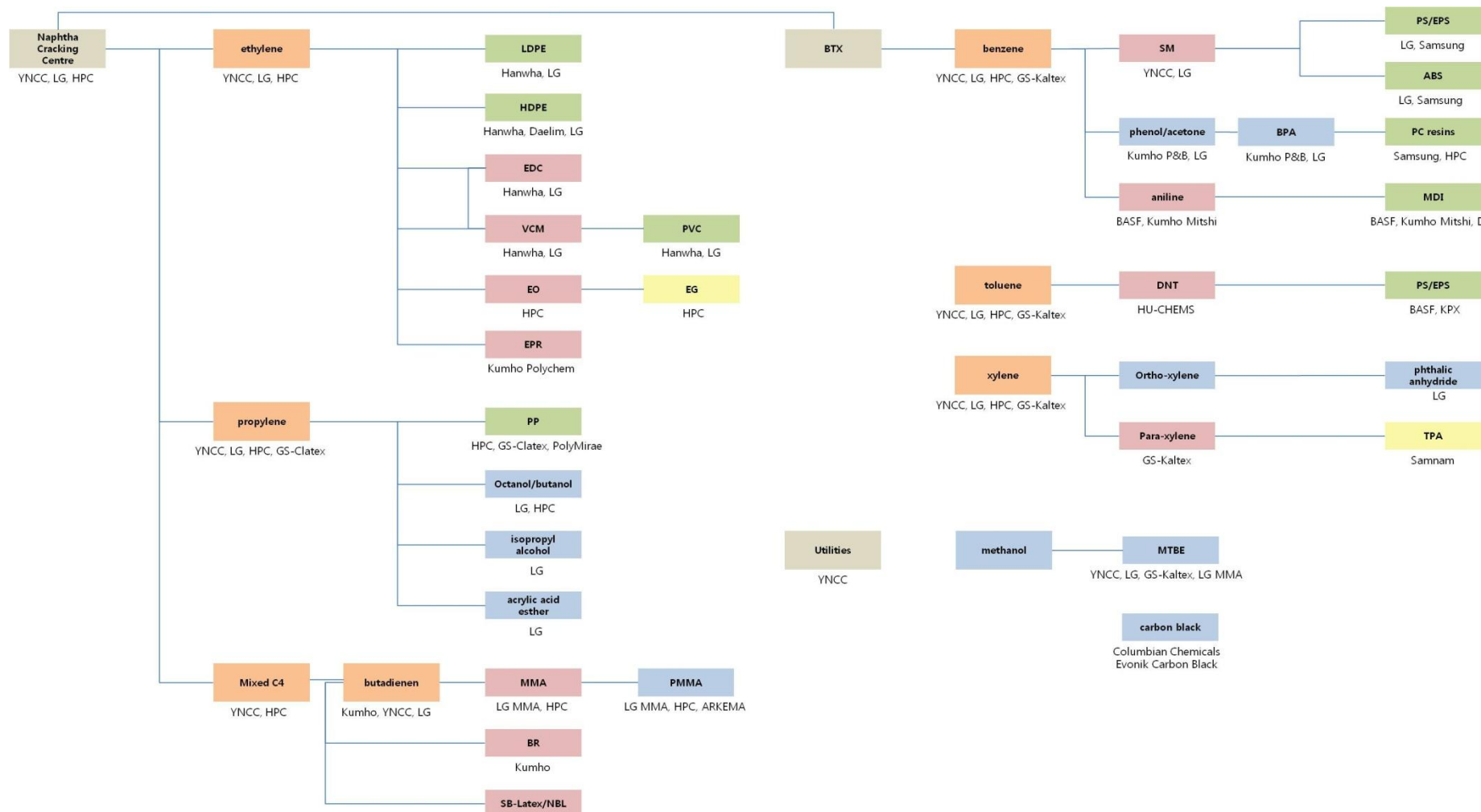
Precisely speaking, the Yeosu industrial complex is a combination of petroleum refinery sector, petrochemical sector, chemical sector and the other related industrial sectors. The first three sectors constitute the core of petrochemical *kombinat*, the forward vertical linkages among large production facilities. This unique structure of local production system attributes to high codification of technology and high minimum efficient scale. The backward vertical linkages are composed of engineering service providers and construction units that are normally SMEs surrounding the core industry.

The petroleum refinery in the Yeosu area is GS-Caltex. The oil refinery imports crude oil from oil-producing countries and produces 2% LPG, 8% gasoline, 12% naphtha, 35% paraffin and diesel, 38% bunker-C oil, and 5% asphalt (Korea Petrochemical Industry Association, 2009). This part is the petroleum refinery sector which is monopolised by GS-

Caltex in the Yeosu industrial district. As the sole refiner, GS-Caltex has a matchless position in Yeosu and its production facilities are protected by the central government in regard to the national security.

Naphtha is the most basic raw material from which various chemicals can be produced. In the Yeosu petrochemical cluster, GS-Caltex supplies Naphtha to three naphtha cracking centres; YNCC, LG Chem, and Honam Petrochemical Corporation. Naphtha is decomposed into 31%ethylene, 16%propylene, 10%C4, 14%raw pyrolysis gasoline, and 29%others like methane and hydrogen (Korea Petrochemical Industry Association, 2009). Again, these intermediate materials are provided to subsequent stages of the petrochemical manufacturing processes. The petrochemical value chain stretches in this way across the complex. The main products and producers are illuminated in figure 4-8. As a whole, the Yeosu petrochemical cluster can be categorised as a producer-driven value chain. Producer-driven value chains refer to vertical production networks in which large manufacturers play the key roles in coordinating the whole production stages (Gereffi, 1999). A typical producer-driven value chain consists of one or a few large assemblers and a large number of component suppliers, as in the automobiles, aircraft and computer manufacturing industries. In contrast to typical form, a petrochemical value chain consists of several large firms that are in an input-output relationship. Petroleum refinery units and naphtha cracking units that play the integral role in coordinating production networks are not assemblers but suppliers.

[Figure 4-6]The Main Production Network in the Yeosu Petrochemical Cluster



* Source: Korea Petrochemical Industry Association (2009, pp. 84-85)

4.3. Environmental Concerns and Societal Interactions in Banwol-Sihwa

4.3.1. Introduction to Environmental Problems in the Dyeing Sector

It would be helpful to understand the basic textile dyeing process and its pollutants before turning to environmental challenges for the Banwol-Sihwa dyeing cluster. Dyeing is unique among all steps to make cloth from spinning to sewing. Dyeing is the decisive value-added process to decorate fabric materials with colours and patterns as well as to improve fibre texture, strength, and elasticity. Unfortunately, dyeing is also the most environmentally hostile process because a considerable amount of water and energy and a variety of chemical agents are consumed. Three main pollutants from the dyeing process are effluent, odour and sludge.

Dyeing is a water-intensive industry. Its basic process is colouring or decolouring fibrous materials with dyestuff and chemical additives after removing dusts and impurities that have clung to textiles. A lot of water is needed for these processes. Moreover, the dyeing process is diversified in accordance with changes in fashion trends, seasons and customers' taste. This leads to technical difficulties in the dyeing effluent treatment. In general, dyeing effluent contains about 10 to 50 percent remained dyestuff and various chemical additives such as polyvinyl alcohol, terephthalic acid, ethylene glycol, oxidizer and surfactant. In addition, some parts of the dyeing process cause unpleasant smells. The evaporation of dyestuffs from printing, mercerising, and dye-making can cause odours. Tentering, which is the process to iron out dyed textiles, is the main source of dyeing odour (Interview AN-I1). Some materials and chemicals in fabrics during tentering evaporate with steam, generating white smoke and causing bad smell. Because the dyeing odour is diffused as an air pollutant, it is technically difficult to cope with and physically damaging to local communities. The final pollutant from dyeing is sludge which remains after the textile dyeing effluent treatment. The sludge was not a tricky issue for Korean dyers because sea dumping was permitted in the past (Interview AN-I1, AN-I2, AN-I4). However, regulations on sludge treatment have been reinforced and the Korean government announced that the sea dumping of sludge will be prohibited in the very near future. All three pollutants from the textile dyeing business cause external diseconomies and the

Banwol-Sihwa dyeing cluster's environmental performance is in fact related to its response to these pollutants.

4.3.2. The First Phase: Water Pollution Crisis

Until the mid-1970s, South Korea did not have a proper environmental regulation framework. Although the first environmental law, the Pollution Prevention Act, was enacted in 1963, this law was ignored in practice because the government regarded environmental problems as a side issue (Ministry of Environment, 2010). As economic growth was of the highest priority in the 1960s and 1970s, state bureaucracies were deliberately reluctant to address environmental issues (Jo, 2010). During the period of rapid economic growth in South Korea, there was large-scale rural-urban migration and a concentration of manufacturing facilities within the capital city, Seoul. As a result, the water quality of the Han River, which flows through Seoul from west to east, seriously deteriorated during the 1970s (The Office of Waterworks Seoul Metropolitan Government, 2008). Many textile dyeing mills were dispersed along the Han River and its tributaries in Seoul at that time. Although the dyeing business was not the only source of pollution in the Han River, the dyeing business was blamed as one of the main polluters because its dyeing process discarded a large amount of effluent into the river (Interview AN-I2).

Responding to the environmental degradation, the government proclaimed the Environment Preservation Act in 1977. This law became the first effective environmental regulatory framework in South Korea (Ministry of Environment, 2010). According to the enactment of the Environment Preservation Act in 1977, some environmental regulation systems like effluent quality standard, permission to establishment of discharge facilities and administrative order were first introduced. However, the water pollution in Han River continued to go from bad to worse. As for the dyeing industry, its effluent volume increased despite the effluent quality standard and the regulation activities based on the law because the number of dyeing mills had increased during the 1970s when the garment and textile industry was in its heyday (Interview AN-I2).

Eventually, the government decided to take much stronger action. In 1976, the government ordered over 900 pollution-emitting firms to leave the capital city and gave a warning that anyone who did not follow this instruction would be deprived of water supply, electricity

supply and tax benefits. Moreover, the Manufacturing Industries Placement Act in 1979 was enacted to facilitate the decentralization of industrial activities across the country. Most dyeing mills that had been singled out as the notorious pollutants of Han River took a direct hit by this administration order (Interview CE-I1) and had no choice but to follow the decision under the authoritarian military regime (Interview AN-I2).¹⁴

However, it was not easy for the dyeing firms to find a suitable place to locate where water source could be secured. Most potential candidate areas were near the Han River and the dyers had to avoid any probability of further polluting the Han River again. While spending time to search for new locations, the idea was suggested that textile dyeing effluent could be treated in an effective way if dyeing mills agglomerated in a specific area and shared an effluent treatment plant together. An informant working for BDEC flashes back to the day as follows;

Then, we realised that we couldn't maintain the competitiveness if we would behave individually after the Environmental Pollution Prevention law came to us. With this recognition, the idea was proposed; "If we have to move out, why don't we move as a group and build a common pollution preventing facility collectively?" (Interview AN-I2)

The textile mills which are currently clustered in Daegu were the leading group in this joint action. Some dyers formed an industrial cluster in Bisan-dong, Daegu and began to build their common effluent treatment plant and cogeneration plant (Korea Association of Dyeing Enterprise Cooperatives, 2004). This collective behaviour was unprecedented but soon became the epitome in the Korean textile industry. Following the Daegu dyeing cluster, some dyeing firms in Seoul made a decision to migrate en masse and build a cluster equipped with a common effluent treatment plant and a cogeneration plant in the Banwol National Industrial Complex (Interview CE-1, AN-I2).

In 1986, a dyeing cluster was established in the Banwol area after negotiation with the government to secure water supply and the common textile effluent treatment plant was

¹⁴ The military regime began with the coup by the ex-president Jung-Hee Park in 1961 and ended with the June Democratic Uprising in 1987. The military leadership had led rapid economic growth and modernisation despite its undemocratic repression. Therefore, this era is called Developmental Dictatorship Period in Korea.

built. The other dyeing cluster in the Sihwa area began to operate in 1992. Both clusters have their own cooperatives; BDEC and SDEC. These two organizations are not only a business association but also a specialized agency to operate the common effluent treatment plants.

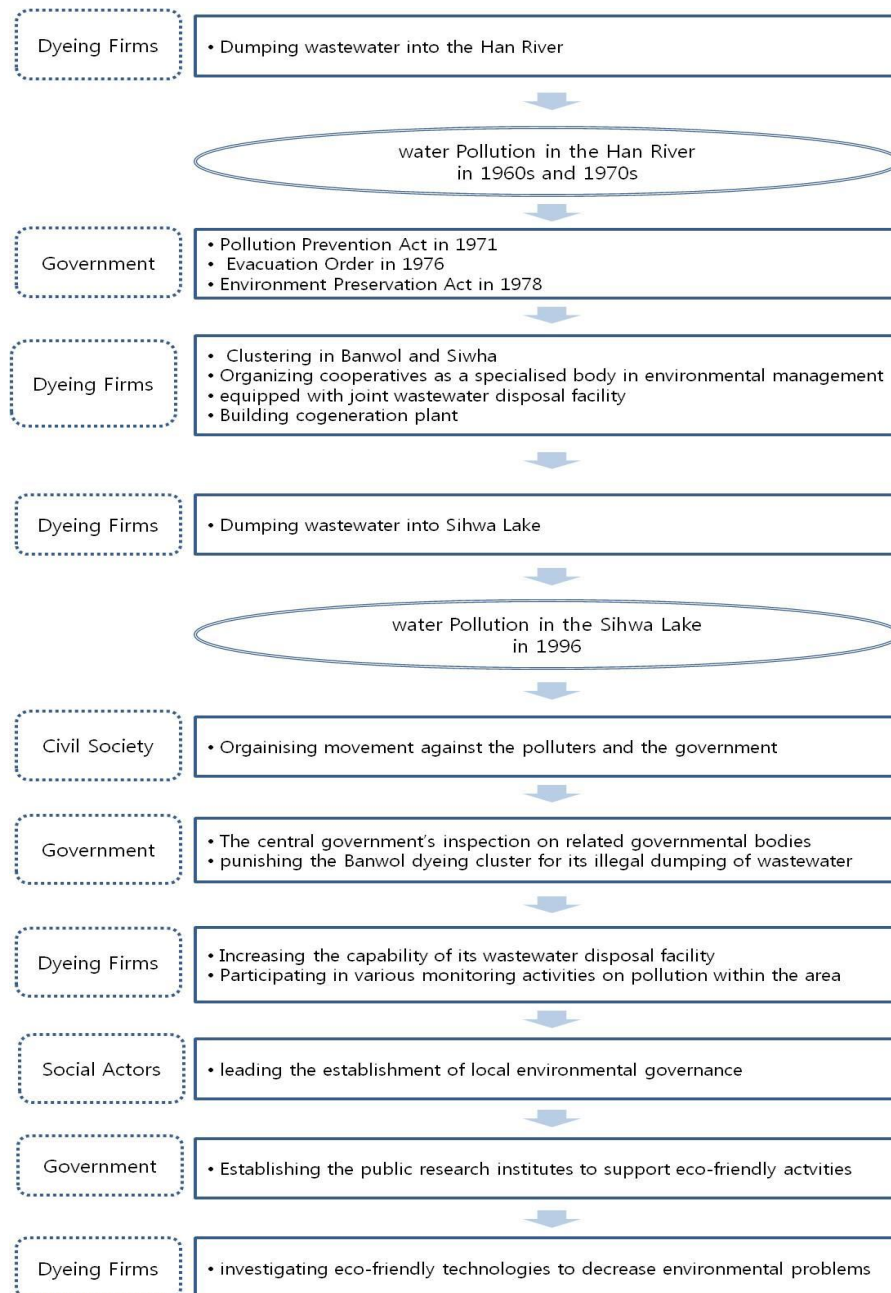
This is not the end of the story about textile dyeing effluent. After locating in the Banwol-Sihwa national industrial complex, the dyeing cluster experienced the worst pollution disaster in Korean history, the Sihwa Lake Pollution Accident. Sihwa Lake, which has its notorious nickname 'Lake of Death', is the symbol of environmental problems in the Banwol-Sihwa region. The main plan in designing Sihwa Lake was building a 12.4km seawall between two islands. Despite a lot of criticisms and campaign against the plan, the government, keen to support the construction industry and use idle labour and equipment, enforced the plan (Sha, 2003). The result was a disaster. The lake was extremely polluted and the tideland near Ansan and Siheung was seriously destroyed because of the huge amount of wastewater that came from the neighbouring factories (Park, 1997; Kim, 2004; Jung, 2006). The Board of Audit and Inspection of Korea made a disclosure of the government's criminal negligence on the construction planning and environmental management through an investigation on the historical pollution case. The investigation report also exposed that BDEC and eighteen dyeing firms had illegally discharged wastewater into the Sihwa Lake.¹⁵

Paradoxically, this triggered a variety of eco-friendly activities in the Banwol-Sihwa industrial complex. Most of all, this pollution accident aroused the conscience of local communities to the environmental concerns. Local residents, NGOs and the academic society undertook various actions such as demonstrations, research studies, workshops and public hearings against the government's blunder. These actions produced, and reproduced, a series of alliances and solidarities among local NGOs and activists during the last 1990s. As a result, The Sihwa Regional Council for Sustainable Development, which is considered as the leading example citizen-led environmental governance in South Korea, was established (Interview AN-R1).

¹⁵The Board of Audit and Inspection of Korea did not open original reports to the public prior to August 2003. For this reason, the investigation report on the Sihwa Lake case is not publicly available. Accordingly, I ascertained the dyeing sector's involvement in the water pollution scandal by reviewing multiple media reports and verified it through the interviews with local informants.

As for the dyeing cluster, it was a bitter lesson again. Although the pollution accident was the manifest failure of government policy, the dyeing cluster could not be free from the taint of polluter (Interview AN-I5). Moreover, dyeing effluent accounted for about 60 percent of the total industrial wastewater from the Banwol-Sihwa Industrial Complex at that time. Obviously, it gave the cluster a stigma (Interview AN-I5). At the same time, it also gave the dyeing cluster a motivation to concentrate on inventing eco-friendly technologies rather than simply expanding its waste disposal capability. The chain reactions surrounding the water pollution crisis caused from textile dyeing effluent are summarized in figure 4-7.

[Figure 4-7] Chain reactions through water pollution crisis from the dyeing sector



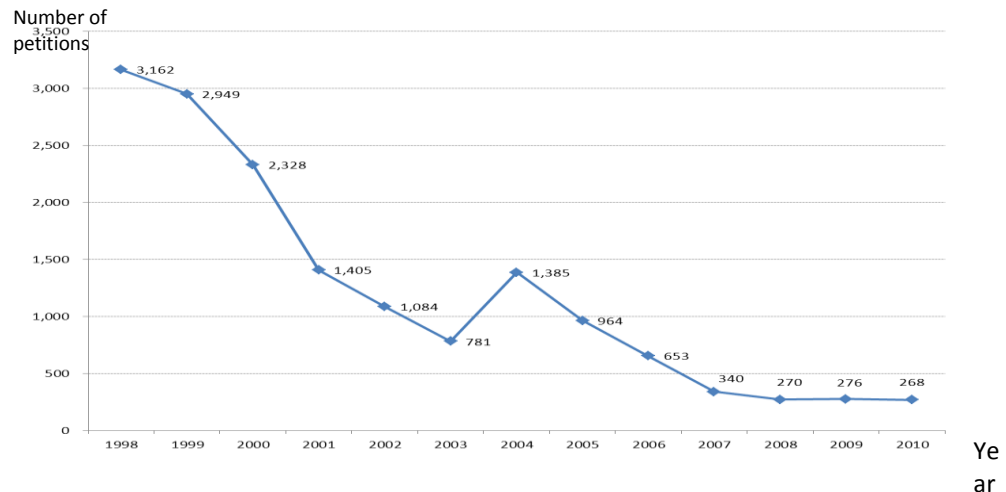
*Source: Author

4.3.3. The Second Phase: Air Pollution Crisis

The water pollution issue was settled with the establishment of the regional environmental governance in 2003. However, another environmental issue began to stir the residential community in Ansan and Siheung; the odour coming from the industrial area. The odour resulting from dense industrial activities began to be controversial from the late 1990s in

the Banwol-Sihwa industrial complex. Many petitions on the odour issue were filed by local residents as shown in figure 4-8. The number of petitions continued to be over one thousand until 2004 and then slowly decreased from 2005 when the Odour Prevention Act was passed.

[Figure 4-8] The number of petitions about odour in Ansan and Siheung from 1998 to 2010



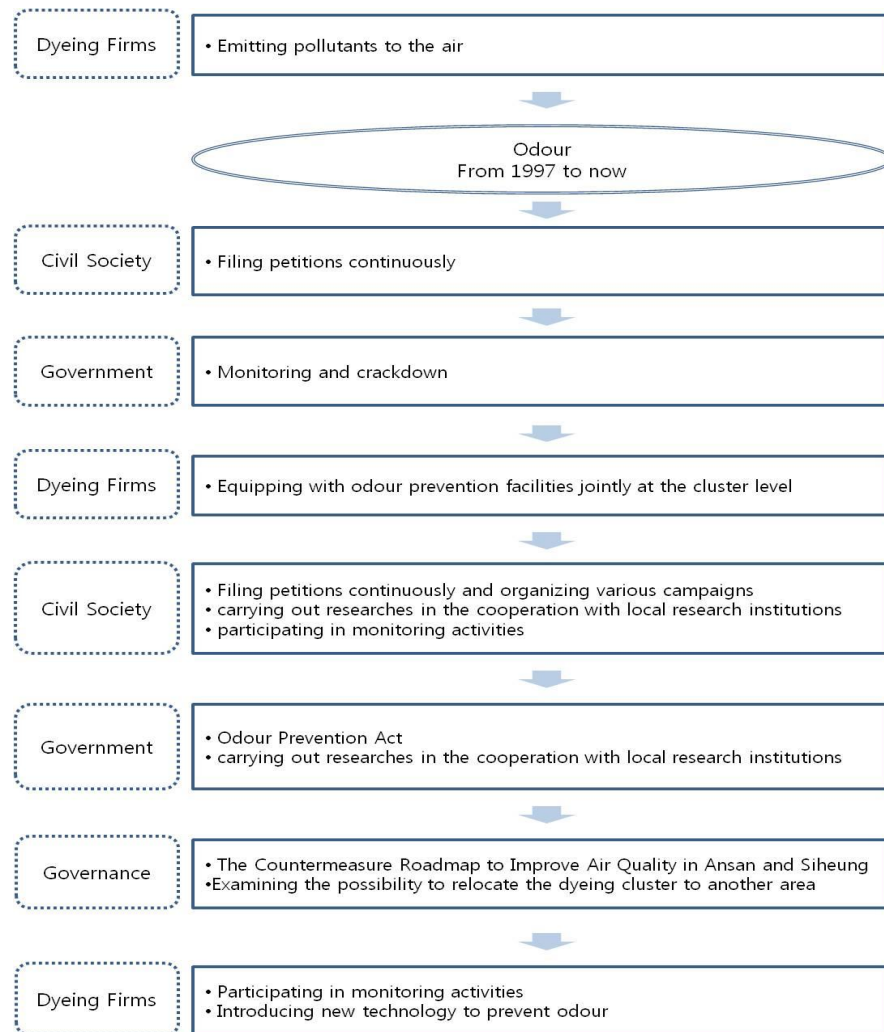
* Source: Raw data from Gyeonggi Provincial Government (2010) and modified in the form of graph

In contrast to the water pollution accident, the odour directly damaged the residential areas. Therefore, residents actively engaged against the odour issue while professional NGO activists were the main actors campaigning against the water pollution of Sihwa Lake. The odour had disturbed people's everyday lives and a lot of local people were morally indignant about it. A leader who led the residents' movement testifies that the odour was so bad that pupils could not do physical activities at local schools (Interview AN-R2). At the initial stage of the controversy on the odour in Banwol-Sihwa, the business community saw the complaints from the local community as a hindrance to their industrial activities, while the local residents regarded the local firms as immoral profit-hunters (Interview AN-R2). The local residents cooperated with local experts working for universities and public research institutes in order to present scientific evidence on the damage caused by the air pollution and suggest potential solutions (Interview AN-R1, AN-R2). The government designated two university-based research institutes as environmental technology centres: Ansan Green Environment Centre (AGEC) based in Hanyang University and Siheung

Green Environment Centre (SHGEC) based in Korea Polytechnic University. In addition, a few public bodies specialised in environmental management were installed in the Banwol-Sihwa industrial complex.

The dyeing cluster stigmatised as the trouble-maker since the Sihwa Lake Pollution Accident became the first and major target of blame from the other local actors in the controversy surrounding the odour issue (Interview AN-I2, AN-R2). Technically speaking, it seems unfair to accuse the dyeing cluster of the major polluter of the odour because the dyeing odour is not recorded as strong as the other major air-polluters (Gyeonggi Research Institute, 2009). Regardless of their social reputation, the dyers did not repeat the same mistakes in the case of water pollution. The members of BDEC and SDEC voluntarily, and jointly, equipped themselves with odour control facilities in a joint way before the Odour Prevention Act came into effect (Interview AN-I1, AN-F1). Furthermore, the dyers participated in the environmental monitoring watchdog in cooperation with other industrial sectors, government agents and local NGOs (Interview AN-I1). The chain reaction surrounding the odour issue can be illuminated in figure 4-9.

[Figure 4-9] Chain reactions surrounding air pollution crisis from the dyeing sector



*Source: Author

4.3.4. The Third Phase: Global Challenges

In parallel with the pollution crises at the local level, the Banwol-Sihwa dyeing cluster has faced a series of global challenges. As the Banwol-Sihwa dyeing sector is an export-oriented cluster, its industrial activities have been affected by changes in the global market on such sensitive manners.

The first global challenge is related to sludge, one of three main pollutants from the dyeing and printing sector. Since 2012, the Korean government has totally prohibited the ocean dumping of sludge so as to meet the regulation of an international treaty, the so-called

London Dumping Convention.¹⁶ In accordance with this newly introduced regulation, the sludge generated from the BDEC and SDEC' effluent treatment plants must be treated on land. An informant working for the dyeing cluster explains that there are three options that the dyeing business can choose to deal with the sludge; incineration, landfill and recycling (Interview AN-I1). Incineration is not popular because of the soaring price of fuel necessary for incineration. Land fill is no more useful than incineration because the sludge has to be dried before burying according to the law. This implies the dyeing and printing business should make a choice between the increasing sludge treatment cost and recycling (Interview AN-I1, AN-I4). Currently, BDEC supplies about half of the sludge to cement manufacturers as a recycled material and SDEC provides all its sludge for recycling (Interview AN-I1, AN-I4, AN-F8). A cement manufacturing plant has been using the textile dyeing effluent sludge from the Banwol-Sihwa dyeing cluster as a substitute material for clay since 2007 (Interview AN-F8).

The second mode of global-level environmental challenge is the demand for technical upgrading. The growing importance of environmental concerns within international trade in the 1990s became a risk for the Korean textile industry that fell behind in terms of environment-friendly technologies (Jeon, 1995). More specifically, since the late 1990s, global apparel brands and retailers asked their suppliers located in Banwol-Sihwa to meet global standards like ISO 14001, ISO 9001, eco-labels and codes of conduct. Global standards which are considered as new trade barriers by the dyeing and printing firms (Interview AN-F3) pushed, local suppliers to upgrade their production process and the quality of their products in environment-friendly ways. The local dyeing manufacturers who had limited access to information on global standards were in trouble at first, but were able to meet the demand from their buyers thanks to information and technical assistances provided by public support institutions (Interview AN-F3). For example, in response to this challenge, the Korean dyeing business including the Banwol-Sihwa dyeing cluster participated in a national-level R&D project, called DYETECH21, led by Korea Institute of Industrial Technology (KITECH), a key partner research institute with the Banwol-Sihwa dyeing cluster.

¹⁶The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, commonly abbreviated as the London Dumping Convention, was signed in 1972 and entered into force in 1975. This treaty aims to prohibit or limit dumping of pollutants and wastes which could damage the ocean ecosystem. The Korean government joined it in 1993 and announced all types of sea dumping will be stopped by 2012. However, this plan is delayed because of the petition from the Korean industrial society.

The other global challenge is the energy crisis. The dyeing and printing business is one of the most energy-intensive industries. As price of energy soared since the mid-2000s, energy costs became a pending issue in the Banwol-Sihwa dyeing cluster (Interview AN-F4, AN-F5, CE-I6). The energy cost is closely related to water consumption in the dyeing process because the dyeing firms use most energy to boil water. Again, the dyeing cluster has participated in a R&D project to invent new type of dyeing equipment that reduces water consumption. This project was led by KITECH and a few dyeing machinery manufacturers with cooperation from university-based research teams and dyestuff suppliers.

4.4. Environmental Concerns and Societal Interactions in Yeosu

4.4.1. Introduction to Environmental Problems in the Petrochemical Sector

It is commonly known that the petrochemical sector is a potentially heavy polluter. This is because the petrochemical industry deals with and produces a variety of chemicals, some of which are very toxic. In this regard, the most serious environmental issue that can occur in the petrochemical industry is leakage. Leak of oil or other chemical materials can pollute a vast area and/or cause death and injury. Another most distinctive environmental concern in the petrochemical industry is industrial accidents like explosions and fire. As materials in gas or liquid status are processed at high temperatures and pressure, the petrochemical industry has higher potentiality of industrial accidents than most other industries. In the case of Yeosu, there have been 214 accidents and 2,937 casualties from the start of operation in mid-1960s to the mid-2000s (Jeong *et al.*, 2005).

However, there exists somewhat different standpoint about the high risk of environment and safety concerns in the petrochemical sector. Recognising such high potential risk, it is argued that the petrochemical sector tends to be better equipped with risk monitoring systems than other sectors (Interview YO-F2), and integrate pollution treatment systems into its main production lines (Interview YO-I3). Even if one takes the positive view on the environmental issues in the petrochemical industry, a few lingering questions remain. First of all, although individual firms emit pollutants within the legal standard, the absolute quantity of pollution in an industrial area is much higher than residential areas due to the

intensity of firm agglomeration (Jo, 2006). This attribute of environmental problems in industrial sites can be enhanced in accordance with high toxicity of chemical materials and high minimum efficient scale of the petrochemical production system.

The other point that should be considered in terms of environmental problems in the petrochemical industry is related to material flows. Products and by-products generated from crude oil are not easily decomposed in nature and give rise to serious environmental damages (Lee, 2006). Accordingly, minimising wastes and maximising recycling is essential to address environmental sustainability.

4.4.2. The First Phase: Explosion of Environmental Disputes

The Yeosu industrial complex experienced a major environmental accident in the mid-1990s. In July 1995, LG-Caltex's oil tanker, *Seaprince*, ran aground off the coast of Yeosu, spilling 9,000 tons of crude oil and 1,000 tons of bunker-C oil. Even before the anger on this accident cooled down, one more oil-spill accident occurred with another LG-Caltex's oil tanker, *Sapphire* in November 1995. The oil spills awoke the local community and triggered a series of environmental disputes (Interview YO-R1). The local residents and NGOs organised a strong movement against LG-Caltex and a series of actions like protest and boycott continued. In response, LG-Caltex promised its social contribution to the local community including compensation (Interview YO-F1). The change of the petroleum refinery's attitude influenced most local firms because LG-Caltex occupied the position of being the monopolistic supplier in the localised production network in the Yeosu industrial complex.

The Korea Institute of Science and Technology released the report on the environmental condition of the Yeosu area in 1996. The report contains the striking conclusion, "Yeosu is the land where human beings cannot live in" (Interview YO-F2, YO-R1, YO-R2).¹⁷The report poured oil over the flame of environmental disputes. The Ministry of Environment scrutinised the environmental condition in the area and the central government designated it as the Special Air-pollution Prevention Area (Interview YO-F2, YO-R1). In response to these pressures from the local community and the government, the clustered firms

¹⁷The exact wording in the report is "the environmental condition in villages near the industrial complex is judged unfit for human habitation" (Korea Institute of Science and Technology, 1996: 5).

launched an independent body to perform their joint actions on local environmental concerns (Interview YO-F2, YO-30), Yeosu Industry Environment Association (YIEA). Individual firms started spurring their environmental performance by equipping with advanced environmental management systems.

4.4.3. The Second Phase: Political Challenges

A series of environmental disputes continued until the mid-2000s. Several large-scale industrial accidents occurred in the early 2000s. While the local residents and NGOs aggressively protested and criticised the large petrochemical and chemical firms in aggressive manners, the clustered firms responded in defensive manners in this period (Interview YO-F1). The joint actions of clustered firms led by YIEA were more focused on legal action to advocate the local firms' stance. During this period, two major political actions to relieve mutual distrust and complaints between the clustered firms and the local community took place in Yeosu.

First, as one of efforts to end the unceasing environmental disputes at the local level, the Committee for Co-development of Yeosu City and Yeosu Industrial Complex was established in 2000. The committee consisted of 11 firms, 10 NGOs and 11 public agencies that represent the business sector, the civil society and the public sector respectively. The main agenda is regional economic development and environment and safety. At the initial stage local politicians made efforts to persuade large firms to participate in the committee, however, this regional consultative committee remained as an unpractical consultative body until the mid-2000s because the business community was sceptical about roles of the regional committee (Interview YO-R1). The committee started to secure its function properly since the late 2000s. The firms have been convinced that meeting and discussing with other actors is beneficial for their economic activities (Interview YO-R1) while the large firms want to be credited for their social contribution (Interview YO-R1, YO-F1). The secretary-general of the committee points out that the cause of this political change in the relation between three sectors stems from recurring contacts.

I think this is because our network is based in the intimate relationship. When we were in conflicts, most of us used to refuse cooperation and choose fighting. But now it is difficult for all of us to say no because we frequently meet and talk each

other... This is the expansion of personal networks. While we knew each other personally in the past, now people taking a higher position in each institution should attend in the committee naturally (Interview YO-R1).

The other major political action was taken by local NGOs. The Yeosu-based NGOs took two-way strategy in order to solve environmental concerns. First, they organised a national-level movement aiming to reform the regulatory framework on industrial complex management. Second, the NGOs suggested establishing a consultative body between the business sector, the public sector and the civil society to discuss common environmental issues at the local level. The basic idea was that Yeosu needs an independent and specialised committee to make collective decisions on environmental issues (Interview YO-R3). This suggestion was partly accepted and consequently the Committee for Co-development of Yeosu City and Yeosu Industrial Complex has a sub-committee dealing with environment and safety issues.

4.4.4. The Third Phase: EIP Agenda Setting

The story about the societal interaction has now moved beyond the geographical boundary of Yeosu. As mentioned before, The NGO movement in Yeosu expanded to a national-scale political action. The Yeosu-based NGO activists felt “the movement at the local level is limited” and thought “The other regions where industrial district are situated must have the same problems to us” (Interview YO-R3). They suggested a national level movement to improve the environment of industrial districts and thus the NGOs from 22 industrial areas launched the National Solidarity to Improve Environment in National Industrial Complexes and Reform Policy. Two organisations that had actively led the protest against the petrochemical firms, Yeosu YMCA and Yeosu Federation for Environmental Movement, are local branches of Korea YMCA and Korean Federation for Environmental movement respectively. Their organisational network across the nation played an integral role in organising this national scale movement. In addition, Korean Federation of Trade Unions participated in this movement for the sake of workers’ interest.

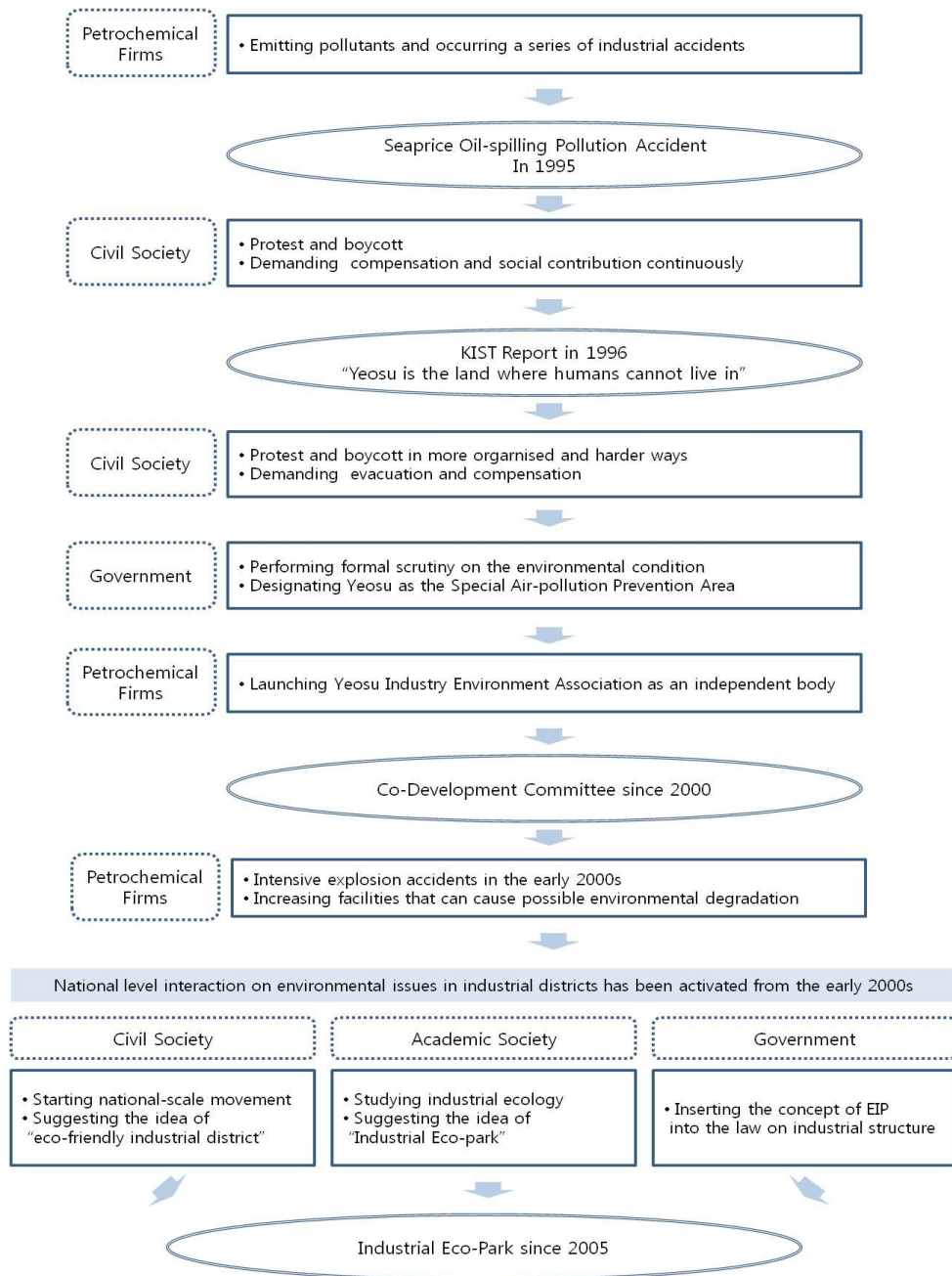
This solidarity organisation had continuously held conferences on environmental issues in industrial areas with national assembly members because they believed reforming the regulatory framework is the key to solving environmental issues in industrial areas

(Interview YO-R3). The NGOs suggested their idea about a new model, so-called 'environment-friendly industrial district'. This refers to three strategies; integrated and specialised regulatory framework for industrial complex management, participatory approach to environmental management in industrial complexes by the involvement of workers and civil society and planning to consider industrial complex life cycle of establishment, growth, maintenance and deconstruction (Kim, 2006).

Meanwhile, separated from this civil movement, a group of researchers started to study industrial ecology in 2002. A researcher working for Korea National Cleaner Production Centre of KITECH proposed this study and invited several researchers who had studied industrial ecology individually at that time (Interview YO-I3). Sponsored by the government, they investigated some European models like NISP in the UK and EID in Germany and Austria (Interview CE-I6). They concluded that EIP is a proper model for South Korea, considering that the manufacturing industries are intensively agglomerated in industrial complexes (Interview YO-I3). After finalising the research project in 2003, the members of this research group went to a few industrial areas and organised study groups at the local level in 2004 and 2005. In Banwol-Sihwa, researchers from KITECH, KTL, Hanyang University and Korea Polytechnic University participated in the study group (Interview AN-I4). In Yeosu, the research team consisted of university-based researchers external to the Yeosu industrial complex and engineers from a few petrochemical firms (Interview YO-I3). Both groups became the EIP project teams in two areas respectively and played the key role to launch the EIP initiatives at the local level.

The bottom-up movement from civil society and the research activity from academia encouraged the government to adopt the notion of EIP as an industrial policy. The 8th national workshop held by the National Solidarity to Improve Environment in National Industrial Complexes and Reform Policy was the milestone toward the EIP initiative. Under the title "National Workshop for Successful Introduction and Management of Eco-Industrial Park in Korea", the government, academia and civil society came together. Academia presented the research on EIP, while civil society groups suggested their idea on environment-friendly industrial district. The government formally disclosed their plan on EIP at this workshop. Since then the EIP initiative has been accelerated by the central government. As a result, Yeosu and Banwol-Sihwa were designated as EIP in 2005 and in 2006 respectively.

[Figure 4-10] Chain reactions surrounding Environmental Issues in Yeosu



*Source: Author

4.5. Comparative Analysis and Discussion

The two industrial clusters have suffered from a variety of environmental problems and experienced historical environmental disasters in the mid-1990s respectively. The environmental problems generated in an industrial cluster are a public issue in which most

actors co-located in the area are involved. The narrative from Banwol-Sihwa and Yeosu demonstrates what sorts of environmental problems arise to the actors located in an industrial district and how the collective failure can be re-directed.

4.5.1. Collective Inefficiency in Banwol-Sihwa and Yeosu

Theoretically speaking, external diseconomies have the nature as *passive loss* because no one intends to bring about public damages. In contrast, collective failure takes place when clustered firms fail to take joint action to solve common problems. Accordingly, the notion of collective failure implicitly presume a case that firms cannot take joint action in a proper way despite their intentional efforts or firms do not take joint action intentionally. The combination of external diseconomies and collective failures is, arguably, *collective inefficiency* as the complete opposite of collective efficiency.

The empirical evidence from the Banwol-Sihwa dyeing cluster shows how collective inefficiency has been redirected to collective efficiency. When the Han River was seriously polluted, the dyeing and printing firms continuously failed to be equipped with effluent treatment systems despite the tightening regulations because they had little financial capacity. In this stage, they were in collective inefficiency. As for the odour problem, although the dyeing and printing firms generated the environmental external diseconomy unintentionally, they purchased pollution control equipments collectively when they recognised the common problem. Since the mid-2000s, the dyeing cluster has enjoyed external economies from their physical infrastructure like common effluent treatment plants and from institutional infrastructure like neighbouring research institutes. From this time, clustered firms have sorted out some environmental challenges like global standards and energy crisis in more proactive manners. Accordingly, it can be concluded that the Banwol-Sihwa dyeing cluster is now in the status of collective efficiency at least in terms of environmental management.

The Yeosu petrochemical cluster also experienced the stage of collective inefficiency. The interviews reveal that pollution was serious in Yeosu during the 1970s and 1980s. Although there had been little scientific investigation on the environmental problems in this period, it seems obvious that the residential community was seized with fear about pollution. The stacks of plants emitted black smoke during the 1970s and 1980s (Interview YO-F2) so that dreadful rumours about health problems and diseases had circulated among

local people (Interview YO-R1). Moreover, the petrochemical industry uses a vast range of land. The expansion of the industrial site, combined with the fear of air pollution, urged native local people to leave their home. The situation can be summarised in the comment, “Profit goes to the firms, tax goes to the government, and environmental damage goes to the local community” (Interview YO-R3).

This collective inefficiency condition had been sharply changed through a series of environmental disputes between the clustered firms and the local community over ten years. YIEA, the local trade association specialised in environmental management, began to function in the late 1990s. Although its role was focused on negotiations with the local community, this clearly suggests that the petrochemical and chemical firms started to undertake joint actions in response to environmental external diseconomies. The compensation for people’s evacuation and the expansion of social contribution to the local community can be understood as an action to internalise social costs generated from external diseconomies.

Whether the petrochemical cluster has reached at the status of collective efficiency or not cannot be judged yet with the narrative analysis on the societal interaction in this chapter. Most of all, the large firms prefer individual behaviours (Interview YO-I2) because each firm has sufficient financial and technical resources. Besides, the case study on Yeosu reveals that political challenges have significantly promoted environmental upgrading. My argument is that collective efficiency exists to some extent in the Yeosu petrochemical cluster. I discuss this in chapter 6 with the evidence from the hydrogen recycling network.

The empirical evidence from the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster shows that collective inefficiency has been redirected to collective efficiency in terms of environmental concerns. The first state is fusion of external diseconomies and collective failures. If clustered firms make efforts to correct their common problems, collective inefficiency moves into the intermediate status in which external diseconomies and joint actions exist together. If joint actions are continued and successfully carried out, an industrial cluster can reach the status of collective efficiency. One more status that can be theoretically imagined is the combination of external economies and collective failures. The patterns demonstrated in Banwol-Sihwa and Yeosu can be summarised in table 4-3.

[Table 4-3] Collective inefficiency to collective efficiency in Banwol-Sihwa and Yeosu

	Banwol-Sihwa	Yeosu
External Diseconomies Collective Failures	Water pollution crisis in the 1970s	Environmental degradation until the mid-1990s
External Diseconomies Joint Actions	Air pollution crisis in the early 2000s	YIEA, compensation, social contribution and participation in political governance since the oil-spill accidents
External Economies Joint Actions	Environmental upgrading in response to global standards, energy crisis and the EIP initiative	The EIP initiative
External Economies Collective Failures	Illegal effluent dumping scandal during Sihwa Lake pollution accident	

*Source: Author

4.5.2. Societal Interaction Dynamics to Redirect Collective Inefficiency

The notion of collective failure implies there are some elements that restrain clustered firms from doing joint actions. Such elements embrace inadequate regulatory frameworks, lack of financial ability and technical deficiency. The point here is how to minimise the influence of these elements. The narrative on the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster shows that societal interaction between clustered firms and other stakeholders can get rid of what had hindered environmental upgrading of the two clusters.

Environmental externalities do affect not only firms but also many other stakeholders. In the industrial cluster context, this tendency is more intensive due to the cohabitation of various stakeholders including clustered firms. For example, Kennedy's case study (1999) on the pollution crisis in the Palar Valley, India, demonstrates that a variety of actors like local residents and public agencies were affected by the environmental performance of clustered firms. Although the patterns of societal interaction illuminated in the previous studies are of course different from the Banwol-Sihwa case and the Yeosu case due to the

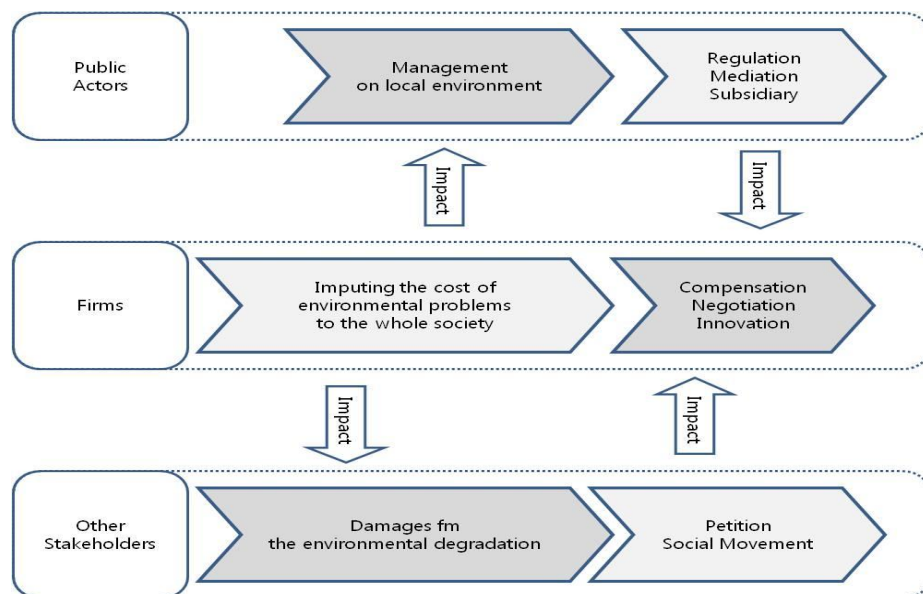
region-specific features, the contribution to environmental upgrading through societal interaction dynamics is commonly observed.

The environmental externalities in the two industrial clusters take various forms of social cost beyond the firm agglomerations. A variety of actors have been involved in the interaction. The main players are the clustered firms, the local residents and the government. The civil society has been concerned about the environmental externalities and taken various actions, while the clustered firms were initially relatively passive. In response, the Korean government has tightened the regulatory framework. In the case of the dyeing sector, the government ordered the dyeing and printing firms to leave Seoul in response to the water pollution crisis. Prohibiting the sea dumping of sludge is also a government regulation in accordance with the international treaty. In Yeosu, the government enhanced its regulation by designating the Yeosu industrial complex as the special air pollution prevention area.

Based on this narrative, a scenario on the series of interactions between actors causing and being impacted by environmental externalities within an industrial cluster can be sketched. If the firms are not under any regulation or external pressure as shown in the status of collective inefficiency of the dyeing sector and the petrochemical sectors, they have no duty to internalise costs related to environmental damages. It means, irrespective of their intention, that the firms impute their cost to the whole society. Although the firms do not pay for the damages, this does not imply that the damages are costless. Generally, public agencies like the government fulfil the payment and try to address the complaint from local people with public expenditures. However, if the cost generated from environmental externalities continues to increase and start to threaten the quality of life within and around the industrial area, the pressure on firms from the local community will become more pronounced and explicit. Yeosu-based NGOs have taken actions like filing petitions, protest, boycott and negotiation. In Banwol-Sihwa, the local residents filed petitions and prepared a lawsuit to solve the odour problem. Simultaneously, the government tends to take up more active measures such as monitoring the behaviour of firms, facilitating firms to prevent pollution with subsidy, mediate the local environmental conflicts between local people and firms. As shown in the two case studies, the government has enhanced its regulation through enactment of new laws and designating the industrial areas as special air pollution prevention zones. These changes led to the increase of costs to firms; that is to say, the internalised form of external diseconomies. The pollution crises in the two areas

triggered a string of actions and reactions among many actors, respectively showing a pattern of societal interaction. The diversity of actors involved in the same environmental issues in a limited space implies that the collective failure pertaining to environmental externalities can generate various forms of burden. Arguably, all actors behave to mitigate the burdens and thereby their actions plug into each other as a series of societal interactions. Their interaction functions as social dynamics to minimise some barriers towards environmental upgrading in an industrial cluster. The pattern of societal interaction surrounding environmental externalities can be diagrammed as shown in figure 4-11 below;

[Figure 4-11] The Chain Reactions surrounding Environmental Externalities



*Source: Author

4.6. Conclusion: Impetus for Cluster Environmental Upgrading

The research question addressed in this chapter is “what sort of environmental problems arise from an industrial cluster?” The narrative analysis on the societal interactions in the Banwol-Sihwa region and the Yeosu region provides the answers to this question. Both the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster had generated serious pollution crises. One problem that was provoked by the pollution crises is the command-and-control regulations. The government commanded the dyeing and printing firms to

leave Seoul in 1976 and designated Yeosu as the Special Air Pollution Prevention Area 1996. In addition, the Odour Prevention Act was proclaimed in 2005 and the prohibition of sludge dumping at sea was announced in 2012. Another problem that the two industrial clusters had faced is a series of environmental disputes with local civil societies. The environmental conflicts were especially fierce in the Yeosu region because the clustered firms and the local civil society directly confronted with each other. The last problem is economic issues like resource depletion and environmental trade barriers. These concerns are especially evident in the Banwol-Sihwa dyeing cluster. The dyeing and printing firms have suffered from increasing energy prices. Moreover, global buyers who have trade ties with the dyeing cluster urged the dyeing and printing firms located in Banwol-Sihwa to comply with their codes of conduct and qualify for various international environmental standards.

These three types of environmental problems have triggered clustered firms' joint actions to re-direct collective inefficiency to collective efficiency. The empirical evidence shows that a series of societal interactions brought forward the EIP agenda at the local level as well as the national level. Government regulation has been repeatedly reported as an important driver of environmental upgrading in industrial clusters (Kennedy 1999; Crow and Batz 2006; Almedia 2008). Accordingly, government actions to encourage industrial clusters to improve environmental performance can be termed as political impetus. Such government actions are often undertaken in response to petitions from residents and NGO movements (for example, Kennedy, 1999; Crow and Batz, 2006). Hence, civil society actions can be regarded as social impetus to environmental upgrading of clustered firms. Last, the Banwol-Sihwa dyeing cluster shows that some economic concerns related to environmental problems like resource depletion and environmental trade barriers also induce clustered firms to improve environmental performance. Distinct from the political impetus and the social impetus, these economic issues can be termed as economic impetus.

The narrative from the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster also raises two questions that are not addressed in this chapter. The societal interactions are, in a sense, changes in circumstance surrounding two clusters. If so, how have the clustered firms achieved environmental upgrading *pari passu* with the societal interactions? To answer this question, the internal dynamics of local production system in the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster should be investigated. The other area of inquiry related to the behaviour of two main institutional actors: academia

and government agencies. As described before, a group of researchers played an essential role in EIP agenda setting. Various research institutes like public R&D centres and universities were, and are involved in the EIP programme with the support from the government. This imposes a question about the dynamics of institutional support system underlying EIP developments. These two issues are discussed in the next two chapters.

V. ENVIRONMENTAL UPGRADING IN THE BANWOL-SIHWAS TEXTILES DYEING CLUSTER

5.1. Introduction

Political, economic and social impetuses from various actors have driven the dyeing and printing firms located in Banwol-Sihwas to improve their environmental performance. This implies that certain dynamics within the dyeing cluster have been activated in response to a series of societal interactions. This chapter seeks to identify the dynamics underlying the EIP development in the Banwol-Sihwas dyeing cluster. As suggested in chapter 2, the cluster's environmental upgrading is related to the nature of the local production system and the institutional support system. Therefore, this chapter addresses the research questions of "how does the nature of local production system affect the EIP development of clustered firms?" and "in what ways does institutional support system facilitate collective actions of clustered firms to promote the EIP development?"

The integrated conceptual framework of this doctoral study draws on the industrial ecology literature which suggests that four social factors are important for EIP development: mental distance, roles of champion, institutional setting and planning. I also identify three main dynamics of industrial cluster upgrading: collective efficiency, value chain governance and regional innovation system. If EIP development is the environmental upgrading of an industrial cluster, the four social factors of industrial ecology can be reinterpreted with the three dynamics of cluster upgrading. The cluster upgrading dynamics are activated reflecting the nature of local production system and institutional support system. Accordingly, analysing the dynamics underlying the EIP development will expose how the nature of local production system and institutional support system of the Banwol-Sihwas dyeing cluster might affect EIP development.

This chapter consists of four sections. Following the introduction, Section 5.2 investigates the structure of the production system and the institutional support system in the Banwol-Sihwas dyeing cluster. The first part of this section analyses the production system of the Banwol-Sihwas dyeing cluster. The second part of section 5.2 reviews the institutional support system within the cluster. Section 5.3 describes the cluster's environmental management practices and industrial symbioses. This section also outlines the

environmental management system of the Banwol-Sihwa dyeing cluster, demonstrating flows of energy and by-products at the inter-firm and inter-sector level. Section 5.4 analyses the social dimension of the dyeing cluster's EIP development with the four social factors of industrial ecology. Second, the evidence on these four elements is reinterpreted with the dynamics of collective efficiency, value chain governance and innovation system. The last part of section 5.4 is dedicated to analysing the influence of the nature of the cluster's production system and institutional support system on the EIP development. In the final section 5.5, this chapter concludes with a brief summary of findings and discussions.

5.2. Local Production System and Institutional Support System

The first task in investigating the influence of a cluster's local production system and institutional support system on EIP development is identifying the industrial structure of the Banwol-Sihwa dyeing cluster. I suggest that an industrial cluster is composed of two distinctive areas: local production system and institutional support system. A local production system consists of three sets of inter-firm relationships: horizontal linkages, forward vertical linkages and backward vertical linkages. The institutional support system is a tier of non-firm institutions that function to support industrial activities of agglomerated firms. In accordance with this conceptual framework, I analyse the structure of the Banwol-Sihwa dyeing cluster.

5.2.1. Production System of the Banwol-Sihwa Dyeing Cluster

Horizontal Linkages

The apparel industry is highly sensitive to customer preferences. Colour is one of the most heterogeneous aspects of customer preferences. Besides, there are a variety of textile fabrics that require specific dyeing or printing technologies. The dyeing and printing units clustered in the Banwol-Sihwa dyeing cluster are individually specialised in narrow activities in accordance with distinct types of dyeing processes, sorts of fabrics and different types of garment and textiles products (Interview AN-F1, AN-F2, AN-F3, AF-6,

AN-I6). Few firms have the scale or resources to possess an extensive range of knowledge or equipments to undertake all dyeing activities. Hence, the cluster is highly segmented and individual firms are highly specialised (Interview AN-F1). However, the dyeing and printing firms are basically engaged in the same production stage of the apparel value chains so that they have many common interests in their industrial activities. When such interdependence is maintained, disaggregation in production activities tends to require more inter-firm coordination (Arikan and Schilling, 2011). Together with the increasing technical complexity at the cluster level, the persisting inter-firm interdependence has resulted in a high degree of coordination in the horizontal linkages of the Banwol-Sihwa dyeing cluster.

The inter-firm interdependence within the dyeing cluster is mainly coordinated by two business cooperatives, Banwol Dyeing Enterprise Cooperative (BDEC) and Sihwa Dyeing Enterprise Cooperative (SDEC). Their influence has been formed through a long history of joint actions. These two dyeing cooperatives stemmed from the Seoul and Central Regional Dyeing Enterprise Co-operative (SCDEC) which was established in 1966.¹⁸ The member firms of SCDEC raised from 56 in 1966 to over 150 by the mid-1980s before the establishment of BDEC. One of the main reasons why the dyers organised themselves collectively was to do group purchase of raw materials. Group purchase practices were well entrenched by the 1980s. In addition, since 1980 SCEDC began to implement various sorts of management guidance activities like seminars, lectures, on-site consulting and training in cooperation with public agencies. Furthermore, SCDEC supported its member firms to carry out marketing activities such as foreign inspection tours, field trips and participation in domestic and international trade fairs. The horizontal tie that was already institutionalised as a collective decision-making system was transferred into the Banwol-Sihwa area when SCEDC's member firms moved from Seoul to the Banwol-Sihwa region, in response to the government's environmental regulation, forming BDEC and SDEC.

¹⁸ The origin of the dyeing business in South Korea is very small-scaled dyeing mills that bleached or coloured military uniforms discarded from the US army during the Korean War in the early 1950s. In this period, the dyeing business formed a social gathering with spinning firms, weaving firms and towel manufacturers and this club had advanced to a voluntary association called Seoul Dyeing Craft Guild in 1954. When the government announced the Small and Medium Enterprise Co-operatives Act in December 1961, about 30 dyeing and printing firms organised Korean Weaving and Dyeing Craft Guild with small and medium-sized weaving firms, spinning firms and towel manufacturers again. The dyeing sector established their national-level association, Korean Dyeing Business Co-operative in June 1963 and this organisation was reorganised as an association of three regional cooperatives; Seoul, Daegu and Busan in 1966. The Seoul and Central Regional Dyeing Enterprise Co-operative was established at this time.

Agglomeration gains and joint actions in the horizontal linkages of the Banwol-Sihwa dyeing cluster are substantially managed and arranged by the two local business cooperatives. Most of all, the two dyeing business cooperatives are a part of the cluster's production network. BDEC and SDEC have two common effluent treatment plants which are physically connected to all dyeing and printing units through drain pipes. In addition to providing environmental management services and operating the two common effluent treatment plants, there are three further roles devolved to BDEC and SDEC. First, the two business cooperatives represent their member firms in communicating with government authorities and other actors. Proposing collective ideas of the dyeing and printing firms and achieving common interests of the member firms in negotiations with their counterparts are one of the main missions carried by BDEC and SDEC. Second, BDEC and SDEC circulate information related to industrial policies and environmental regulations among their member firms. Third, BDEC and SDEC are directly involved in R&D projects in cooperation with local research institutions and encourage member firms to collaborate with such non-firm institutions. As BDEC and SDEC have implemented a vast range of activities favourable for the dyeing sector, a firm manager commented, "the business cooperatives do everything beneficial for their member firms" (Interview AN-F4).

The SME-dominated industry needed to organise itself so as to coordinate and represent common interests. This need has been materialised in the form of the business cooperatives. Although some conventional types of joint action like group purchase of raw materials have been phased out according to the specialisation of industrial dyeing and printing firms, they still have many common issues that can be effectively addressed through joint actions coordinated by the business cooperatives. BDEC and SDEC play the role of formal collective decision-making bodies in the Banwol-Sihwa dyeing cluster. The representative directors are elected from the CEOs of their member dyeing and printing firms and their common issues are discussed at regular general meetings. The dyeing and printing firms collectively approve entrance of new firms into the cluster at membership meetings of BDEC and SDEC. In short, BDEC and SDEC represent the network governance of the cluster's horizontal linkages.

Forward Vertical Linkages (Global Apparel Value Chain)

The Banwol-Sihwa dyeing cluster is a part of global apparel value chain. Most dyeing and printing units located in Banwol-Sihwa are subcontracted suppliers closely linked to the global market as suppliers of high-end textiles. Their main buyers are top-branded global retailers like The Limited, GAP, Wal-Mart and Coach (Interview AN-F2, AN-F3, AN-F4, AN-I2, AN-I5). Although a few buyers directly trade with the dyeing firms, most global buyers prefer working with the dyeing and printing firms via middle agents or their regional production sourcing team based in key hubs like Hong Kong and Seoul. The basic role of middle agents is the intermediate tasks between order-taking and production sourcing. While the marketing channel is managed by the middle agents, the production linkage with the dyeing cluster is largely with Korea-based original design manufacturers (ODM) of garments, so-called vendors, like Hansoll, Hansae and Sae-A. These firms are large first tier garment suppliers who have huge production capacities to cut and sew garments in factories located in China, Southeast Asia and Latin America. They use textiles that have been processed by the bleaching, dyeing and printing firms within the Banwol-Sihwa dyeing cluster.

A series of interviews in the fieldwork identify the main characteristics of the cluster's forward production linkage. First, although the cluster is engaged in a typical buyer-driven value chain, the dyeing and printing firms are substantially independent from their buyers. There is little investment, personnel exchange and knowledge transfer from either the global buyers or Korean vendors to the cluster (Interview AN-F6, AN-F7). The finding through the interviews suggests that despite the lack of such cooperation with buyers there are strong vertical ties in the form of long-term commitment. The fundamental cause of the strong long-term commitment between the clustered firms in the Banwol-Sihwa dyeing cluster and their customers is the dyeing firms' specialisation.

The vendors and middle agents know which dyeing and printing firms are specialised in which products, and processes. Therefore, the buyers do not choose their suppliers at random and do not want to change their business partners frequently (Interview AN-F6). This leads to the relatively stable buyer-supplier relationship between the multinational clothing makers and the Banwol-Sihwa dyeing cluster. These reflect the characteristics of the Korean textiles industry as a full package production of relational apparel value chains (Gereffi et al. 2005).

Backward Vertical Linkages

Raw textile materials like grey fabric are supplied from outside the cluster. There exist some large natural fabrics producers in South Korea, but the Korean textile industry depends significantly on imports of natural fabrics like cotton. As for artificial fibres, several large producers like Hysoungm, Kolong and SK located in the southern chemical sites are main suppliers (Interview AN-F1, AN-I5). The relationship between the clustered dyeing and printing firms and their grey fabric suppliers is basically market-based.

The other part of the backward supplier linkages on which I give more attention is the relationship with two basic raw materials suppliers for dyeing and printing: dyestuffs/chemicals and dyeing equipments. In terms of the dyestuffs and chemical additives, it is important to note that dyestuff manufacturers and the chemical sectors are also agglomerated in the Banwol-Sihwa industrial complex. There are about forty dyestuff producers in South Korea and eleven of them have their headquarters and production facilities in Banwol-Sihwa. The dyestuff manufacturing business is an oligopoly market in which two lead firms hold about 70 percent of the market (NICE Credit Information Service, 2010) and these two firms' main plants are located in the Banwol-Sihwa industrial complex. There are middle agents between the two sectors and some dyeing and printing firms prefer imported dyestuffs (Interview AN-F4, AN-F5). The last but equally important supplier to the dyeing cluster is the dyeing equipment manufacturers. Three cotton dyeing machine producers and five synthetic dyeing machine producers compete in the multiply segmented market along with the dyers' specialisation (Interview AN-I6). The equipment producers are also located in Banwol-Sihwa, Daegu and the Northern Gyeonggi where major dyeing clusters are situated. The trade between the dyeing sector and the dyeing equipment sector is also mediated by middlemen. Thus the backward vertical linkages of the Banwol-Sihwa dyeing cluster are basically market based relations.

5.2.2. Institutional Support System of the Banwol-Sihwa Dyeing Cluster

The Banwol-Sihwa region not only accommodates firms but also hosts various non-firm institutions such as public agencies, R&D centres and local universities. These non-firm institutions directly or indirectly support industrial activities of agglomerated firms, forming a tier of business supporting institutions. Through a series of interviews with firm

managers and CEOs working in the dyeing cluster, I notice three groups of non-firm actors that have actively engaged in knowledge development activities of the dyeing sector: Gyeonggi Regional Headquarter of Korea Industrial Complex Corporation (KICOX), public research institutes and local universities.

Gyeonggi Regional Headquarter of Korea Industrial Complex Corporation (KICOX)

KICOX is a public industrial complex estate and supervision agency. Its basic role is creating industrial areas, leasing factory sites to firms and managing physical infrastructure of industrial complexes. Simply speaking, KICOX is a real estate manager for national industrial complexes. While holding this primary mission, KICOX has expanded its activities by taking on the role of an implementation agency for policy measures to improve competitiveness of industrial clusters since the mid-2000s. Each regional branch of KICOX conducts such national programmes at the local level with the financial resources allocated by the central government. How KICOX delivers financial innovation resources to local actors is a more essential matter. KICOX has continued to organise and manage various industry-university-public alliances at the local level. Local firms and other actors can access to the government funds only by participating in these networks. In this regard, “networking itself” is one of the main tasks undertaken by KICOX (Interview CE-I5, AN-I8).

The EIP programme is a representative policy measure for which KICOX plays the role of an implementation body. At the national level, the headquarter of KICOX supervises the EIP programme with R&D funds from the Ministry of Trade, Industry and Energy. In Banwol-Sihwa, the Gyeonggi EIP Centre is a department of Gyeonggi Regional Headquarter of KICOX. It researches into potential industrial symbioses, build networks between by-product suppliers and users and coordinates R&D projects. In short, KICOX is a main funding body and a coordinator that also encourages firms and non-firm institutions to meet, communicate and cooperate with each other.

Public Research Institutes

The Banwol-Sihwa region hosts regional branches of three government research institutes: Gyeonggi Division of Korea Institute of Industrial Technology (KITECH), Gyeonggi Office of Korea Testing Laboratory (KTL) and Ansan Branch of Korea Electro-technology

Research Institute. The government research institutes are a unique element of South Korea's national innovation system. Before joining the groups of industrialised countries, South Korea was a poor country that had little financial and technological capability. In order to improve national innovation capacity, the government began to establish government research institutes with foreign aids and hired highly educated human resources. The organisational scale of this unique governmental R&D sector had continued to be expanded,¹⁹ given that the private R&D capability like universities and research departments of private companies had not entrenched by the late 1980s. One of the negative effects of this policy was the over-centralisation of innovation capacity in the capital area and the marginalisation of local SMES that was not within the sphere of the government-led innovation system. In response, the central government has gradually transplanted government research institutes into non-capital regions and made regional branches of government research institutes to foster industry-academic-public cooperation at the local level. The Banwol-Sihwa industrial complex is the primary target region of this industrial policy (Interview CE-I2, CE-I3, CE-I4), given that about thirteen thousand SMEs working for a variety of industrial sectors are agglomerated in the region. By being located in the Banwol-Sihwa region, the three government research institutes play integral roles in supporting SMEs and improving the local-level innovation capacity.

In terms of the textile dyeing sector, Gyeonggi Division of Korea Institute of Industrial Technology (KITECH) should be highlighted. KITECH is a public research institute owned and supervised by the central government. KITECH launched a seven-year large-scale R&D project, called DYETECH21 in 1994. DYETECH21 aimed to improve the dyeing technology in four areas; the technical development on cleaner production, the invention of high value added textiles, the improvement of dyestuff, chemical additives and dyeing equipments and the codification of dyeing process (Jeon, 1995). As a part of this project, KITECH installed a pilot dyeing plant in the Banwol-Sihwa area in 1995. The pilot plant has developed as one of KITECH's regional branches and is the sole public research institute specialised in textile manufacturing technology. This spatial co-location of the lead governmental research institute specialised in the textile manufacturing technology is a big advantage for the Banwol-Sihwa dyeing cluster.

¹⁹Currently, 14 institutes in the industrial technology field, 11 institutes in the basic science field and 26 institutions in the social science field are in operation at the national-level. In addition, each megalopolis government and province normally has one or more public research institutes.

There are roughly three ways through which KITECH supports the dyeing and printing firms. As for individual firms, KITECH provides technology consulting or test products by using the pilot plant in the case of relatively simple engineering issues. If a firm face a problem which demands new technology, KITECH launches a long-term R&D project together with the firm concerned by using public R&D funds. Another way to support the dyeing and printing firms is through cooperation with BDEC and SDEC. There are some cases that KITECH need to make a public announcement to all dyeing and printing firms, give a seminar to disseminate new technologies or announce open call for participation in a large-scale R&D programme. In these cases, KITECH directly attends regular meetings of BDEC and SDEC or conveys messages through BDEC and SDEC. Besides, KITECH researchers not only supply technical assistance but also provide management consulting service, foreign market survey and even social events like hiking with the dyeing and printing firms (Interview AN-I7).The dyeing and printing firms can use knowledge of professional engineers, equipments of the pilot dyeing plant and government funds for R&D activities.

Local Universities

There are two local universities that regularly collaborate with the Banwol-Sihwa dyeing cluster: Hanyang University and Korea Polytechnic University (KPU). Hanyang University founded its second campus in Ansan according to the government plan to develop the Banwol-Sihwa area as a new urban region in 1980(Interview CE-I3). Department of Textile Design of Hanyang University has provided various training programmes on leadership, production quality control and factory accounting for the dyeing and printing firms. Department of Chemistry has collaborated with the two dyeing business cooperatives in order to improve effluent treatment methods applied to the common effluent treatment plants. In addition, Hanyang University has a research centre specialised in environmental technology and engineering consulting, Ansan Green Environment Centre (AGEC). This university-based research centre monitors pollution and provides technical assistances to tenant firms located in the Banwol-Sihwa industrial complex including the dyeing sector.

While Hanyang University is the key actor of industry-academy cooperation in the Banwol area, Korea Polytechnic University (KPU) plays a central role of industry-academy

cooperation in the Sihwa area. KPU was spun off from KITECH as a higher educational institution specialised in industrial technologies in 1998. Compared to Hanyang University, KPU is more focused on SME-dominated industries because the central government intends to use the university as a region-specific innovation resource and a human resource supplier for SMEs. Given that the SME dominated textile dyeing business is one of the main industries in the Banwol-Sihwa region, KPU and the dyeing cluster have maintained close relationships. For instance, KPU contributed to developing product designs when ten dyeing and printing firms launched their common brand. The most important aspect of the cooperation between KPU and the dyeing cluster is upon environmental concerns. KPU also has an environmental technology development centre, Siheung Green Environment Centre (SHGEC). The function of SHGEC is basically same as AGECE of Hanyang University, as both centres were established under the central government's scheme to solve environmental problems at the local level.

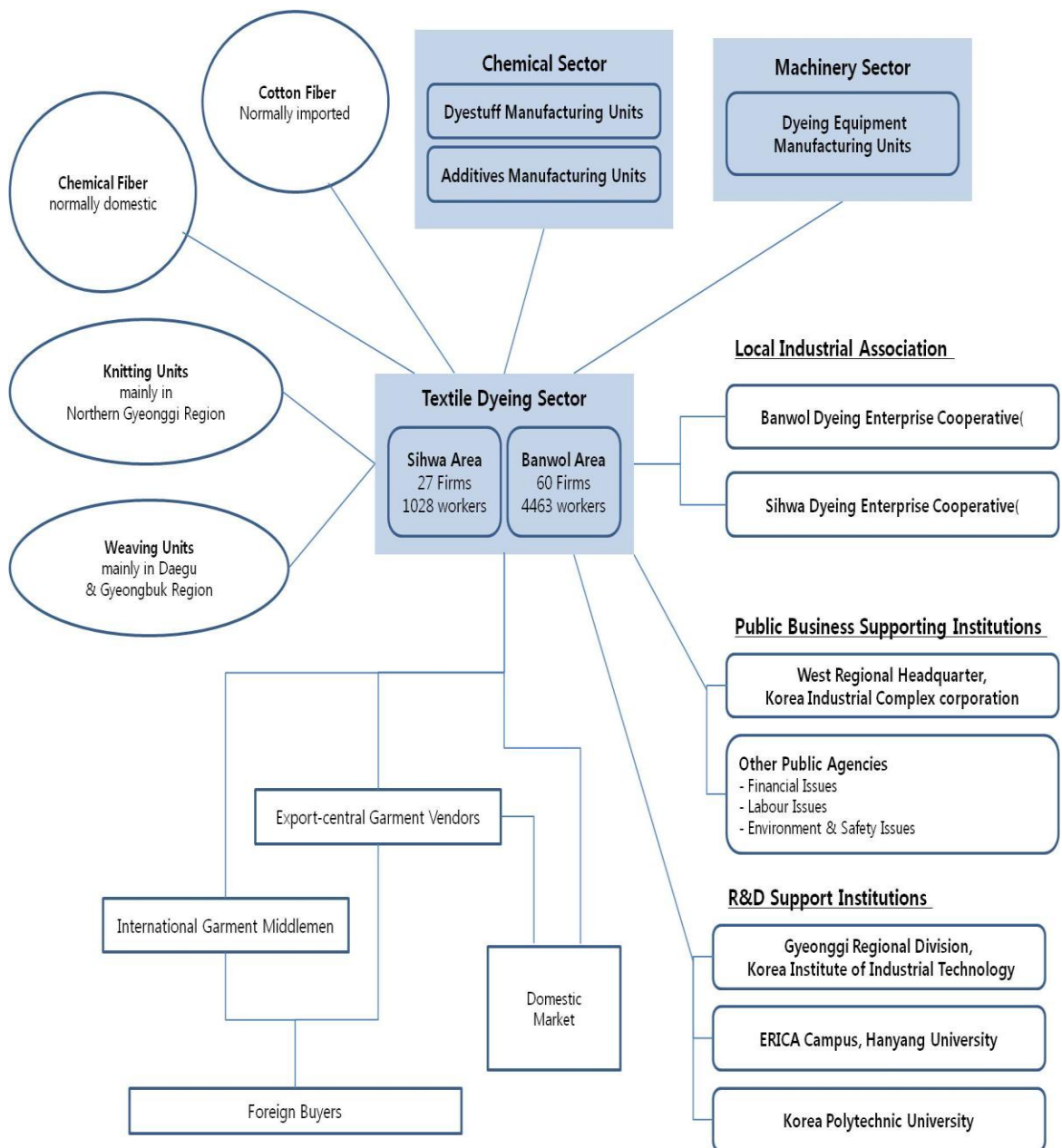
5.2.3. Summary: Structure of the Banwol-Sihwa Dyeing Cluster

The production system of the Banwol-Sihwa dyeing cluster can be characterised with its three inter-firm linkages. In the horizontal linkage context, the dyeing cluster is an agglomeration of locally owned SMEs. Being engaged in the same production stage, they have a variety of common interests and maintain interdependence at the local level. As a result, a high degree of coordination in the horizontal linkage has developed. Their two business cooperatives, BDEC and SDEC, play the role of collective decision-making body. As for the dyeing cluster's forward vertical linkage, the dyeing and printing firms are textile suppliers of global apparel value chain. Due to the dyeing cluster's relatively high competence, the relationship between the dyeing and printing firms and their buyers can be regarded as relational value chain governance. Some dyestuff and chemical additives suppliers and dyeing equipment manufacturers are also located in the Banwol-Sihwa region, forming the backward production linkage of the dyeing cluster. The inter-firm relationship in this backward vertical linkage is basically market-based.

The Banwol-Sihwa dyeing cluster is surrounded by various public business supporting agencies, R&D centres and local universities. Four non-firm institutions are crucial innovation resources for the dyeing sector in the Banwol-Sihwa region: KICOX, the government research institutes like KITECH and the local universities. KICOX functions

as an implementation agency of policy measures to promote industry-academic-public cooperation at the local level. KITECH is a government research institute that has led many R&D programmes in cooperation with local industries and other innovation organisations. The two local universities have collaborated with the dyeing cluster by participating in KITECH's policy networks and/or KITECH's R&D programmes. As a whole, the structure of the Banwol-Sihwa dyeing cluster can be mapped as in figure 5-1.

[Figure 5-1] Cluster Map of the Banwol-Sihwa Textile Dyeing Cluster



*Source: Author

5.3. Environmental Management System and Industrial Symbiosis

The next step is to understand how the local production system and institutional support system of the dyeing cluster affect the EIP development of clustered firms. This section reviews the Banwol-Sihwa dyeing cluster's environmental management practices including EIP projects. The dyeing and printing firms in the Banwol-Sihwa region have adopted environmental management practices in the sequence of pollution control, cleaner production and EIP since they clustered in the mid-1980s. By investigating these practices, the cluster's environmental management system over by-product flows and energy-cascading through inter-firm networks is elucidated.

5.3.1. Environmental Management Practices Prior to EIP

Pollution Control

The first stage of environmental upgrading in the Banwol-Sihwa dyeing cluster was sharing the two common effluent treatment plants and the collective installation of odour control equipments. The effluent treatment plants and the odour control systems are pollution control measures. Given that the dyeing and printing firms operate at the same production stage and generate similar types of pollutants, they have common interests pertaining to pollutant emission. Clustering has made the dyeing and printing firms realise economies of scale for environmental performance. The two local business associations, BDEC and SDEC, have led and facilitated the pollution control type of environmental upgrading.

There was little assistance from the government or other non-firm actors when the dyeing cluster initiated the pollution control practices. It is partly because end-of-pipe methods like effluent treatment plant and air pollution control equipment are seen as basic environmental management practice which do not require high technologies. However, as the facilities have become obsolete after operating for a long time, the pollution control equipments should be updated. Especially in terms of air pollution control, the dyeing cluster has cooperated with the two university-based environmental technology development centres, AGECE and SHGEC (Interview AN-I1, AN-I2). AGECE and SHGEC carried out a total inspection of air pollution levels and odour causing substance of the

dyeing cluster between 2007 and 2008 and then their collaboration continues through regular on-site engineering consulting.

Cleaner Production

The dyeing and printing firms located in Banwol-Sihwa, through their engagement in the global apparel value chain, began to face new trade barriers, in the form of environmental standards, from the early 2000s. They have been required to be qualified for various standards like ISO14001, Organic Exchange and Global Organic Textiles Standard (Interview AN-F2, AN-F3, AN-I2) and the compliance team of the foreign buyers and Korean vendors regularly check the environmental problems like effluent treatment and toxicity of input materials (Interview AN-F2, AN-F4, AN-F6). The compliance takes the form of codes of conduct to maintain reputation in the main market. An informant working for a top-branded retailer mentioned the importance of compliance issue as follows;

If our production activity is not satisfied in compliance with its codes and regulations, we cannot sell anything in the US. For example, any flammable textile should not be used to produce bedclothes for children or any product made by child labour or in sweatshops is prohibited. We should pay a lot of attention to compliance because of its huge influence over our market. The most ultimate reason is that unethical companies cannot be successful in the business. If an unethical behaviour is reported or accused, we will be in big trouble in the market (Interview AN-F6).

The other global challenge is energy costs. The dyeing business is one of the most energy-intensive industries. As price of energy soared since the mid-2000s, energy costs became a pending issue and a real burden in the Banwol-Sihwa dyeing cluster (Interview CE-I6, AN-F2, AN-F4, AN-F5). Energy costs are closely related to the water consumption in the dyeing process because the dyeing firms use most energy to boil water (Interview AN-I6). The average water consumption per one dyeing unit is about 1,200 to 1,500 tons per day (Interview AN-I5). Under the condition that the dyeing and printing firms should continue to increase their production volume in order to maintain profits, rising energy prices and the shortage of industrial water have driven the clustered firms to improve their resource productivity.

In response to buyers' codes of conduct, international environmental standards and increasing energy prices. The dyeing and printing firms have carried out various R&D activities to substitute toxic chemical inputs, reduce energy consumption and improve equipments; thus adopting cleaner production practices. The first R&D activity that contributed to the cluster's cleaner production is a national-scale R&D project, so-called DYETECH21, led by KITECH from 1994 to 2000. DYETECH21 aimed to improve dyeing technology in four areas; the technical development on cleaner production, the invention of high value added textiles, the improvement of dyestuff, chemical additives and dyeing equipments and the codification of dyeing process (Jeon, 1995). This R&D project brought about crucial effects. First of all, as the project had been implemented for seven years in the form of industry-academic-public cooperation, the partnership between the Banwol-Sihwa dyeing cluster and KITECH was fully settled down as a cluster-wide institutional linkage pertaining to RIS dynamics. Second, the pilot dyeing plant in the Banwol-Sihwa that was the matrix of KITECH's Gyeonggi Regional Division was built via this project. Thanks to the pilot dyeing plant, KITECH has continuously developed the relationships with the dyeing sector, the dyestuff and chemical additives manufacturing sector and the dyeing equipment manufacturing sector in Banwol-Sihwa.²⁰ Last but most important as for the dyeing cluster's environmental upgrading, the project triggered various technical development initiatives toward cleaner production in the dyeing industry, as DYETECH21 included the plan to develop low temperature dyeing technology, low-liquor ratio dyeing technology, effluent treatment technology and even waste heat collection technology (Jeon, 1995). Especially from the point of view of industrial ecology, it is noticeable that the technological development to collect and reuse waste heat from the dyeing process was already considered in the late 1990s.

²⁰ The pilot plant generated a sort of cafeteria effects and consequently fitted the KITECH-led R&D consortium out with the cultural element of regional innovation systems. The director of Dyeing & Finishing Technology Centre of KITECH looked back as follows; "they saw us as a neighbour who talks the same language, rather than a research institute. We visited them first, but after getting some friendliness, they came. They came to us because we are their neighbour. They just stopped by us on the way. Moreover, as dozens of local firms visited us to get advices and use the pilot plant. Who has come? Dyers, dyestuff supplier and dyeing equipment producers. Even when we were absent, they had chat each other over a cup of coffee in our place and naturally our previous building became a place for social meeting and knowledge sharing. Sometimes we thought this place looks like a village pub rather than a research institute. (I replace the colloquial expression used by the informant with 'village pub') Such intimate personal relations and social networks have eliminated some sorts of barrier between us and them" (Interview AN-I6).

In sequence, the Banwol-Sihwa dyeing cluster and KITECH implemented a project to study some international environmental standards and develop a Korean standard, so-called 'Eco-Safe' in the mid-2000s. Two other R&D projects from 2006 to 2009 are also examples of the cleaner production approach in the Banwol-Sihwa dyeing cluster. One project, so-called Development of Clean Dyeing Technology to Reduce Heavy Metal, aimed to reduce the toxicity in dyestuffs and other chemical ingredients used in the dyeing process and thereby counteracting the hazards of textile effluent sludge (Interview AN-I5). At the dyeing sector's request, KITECH invited one dyestuff manufacturer and one chemical additives manufacturer and organised a joint research team between the three related sectors. The other R&D project, called Technology Development of Optimizing the Lowest Liquor Ratio Dyeing Process, aimed at inventing new dyeing equipments with which water consumption in the dyeing process can be sharply reduced. As the volume of water consumed in the dyeing process influences amount of energy used to boil water and amount of chemical inputs, reducing water consumption in the dyeing process offers cost saving related to energy and raw materials for the dyeing sector. KITECH and three university-based research teams performed this project in concert with three dyeing equipment manufacturers, one dyestuff supplier and the dyeing industry. The newly invented dyeing equipments by this R&D project have been widely disseminated across the Banwol-Sihwa dyeing cluster (Interview AN-I6).

The dyeing cluster's cleaner production approach shows two features that are distinctive with the pollution control approach. First, the cleaner production approach have been developed and adopted by collaboration between the dyeing sector, their raw materials and capital goods suppliers and innovation support organisations. Different from end-of-pipe methods, cleaner production practices prevent the use of environmentally harmful inputs in advance or adjust a production process. Accordingly, the dyeing cluster's cleaner production practices have inevitably promoted innovations in the dyestuff and chemical additives supplying sector and the dyeing equipment manufacturing sector. In addition, the partnership between the dyeing sector and the local innovation support institutions became full-fledged while various R&D projects based on the cleaner production approach have been implemented. Because the cleaner production approach has the nature of product and process upgrading, more scientific knowledge and R&D activities are required. Given that the textile dyeing and printing firms have little financial and technological capacity, the SMEs have increasingly become reliant on public R&D funds and neighbouring

knowledge generation institutions like KITECH and local universities while upgrading towards cleaner production.

5.3.2. Industrial Symbiosis

EIP is the most recently introduced environmental management strategy of the Banwol-Sihwa dyeing cluster. The dyeing industry has participated in the EIP programme since 2006 and currently three industrial symbioses are in operation.

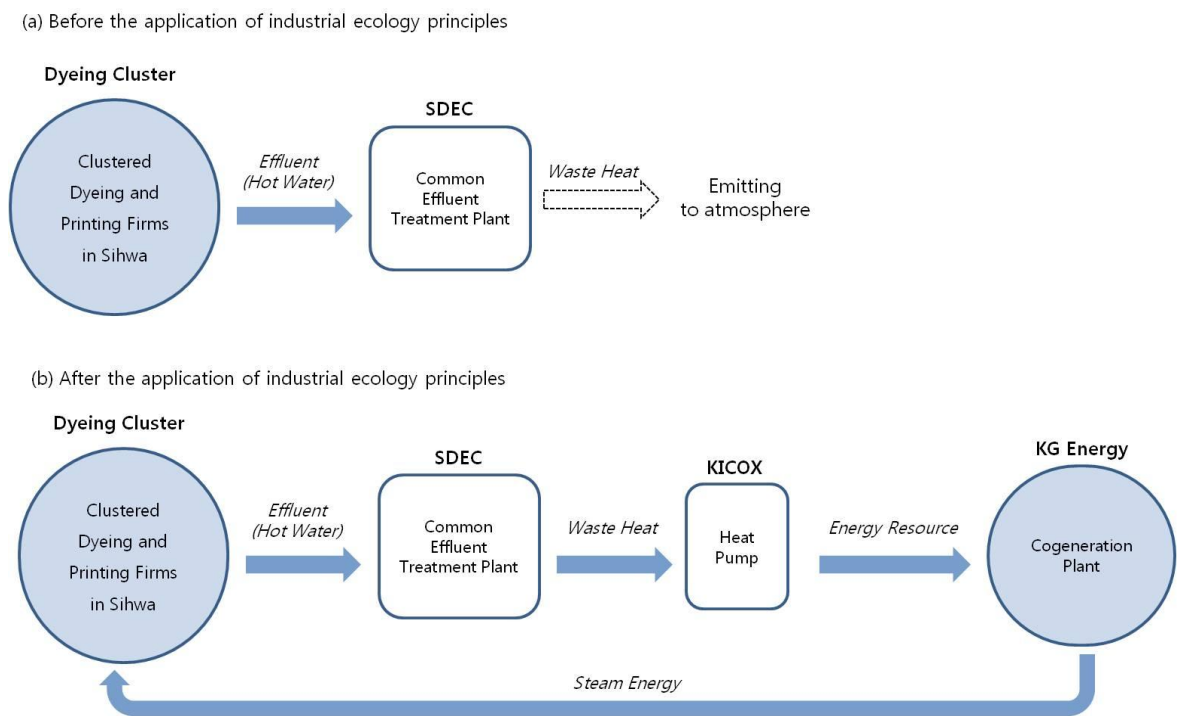
Wastewater Heat Exchange Network

The wastewater heat exchange between SDEC's effluent treatment plant and its neighbouring cogeneration plant, KG Energy, in the Sihwa area has been initiated at the early stage of the EIP programme in Banwol-Sihwa. Textile dyeing effluent is hot water whose temperature is between 40 to 50 degrees Celsius. Accordingly, effluent can be used as an economically valuable energy source if it is properly heated (Interview AN-I1, AN-I2, AN-I7). This wastewater heat exchange system is operated through specific equipment called heat pump. SDEC has provided a plot of land where the heat pump was installed, while the cogeneration plant provides steam to the dyeing and printing firms with cheaper price in return. In addition, 4.5 percent of the total sales from the wastewater heat network are allocated to SDEC (Interview AN-F1). KICOX made a direct investment on this project and established a subsidiary company to manage the network as the intermediate trader (Interview AN-I3, AN-I7). The project was coordinated by Gyeonggi EIP Centre and the research on its economic feasibility was investigated by KITECH. The wastewater heat exchange network can be diagrammed as in figure 5-2 below.

As the wastewater heat exchange network was built by using the existing physical infrastructure, it is obvious that the geographical proximity between the dyeing cluster and the cogeneration plant was a decisive advantage in establishing this industrial symbiosis. The dyeing and printing firms have collectively shared SDEC's effluent treatment plant and received steam from KG Energy. This industrial symbiosis was simply designed to change linear energy flow from the cogeneration plant to the dyeing cluster to energy circulation between both sides. Accordingly, the wastewater heat exchange network can be regarded as utility sharing type of industrial symbiosis.

KITECH and KICOX are the main non-firm actors involved in establishing the wastewater heat exchange network between SDEC and its neighbouring cogeneration plant. A research team from KITECH's headquarter implemented the feasibility study on the wastewater heat exchange network. In fact, the technology to collect waste heat and reuse as an energy source was already examined in a R&D project carried out by Gyeonggi Regional Division of KITECH between 1994 and 2000. Accordingly, the stage of feasibility study was completed without particular technical engineering problems (Interview AN-I7). Based on the positive result from the feasibility study, KICOX directly invested in installing heat pumps and set up a subsidiary company to trade the by-product energy source between the dyeing sector and the energy sector.

[Figure 5-2] Wastewater heat exchange network in the Sihwa area



*Source: Author

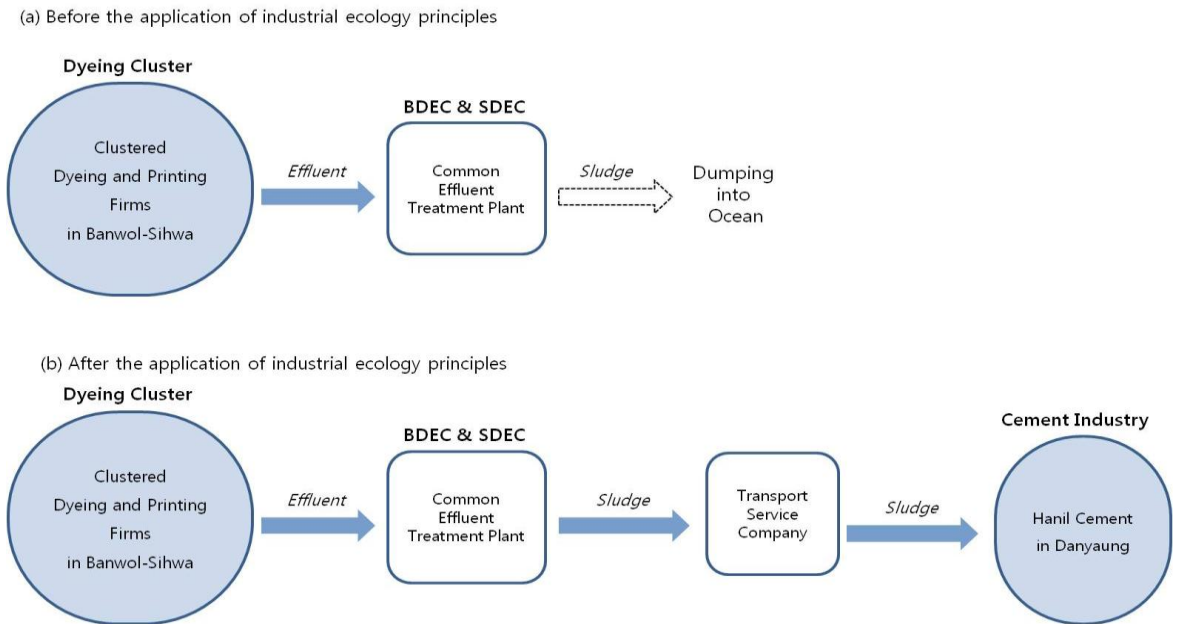
The wastewater heat exchange network is a solution to reduce the cost burden, given that the energy crisis is an urgent pending issue in the cluster (Interview CE-I6). The dyeing and printing firms interviewed during the fieldwork reveal that they perceive the energy issue as one of the most serious environmental crisis because the energy cost is the second

largest burden after the wage cost (Interview AN-F1, AN-F4). KICOX reports that 3,759 Toe (Tonnage of Oil Equivalent) of energy consumption and 15,377 tons of CO₂ emission can be reduced by the wastewater heat network (Ministry of Knowledge Economy and Korea Industrial Complex Corporation, 2011). In addition, the temperature of dyeing effluent becomes lower through the engineering process and consequently the microorganisms in the biological effluent treatment become more active (Interview AN-I1, AN-I7). This results in lower cost to operate the cooling tower of the effluent treatment plant and the reduced consumption of chemical inputs in the sewage disposal process. In this regard, the informant working for the dyeing cluster points out that the industrial symbiosis is a win-win project (Interview AN-I1).

Effluent Sludge Recycling Network

The dyeing cluster's second industrial symbiosis is the exchange of textile effluent sludge between the dyeing cluster and a cement manufacturer. The Korean government will totally prohibit the ocean dumping of sludge in the near future so as to meet the regulation of an international treaty called London Dumping Convention. In accordance with this announcement, the sludge generated from the two common effluent treatment plants should be treated on land (AN-I1, AN-I4). BDEC and SDEC, through an EIP project, chose to provide the sludge they were generating as an input for a cement producer. The textile dyeing effluent sludge can be used as a substitute for clay in the cement manufacturing process (Interviews AN-I1, AN-F8). As cement furnaces burn sludge at 1,450 degrees Celsius, the dyeing and printing firms do not need to be concerned about energy costs, secondary pollution, intermediate treatment and the percentage of water content in sludge (Interview AN-I4). The effluent sludge recycling network can be diagrammed as in figure 5-3 below.

[Figure 5-3] Effluent Sludge Recycling Network



*Source: Author

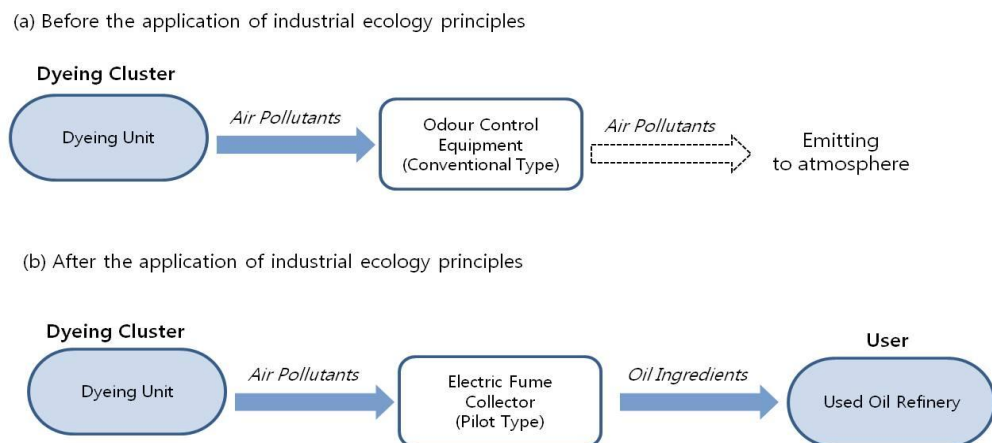
In fact, two more alternatives to treat sludge are in gestation. One alternative sludge treatment method is the carbonisation of sludge (Interview AN-I4). This method is to produce activated charcoal by burning effluent sludge. Activated charcoal is a powdered material that has high absorption of gas and moisture. Due to this attribute, activated charcoal is used as an input in operating air pollution control equipments. The research project to examine the sludge carbonisation method was carried out in cooperation between the two dyeing business cooperatives and a government research institute located in the Banwol-Sihwa region, Korea Testing Laboratory (KTL). As sludge generated from the dyeing cluster's effluent treatment plants has relatively low percentage of water content, it is not technically difficult to make activated charcoal by burning the sludge. In addition, many firms located in the Banwol-Sihwa industrial complex are equipped with air pollution control facilities for which activated charcoal is used (Interview AN-I4). Accordingly, the carbonisation method has been evaluated as the best available practice in terms of technical and economic feasibility so far. However, the carbonisation method has not been commercialised yet because of the environmental regulation and the necessity of large initial investment costs (Interview AN-I2, AN-I4). The other potential industrial symbiosis is a plan to use effluent sludge to produce biomass fuel. The R&D project on

this method is currently underway in the collaboration between the dyeing business cooperatives and a university-based R&D centre.

Collection and Reuse of Oil Ingredient from Air Pollutants

The latest industrial symbiosis of the Banwol-Sihwa dyeing cluster is the collection and reuse of oil from air pollutants generated from the tentering process. Air pollutants from the dyeing industry contain oil ingredients which contaminate the atmosphere and induce odour. Siheung Green Environment Centre (SHGEC), an environmental technology development centre based in KPU, has improved the function of a specific odour control system, called electric fume collector (EFC), aiming at preventing odour as well as reusing oil ingredients. Because the university-based research centre had little capability to market the engineering solution, it sought support from the EIP programme (Interview AN-I3). Gyeonggi EIP Centre searched for a dyeing firm that wanted to be equipped with this new odour control system and a chemical firm that want to use by-product oil ingredients. KITECH was also involved in this project in order to test the economic feasibility and provide technical consulting to SHGEC and the EIP centre. In fact, this industrial symbiosis has deficiency in terms of economic feasibility. The cost to be equipped with EFC is too high (Interview AN-I1, AN-I3, AN-I7). Accordingly, this industrial symbiosis is currently in operation only between one dyeing firm and one chemical firm in the form of a pilot project and the improvement of the equipment is underway.

[Figure 5-4] EFC Pilot to Collect and Reuse Oil Ingredients from the Dyeing Process



*Source: Author

5.3.3. Summary: Environmental Management System of the Banwol-Sihwa Dyeing Cluster

The main methods of the cluster's pollution control approach are the common effluent treatment plants and the odour control equipments. The common effluent treatment plants were built in the form of facility sharing while equipping with the air pollution control equipments was carried out through group purchase. Both pollution control practices have been led by the two local business cooperatives that are the representative horizontal tie among the dyeing and printing firms. Accordingly, the cluster's pollution control practices can be seen as a typical joint action emerged from its horizontal linkages.

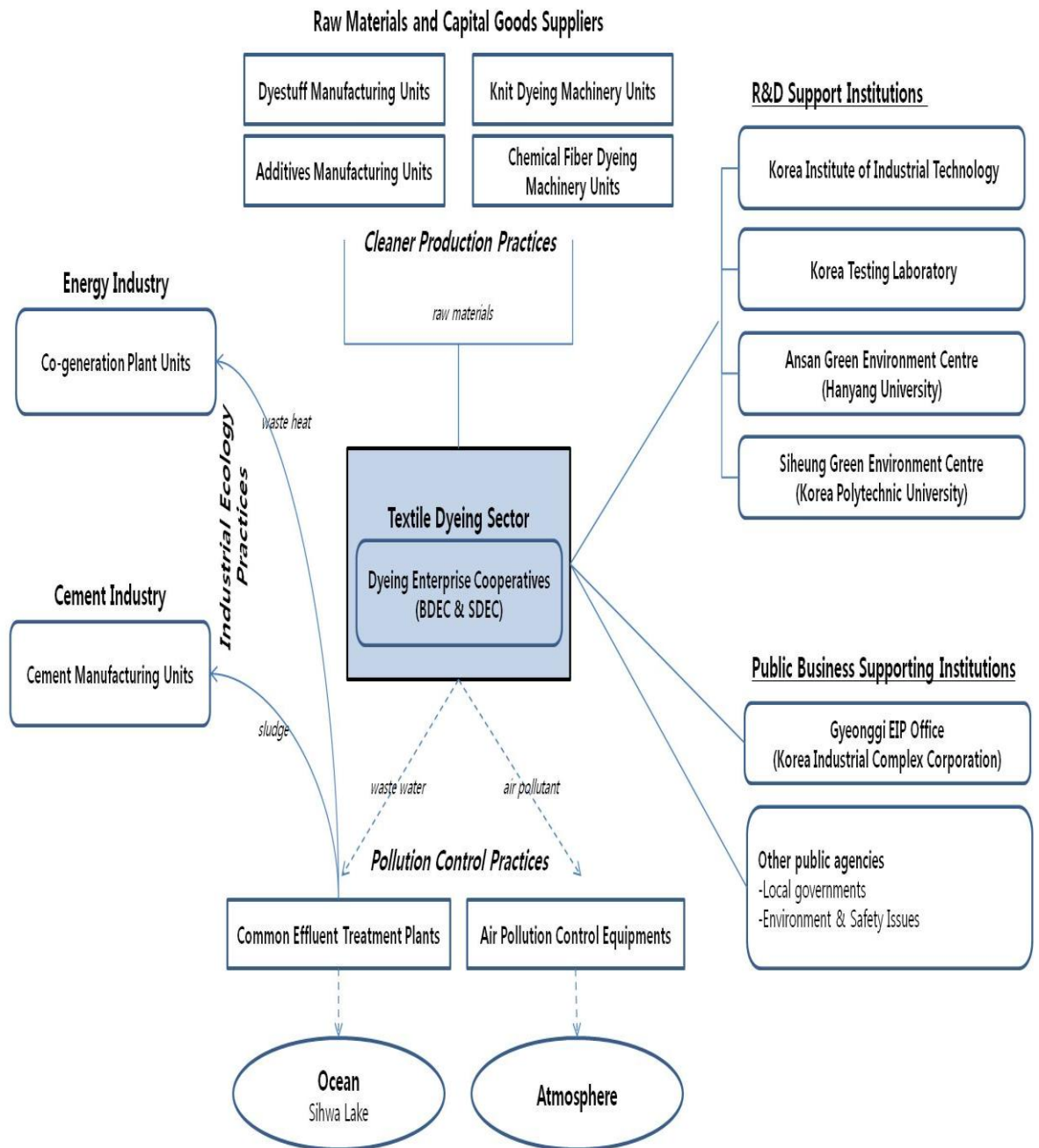
The cluster's cleaner production practices aim to introduce environment-friendly production methods like toxicity reduction and equipment substitution and thus to achieve process upgrading. Due to technical links between the dyeing sector, the dyestuff and chemical additive manufacturing sector and the dyeing equipment manufacturing sector, the cleaner production approach has given rise to a degree of interactive learning between these three related industries. This means that the cleaner production practices tend to emerge from the cluster's backward vertical linkages.

EIP is the most recently applied environmental management practice in the Banwol-Sihwa dyeing cluster. In contrast to the pollution control practices and the cleaner production practices, the three industrial symbioses have emerged in the form of inter-sector linkages. The EIP development goes beyond the sectoral boundary of the dyeing industry and has created new supply chains specialised in by-product exchanges and energy cascading. This phenomenon clearly reflects the industrial ecologist argument that industrial symbiosis can result in a synergy effect between traditionally less related industries (Bass and Boons, 1997). In the technological context, the EIP development gives rise to the use of technologies that, to date, have not been relevant to textile dyeing and printing.

By reviewing the gradual development of environmental management practices in the Banwol-Sihwa dyeing cluster, the cluster map, figure 5-1, provided in section 2 can be modified as in figure 5-5. The bottom area of this map is the pollution control dimension where the dyeing cluster treats and discards its pollutant to nature. The backward vertical linkage on the upper area of this map is the dimension where cleaner production practices have emerged and are situated. The EIP programme is implemented in the inter-sector

linkages on the left area of this environmental management map. Last, the map shows a list of local non-firm institutions that have been involved in the cluster's environmental management strategies on the right side.

[Figure 5-5] Environmental Management Structure of the Banwol-Sihwa Dyeing Cluster



*Source: Author

5.4. Cluster Dynamics Underlying the EIP Development

The previous section sketched the pollution control practices and the cleaner production practices of the Banwol-Sihwa dyeing cluster. This section analyses the dyeing cluster's EIP development with the four social elements of industrial ecology: mental distance, roles of champion, planning and institutional setting. The social dimension of the dyeing cluster's EIP development is then reinterpreted with the three industrial cluster dynamics of collective efficiency, chain governance and innovation system in order to provide potential answers to the question of how local production system and institutional support system influence EIP development.

5.4.1. Social Dimension of the Banwol-Sihwa Dyeing Cluster's EIP Development

Mental Distance

The original concern about mental distance in the industrial ecology literature lies in relations between industrial symbiosis counterparts. In the case of the Banwol-Sihwa dyeing cluster, this original mental distance matter is relevant to the inter-sector relationships because the dyeing cluster's three industrial symbioses link to an energy supplier, a cement manufacturer and a chemical firm. Second, it is necessary to investigate the inter-firm mental distance in the intra-sector dimension of the dyeing sector, although the industrial ecology literature has rarely reported collective participation of clustered firms engaged in the same and similar production activities. The dyeing and printing firms participate in the EIP programme as one integrated unit. This collective behaviour raises the question of how mental distance has encouraged the dyeing and printing firms to involve in the EIP projects. Last, the empirical evidence from the Banwol-Sihwa dyeing cluster shows that a few non-firm actors, especially the knowledge providers like KITECH, have actively involved in implementing the EIP projects of the Banwol-Sihwa dyeing cluster. In this regard, it would be useful to inquire into the matter of mental distance between the dyeing and printing firms and the non-firm institutions.

Mental Distance in the Intra-sectoral Level

The Banwol-Sihwa dyeing cluster was selected as a group of firms that has high potentiality for EIP development from the very early stage of the EIP programme in Banwol-Sihwa. In this regard, the EIP practitioners interviewed provided comments that have connotation of mental distance. The previous director of Gyeonggi EIP Centre explained as follows;

Another important reason is that the dyeing and printing firms have a strong inter-firm bond. The firms are well managed by their cooperatives... The firms located in the dyeing cluster share the effluent treatment plants and the cooperatives have all information upon their member firms. Accordingly, it was easy to get cooperation from the firms through the business cooperatives (Interview CE-I6).

This comment shows that EIP practitioners utilised the advantage of strong cohesion in the cluster when they initiated the EIP programme with the dyeing sector. The inter-firm cohesion is underpinned by the clustered firms' common purposes. The most basic common purpose is collective environmental management (Interview CE-I1, AN-F3, AN-F4, AN-F5, AN-I2). The dyeing and printing firms do not accept a firm whose industrial activities are not relevant to this common purpose as a member of the dyeing cluster (Interview AN-F3, AN-I1). An informant working for BDEC affirmed that their common sense of purpose has already embraced the industrial ecology principles.

You may see the placard outside. 3R. This is most important in this industry. The most essential task is 'reduction', isn't it? Reducing the consumption of raw materials while maintain quality of products. And, as I told you before, 'recycling'. Recycling by-products. The last one is 'reuse'. So to speak, we should exchange what we cannot use any more with others (Interview AN-I2).

In order to accomplish this purpose, they have organised the two local business associations through which the member firms regularly meet and communicate with each other. This is another reason of why the dyeing sector was selected as a first targeted industrial sector in the EIP programme in Banwol-Sihwa. Another EIP practitioner commented that "active exchange of information and opinions among firms" in the dyeing

cluster is a condition to produce a great ripple effect in the EIP programme (Interview AN-I3). Due to their collective environmental management practices, the dyeing and printing firms share information about environmental concerns with each other. In addition, the two business cooperatives are totally entrusted with tasks of collective environmental management (Interview AN-F1, AN-F3, AN-F4). Hence, BDEC and SDEC function as an archive of commonly shared information on environmental management and pollution hazard. The dyeing and printing firms share common goals, open individual information on pollution to each other and entrust collective environmental managements to their business cooperatives. Shared purpose, openness and trust can be seen as materialised forms of close mental distance among the dyeing and printing firms by which the cluster's EIP development has been facilitated.

Mental Distance in the Inter-sectoral Level

The cluster's three industrial symbioses are relations with a cogeneration plant, a cement manufacturer and a used oil refinery firm. Although the cogeneration plant is a steam supplier to the dyeing cluster, the relationship between the dyeing sector and the energy sector is totally a market based relation. The cement manufacturer and the chemical firm did not have any relationship before the EIP programme. In the case of the wastewater heat exchange network, the energy sector showed even passive and defensive attitude. The research project manager who led the feasibility study on the wastewater heat exchange network poured out his feeling of dejection, saying "the steam suppliers looked like they only want to do their own business. It seemed that they see us as a troublemaker in their work" (Interview AN-I7). Given that close mental distance was absent between the two sector, this is a natural response in a sense. Therefore, the argument that close mental distance is necessary for a firm to be engaged in an industrial symbiosis is not valid as to the relations between the dyeing cluster and its industrial symbiosis counterparts.

Roles of Champion

Close mental distance alone cannot assure material exchanges and energy cascading in the inter-sector context although it is a condition favourable for EIP development. There is a need for leadership that encourage firms to participate in the EIP programme and

coordinate industrial symbioses. Especially in the case of the Banwol-Sihwa dyeing cluster, someone has to mediate between the 82 firms or at least get their consents. The notion of champion can be understood in two different ways: lead firm in the industrial cluster and value chain literature and anchor tenant in the industrial ecology literature.

Champion Substituting Lead Firm

The industrial cluster literature and the value chain literature have traditionally regarded lead firms governing a value chain as champion (Gereffi, 1999). This traditional notion of champion cannot be directly applied to the Banwol-Sihwa dyeing cluster. There is no lead firm within the cluster. Although the apparel value chains in which the dyeing and printing firms are engaged is governed by some global buyers, it turns out that they are not directly involved in the dyeing cluster's EIP development. An informant working for a global buyer said in an interview, "We don't need to worry about compliance with the environmental regulation because they treat textile dyeing effluent through their common facilities collectively" (Interview AN-F6). In addition, the global buyers interviewed confirmed that they do not know about the EIP in the Banwol-Sihwa dyeing cluster. Accordingly, the proper question is who has replaced the position of lead firm in implementing the EIP projects.

With regard to this modified question, a point which claims attention is that environmental management practices in the cluster are managed in a highly centralised manner (Interview CE-I6). The two local business cooperatives are the main agencies of the cluster's centralised environmental management system. Thanks to broad-scale delegation of authority on environmental issues to BDEC and SDEC, the two business cooperatives have represented their member firms in the EIP programme. With this specialised part of the local production system, the member firms can concentrate on their economic performance while the cooperatives address their collective environmental issues (Interview AN-F2, AN-F3, AN-F4, AN-F5, AN-I1, AN-I5). An informant working for SDEC explained that the business cooperatives have participated in the EIP on behalf of their member firms as follows;

In a sense, they (the member dyeing and printing firms) might not know the business cooperative is participating in EIP. The cooperative has to find a way to

cut down costs so that the member firms can be beneficial. This is what the cooperative should do. We report what we have done to the president of the business cooperative regularly and the member firms at general meetings (Interview AN-I1).

BDEC and SDEC are not only local trade associations but also registered waste treatment companies. BDEC and SDEC raise revenues from the charges for effluent treatment paid for by member firms as well as from membership fees. This drives the cooperatives to make continuous efforts to decrease the environmental management cost, develop new business models and introduce advanced environmental management technologies (Interview AN-F1). The interviewee from the SDEC expressed the business relationship between the individual firms and the cooperatives as follows;

The increasing environmental management cost means more charge to our members. If our member firms are in financial difficulty, we are also going to be in trouble. There would be a structural adjustment or layoff. This is the matter of our livelihood. Therefore, we must find out a way to cut off the cost (Interview AN-F1).

The two business cooperatives have the leadership as the formal collective decision-making bodies at the local level. In addition, they are in effect the spin-off companies of the clustered firms or ancillary service units that are in charge of operating the two common effluent treatment plants and providing environmental management services over the whole cluster. These characteristics together render BDEC and SDEC as the substitute for a lead firm at the local level.

Champion as Anchor Tenant

The industrial ecology literature has documented the importance of anchor tenant that attract other firms and coordinate industrial symbiosis networks. An anchor tenant's role as champion is basically similar to a lead firm in value chains. An anchor tenant manages inter-firm relationships which are arranged along with its supply chains. The only distinctive feature is that an anchor tenant's supply chains are specialised for by-product exchanges and energy cascading.

In the Banwol-Sihwa dyeing cluster, the function as the common effluent treatment plants units assigns the characteristics of an anchor tenant to BDEC and SDEC. The firms have drain facilities, while the cooperatives are totally responsible for effluent treatment (Interview AN-II). On the one side, BDEC and SDEC collect all textiles dyeing effluent generated from the individual dyeing into the common effluent treatment plants. On the other side, the business cooperatives have continued to search for a potential user of by-products, create new input-output relationships and supply heat source and sludge to the other industrial sectors. This is a typical function of an anchor tenant in most EIPs.

Institutional Setting

At the local level, institutional setting for EIP development has two distinguishable aspects. The first is role assignment among actors participating in the EIP programme. The non-firm actor's roles in the EIP programme have been arranged in accordance with their organisational characteristics. The other aspect of institutional setting is the EIP implementation framework pertaining to the system of information sharing, decision-making, financial supporting and performance assessment. In the Korean context, the latter aspect of institutional setting can be better understood as a planning system.

Institutional Setting as Role Assignment Framework

In the Korean EIP programme, non-firm actors' roles can be categorised into four tasks: network broker, knowledge provider, financial sponsor and administrative process manager. Financial support and administrative processes are controlled by the central government in the EIP programme. Accordingly, the roles of network broker and knowledge provider are the main function of non-firm institutions at the local level.

The first actor who should be highlighted is the coordinator in Banwol-Sihwa's EIP programme, KICOX. As described earlier, KICOX is the implementation body of the EIP programme and Gyeonggi Regional Headquarter of KICOX operates Gyeonggi EIP Centre as one of its departments. The wastewater heat exchange network between SDEC and KG Energy is a representative example that shows KICOX's role as a coordinator. Both the dyeing sector and the energy sector neither took a flexible position nor made a concession in the negotiation to commercialise the industrial symbiosis despite the scientific evidence

proving potential economic and environmental benefits. KG Energy was very sceptical about investing in the industrial symbiosis. SDEC demanded a part of profits from this project although they admitted that wastewater heat can be used for free. To overcome these difficulties, KICOX intervened in commercialising the wastewater heat exchange network. Gyeonggi EIP Centre judged that the wastewater heat exchange network must be accomplished in order to provide an example of success by which other SMEs can be convinced of the necessity of EIP development (Interview CE-I5, AN-i7). Accordingly, Gyeonggi EIP Centre was actively involved in the negotiation process between the two industries and, finally, KICOX made direct investment in this industrial symbiosis as the intermediate trader.

As shown in the wastewater heat exchange network, Gyeonggi EIP Centre mediates relations between traditionally less related industries and encourages local firms to build industrial symbioses. A researcher who was involved in Banwol-Sihwa's EIP programme at the initial stage exposed how KICOX's authority has affected the EIP programme as follows;

It is easy for KICOX to get cooperation from firms because KICOX manages and regulate the affairs of the industrial complex, in a sense, holding a prominent position. You see what I mean? If KICOX ask firms to participate in the EIP programme, firms would hardly refuse. This made our work much easier (Interview CE-I6).

As a subordinate administrative agency of the Ministry of Trade, Industry and Energy, KICOX has implemented national policy measures at the local level on behalf of the central government. Accordingly, KICOX has significant political influence over tenant firms. In addition, KICOX has accumulated extensive information and data about local firms and industries while it has managed a variety of industrial affairs in the Banwol-Sihwa industrial complex since 1977. These characteristics allow KICOX to serve as a network broker, or an institutional anchor tenant as termed by Gibbs (2008).

Another core party in the set of institution is knowledge providers. Because EIP is basically an engineering solution, a degree of scientific knowledge is necessarily required. The informant who explained KICOX's influence also mentioned about roles of knowledge providers as follows;

However, we (KITECH) should induce firms to participate voluntarily to the ultimate. So we did help firms to understand what an EIP is and provide technical engineering consulting (Interview CE-I6)

KITECH carried out the feasibility study on the wastewater heat exchange network between the dyeing cluster and the cogeneration plant. In the case of sludge reuse, KTL, another governmental research institute located in the Banwol-Sihwa region, examined some technical methods to discover a potential industrial symbiosis. The knowledge provider engaged in the network to collect and reuse oil ingredient from air pollution of the dyeing sector is SHGEC based in KPU. All these three institutions frequently cooperated with the dyeing cluster with regard to environmental upgrading even before the EIP programme was launched in the Banwol-Sihwa region. SHGEC is one of the two university-based environmental technology centres that have provided environmental engineering service to the dyeing and printing firms since the early 2000s. KITECH and the dyeing sector carried out various large-scale R&D projects to promote cleaner production practices as described before. KTL has supported the individual dyeing and printing firms to obtain foreign certifications required for product exporting as a public testing and certification body.

All the non-firm institutions involved in the dyeing cluster's EIP development, KIOCX, KITECH, KTL and SHGEC, are the major actors of the cluster's existing institutional support system. In other word, the institutional setting for the EIP development in the dyeing cluster is exactly same to the dyeing cluster's institutional support system. A set of institutions was not newly organised for the EIP programme. Rather, the dyeing cluster has adapted itself to the new state initiative by using its exiting institutional support system.

Planning

The EIP implementation framework of decision-making, financial supporting and performance assessment does not have region-specific nature because the system has been totally designed by the central government and applied to all the industrial regions designated as EIP. While the institutional setting as role assignment is endogenously organised at the local level, the institutional setting as EIP implementation framework

exogenously built. This reflects the characteristics of planned EIP in the Korean context. In addition, a finding in the Banwol-Sihwa region is the strong state intervention for the EIP development. This also reflects the factor of planning in the EIP programme as a state initiative.

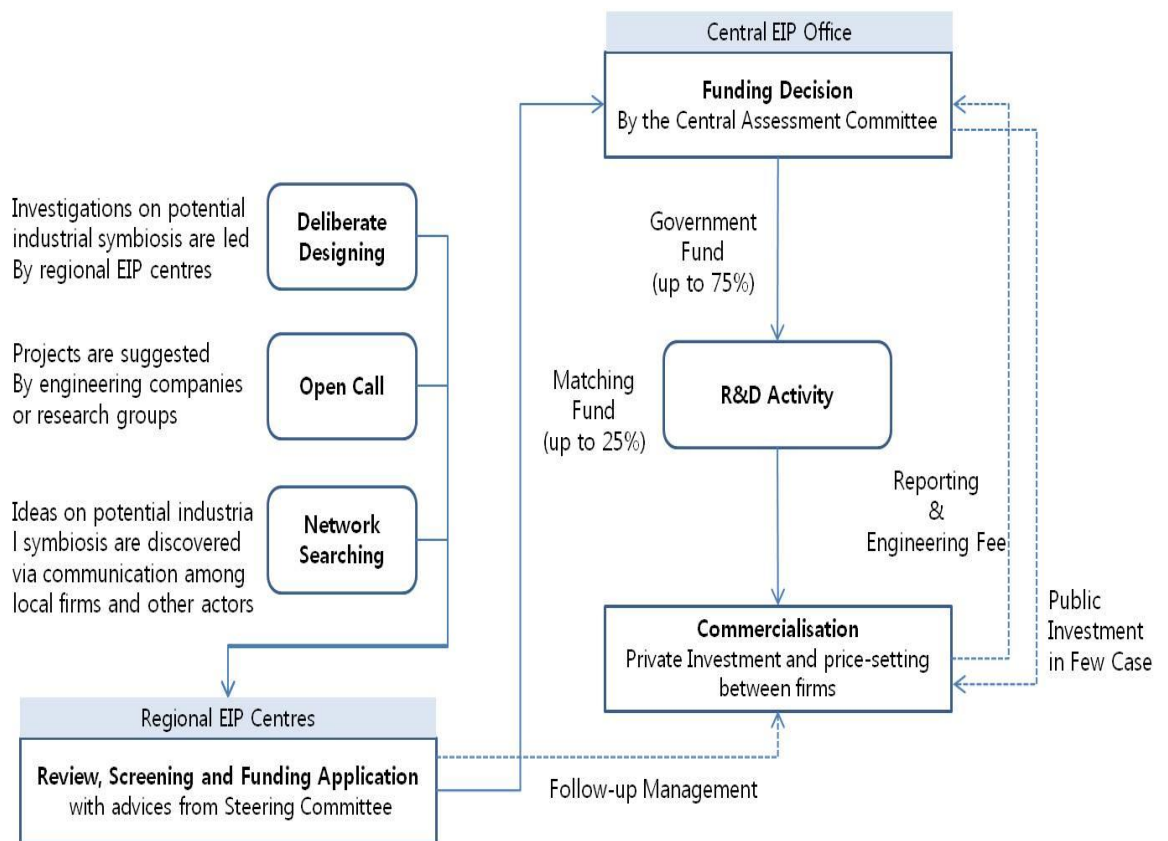
System of Decision-making, Financial Support and Assessment

At the local level, the regional EIP centres have two types of support groups; local steering committee and coordinator. A local steering committee consist of high-level environmental managers working for major local firms and delegates from local institutions. The steering committees play the role as an advisory board by reviewing plans and final reports on individual EIP projects at the local level (Interview CE-I5). The coordinators are local experts or environmental management practitioners who support the activities of the regional EIP centres (Interview AN-I3). Despite the importance of factory visits and communication with firms, the number of working staffs of Gyeonggi EIP centre is only five. The coordinator system is a method to overcome the shortage of human resource in EIP. In addition, the regional EIP centres organise and operate various meetings among local firms and other actors through so-called 'forum'. Forums function as a platform through which local firms can meet each other, exchange information, search potential EIP projects and review the projects in process.

There are three ways to identify potential industrial symbioses at the local level; deliberate designing, open call for projects and network searching (KICOX 2007). The deliberate designing is a typical top-down method by which the regional EIP centres investigate potential by-product exchange opportunities and try to make it into a functioning an industrial symbiosis. It is normal that this activity is focused on the firms or industrial sectors which cause serious environmental degradations within an industrial district. Second, open call for EIP projects is the way through which firms and research groups test and realise their ideas about potential industrial symbioses. Firms and research groups can be allocated public funds to carry out R&D activities and supported with administrative services and networking with other local actors. Finally, network searching is the most distinctive way to discover the opportunities to develop industrial symbioses. Local firms can share information and opinions on environmental issues in various forum meetings, and thereby find out many ideas which can be the source of future EIP projects.

Outwardly, the main activities in the EIP programme are R&D. If an EIP project is discovered through one of the three methods, the feasibility of the project is reviewed with the local steering committee. If the project is judged as a positive trial at the local level, the regional EIP centre submits the application to the central EIP office for the R&D funding. Through the evaluation procedure in the assessment committee at the central level, the decision about the fund allocation is made. The government funding is up to 75 percent of the total R&D cost and the participants like local firms and other actors involved in the project provide matching funds of 25 percent. The R&D activity is implemented in collaboration between the participant firms and researcher groups like research institutes, universities or engineering companies. This R&D activity aims to examine the economic feasibility and seek out the best available technology (Interview CE-I6), rather than a cutting-edge technology. If the project is economically feasible, the participants firms are encouraged to commercialise the industrial ecology practice. The investment and price-setting for by-product or energy exchanges are decided by the participant firms through autonomous negotiations. The participant firms should report the result of commercialisation to KICOX and pay for an amount of engineering fee because the R&D activity is carried out with government funds. If a new technology is invented, the intellectual property right belongs to the research group that participated in the project.

[Figure 5-6] The Procedure from Project formulation to Commercialisation in EIP



*Source: Author

State Intervention

It is notable that the public agencies, KICOX, KITECH and KTL, have been actively involved in the EIP programme in the Banwol-Sihwa region. This reflects the characteristics of the EIP programme as a state initiative. An interview reveals the importance of the state's role in establishing and implementing EIPs as follows;

Rather than policy measures, this is a matter of the state's will and vision. In fact, individual firms are only concerned about their own interests. "Can I get a benefit?" "Can I solve my problems?" They consider only limited parts that are directly related to their own interests. However, it is obvious that there are social needs to solve environmental concerns. In our country, EIP can be achieved more effectively because the state has national-level driving force (Interview CE-I6).

This comment suggests that Banwol-Sihwa's EIP programme can be understood with the last social factor of industrial ecology, planning. However, it cannot be said that Banwol-Sihwa's EIP programme is totally based on top-down measures. While establishing the industrial symbioses of the Banwol-Sihwa dyeing cluster, the public agencies, KICOX, KITECH and KTL, have supported the dyeing cluster by forming networks of academic-industry-public cooperation. An interviewee working for the dyeing cluster affirms that the public-private cooperation is a major part of their business in the Banwol-Sihwa region and points out changes in the government's behaviour.

In the past, the authorities mainly concentrated on crack-down and punishment. But they are turning to consulting. They are doing many new projects in cooperation with industries (Interview AN-I2).

This change in the perception of the government's role is also strongly expressed by the public agencies interviewed. A general manager of KICOX who is charge of the EIP programme at the central level discloses that their current organisational aim is to approach firms first as a business supporting institution (Interview CE-I5). A researcher of KITECH argues that KITECH is "a service unit because they exist to support firms" (Interview AN-I5). Based on the changed perception "the government has to serve not as a supervisory office but as a supporting institution" (Interview AN-I3), the localised public agencies have placed a lot of emphasis on building cooperative networks between the public sector and the private sector while implementing the EIP programme in Banwol-Sihwa. A policy-maker who was involved in designing the EIP programme stresses that the EIP programme was devised as a bottom-up policy measure.

We are normally familiar with top-down approaches. However, in order to implement the EIP programme based on industrial ecology principles, interactive communication is very important. We have learned this. And we realise that Korea has little experience about such bottom-up approaches. This weakness is what we have made efforts to make up for (Interview CE-I6).

South Korea's EIP is a state initiative. It is true that all regional EIP programmes in South Korea are under the central government's planning system. The state's influence on EIP

development is much stronger in the Banwol-Sihwa region than in other regions. However, the strong influence of planning does not imply a command-and-control approach in the context of the Korean EIP model. Planning within this cluster has realised as a consequence of the invigoration of public-private cooperation in Banwol-Sihwa.

5.4.2. Cluster Upgrading Dynamics Underlying EIP Development

The Banwol-Sihwa dyeing cluster has attained EIP development by continuous improvement of its environmental management system and participation in the EIP programme. All the four social factors of industrial ecology have come into the EIP development to some extent. This subsection is devoted to reinterpreting the effects of the four social factors with the three cluster upgrading dynamics of collective efficiency, value chain governance and innovation system. By analysing the cluster dynamics underlying the EIP development, the question of how the local production system and the institutional support system have affected the EIP development in the Banwol-Sihwa dyeing cluster can be answered.

Collective Efficiency and EIP

The dyeing and printing firms located in the Banwol-Sihwa dyeing cluster are engaged in the same stage of garment production and have the same types of buyers. Despite their individual specialisations in response to ever-changing customer preference in the garment market, the dyeing and printing firms have common interests in their relations with the buyers, with the other industrial sectors and with non-firm actors. When such interdependence is maintained, disaggregation in production activities tends to require more inter-firm coordination (Arikan and Schilling, 2011). The coordination over inter-firm relation in the horizontal linkages of the Banwol-Sihwa dyeing cluster is implemented by their two business cooperatives, BDEC and SDEC. BDEC and SDEC are the materialised form of network-based economic governance in the Banwol-Sihwa dyeing cluster.

The dyeing and printing firms are engaged in the same industrial activity and thus generate similar types of by-products. Naturally, they are under the same regulatory framework and the same external pressures. Such common environmental concerns also give rise to high

need for coordination among the dyeing and printing firms. They clustered to treat and discard industrial wastes in collective manners and, thereby, established the two business cooperatives specialised in operating common effluent treatment plants. In order to activate this centralised environmental management system properly, the dyeing and printing firms disclose individual information on environmental issues and empower BDEC and SDEC as a coordination body over the horizontal inter-firm linkages for the environmental management system. This network governance of the cluster's horizontal inter-firm linkages has emerged as the phenomenon of close mental distance in the EIP programme.

Clustering has provided the dyeing and printing firms with agglomeration gains favourable for the EIP development. The volume and quality of industrial wastes are technically important to ensure the economic feasibility of an industrial symbiosis. Thanks to clustering, the dyeing and printing firms in Banwol-Sihwa have achieved economies of scale in their industrial symbioses. Besides, the Banwol-Sihwa dyeing cluster is equipped with two common effluent treatment plants which are located across a road and a stream from their neighbouring cogeneration plants. As the industrial ecology literature classifies facility sharing as one of three industrial symbiosis types (Chertow *et al.*, 2008), the dyeing cluster's collective pollution control systems like the collective effluent treatment plants can be seen as a nascent type of industrial symbiosis. Based on these agglomeration gains, the dyeing and printing firms have horizontal inter-firm governance through which they can organise joint actions efficiently. Their participation in the EIP programme can be seen as a joint action aiming at adopting a more advanced environmental management practice.

Value Chain Governance and EIP

The empirical evidence from the Banwol-Sihwa dyeing cluster shows that lead firms in the garment value chains have not been involved in the dyeing cluster's EIP development and the roles of champion have been taken by the local business cooperatives and Gyeonggi EIP Centre. In other word, the cluster's EIP development has been little underpinned by the dynamics of value chain governance. Although the compliance team of the foreign buyers and Korean vendors regularly check environmental problems like effluent treatment and toxicity of input materials (Interview AN-F2, AN-F4, AN-F6), the environmental pressure through the vertical production linkages has not directly affected the EIP

development in the Banwol-Sihwa dyeing cluster. The buyers interviewed during the fieldwork confessed that they do not know about EIP.

In this regard, a potential explanation can be suggested. Due to the relatively high competence of suppliers located in the Banwol-Sihwa dyeing cluster, global buyers and first tier suppliers do not need to be actively engaged in the local production system. In the same vein, it seems that managing environmental issues remain as the local producers' own responsibility. The informants from the global buyers commented that they "do not worry about environmental issues in the Banwol-Sihwa dyeing cluster" because the cluster's environmental management system is well equipped.

It is evident that environmental pressures through the forward vertical linkages have driven the dyeing and printing firms to develop and adopt cleaner production practices. In the process of environmental upgrading for cleaner production, the dyeing cluster has built close partnerships with local innovation support organisations that constitute the cluster's institutional support system. The industry-academic-public cooperation surrounding the Banwol-Sihwa dyeing cluster casts light on the dynamics of innovation system in EIP development.

RIS and EIP

The elements of institutional setting and planning have played integral roles in building the three industrial symbioses between the dyeing sector and the other sectors. Without taking into account the role of non-firm institutions, the Banwol-Sihwa dyeing cluster's EIP development cannot be explained. KICOX has served as a network broker, while KITECH, KTL and SHGEC have provided knowledge to the dyeing cluster in the EIP programme. All these institutions are main actors engaged in the institutional support system of the dyeing cluster. In other words, the dyeing and printing firms already have rich experience of cooperation with these local actors. Such experience of cooperation on past projects at the local level tends to engender local institutional capacity for EIPs (Gibbs and Deutz 2007). In this regard, the EIP development can be regarded as a result from the already existing cooperative relationships between the dyeing cluster and the local innovation support institutions.

Two main functions of the dyeing cluster's institutional support system can be recognised by probing the ways that the non-firm institutions collaborate with the dyeing and printing

firms. First, as normally documented by most case studies on innovation support institutions in the RIS literature, the dyeing cluster's institutional support system functions to develop and disseminate knowledge. In the case of the EIP development, collaboration between the dyeing sector and the innovation support institutions is especially important. The textile dyeing industry has been regarded as a traditional low-tech based sector in which tacit knowledge pertaining to know-how and craft is dominating. However, environmental challenges have required some high tech knowledge for energy saving and resource productivity improvement on the dyeing cluster. This situation has urged the dyeing and printing firms to employ scientific solutions with which environmental concerns can be alleviated. Consequently, research collaboration between the dyeing and printing firms and the R&D institutions is increasingly important.

The other main function of the dyeing cluster's institutional support system is coordinating inter-sector relations. As identified before, there is little knowledge transfer between the local producers located in the Banwol-Sihwa dyeing cluster and their buyers. Rather, the cluster's forward vertical production linkage is a channel through which branded apparel companies, global retailers and first tier manufacturers transmit their demands upon product qualities and manufacturing process managements. In response to needs from buyers, knowledge exploitation and knowledge generation have intensively occurred at the local level. Within the Banwol-Sihwa region, the dyeing and printing firms are co-located with their component and capital goods suppliers. However, the backward vertical linkage of the dyeing cluster takes a form of market based governance and thus it seems that autonomous inter-firm collaboration for innovation activities is somewhat low. The low degree of interaction in the user-supplier relation is in turn reinforced by active involvements of non-firm institutions in Banwol-Sihwa. The fieldwork in Banwol-Sihwa revealed that the backward vertical linkages of the Banwol-Sihwa dyeing cluster have been highly coordinated by public institutions like KITECH and KICOX. KICOX offers financial resources and entice local actors into networking in the form of local-level industrial policies. KITECH also provides channels through which the dyeing sector and the other industrial sectors have undertaken cooperative R&D interactions (Interview AN-F3, AN-I5, AN-I6, AN-I8). The inter-sector exchanges of energy and by-products emerged in the EIP programme were also coordinated by the public agencies. Accordingly, the institutional setting for the EIP programme is not different from the existing institutional support system of the dyeing cluster.

The institutional support system of the dyeing cluster is a subsystem of the local dyeing industry as well as a part of Banwol-Sihwa's institutional infrastructure. The whole region of the industrial complex can be seen as a RIS whereas the dyeing sector is one of the clusters existing within the RIS. The cluster's institutional support system resonates with the features of Banwol-Sihwa's RIS. The RIS literature suggests there are three types of RIS: grassroots RIS, network RIS and dirigiste RIS (Asheim and Isaksen, 2002; Asheim and Coenen, 2005; Cooke, 2004; Hassink, 2004). This typology is a tool to capture characteristics in accordance with endogeneity of initiatives, financial innovation sources, main stimulus of cooperation and location of innovation support organisations. This framework can be applied to identifying the characteristics of the dyeing cluster's institutional support system.

It is firstly noticed that a large part of the interactions between the dyeing and printing firms and the main non-firm institutions in the institutional support system have been exogenously promoted by state initiatives. In this sense, Banwol-Sihwa's RIS can be categorised as dirigiste RIS. Despite its characteristics as a state-led regional innovation system, state initiatives are not totally based on top-down approach. The central government have deliberately strengthened Banwol-Sihwa's institutional infrastructure by deploying regional branches of public agencies like KICOX and KITECH. In other words, the central government has provided not only financial resources but also organisational and human resources. The public agencies have intentionally coordinated collective innovation activities among local actors with national R&D budgets. Their main approach is building industry-academy-public cooperation. The public agencies transplanted from the central level to the local level have actively formed relationships with local firms and consequently *localised*. The EIP programme has been planned and implemented in the same way. Gyeonggi EIP Centre that is a department of Gyeonggi Regional Headquarter of KICOX has arranged industry-academic-public cooperation with funding from the central government. The innovation support organisations like KITECH, KTL and local universities have carried out feasibility studies on potential industrial symbioses in the form of R&D projects. Therefore, the EIP development of the Banwol-Sihwa dyeing cluster is arguably a product from Banwol-Sihwa's RIS which has the unique character of a localised state-led innovation system.

5.5. Conclusion

This chapter investigates the influence of local production system and institutional support system on the EIP development in the Banwol-Sihwa dyeing cluster. It does so in order to address the following research questions. First, how does the nature of the local production system affect the EIP development of clustered firms? Second, in what way do institutional support systems facilitate the collective actions of clustered firms to promote EIP development? In this conclusion section, I set out my findings with reference to these two questions for the Banwol-Sihwa textiles dyeing cluster.

Currently, three industrial symbioses are in operation in the Banwol-Sihwa dyeing cluster. The three industrial symbioses are proactive joint actions in the way that the dyeing cluster has created new supply chains beyond its traditional sector boundary. It is important to note that the Banwol-Sihwa dyeing cluster has undertaken other joint actions to adopt end-of-pipe methods and develop various cleaner production practices like before the EIP was initiated. The dyeing cluster's environmental joint action started from a typical end-of-pipe solution, building and sharing common effluent treatment plants and advanced to cleaner production practices like toxicity reduction. Their common effluent treatment plant has become the physical infrastructure through which the two business cooperatives can manage a substantial volume of by-products for their industrial symbioses. While the dyeing cluster carried out various R&D projects to develop cleaner production technologies, the cooperative relationships with innovation support institutions were built. These relationships have become the institutional setting for the EIP programme. Accordingly, the EIP development in the Banwol-Sihwa dyeing cluster should be understood as a process of gradual and continuous environmental upgrading.

The production system of the Banwol-Sihwa dyeing cluster can be characterised in accordance with its horizontal, forward vertical and backward vertical linkages. The textiles dyeing cluster's horizontal linkages have the nature of high coordination governance due to the necessity for coordinating the division of labour between the significantly specialised firms, mediating conflicts of individual interests (for example, poaching skilled workers) and organising joint actions (for example, collective environmental managements). Second, the relation relationship between the dyeing and printing firms, their global buyers and first tier suppliers within the apparel value chains are not marked by sharply asymmetric power relationships. Contrary to the conventional

notion of captive production networks in the garment industry, the dyeing and printing firms in the Banwol-Sihwa cluster are relatively independent due to their high degree of technical competency. This reflects the character of the Korean textile industry as full package production (Gereffi *et al.*, 2005). The relationship between the dyeing sector and its suppliers like dyestuff manufacturers, chemical additives suppliers and dyeing equipment are market based. Interestingly, despite the nature of the backward vertical linkages as market governance, the dyeing and printing firms have often cooperated with their suppliers working in the backward vertical linkages in a form of R&D consortium. This is due to the existence of a well-developed institutional support system that has characteristics of dirigiste RIS. Two public agencies, KICOX and KITECH, have deliberately coordinated a variety of R&D activities and encouraged local firms to interact with each other using their convincing power as a localised state organs and scientific knowledge provider.

The nature of the production system and the institutional support system has affected the textiles dyeing cluster's environmental upgrading toward EIP development. Most of all, the high coordination governance of the cluster's horizontal linkages is one of the keys to its successful environmental upgrading. As the dyeing and printing firms in Banwol-Sihwa are clustered within a limited geographical boundary and share two effluent treatment plants, they generate and treat similar sorts of by-products in collective ways. These common interests and collective behaviours have emerged as the close mental distance among the dyeing and printing firms and the two business cooperatives' roles of champion in the EIP development. Their clustering and facility sharing have resulted in a substantial volume of by-products for material and energy exchanges with other sectors. On the basis of this agglomeration gain, the Banwol-Sihwa dyeing cluster has made new input-output relations specialised in by-product exchanges and energy cascading in the inter-sector dimension. In this regard, it is evident that collective efficiency is one of the dynamics underlying the EIP development of the Banwol-Sihwa dyeing cluster. The dynamics of collective efficiency for environmental upgrading has been underpinned by the high coordination governance of the cluster's horizontal linkages.

On the other hand, it turns out that the vertical production linkages of the Banwol-Sihwa dyeing cluster is not directly related to the EIP programme. Given that the supplier competence is relatively high in the Banwol-Sihwa dyeing cluster, top branded clothing companies and Korean garment vendors are not engaged in driving technological changes

among the local producers. Environmental upgrading through the vertical linkages tends to be accomplished in the backward vertical linkages. Global buyers have continuously encouraged the dyeing and printing firms to quality for international environmental standards and eco-labels. In order to meet such environmental standards, the dyeing and printing firms have carried out various R&D activities to develop and adopt cleaner production technologies. Technical changes in the textiles dyeing sector necessarily give rise to simultaneous technical changes in the dyestuff manufacturing sector and the dyeing equipment manufacturing sector due to their technical interconnection. Innovation support organisations like KICOX, KITECH and local universities have been actively involved in the R&D activities and coordinated the cooperation among the three related industries. In short, the cleaner production approach has triggered innovations in the backward vertical linkages and learning-by-interaction at the local level.

The last, and the main, dynamic underlying the EIP development in the Banwol-Sihwa dyeing cluster is RIS pertaining to the institutional support system. As the EIP programme is a government policy, the roles of each participant institutions have deliberately structured and the financial resource for EIP development has allocated from national R&D funds. All non-firm institutions that have engaged in building the dyeing cluster's industrial symbioses have been in cooperative relationships with the dyeing cluster before the EIP programme was launched in the Banwol-Sihwa region. The innovation support organisations such as KICOX, KITECH, KTL and local universities have functioned for the EIP development in the very same ways as they used to do in other national programmes and R&D activities. KICOX has served as a network broker and the innovation support institutions like KITECH, KTL and local universities have taken the role of knowledge provider. The cluster upgrading dynamics underlying the active involvement of the non-firm institutions in the EIP programme is obviously RIS. In a sense, the EIP programme is just one more state initiative posed on Banwol-Sihwa's RIS.

VI. ENVIRONMENTAL UPGRADING IN THE YEOSU PETROCHEMICAL CLUSTER

6.1. Introduction

This chapter analyses the empirical evidence from the Yeosu petrochemical cluster and poses the research question of; “how does the nature of local production system affect the environmental performance of clustered firms?”; and “in what ways does institutional support system facilitate collective actions of clustered firms to improve environmental performance?” As in the previous chapter on the Banwol-Sihwa dyeing cluster, the four social factors of industrial ecology are used as the first analytical tool. Next, I reinterpret the social dimension of the EIP development in Yeosu with the three dynamics of collective efficiency, value chain and regional innovation system.

This chapter consists of four sections. Section 6.2 identifies the production system and the institutional support system of the Yeosu petrochemical cluster. Section 6.3 portrays the cluster’s environmental management practices and industrial symbioses. In this process, the environmental management system and by-product flows of the Yeosu petrochemical cluster are sketched. Section 6.4 investigates the social dimension of the Yeosu petrochemical cluster’s EIP development with the four social factors of industrial ecology. Based on the understanding of the social dimension, I analyse the dynamics underlying the EIP development and thereby provide answers to the two research questions that are addressed in this chapter. In the final section 6.4, I conclude with a brief summary of findings and discussions.

6.2. Local Production System and Institutional Support System

This section describes the local production system and the institutional support system of the Yeosu petrochemical cluster. The petrochemical cluster’s production system can also be decomposed into three inter-firm linkages: horizontal linkages, forward vertical linkages and backward vertical linkages. The cluster’s institutional support system has somewhat distinctive characteristics because of a high degree of interaction between the

industrial cluster and the local community. Accordingly, the structure of the institutional support system is described in two different ways: knowledge development support system and social upgrading support system.

6.2.1. Production System of the Yeosu Petrochemical Cluster

Horizontal Linkages

The petrochemical industry is a resource processing sector that is dominated by very large firms and plants. Each production stage tends to be occupied by one or a few large firms forming vertically integrated input-output relationships. The Yeosu petrochemical cluster is a typical example of petrochemical complexes. Considering this vertically integrated structure of the local production system, it is apparent that horizontal linkages are not as essential as in the Banwol-Sihwa dyeing cluster. In fact, inter-firm relations in the horizontal linkages of the Yeosu petrochemical cluster are rarely recognisable in the conventional notion of horizontal ties in the industrial cluster literature. However, a closer observation during the fieldwork uncovered two particular types of horizontal linkages.

Most large firms in the Yeosu petrochemical cluster are production facilities owned by Korean *chaebols* or multinational companies. Accordingly, the large petrochemical and chemical plants are grouped into several affiliate firm groups (Interview YO-F2, YO-F3) and, naturally, firms in the same affiliate group communicate and cooperate with each other. These groups of affiliate firms form several inter-firm horizontal linkages in Yeosu. Another, and the most important horizontal linkage of the Yeosu petrochemical cluster in this study, is the Yeosu Industry Environment Association (YIEA). YIEA brings together the environment and safety management departments from 29 petrochemical, chemical and energy firms in order to cope with environmental issues generated from the economic activities in the Yeosu industrial complex (Interview YO-F2, YO-F3, YO-I1, YO-I3). The central government ordered the petrochemical firms to establish it so as to respond to the growing concern about the environmental and safety issues in the region in 1982 and YIEA became an independent private body in 1997 (Interview YO-I1).

Forward Vertical Linkages

The Yeosu petrochemical cluster consists of five industrial sectors: the petroleum refinery sector, the petrochemical sectors, the chemical sector, the energy sector and the construction and engineering service sector. Due to its unique characteristics as a process industry, the first three sectors are normally regarded as one integrated sector in which firms formulate a set of highly cohesive forward vertical linkages. One oil refinery is the starting point of the producer-driven value chain in the Yeosu petrochemical cluster. All production lines in the cluster are spread from three naphtha cracking firms which deal with naphtha supplied by the oil refinery like tree branches.

The petrochemical and chemical firms reduce logistics cost dramatically by clustering. Their spatial agglomeration and physical connectivity is an inevitable choice, given that they process and exchange raw materials and products in gas or liquid state. The oil refinery imports crude oil from oil-producing countries and provides various oils and gas. Naphtha is the most essential and basic material with which all petrochemical and chemical manufacturing processes are organised. The oil refinery supplies Naphtha to three naphtha cracking centres and the naphtha cracking centres decompose it into various chemical materials. These three naphtha cracking centres send products to their neighbouring plants which are equipped with the next production stages. This sequence of production is continued to end goods of the chemical sector according to the codified chemical engineering process.

The forward vertical linkages of the Yeosu petrochemical cluster reflect that the petrochemical production system has the characteristics of high technical complexity as well as high separability. Due to high technical complexity, it is reasonable for firms to be specialised in a manageable and narrow production stage. This need for vertical division of labour is facilitated by high separability that results from high codification of the petrochemical engineering process. In addition, the petrochemical sector requires massive plants and equipments. This feature as a capital-intensive industry prohibits SMEs from entering into forward vertical production linkages of the petrochemical sector. As a result, the forward vertical linkages in which only large firms are present is established in the Yeosu petrochemical cluster. All production stages in the forward vertical production linkages are organised in accordance with the codified technologies and physically connected to each other. Each production stage is operated by one or a few large firms that

have high level of technological competence with gigantic capital goods. In these circumstances, a producer is hardly able to substitute its supplier in the forward vertical linkages of the petrochemical and chemical industry in Yeosu. That is to say, the user-supplier relations between every production stage are formed around closely integrated modular value chain governance. As a result, one or a few firms cannot have overwhelming economic power over inter-firm relations in forward vertical linkages.

The other equally important dimension of the vertical production linkage is corporate governance. Most large firms in the Yeosu petrochemical cluster are production facilities owned by Korean *chaebols* or multinational companies. Accordingly, they can be grouped into several affiliate firm groups. For example, GS and LG was the same company under the ownership of two business partner families, Hur and Koo. GS-Caltex is originated from Honam Oil Refinery Co.,Ltd. which was established by joint investment from Lucky Chemical (currently LG Chemical) and US-based Caltex Petroleum Corporation, a subsidiary company of Chevron. Honam Oil Refinery changed its name to LG-Caltex in 1996 and was split off from the LG Group in 2004, when the Hur family and the Goo family decided to separate their business into GS and LG. Currently, GS-Caltex is under the fifty-fifty ownership of Hur family and Chevron as one of the affiliate companies of GS Holdings Corporation. This type of corporate governance is common in the Yeosu petrochemical cluster. Distinct from the production network, this corporate governance is an important mechanism to activate joint actions at the local level. A business manager working for another group of affiliate firms explains the relationships between their affiliate firms in the Yeosu petrochemical cluster as follows;

In the past, we were one company. After the economic crisis in 1997 broke out, a series of mergers and acquisitions happened. It's a bit complicated now. But, in the capacity of relative firms, we run our own autonomous consultative group through which the plant managers can discuss common issues (Interview YO-F2)

The value chain governance and the corporate governance are intertwined with each other. Affiliate firms are normally in an input-output relationship in the Yeosu petrochemical cluster. Accordingly, the petrochemical and chemical firms can coordinate production issues through corporate governance. With regard to environmental performance, this governance structure affects each affiliate firm group's corporate social responsibility (CSR) policy.

Backward Vertical Linkages

There are a lot of SMEs²¹ that play a role as ancillary service units or related industries to the forward vertical linkages. Most SMEs are specialised on construction and engineering service providers who have subcontracting relations with the large petrochemical units. This construction and engineering service sector composes the backward vertical linkages of the Yeosu petrochemical cluster. In addition, two thermal power generation plants and three cogeneration plant are located in the petrochemical cluster, forming the energy sector. The co-location with the energy sector is very important because the petrochemical industry consumes huge amounts of energy in processing chemical materials at high pressure and temperature.

The large firms in the forward vertical linkages constitute a collective leadership system over the whole local production system in Yeosu. They have disproportionate power in the region in the economic context as well as the political context. However, it cannot be said that the governance in the backward vertical linkages is hierarchical. The capability of subcontracted suppliers has been significantly improved (Interview YO-F3). Due to the high technical capability of the small subsidiary service providers, the inter-firm governance in the backward vertical linkages is modular type.

6.2.2. Institutional Support System of the Yeosu Petrochemical Cluster

To investigate the institutional support system of the Yeosu petrochemical cluster, some nature of the petrochemical industry should be recalled. First of all, the petrochemical industry is based on a bulk production system that requires large equipment and physical infrastructure. Accordingly, the public business support services are concentrated on managing physical infrastructure like harbours and pipelines. Second, the petrochemical production technology is highly codified and the large firms located in the Yeosu petrochemical cluster have high levels of technological competence. This implies that there is relatively less need for regionally based knowledge infrastructure. Third, the

²¹Although these firms are categorised as SMEs, the scale of production facilities and capacity is much larger than SMEs in the other sectors.

petrochemical industry has some hazardous and risky aspects because it processes chemical materials at high temperature and high pressure. This feature has given rise to a series of environmental disputes between the industrial sector and the local community in Yeosu. This has resulted in a unique institutional support system to accelerate social and environmental upgrading of the petrochemical cluster in Yeosu. Considering the nature of the petrochemical industry, I investigate the institutional support system of the Yeosu petrochemical cluster in two different contexts; the regional knowledge development support system that can be understood in the conventional RIS framework, and the social upgrading support system that has materialised in the form of regional consultative committee in Yeosu.

Public Infrastructure Management Agencies

There are four major public agencies in the Yeosu region: K-Water, Yeosu Regional Maritime Affairs & Port Office, Honam Area Headquarters of KICOX, and Yeosu Branch of Korea National Oil Corporation. Their main function is providing infrastructure management services to the clustered petrochemical and chemical firms. K-Water is an industrial site developer, and Yeosu Regional Maritime Affairs & Port Office is a manager of port facilities. Honam Area Headquarters of KICOX's main task in Yeosu is managing pipe-racks installed within the industrial complex. Yeosu Branch of Korea National Oil Corporation reserves and manages crude oil in its oil tanker facilities. In addition, Yeosu Office of Ministry of Labour and Employment and Yeosu Branch of Korea Worker's Compensation and Welfare Service provide public services related to labour issues in Yeosu. A large part of the public sector in Yeosu is devoted to providing a minimum management circumstance for the industrial estate. In contrast to the Banwol-Sihwa region, there are no public knowledge generation institutions in the Yeosu region.

Knowledge Development Support System: Collaboration with Local Universities

The petrochemical industry is based on codified scientific knowledge. The core part of the Yeosu industrial complex is an agglomeration of large production units owned by Korean *chaebols* or multinational chemical companies that normally have large-scale R&D departments in their headquarters. This implies that the petrochemical and chemical firms

are supplied with extensive innovation resources from outside Yeosu's regional economy. As a result, a well developed knowledge generation system is neither required nor present at the local level.

A degree of collaboration between three universities and the petrochemical and chemical firms has developed. As the southwest coastal region of Korea does not have a metropolitan area, higher educational institutions are widely spread across Yeosu and its three neighbouring cities, Suncheon, Gwangyang and Mokpo. Three major national universities that cooperate with the Yeosu petrochemical cluster are Yeosu Campus of Jeonnam Univeristy in Yeosu, Sunchon University in Suncheon and Mokpo National University in Mokpo. The main activities in this industry-academic cooperation is consulting and testing for standard certifications (Interview YO-I2). The industry-academic cooperation in Yeosu does not have a character of planned involvement. Rather, it normally takes a form of interpersonal relationships between individual academic staff and the large firms. In addition, the Yeosu region does not host any government research institute. This suggests that state initiatives to build RIS have little affected the local knowledge infrastructure in Yeosu. As a whole, the knowledge development support system of the Yeosu petrochemical cluster can be regarded as grassroots RIS.

Social Upgrading Support System: Regional Political Governance

The most distinctive and, in a sense, the only structured institutional support system surrounding the Yeosu petrochemical cluster is regional governance initiative called Committee for Co-development of Yeosu City and Yeosu Industrial Complex, co-development committee in short. The committee is a channel through which all local stakeholders discuss their common agenda and make collective decisions. It was established in 1999 when environmental disputes in Yeosu went to extremes in 1999. Local NGOs strongly demanded a consultative body through which all of the industrial sector, the public sector and civil society could solve environmental problems in a cooperative manner. Local politicians exerted political influence on large petrochemical and chemical firms to participate in the committee at the initial stage (Interview YO-R2) and firms decided to join the committee with the intention of contributing to the local community (Interview YO-F1) and consulting on business matters with non-firm actors (Interview YO-R2).

The Co-development Committee is composed of eleven firms, eleven public or private institutions and ten local NGOs. The eleven firms are the most interesting component of the committee. When the committee was initiated in the late 1990s, local politicians asked several “most powerful firms” to participate in the committee (Interview YO-R1). The eleven participant firms now name themselves *coordinator firms* (Interview YO-R1). In other words, the eleven firms are the intersection of political governance and economic governance in the Yeosu area. Through this industry-community interaction channel, a vast range of agenda from firms’ pending issues like expanding factory sites to social contribution are collectively discussed and decided with local stakeholders.

The committee plays an integral role with regard to environmental upgrading of the Yeosu petrochemical cluster. A variety of practical projects to improve the environmental performance of clustered firms has been designed through the industry-community interaction in the Co-development Committee. For example, according to 2010 Activity Report published by the committee, the participant actors discussed the greenhouse gas reduction target planned by YIEA, the industrial complex renovation project suggested by Jeonnam University, the waste heat reuse network proposed by Jeonnam EIP Centre, etc. In addition to environmental performance, the other social contribution activities like donations for marginalised people, scholarship, cultural events and voluntary services that are led by the large firms are discussed and reported in the committee. Therefore, the Co-development Committee can be seen as the petrochemical cluster’s institutional support system aimed at environmental and social upgrading.

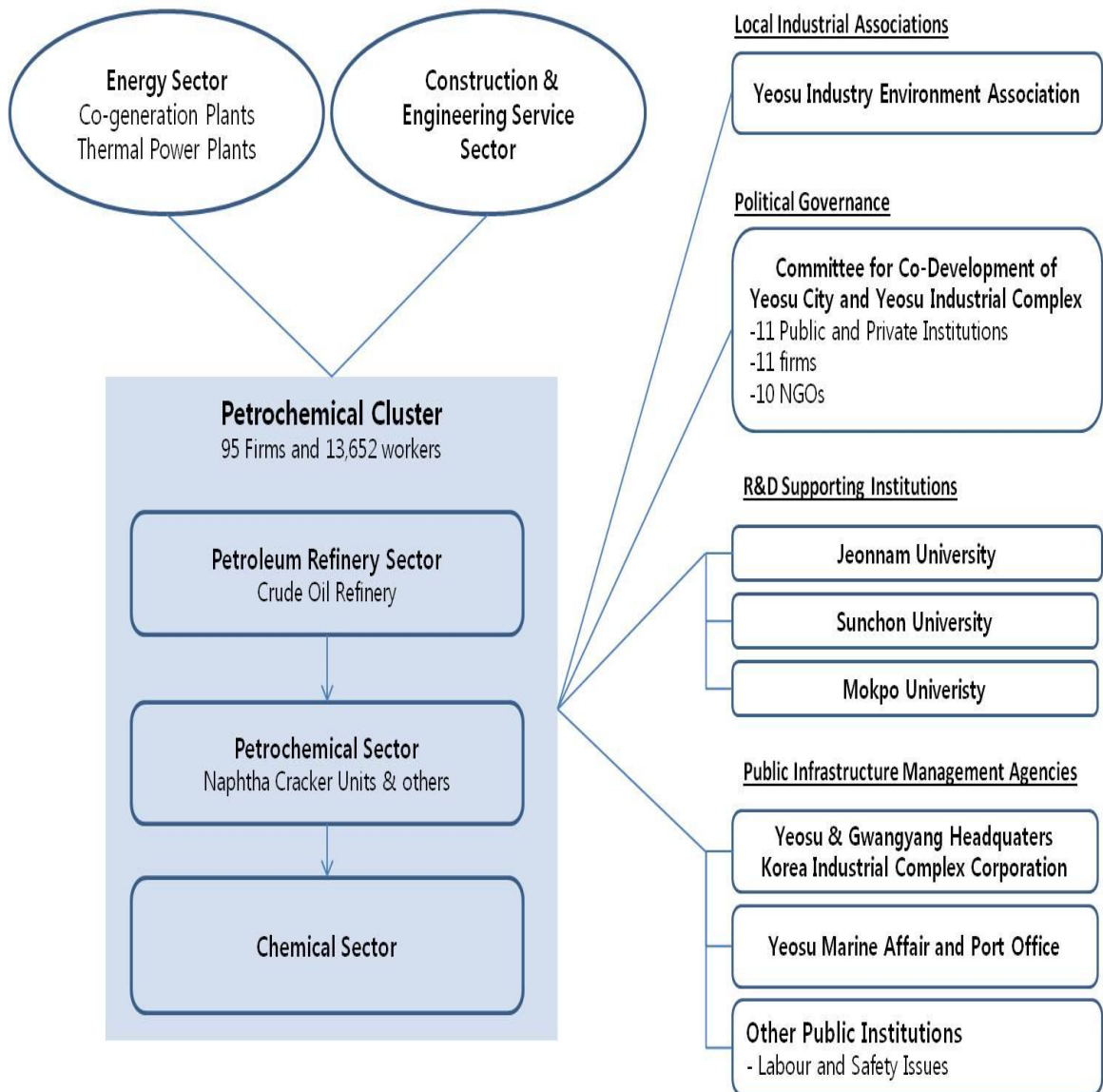
6.2.3. Summary: Structure of the Yeosu Petrochemical Cluster

The Yeosu petrochemical cluster is one of three major petrochemical complexes in South Korea. Precisely speaking, the cluster has four different sectoral components: the petroleum refinery sector, the petrochemical sector, the chemical sector and the energy sector and the construction and engineering service sector. The petroleum refinery sector, the petrochemical sector and the chemical sector belong to the cluster’s forward vertical linkages. One oil refinery is the central point of the producer-driven value chain in the Yeosu petrochemical cluster. All forward vertical production linkages in the cluster are arranged along with the material flows from the petroleum refinery and the three naphtha cracking centres. The energy sector and the construction and engineering sector belong to

the backward vertical production linkages. The firms in the backward vertical production linkages function as ancillary service units or related industries to the large petrochemical and chemical firms in the forward vertical linkages.

The institutional support system of the Yeosu petrochemical cluster can be divided into two different areas: knowledge development support and social upgrading support. The knowledge development support system refers to the industry-academy cooperation in Yeosu. Although a degree of collaboration between the local firms and the local universities has developed, the industry-academy interaction largely relies on interpersonal relationships based on spatial proximity rather than systemically structured interactive learning. On the other hand, the Yeosu region has well organised political institution, the Co-development Committee, in which eleven large firms represent the petrochemical cluster. The clustered firms discuss various environmental and social issues with the other local actors and cooperate with the public sector and the NGO sector. Therefore, this regional committee can be regarded as the social upgrading support system of the Yeosu petrochemical cluster. As a whole, the business structure of the Yeosu petrochemical cluster is mapped as in figure 6-1 below.

[Figure 6-1] Cluster Map of the Yeosu Petrochemical Cluster



*Source: Author

6.3. Environmental Upgrading and EIP in the Yeosu Petrochemical Cluster

This section identifies environmental management practices employed in the Yeosu petrochemical cluster and explains three industrial symbioses. In Yeosu, pollution control practices and cleaner production practices have been normally adopted and developed at

the individual firm level. In terms of the industrial ecology approach, their industrial symbioses tend to take a form of intra-sector material circulation due to the sector-specific nature of the petrochemical cluster.

6.3.1. Environmental Upgrading Prior to EIP

The environmental upgrading pertaining to pollution control and cleaner production have not taken the form of joint action in the Yeosu petrochemical cluster. As the petrochemical and chemical firms located in Yeosu have plenty of technological and financial capacity, engineering solutions to control pollution and improve manufacturing processes in more environment-friendly ways have been adopted through individual actions. Individual firms have continued environmental upgrading individually through methods like leak detection and repair systems, on-site recycling, fuel substitution and company compliance programme (Interview YO-F1, YO-F2, YO-F3). While technical solutions have been developed at the intra-firm level, institutional changes for pollution control and cleaner production have emerged at the inter-firm level in the form of private rules, establishing a local industrial association specialised in environment issues through the horizontal linkages and strengthening CSR compliance through vertical linkages.

Institutionalisation of Horizontal Inter-firm Cooperation

Yeosu Industry Environment Association (YIEA) takes a form of local industrial association in which 29 large firms participate. There are two formal decision-making levels in YIEA. The first one is the working-level meeting. The hands-on workers from the environment and safety department of each firm gather and discuss their common issues. The next level is the gathering between heads of the environment and safety departments. This systematic consultation structure functions as a collective decision-making process upon their common environmental issues in the Yeosu petrochemical cluster. An internal document from YIEA indicates its tasks as follows;

- Monitoring pollution to preserve the atmosphere and nature around the industrial district,
- Monitoring air pollutant emitting level from the member firms,

- Serving business on public petitions, environmental disputes and lawsuits,
- Managing the common facilities of the member firms and compensating for damages to farm crops,
- Engaging with government on environmental laws and deregulation,
- Supporting for external affairs and the prevention of safety accidents in the industrial district,
- Providing seminars on environmental policies and public advertising,
- Providing administrative supports on environmental issues and implementing events for environmental conservation,
- Engaging in other activities related to environmental management and technology sharing between member firms.

When the environmental dispute intensified during the late 1990s, its main role was arbitrating between the business and the residential community or addressing legal processes on the side of clustered firms. In addition, collective monitoring on pollution generated from the member firms is another major task of YIEA. Later, its role has been expanded to a variety of activities like research and cooperation with local stakeholders (Interview YO-F2, YO-I1).

Environmental CSR through Vertical Production Linkages

A group of large firms dominate the local production system and exert strong influence over small construction and engineering service units in the Yeosu industrial complex. To understand why environmental CSR is a critical issue, it might be useful to remember the series of environmental disputes in the Yeosu region triggered by the striking environmental disaster, *Seaprince* Oil-spill Accident in 1995 that GS-Caltex was charged with. Porter and Kramer (2006) argue that companies tend to realise the importance of CSR only after public pressure. This argument can be supported with the Yeosu case. The oil-spill accident provided an opportunity for the lead firm and the other large firms to rethink the issues related to CSR (Interview YO-F1, YO-R3). The firm-level interviews during the fieldwork disclosed the large firms tend to recognise environmental upgrading as a part of CRS and a duty for the local community member (Interview YO-F1, YO-F2, YO-F3). A firm manager interviewed revealed this point of view as follows;

The environmental and safety issues caused by our economic activities are our own responsibility. This is true for most firms in this industrial complex including us. We should invest on it and solve it by ourselves (Interview YO-F2).

The empirical evidence collected from the Yeosu petrochemical cluster illuminates that there are two main patterns which can be embraced into environmental CSR through the vertical linkages. The first is environmental standards. Most large petrochemical and chemical firms are member of the Responsible Care Programme which is the representative sector-specific standards in the petrochemical and chemical industry. In addition, most firms meet ISO14001, OHSAS18001 and ISO26000 standards. It is evident that the lead firm in the Yeosu petrochemical cluster uses such standards to govern the backward vertical linkages. The oil refinery has strongly recommended its trade partners and sub-contractors to comply with ISO series and the company compliance programme (Interview YO-F1). The General Manager of CSR Team of GS-Caltex explained this compliance policy as follows;

GS-Caltex has a CSR committee to share our business values with our business partners. The chairperson of the CRS committee is our CEO. This committee focuses on the seven areas recommended in ISO26000 and encourages our co-operators to follow the same company compliance system to GS-Caltex. Our business partners should be qualified for ISO9000 and ISO14001 as well as agree with us on company compliances. Sub-contracting firms have their own representative body, called co-operator firms association. Through the communication with the association, the business partners and GS-Caltex share business strategies, act together in various social contributions and even do social club activities with us (Interview YO-F1).

Meanwhile, corporate governance also significantly affects environmental management practices and environmental CSR compliances in the Yeosu petrochemical cluster. Environmental managers of individual firms have meetings in each affiliate firm groups (Interview YO-F2, YO-F3). Firms belonging to the same corporate governance share environmental management practices and follow similar environmental CSR compliances. Accordingly, it is evident that corporate governance is also an important inter-firm linkages through which environmental performance of clustered firms are promoted.

6.3.2. Industrial Symbiosis

The principle of closed-loop system argued by industrial ecology is intrinsic to the petrochemical and chemical sector. Most of all, there is no strict separation between main products and by-products in the petrochemical and chemical sector. In addition, firms normally know what sorts of products and by-products are produced by their neighbours because the petrochemical and chemical manufacturing process is highly codified. Due to this sector-specific nature, a few self-organising industrial symbioses have developed in the Yeosu petrochemical cluster (Interview YO-F3, YO-I2, YO-I3). For example, a hydrochloric acid exchange network, so-called Vulcan-Mitsui process, was already in operation between some petrochemical firms before the EIP programme was introduced in Yeosu (Interview YO-I3). A naphtha cracking firm has supplied its two by-products, pentane (C5) and heptane (C7), to other firms as raw materials (Interview YO-F2). Currently, eleven industrial symbioses are in operation in the Yeosu region. Due to the limitation of my research resources and the accessibility during the fieldwork, I selectively investigate three industrial symbioses.

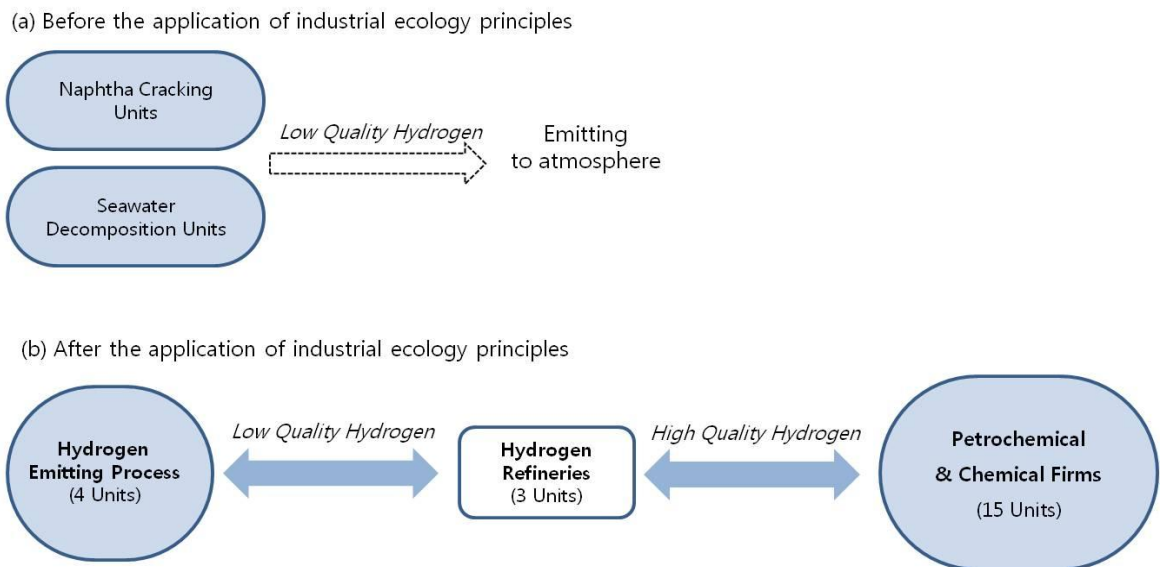
Hydrogen Recycling Network

The biggest industrial symbiosis in the Yeosu petrochemical cluster is the hydrogen recycling network. The naphtha cracking process and the seawater decomposition process generate low purity hydrogen (Interview YO-I2). Before this network was established, hydrogen was used as fuel gas in the naphtha cracking firms as on-site recycling or simply emitted to the atmosphere (Interview YO-F2). This by-product can be reused in other processes if it is refined into high purity hydrogen. Three naphtha cracking plants and one petrochemical plant provide their by-product hydrogen to three hydrogen refineries. The three hydrogen refinery units improve the quality of the by-product and send high purity hydrogen to fifteen petrochemical firms that can use hydrogen as a raw material.

In fact, establishing hydrogen recycling network was already considered by a few large firms before the EIP programme was initiated in Yeosu (Interview YO-I2, YO-I3). The oil refinery offered it to one of the three naphtha cracking firms and this idea was discussed in a meeting among the heads of environment and safety departments (Interview YO-F2). YIEA pulled together the opinions from its member firms and suggested their plan on the

potential hydrogen exchange to the EIP promotion team (Interview YO-I2). After an external university-based research team tested its economic feasibility, the hydrogen recycling network was established in 2009.

[Figure 6-2] The Hydrogen Recycling Network in the Yeosu Petrochemical Cluster



*Source: Author

The hydrogen recycling network shows the typical pattern of industrial symbiosis development suggested by the industrial ecology literature. A successful industrial symbiosis tends to take a gradual development process in the sequence of self-organisation for economic efficiency, third party review and efforts to establish additional symbioses (Chertow, 2007). The hydrogen recycling network was initially devised by a few firms and then diffused across the whole cluster through the coordination of YIEA. A university-based research team reviewed its technical and economic feasibility.

Optimised Recycling of Waste Catalyst

Catalysts in the petrochemical industry refer to materials used to quicken chemical reactions in chemical manufacturing processes (Interview YO-F3). Catalysts are discarded when they cannot function properly after a certain operation time. In many cases, precious metals are used as catalysts (Interview YO-F3, YO-I2). To reuse the precious metal

catalysts, a group of firms located in the Yeosu petrochemical cluster tested a new metal recycling technology and several firms are currently participating in this new business. For example, Kumho Petrochemical has used platinum in its production process of rubber antioxidant. The firms using platinum catalyst exported the waste catalyst to Australia and the US that have high level of metal refining technique (Interview YO-F3).²² However, the refining inevitably causes some loss of platinum in burning process. A retired worker of a petrochemical firm visited the Jeonnam EIP Centre to suggest a new dissolution method with which platinum can be selectively refined via a chemical reaction process (Interview YO-F3, YO-I2). He founded a small metal fabrication service firm with this idea, but failed to make his business successful because of the high entry barriers to the precious metal purification business (Interview YO-F3). Jeonnam EIP Centre supported this person by launching a research project and networking platinum catalyst users (Interview YO-I2). This technology is commercialised now in the Yeosu petrochemical cluster.

This industrial symbiosis case studied during the fieldwork provides three interesting points. First, this is a shared service type of industrial symbiosis. The small metal fabrication service company receives waste catalyst platinum from the petrochemical sector and returns refined metals to the petrochemical sector. Second, the metal fabrication service unit was founded with a new technology to recycle catalyst metals and has expanded its business with the support from the regional EIP centre. This can be seen a sort of spin-off effect. In fact, the platinum catalyst recycling network is an example showing that small and medium sized chemical engineering firms have increasingly participated in the EIP programme. While the large petrochemical and chemical firms remain as by-product suppliers, more and more SMEs have obtained opportunities to launch new ancillary services or expand their business areas by participating in the EIP programme in Yeosu (Interview YO-I2). Recently, most ideas on potential industrial symbioses are submitted by SMEs who target the niche market created through the EIP programme (Interview YO-F2, YO-I2). This phenomenon implies that the forward vertical linkages mainly composed of the large firms function as a group of anchor tenants and the

²²This sub-unit case study shows that the petrochemical cluster was already involved in a metal recycling network at the global level. Although this aspect is beyond the research subject of this doctoral study, the metal recycling network can provide an interesting implication to the global value chain literature as well as the production chain approach of industrial ecology.

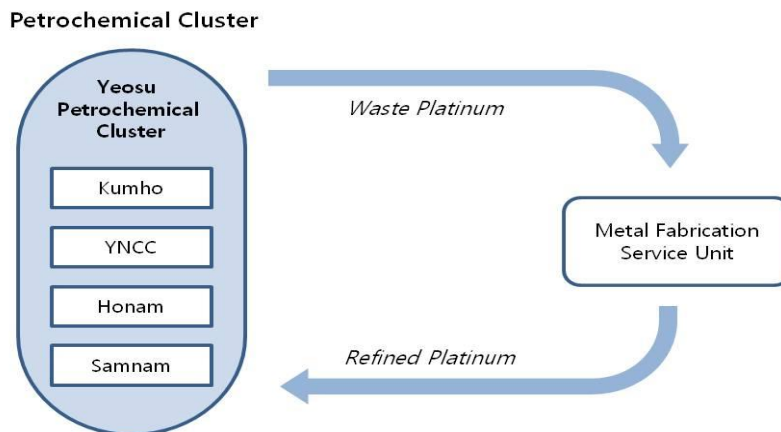
backward vertical linkages are being expanded by building industrial symbioses in the Yeosu industrial complex.

[Figure 6-3] The Network to Recycle Waste Platinum Catalyst

(a) Before the application of industrial ecology principles



(b) After the application of industrial ecology principles



*Source: Author

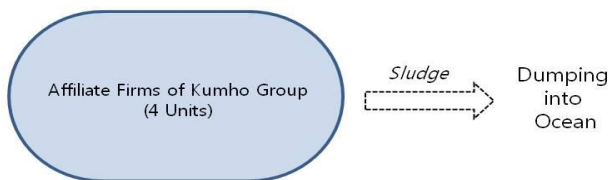
Effluent Sludge Recycling as Energy Resource

The final case investigated during the fieldwork in the Yeosu petrochemical cluster is the industrial symbiosis to recycle effluent sludge as an energy source. Effluent sludge accounts for 65 percent of the total amount of sludge, 83,470 tons, generated from the Yeosu industrial complex (Ministry of Knowledge Economy and Korea Industrial Complex Corporation, 2011). As the ocean disposal of sludge will be prohibited shortly, the petrochemical firms must find a method to treat their sludge on land. The affiliate firms of Kumho Group in the Yeosu industrial cluster have succeeded in using sludge as an auxiliary fuel for their affiliate cogeneration plant. Kumho petrochemical, Kumho P&B Chemical and Kumho Polychem generate organic sludge, while Kumho Cogeneration

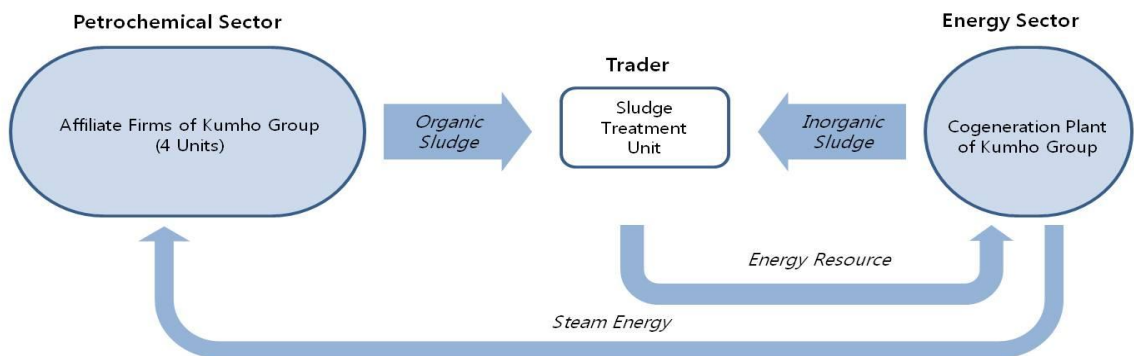
Plant emits inorganic sludge. Organic substances contained in organic sludge have relatively high calorific power. On the other side, inorganic sludge can substitute sand used to improve thermal efficiency in fluidized incinerators of the cogeneration plant. Therefore, the mixture of organic sludge and inorganic sludge is used as fuel by Kumho Cogeneration Plant. The sludge recycling network is an industrial symbiosis situated in the inter-sector linkage between the petrochemical industry and the energy industry. However, considering that this industrial symbiosis is conducted among five affiliate firms of the Kumho group that are in input-output relations, it might be more convincing to regard it as a process upgrading within the value chain.

[Figure 6-4] The Network to Recycle Effluent Sludge

(a) Before the application of industrial ecology principles



(b) After the application of industrial ecology principles



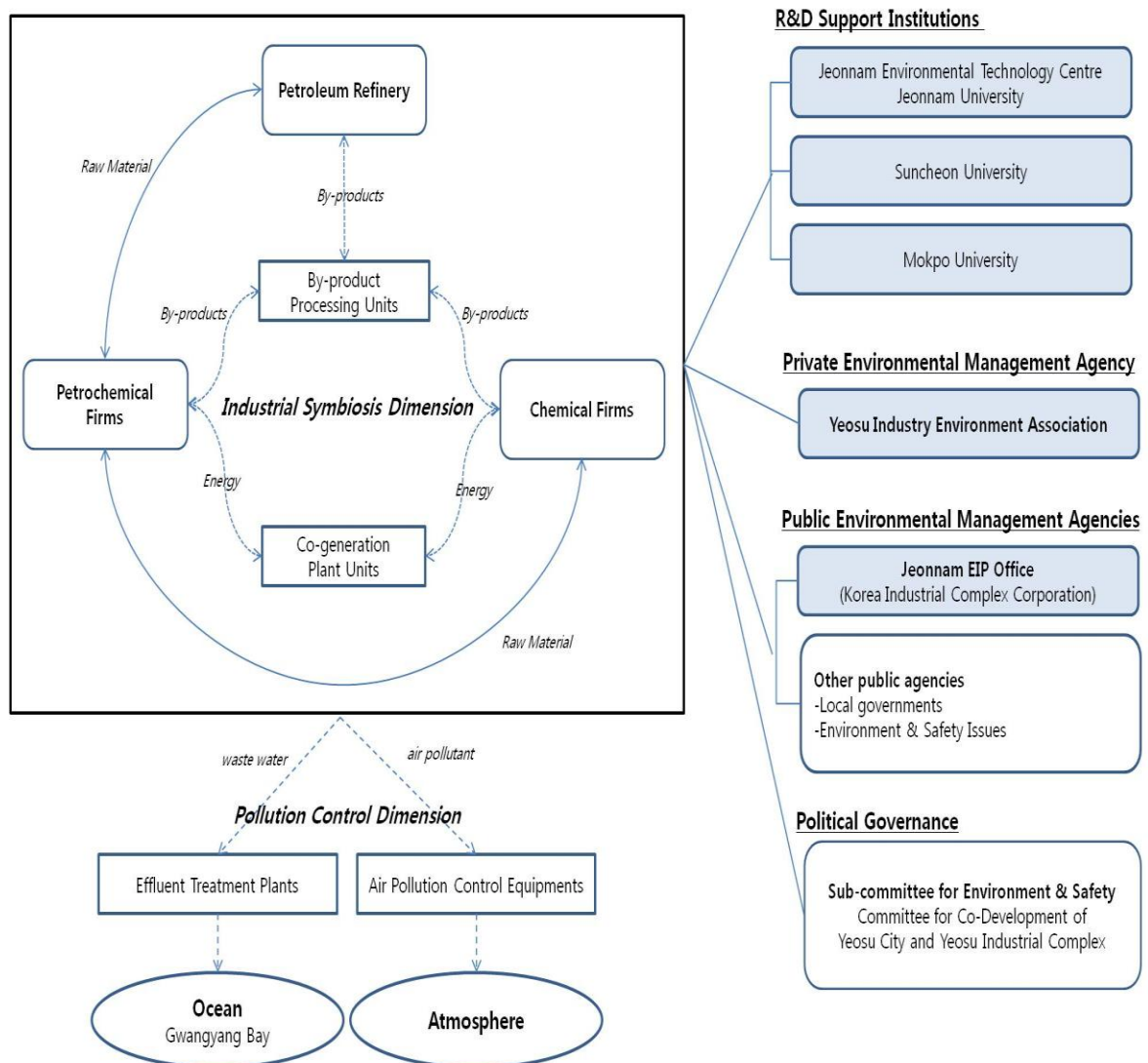
*Source: Author

6.3.3. Environmental Management System

The three environmental management practices are all situated in the local production system of the Yeosu petrochemical cluster. The environmental management structure of the Yeosu petrochemical cluster is significantly different from that of the Banwol-Sihwa

dyeing cluster due to the different nature of the local production system. Pollution control practices and cleaner production practices are normally introduced and implemented individually. Instead of technical solutions, the large firms have taken joint actions related to community petitions such as collective pollution monitoring, compensation for environmental damages and negotiation with local stakeholders. YIEA, the gathering of environment and safety management departments of 29 large firms, plays the role to coordinate collective behaviours in the horizontal linkages, while the environmental management issues in the vertical linkages are governed via the large firms' compliance programmes. The next diagram in figure 6-5 is a modified map of the Yeosu petrochemical cluster focusing on its environmental management.

[Figure 6-5] Environmental Management Map of the Yeosu Petrochemical Cluster



*Source: Author

6.4. Cluster Dynamics Underlying the EIP Development

The Yeosu petrochemical cluster's industrial symbioses take a form of intra-sector material circulation. However, the material exchange networks still emerges from inter-firm relations. Focusing on the inter-firm context, this section investigates the social dimension of the petrochemical cluster's EIP development. In succession, the social dimension is analysed with the frameworks of collective efficiency, value chain and regional innovation system. Based on the analysis, this section provides answers to the research questions addressed in this chapter.

6.4.1. Social Dimension of the Yeosu Petrochemical Cluster's EIP Development

Mental Distance

The mental distance in the Yeosu petrochemical cluster is observed in two different dimensions. First, as in most studies in the industrial ecology literature and the industrial cluster literature, firms' perception on inter-firm relationships is important in organising their joint actions. The other dimension of mental distance is associated with the relationship between the clustered firms and the civil society groups in the Yeosu.

Mental Distance at the Inter-firm Dimension

A firm manager revealed that organising a joint action to build an industrial symbiosis is not easy in reality because the petrochemical and chemical firms located in Yeosu prefer individual behaviours.

I am not totally sceptical about this. If EIP can provide advantages to this region, this industrial complex, or at least other firms, even though it would not be much beneficial for our firm, we have to cooperate for EIP. However, because most firms prefer individual behaviours and work on their own... there should be someone who plays the role of mediator. I am not saying that we don't have such

mediators in Yeosu, but the firms here tend to dislike intervention from outside (Interview YO-F2).

As commented in this, it seems that mental distance among the firms is not significantly close. The short mental distance that alleviates their individualisation lies in relationships between affiliate firms. Most large firms in the cluster can be grouped into several corporate governances. Firms under the same corporate governance are, in many cases, joint-stock companies or in the input-output relations. Such affiliate firms generally have a collective decision-making system at the higher management level as well as the working level under a same ownership although they are formally independent companies (Interview YO-F2, YO-F3). This relationship between affiliate firms has made the cooperation for the EIP programme easier (Interview YO-F3). The network to recycle effluent sludge between the five affiliate firms of the Kumho group is an example. The four petrochemical and chemical units regularly meet with each other and share information. The co-generation plant unit is, although it belongs to the energy sector, highly accessible for the other affiliate firms of the Kumho group because all of them are under the same ownership. A director of environment and safety management department of a Kumho affiliate firm explained about their relationship as follows;

Surely we have actively collaborated with each other for the industrial symbiosis because we belong to the same affiliate company group... Kumho has four production units here. We directors of environment and safety management teams have regular meetings and hold annual workshop. So we discuss common issues and share information about good practices. We have close links with each other (Interview YO-F3).

As shown in the industrial symbiosis to recycle effluent sludge among the Kumho's affiliate firms, the existence of close mental distance among affiliate firms has lubricated the EIP development in the Yeosu petrochemical cluster.

Mental Distance at the Regional Dimension

However, the inter-firm relationships among affiliate firms and through YIEA are not sufficient to explain all aspects of mental distance in the Yeosu region. The fieldwork in

Yeosu exposed that close mental distance is more conspicuous at the regional level than the inter-firm level. An easily noticeable context of mental distance is between the petrochemical industry and the regional academic society. One of the external researchers who dedicated to initiating the EIP programme in Yeosu revealed that the involvement from external actors had limits due to the lack of embeddedness in the local society (Interview YO-I3). The manager of Jeonnam EIP Centre pointed out the advantage of nativeness is a key element in acquiring access to local firms in Yeosu.

After all, interpersonal relationships are very important. If an outsider visits the local firms and demands the information on industrial wastes and by-product, who would gladly give such information? No one would do. People from local research institutions are always interested in our local society and work for this region. Local people are linked with each other and have good relationships. EIP has been developed in these relationships (Interview YO-I2).

The other regional dimension of close mental distance is observed in between the industrial sector and the NGO sector. As described in chapter 4, Yeosu-based NGOs is one of the groups who initiated the EIP programme in South Korea. At the local level, they are a member of local steering committee for the EIP programme and have engaged in a few feasibility studies on industrial symbioses. Such active involvement of local NGOs in the EIP programme is stemmed from relatively amicable relations between the industrial sector and the NGO sector. The local firms believe that they are working together for regional development although they belong to different sectors (Interview YO-F1, YO-F2, YO-F3, YO-R1). A firm manager commented that the firms and the NGOs share common purposes as members of the same local community as follows;

Different from a common external viewpoint, NGOs do not speak out in negative ways in here. They are also local residents like us working for the regional development. They talk and share opinions with us in the framework of co-development (Interview YO-F2).

The notion of mental distance in the industrial ecology literature normally refers to inter-firm relationships. However, In the case of Yeosu, mental distance looks like firms' attachment to the local society. The local firms that I interviewed expressed their opinion

that they have to contribute to regional development (Interview YO-F1, YO-F3). The interviewee working for the petroleum refinery expressed the firm's strong sense of belonging to Yeosu as follows;

GS-Caltex started its business as a petroleum refinery by planting its pipe into this land. We took root in Yeosu in 1967. Our production facility, the matrix of GS-Caltex, is here in Yeosu. Accordingly, GS-Caltex has a strong willingness to play the social role as one of local actors in Yeosu. This is CEO's philosophy as well (Interview YO-F1).

The firms interviewed during the fieldwork commonly expressed strong belongingness to the region and showed local sense of solidarity with other local actors. It seems that the firms' attachment to Yeosu gives rise to strong willingness toward social contribution. Probably, some firms have real sense of belonging to the Yeosu region while others have corporate citizenship based on CSR compliance policies. One evident fact is that the clustered firms have commonly experienced a series of struggles and cooperation between the industrial society and the local community. This experience seems to induce the firms to change their attitude about the local society. A firm manager and a NGO activist explained change of mindset through the societal interactions as follows;

About ten years after the *Seaprince* Accident, no matter whose fault it was in the past, most local people, NGOs, public agencies and firms have changed their mind a lot. It seems that we found out a turning point at the appropriate time. While we were opposed to each other until the early 2000s, the firms changed their mind since the mid-2000s. The local community also began to think they shouldn't dwell on the past... I think local residents and NGOs also recognised that feelings of hostility towards the industrial community have to be resolved. Then our firm is no longer on the defensive and stopped just concealing and denying. We expose our problems and try to solve them together with local stakeholders (Interview YO-F1).

In the past, the firms were the object of monitoring and being hostile. We were clumsy at talking together even though we tried to communicate with each other. Now, it seems that we are heading towards reciprocity in order to achieve regional development. In the past, the firms were quite defensive and NGOs were a bit aggressive. But now our movement is more matured. We have turned to the stage

of collective deliberation and mutual assistance. I feel this way. We are much less hostile than before, continuing to talk with each other (Interview YO-R2).

As a result, local sense of solidarity has been formed between the clustered firms and the other actors. Combined with the local sense of solidarity in Yeosu, the regional consultative committee, Co-development Committee, also encourages the firms to make contribution to the regional development in Yeosu.

Because they frequently meet with each other... This might be a big reason. If being requested to do something that is demanded for the local society, it is hard to refuse. As they often face each other and regularly have meetings, someone cannot say “no”. When they were in struggle, they might think it is better to say no and keep fighting. But now such negative position is not easy to take. The same applies to the other actors like public agencies as well as the firms (YO-R1).

The EIP programme was launched in this cultural and organisational structure of the Yeosu region. The local actors including the industrial community agreed to initiate the EIP programme through Co-development Committee in 2005. Accordingly, the large firms’ participation in the EIP programme can be partly comprehended with the firms’ sense of solidarity with the local community. All the firms interviewed during the fieldwork made comments showing that they regard EIP as a method to contribute to regional development. An informant working for one of Kumho’s affiliate firms answered to the question of why they have participated in the EIP programme as follows;

Kumho is an indigenous company here. Environmental issue is very important in business nowadays. In my opinion, we should make contributions in the environmental context. We are participating a bit actively in this point of view. Our contribution may be smaller than GS-Caltex or YNCC, but you can think that we are, in our own way, making efforts for environment preservation and social contribution (Interview YO-F2).

Roles of Champion

The lead firm in the Yeosu petrochemical cluster is the petroleum refinery. The petroleum refinery is at the zenith of the localised value chain as a monopolistic supplier (Interview

YO-I2, YO-R2, YO-R3). In the case of the hydrogen recycling network, the petroleum refinery played a practical role to suggest idea on the by-product exchange and take a part of the industrial symbiosis as a user of by-product hydrogen. This can be understood as roles of champion in the industrial ecology literature.

In fact, the petroleum refinery's real role in the EIP programme is more symbolic. The informant from the oil refinery expressed his company as "the eldest brother in the Yeosu industrial complex" (YO-F1). Although he used this expression in a very careful and humble manner, such naming suggests the lead firm's significant power. The other large firms located in the Yeosu petrochemical cluster tend to accept GS-Caltex's policies and behaviours as an exemplar (Interview YO-F1, YO-F3, YO-I2, YO-R1). The petroleum refinery's participation provides symbolic value to local projects and gives a signal to the other firms. Accordingly, non-firm actors try to invite the petroleum refinery when they expect involvement from the industrial sector in a local project (Interview YO-I2, YO-R1). The petroleum refinery's leadership is also applied to the EIP programme. The hydrogen recycling network in which the petroleum refinery was a prime mover became a success example (Interview YO-I2) and thus a good method of advertising the EIP programme.

Institutional Setting

If the lead firms are symbolic champions rather than coordinators, someone should take the role of real coordinator. This issue brings about the necessity to investigate institutional setting for EIP development in the Yeosu region. Moreover, the Yeosu petrochemical cluster has not a well structured knowledge generation system at the local level. Rather, the main function of the institutional support system surrounding the petrochemical cluster is encouraging and supporting environmental and social upgrading. The institutional setting for the EIP development in Yeosu reflects these features of the cluster's institutional support system.

Coordinators: YIEA and Jeonnam EIP Centre

Most large petrochemical and chemical firms in the Yeosu petrochemical cluster are linked with each other through their local industrial association, YIEA. As YIEA is a formal channel through which 29 large firms meet on a regular basis, discuss their common

environmental issues and share opinions, this communication channel substantially contributed to the EIP development within the Yeosu petrochemical cluster to a certain extent. YIEA has served as a private coordinator at the early phase of the EIP programme in Yeosu. There are two reasons why YIEA took the role of coordinator in the EIP programme before Jeonnam EIP Centre was established. First, almost all petrochemical firms, chemical firms and energy suppliers are members of this association. Accordingly, YIEA staff are in close relationships with the member firms. EIP practitioners gained good accessibility to the petrochemical and chemical firms by using their networks (Interview YO-I3). The other reason is that YIEA has neutrality among the clustered firms. Because an industrial symbiosis is emerged in inter-firm relations, a real challenge is not technological engineering but interest coordination. YIEA mediated between all firms taking a neutral attitude as the industrial association (Interview YO-I1, YO-3).

On the other hand, Jeonnam EIP Centre serves as a public coordinator in the EIP programme in Yeosu. Jeonnam EIP Centre is a department of Honam Area Headquarter of KICOX. While the large firms' participation in the EIP programme has gradually diminished, an increasing number of SMEs have applied for an EIP project in order to create business opportunities by using by-products in Yeosu (Interview YO-I2). Such SMEs normally aim to expand their business or create new business opportunities by using by-products from the large petrochemical and chemical firms (Interview YO-I2, YO-F2). Jeonnam EIP Centre concentrates on supporting SMEs and mediating between the large firms and the SMEs (Interview YO-I2). Industrial symbiosis is basically a supplier-user relation. If the supplier-user relation is formed between a large firm and a SME, a degree of economic and political power asymmetry between them tend to inevitably occur in the EIP development. Therefore, a public agency is required to involve in building industrial symbioses in order to arbitrate negotiation in a fair manner between the powerful large firms and SMEs. Jeonnam EIP Centre takes this role in Yeosu.

Knowledge Provider: Small and Medium-sized Engineering Companies

I analysed various documents collected from the fieldwork and an internal report provided by Jeonnam EIP Centre. Forty two R&D projects on potential industrial symbioses have been carried out from 2005 to 2011. Thirty projects were led by the industrial sector and twelve projects were performed by university-based research teams. In terms of the

projects led by university-based research groups, six projects were led by external universities and the other six projects were led by the three local universities (Jeonnam University, Suncheon University and Mokpo University). Most projects managed by the academic community were intensively carried out at the early stage of the EIP programme between 2005 and 2008. It is because external university-based researchers actively engaged in initiating the EIP programme in Yeosu.

After the external researcher group withdrew from Yeosu, most R&D projects on potential industrial symbioses have been led by the industrial community, especially small and medium sized engineering companies. Among the thirty projects led by the industrial sector, only one project was carried out by a large firm located in the Yeosu petrochemical cluster. These figures suggest that SMEs have played a significant role in providing knowledge for the EIP development while the clustered large firms have rarely used their R&D capacity in the EIP programme.

Planning

As explained before, the EIP implementation framework of decision-making, financial supporting and performance assessment was designed by the central government and applied to all EIP regions. Accordingly, the system of decision-making, financial support and assessment is largely equivalent to the Banwol-Sihwa region. The central government set up a regional EIP centre and has provided R&D funds for EIP development in Yeosu in exactly the same way as in the other EIP areas. However, as there are few public innovation support institutes in the Yeosu region, strong involvement of public agencies has not happened. A finding unique to the Yeosu petrochemical cluster in terms of planning is the firms' perception of the environmental regulatory framework.

Changes of the Environmental Regulatory Framework

The firms interviewed commonly point out that the environmental regulation has been significantly tightened. Compared to the past, the current environmental regulation is so strict that firms cannot ignore or conceal environmental problems (Interview YO-F2, YO-F3, YO-I1). In accordance with the tightening of environmental regulations, the petrochemical and chemical firms have made substantial investments in environmental

management. Establishing industrial symbioses is a part of their investments (Interview YO-F3). However, environmental regulatory requests are not totally based on a command-and-control framework. A firm manager points out recent changes of the regulatory framework as follows:

In the past it was normal for the government to use coercive measures and order firms to follow certain state initiatives. But now the authorities visit firms first and try to find solutions for firms. The EIP is an example (Interview YO-F2).

This change in the environmental regulatory framework is one of the keys to success in the EIP programme. In contrast to the conventional command-and-control framework, the EIP programme has the characteristics of a consultative and flexible framework (Interview YO-F3, YO-I2, CE-I5). As a result, firms have opportunities to take more proactive and autonomous actions in accordance with their own plans to reduce environmental damage. Especially if firms have a high degree of financial and technical competency, like the petrochemical and chemical firms located in the Yeosu petrochemical cluster, a consultative and flexible government plan might promote the environmental performance of clustered firms in an effective way.

6.4.2. Cluster Upgrading Dynamics Underlying EIP Development

The four social factors of industrial ecology reflect the nature of the local production system and the institutional support system of the Yeosu Petrochemical cluster. The final task to understand how the characteristics of the petrochemical cluster's production system and institutional support system have affected the EIP development is reinterpreting the four social factors with the three dynamics of collective efficiency, value chain governance and regional innovation system.

Collective Efficiency and EIP

As analysed in section 6.2, the chemical engineering technology is highly codified and all the large firms occupying the forward vertical linkages have high technological and

financial competence. Due to these technological and organisational features, the petrochemical and chemical firms have little need to cooperate for technical solutions. Instead, their joint actions have been concentrated on dealing with complaints from the local community. In addition, inter-firm cooperation between affiliate firms is highly active.

The Yeosu petrochemical cluster's forward vertical production linkages can be regarded as a producer-driven value chain. The petroleum refinery has a high degree of influence as a monopolistic supplier in the petrochemical value chain. However, the lead firm does not totally govern the value chain as in hub-and-spoke industrial districts or captive value chains. Every production stage of the forward vertical linkages is modular input-output relation based on high codification of technologies and high capability of producers. Moreover, because of the characteristics as a capital-intensive sector, the entry barrier is high in the forward vertical linkages of the Yeosu petrochemical cluster. This implies that the lead firm's power to coordinate joint actions is relatively limited. With regard to the EIP development, the nature of the producer-driven value chain as modular governance has been materialised as the limited roles of champion in Yeosu.

Despite the limited roles of champion, a few self-organising industrial symbioses had already evolved within the cluster before the EIP programme was introduced. For instance, a hydrochloric acid exchange network had been operated between a petrochemical firm and a chemical firm (Interview YO-I3). A plastic manufacturer had exchanged steam with a petrochemical firm (Interview YO-F3). This endogenous EIP development partly stems from the sector-specific nature of the petrochemical and chemical business as a resource processing industry. There is no clear distinction between raw materials, products and by-products in the chemical engineering field (Interview YO-I3). In addition, all production stages of the petrochemical and chemical industry is circulating materials in gas or liquid state. Accordingly, by-products and wastes generated from petrochemical and chemical firms can be reused as economically useful materials by other firms operating in the same industrial sector. Due to this sector-specific nature, some industrial ecologists categorise the petrochemical and chemical industry as an exception (Baas and Boons, 1997; Chertow, 2007).

In the industrial cluster context, a firm's opportunities to reuse by-products generated from neighbouring firms free of charge or at low price can be regarded as external economy. If this externality is widely distributed across an industrial cluster, it can be seen as an

agglomeration gain. This condition is applied to the petrochemical industry. Given that raw materials, products and by-products in the cluster-wide context are not strictly distinguished, petrochemical and chemical firms that are intensively located within a limited space can get the agglomeration gain of by-product exchange and energy cascading. In this regard, the self-organising industrial symbioses developed in the Yeosu petrochemical cluster are a materialisation of sector-specific agglomeration gain.

The sector-specific nature of the petrochemical and chemical industry does not seem to be enough to disseminate industrial ecology practices across a whole cluster. In reality, the self-organising industrial symbioses in the Yeosu petrochemical cluster have remained as small-scale networks between two or a few firms. In order to disseminate industrial ecology practices, cluster-wide joint action is required. Such joint actions normally demand a high degree of coordination. The challenge is how to organise a cluster-wide joint action given that inherent coordination is low in the Yeosu petrochemical cluster. The coordination problem among the large firms in the EIP programme has been solved by involvements from various non-firm actors. First, the local industrial association, YIEA, served as a coordinator in order to initiate joint actions for the EIP development by using its relationships with 29 member firms. Second, the local governance institution, the Co-Development Committee, in which eleven ‘powerful’ firms participate, encouraged the industrial community to be engaged in the EIP programme. Third, external actors who are mainly university-based researchers actively took part in disseminating industrial ecology practices and providing knowledge to the clustered firms at the early phase of Yeosu’s EIP. While a substantial amount of opportunities to exchange by-products in the form of external economy indwelling in the petrochemical sector, the clustered petrochemical and chemical firms triggered the joint actions to establish industrial symbioses by overcoming the inherent nature of low coordination with supports from various non-firm actors and, thereby, the dynamics of collective efficiency has been activated for EIP development in the Yeosu petrochemical cluster.

Value Chain Dynamics and EIP

Once the EIP development began to be underpinned by the dynamics of collective efficiency, an increasing number of potential industrial symbioses have emerged in the Yeosu petrochemical cluster. The main actors in this stage are small and medium sized

engineering companies. A general manager of Jeonnam EIP Centre testified that recently the greater part of R&D projects to discover potential industrial symbioses are suggested and led by SMEs in the Yeosu region. This phenomenon reflects the nature of the petrochemical production system and structural changes in its backward value chain.

In many cases, by-products generated from an industrial sector need to be refined or processed before they are used by the other industrial sectors. This also applies to the petrochemical and chemical industry. One difference is that by-products from the petrochemical and chemical sector tend to be returned to the same industrial sector after the refining process. By-product exchanges normally take a form of intra-sector material circulation within the petrochemical industry. Because of this character of the petrochemical sector as a material circulation system, the petrochemical value chain has been enhanced quantitatively as well as qualitatively.

In the quantitative aspect, the expansion of the cluster's backward vertical value chain has taken place through the EIP development. The small and medium sized engineering firms that are engaged in the refining process of by-products in the EIP programme belong to the cluster's backward vertical linkages. Such SMEs aim to create new business opportunities or expand their existing business area with by-products generated from the large petrochemical and chemical firms occupying the cluster's forward vertical linkages. A representative example is the hydrogen recycling network. Thanks to this newly established hydrogen supply chain, three hydrogen refinery firms expanded their existing facilities or newly entered into the petrochemical cluster's backward vertical linkages (Interview YO-I2).

On the other hand, there have been qualitative improvements of the cluster's backward vertical value chain through the EIP programme. The petrochemical industry is a high tech sector that utilises highly codified chemical engineering technology. In addition, there is no clear distinction between raw materials, products and by-products in the petrochemical and chemical cluster. This technological circumstance means that SMEs engaged in the by-product refining and processing process also need to be equipped with high-tech knowledge. The technological qualifications required to SMEs that intend to participate in Yeosu's EIP provide an explanation of why small and medium chemical engineering companies function as a knowledge provider. The chemical engineering companies intending to participate in the EIP programme are, although the local informants expressed them as SMEs, actually high-tech firms. The network to optimise recycling of waste

catalyst represents the qualitative improvement of the petrochemical value chain through the EIP programme. The metal fabrication service firm that suggested this industrial symbiosis has substituted the previous practice of exporting by-product platinum to other countries with new technology. The effluent sludge recycling network between five affiliate firms of the Kumho group can be understood in the same vein. Kumho cogeneration plant, the user of sludge in this industrial symbiosis, belongs to the energy sector which composes the backward vertical linkages of the petrochemical cluster together with the engineering service sector. By building the sludge recycling network, the cogeneration plant functions to treat sludge as well as supply energy. Although the cogeneration plant is not a SME, the industrial symbiosis is a functional enhancement of the backward vertical linkages.

RIS and EIP

The Yeosu region hosts a relatively small number of innovation support organisations and the knowledge generation system is not well structured at the local level. Although a degree of industry-academy collaboration has developed in the Yeosu region, the interaction between the industrial community and the academic community mainly relies on interpersonal relationships. Accordingly, Yeosu's innovation system can be categorised as grassroots RIS. This weak development of knowledge generation system seemed to bring about the strong involvement of external university-based research groups at the initial phase of the EIP programme in Yeosu. Clearly, the role of local universities and R&D centres to generate and provide practical knowledge for industrial symbioses is not essential in Yeosu's EIP. The large petrochemical and chemical firms have high technological competence. Small and medium engineering firms based in Yeosu are also equipped with high technology so that they have played the role of knowledge providers in the EIP programme.

An interesting point is that the local firms' awareness of EIP has been formed through regional learning-by-interaction between a variety of local actors such as local firms, local authorities, universities and NGOs. Baas and Boons (2004) modify the RIS framework to be relevant to EIP developments. They suggest that EIP development tends to undergo a phase of knowledge exchanges and defining sustainability, so-called regional learning, in which non-firm actors like local residents and NGO movements may be involved. The case

study on the Yeosu petrochemical cluster strongly supports this argument. Yeosu-based NGOs are one of the leading groups who made a significant contribution to initiating the EIP programme at the local level as well as at the national level.

Yeosu has experienced a series of environmental disputes and cooperation between various stakeholders. As a result of this societal interaction, the local governance, Co-Development Committee, was established in 1999. Eleven large firms represent the industrial community in the committee. Most issues related to environmental problems generated from the petrochemical cluster are discussed with the public sector and the NGO sector. Furthermore, the firms report their social contribution activities to the committee and get supports and feedback from the other local actors. The public sector and the NGO sector also suggest their ideas on firms' social contribution and plan cooperative projects with the industrial sector within the committee. Therefore, Co-development Committee can be seen as an institutional support system for the cluster's social upgrading.

Through frequent contacts with the non-firm local actors and various collaborative projects, the sense of belongingness to the Yeosu region and solidarity with other local actors has formed among the large petrochemical and chemical firms. It seems that the firms' attachment to the Yeosu region encouraged themselves to participate in the EIP programme. The local actors agreed to initiate the EIP programme in Yeosu at a meeting of Co-development Committee (Interview YO-R1). All the firms interviewed during the fieldwork disclosed their opinions that EIP is a contribution to the regional development (Interview YO-F1, YO-F2, YO-F3). Therefore, it can be argued that the firms' recognition of the EIP programme as a social contribution to regional development is a result from interactive learning for regional sustainability.

6.5. Conclusion

By drawing on empirical evidence from the Yeosu petrochemical cluster, this chapter addresses the two research questions: "how does the nature of the local production system affect the EIP development of clustered firms?" and "in what way do institutional support systems facilitate the collective actions of clustered firms to promote EIP development?" This concluding sector discusses the findings from the case study on the Yeosu petrochemical cluster with regards to the two research questions.

Petrochemical and chemical firms tend to agglomerate within a geographically limited area. Because they process materials in gas or liquid state, clustering is inevitable to save logistics costs. All production stages of the petrochemical industry are arranged in accordance with highly codified chemical engineering technology. These characteristics as a capital and technology intensive industry as well as a material circulation system are embodied in the unique form of localised producer-driven value chains. The forward vertical linkages of the petrochemical cluster consist of vertically integrated production stages which are respectively occupied by one or a few large firms. The backward vertical linkages are comprised of chemical engineering and construction service units that are normally high-tech SMEs. Due to the nature as a high tech industry, the petrochemical value chains can be categorised as modular governance. As for the cluster's horizontal linkages, it is noticeable that 29 large petrochemical and chemical firms constitute their horizontal tie in the form of local industrial association. They regularly meet, share information and make collective-decisions and organise joint actions in terms of environmental issues. The Yeosu region hosts few innovation support institutions. Instead, the industrial sector, the public sector and the NGO sector has a regional consultative committee through which all local stakeholders can discuss common issues and organise collaborative projects.

The nature of the production system and the institutional support system has influenced the petrochemical cluster's environmental upgrading toward EIP development. First of all, the sector-specific features of the petrochemical industry should be considered. The petrochemical and chemical industry is basically a material circulation system. Moreover, by-products from a firm can be easily reused by other firms in the petrochemical and chemical sector. Accordingly, the potential to exchange by-products is an agglomeration gain. However, this sector-specific nature alone cannot explain how the EIP development has entrenched in the Yeosu petrochemical cluster from a few self-organising industrial symbioses to the planned EIP.

Thanks to this agglomeration gain inherent in the petrochemical industry, a few self-organising industrial symbioses have been established in the Yeosu petrochemical cluster. However, industrial symbiosis practices had not been disseminated across the whole cluster before the EIP programme was launched in the Yeosu region. In order to disseminate industrial ecology practices and establish various industrial symbioses at the whole cluster level, cluster-wide joint actions should be taken place. The local industrial

association, YIEA, served as a coordinator at the initial phase of the EIP programme and a channel through which industrial ecology principles are disseminated. This suggests the importance of high coordination governance of the cluster's horizontal linkages for the EIP development. Combined with the agglomeration gain of by-product exchange inherent in the petrochemical sector, the coordinated joint actions have triggered the dynamics of collective efficiency toward the EIP development in the Yeosu petrochemical cluster.

Once the dynamics of collective efficiency has been activated, the EIP programme gives rise to the effect of enhancing the backward vertical linkages in accordance with value chain dynamics. An increasing number of small and medium sized chemical engineering companies have applied for the EIP programme. The small and medium sized engineering companies located in the region are high-tech firms. As they are engaged in the subsystem of the petrochemical and chemical industry as subsidiary engineering service units, the SMEs have to be equipped with advanced technical and engineering knowledge. While participating in the EIP programme, the SMEs aim to create new business opportunities or expand their current business by using by-products generated from the large petrochemical and chemical firms. In this process, various ideas are suggested and new technologies are tested. This means that that SMEs working in the backward vertical linkages of the Yeosu petrochemical cluster play the role of knowledge providers in the EIP programme. As their activities belong to the cluster's backward vertical linkages, this phenomenon has resulted in the functional improvement as well as the organisational expansion of the backward vertical linkages.

The influence of the cluster's institutional support system on EIP development is relatively weak in the Yeosu region in terms of knowledge generation. The small contribution to the EIP development from the innovation support organisations largely stems from the characteristics of the cluster's institutional support system as grassroots RIS. However, it cannot be ignored that the local community has been actively involved in the environmental upgrading of the petrochemical cluster. The petrochemical sector has collaborated with the public sector and the NGO sector through their regional consultative body, Co-Development Committee, which can be regarded as a social upgrading supporting system. Combined with the long experience of struggles and cooperation with the local community and, the interaction with local stakeholders through the regional political decision-making system has helped the large petrochemical and chemical firms to have the sense of belongingness to the region and solidarity with the local community. The

firms' attachment to the Yeosu region provides the explanation of why the petrochemical and chemical firms tend to see their participation in the EIP programme as a contribution to the regional development. Although this aspect is less relevant to the conventional frameworks of the industrial cluster approach and the RIS approach, it is evident that some sorts of socio-cultural dynamics underpin the EIP development in the Yeosu petrochemical cluster.

VII. COMPARATIVE ANALYSIS AND LESSONS

7.1. Introduction

The Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster have very different structure of production systems and very different characteristics of institutional support systems. Despite these differences, both clusters have shown meaningful environmental upgrading including EIP developments. This raises the last research question: “what are the comparative lessons from the different environmental upgrading strategies between the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster?”

In order to answer this question, this chapter takes three analysis steps. As the first step, section 7.2 compares the two clusters’ environmental upgrading patterns emerging from three structural differences: SME cluster versus large firm cluster, globalised buyer-driven value chains versus localised producer-driven value chains and state-led institutional support system versus community-led institution support system. Second, section 7.3 is dedicated to analysing the similar and/or different influences of the four social factors of industrial ecology on the two clusters’ EIP development. Through this I explore the key determinants that promote environmental upgrading of clustered firms. Finally, section 7.4 is summarises the main findings from the comparative analysis and the implications for formulating a collective eco-efficiency mechanism.

7.2. Comparative Analysis on Environmental Upgrading

Although both industrial clusters have achieved EIP developments, their environmental management systems and specific types of environmental joint actions are differentiated due to the unique characteristics of the production and institutional support system in each cluster. The Banwol-Sihwa textiles dyeing cluster and the Yeosu petrochemical cluster have three noticeable differences. These relate to the size of clustered firms, the types of value chains they are inserted into, and the context of institutional structures. Through a comparative analysis, focusing on these three differences, this section identifies similarities

and differences in environmental management systems and environmental joint actions between the two clusters.

7.2.1. SME Cluster versus Large Firm Cluster: Environmental Upgrading through Horizontal Linkages

The first and the most basic difference between the two clusters is the scale of clustered firms. While the Banwol-Sihwa dyeing cluster is an agglomeration of SMEs, the Yeosu region is dominated by large firms. This different scale of clustered firms has generated different organisational changes and different joint actions within a similar environmental upgrading pattern.

Organisational Changes for Environmental Performance

In both the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster, environmental external diseconomies have been generated in similar ways. The dyeing and printing firms emit similar types of pollutants because they operate similar production lines with similar inputs. Accordingly, they have collectively faced environmental regulations and pressures from the local community. In Yeosu, the situation that the petrochemical and chemical firms have faced is not very different from the dyeing cluster. Due to a series of environmental crises and pollution scandals, for which the clustered petrochemical and chemical firms are commonly responsible, the Yeosu petrochemical cluster has also faced political pressures from the government and the local civil society.

An increasing number of studies have reported that that clustering can bring about economies of scale to redirect negative environmental externalities to positive externalities (Crow and Batz, 2006; Almeida, 2008; Mazzanti and Zoboli, 2009). The case study on the Banwol-Sihwa dyeing cluster resonates with these previous studies. In addition, the Yeosu petrochemical cluster shows that, although the types of joint action were different from the SME cluster, large firms also tend to act collectively in order to reduce transaction costs that would be associated with individual pollution monitoring and case-by-case bargaining.

An interesting point is that local firms in both clusters have demonstrated similar forms of organisational behaviour through horizontal inter-firm linkages. The dyeing and printing

firms in Banwol-Sihwa established two business associations, BDEC and SDEC, at the local level. Similarly, the petrochemical and chemical firms in Yeosu are members of YIEA. These industrial associations are specialised in managing environmental issues. BDEC and SDEC in Banwol-Sihwa and YIEA in Yeosu are horizontal inter-firm networks which function as an effective information-sharing channel. Local firms discuss their common environmental issues and make collective decisions upon environmental joint actions

Environmental Joint Actions Based on Pollution Control Based Approach

Although the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster are equipped with similar types of local industrial associations, the environmental joint actions arranged by the two dyeing business cooperatives and the local petrochemical industry association are differentiated. The dyeing and printing firms have focused on introducing and developing technical solutions to environmental concerns. Their collective pollution control methods, common effluent treatment plants and odour control equipment are clearly technical solutions. On the other hand, the environmental joint actions of the petrochemical and chemical firms have been weighted towards non-technical solutions. YIEA has mainly served to conduct pollution monitoring, investigate environmental damage to local communities, and mediate compensation.

These different environmental joint action strategies adopted in the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster stem from the differences in types of clusters and the different firms capabilities within each cluster. The Banwol-Sihwa dyeing cluster is a typical SME cluster. All the dyeing and printing firms have limited technical and financial capability to improve individual environmental management systems. Accordingly, BDEC and SDEC make up for the low degree of technical and financial competence of individual dyeing and printing SMEs. In contrast, large firms are dominant in the Yeosu petrochemical cluster. Each petrochemical and chemical firm has a high degree of technical and financial capacity. Therefore, the large production units located in the Yeosu petrochemical cluster have low motivation to collaborate for technical solutions. Instead, the petrochemical and chemical firms face the necessity for joint negotiation with the local civil society that stems from the long history of environmental disputes and the regional political practice of collective consultation between the industrial sector, the

public sector and the NGO sector. This difference between the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster has been reflected in the characteristics of BDEC and SDEC, as technical ancillary units, and the YIEA, as an ancillary administrative service unit.

The other important point is that environmental joint actions via horizontal inter-firm linkages employ the most rudimentary types of environmental management practices based on a pollution control approach. The dyers' first response to the environmental problems was to invest in collective pollution prevention facilities such as common effluent treatment plants and odour control systems. Pollution-monitoring and compensation that have been collectively conducted by the petrochemical and chemical firms are also measures to treat pollutants already generated. These environmental joint actions are reactive, in that they were driven by national regulatory pressures and local community campaigns, and required various forms of local collective action after pollution crises.

The First Phase of Environmental Upgrading: Reactive Collective Eco-efficiency

Given that clustering creates physical conditions under which firms can realise scale economies in environmental management, firms organised local enterprise associations in order to arrange environmental joint actions in both clusters. Regardless of the different scales of clustered firms between the textiles dyeing cluster and the petrochemical cluster, this tendency is commonly observed. Furthermore, the environmental joint actions through the horizontal ties aimed to adopt *ex post* measures based on the pollution control approach in both clusters, although the specific types of such measures are differentiated. Considering that these rudimentary *ex post* environmental management measures tend to be collectively adopted through intra-sectoral horizontal ties, I consider this a 'horizontal' form of collective eco-efficiency and the first phase of each cluster's environmental upgrading.

[Table 7-1] Comparative Analysis: SME Cluster versus Large Firm Cluster

	Banwol-Sihwa	Yeosu	Common Patterns
Structural Difference	SME agglomeration	Large firm agglomeration	Clustering provides a condition under which firms can realise scale of economies in environmental management.
Passive gains	Scales economies in environmental management	scales of economies in environmental management	
Organisational Changes	Local enterprise association as ancillary engineering unit	Local enterprise association as ancillary administrative unit	Intra-sectoral horizontal ties are the main dimension in which firms make primary response to environmental concerns.
Types of joint actions	Technical measures like sharing effluent treatment plants	Non-technical measures like collective negotiation and compensation	Firms tend to undertake <i>ex post</i> measures based on the pollution control approach

*Source: Author

7.2.2. Global Buyer-driven Value Chains versus Local Producer-driven Value Chains: Environmental Upgrading through Vertical Linkages:

The second notable difference between the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster is their value chain types. The dyeing and printing firms in Banwol-Sihwa are part of global buyer-driven value chains, while the petrochemical and chemical firms constitute local producer-driven value chains in the Yeosu region. The different characteristics inherent in these two value chains have also affected the environmental upgrading patterns in the two industrial clusters.

Organisational Changes for Environmental Performance

In the Banwol-Sihwa textiles dyeing cluster, a notable organisational change is that environmental standards set by global lead firms have triggered a variety of R&D consortia to introduce and develop cleaner production technologies in the backward linkages of the

Banwol-Sihwa textiles dyeing cluster. The garment industry produces consumer goods with intermediary goods supplied by raw material processing industries. Accordingly, the main concern of global retailers and multinational branded clothing companies is improving their reputation by showing international environmental certificates or eco-labels on their goods. The global buyers and Korean vendors who trade with the Banwol-Sihwa dyeing cluster regularly check whether the local producers comply with codes of conduct and meet international environmental standards. In response, the dyeing and printing firms have expanded their environmental management strategies from the pollution control approach to the cleaner production approach. Various R&D activities to substitute toxic chemical inputs, reduce energy consumption and improve equipment have been carried out in the Banwol-Sihwa textiles dyeing cluster. These activities have resulted in a series of R&D consortia organised between the dyeing sector, the dyestuff suppliers, the chemical additives suppliers, the dyeing equipment manufacturers and the local R&D centres. The local innovation support institutions like KITECH have actively mediated the interaction between the textiles dyeing business and its input suppliers since the mid 1990s. The dyeing cluster's partnership with KICOX, KITECH, KTL, Hanyang University and KPU has been built while various R&D projects have been repeatedly conducted.

In Yeosu, the lead firms such as the petroleum refinery and the naphtha cracking firms have also encouraged other firms to follow their compliance programmes. This has given rise to organisational changes through the specific corporate governance structure of petrochemical and chemical firms located in the Yeosu region. As identified in chapter 6, most large petrochemical and chemical firms fall into several affiliated groups under the ownership of Korean *cheabols* or multinational chemical companies, and such affiliates are normally in input-output relationships with each other. Each affiliate firm group has their inter-firm channels. Under this type of corporate governance structure, the petrochemical and chemical firms have reinforced 'internal' channels to exchange information on environmental management between affiliated firms or have 'in-house' committees to discuss environmental compliance with partner firms, including subcontractors. The Kumho group's meeting of environmental managers among its five affiliate firms is an example of the former and GS-Caltex's CSR compliance committee is an example of the latter.

Environmental Joint Actions from Cleaner Production to Self-organising Industrial Symbiosis

In both the globalised garment value chain and the localised petrochemical value chain, leading firms take environmental compliance throughout their value chain seriously (Interview AN-F6, AN-F7, YO-F1, YO-F2). However, the types of environmental joint actions taking place along the value chains have become differentiated. As analysed in chapter 5, the main environmental joint actions undertaken by the dyeing and printing firms in response to international environmental standards are R&D activities to localise eco-labels, invent more resource-efficient equipment and reduce toxicity in chemical additives. On the other hand, the petrochemical and chemical firms located in Yeosu have taken a step further toward a distinctive environmental joint action, the establishment of self-organising industrial symbioses throughout the petrochemical value chains.

Why have the joint actions relevant to the value chains of the two industrial clusters become differentiated? To understand this differentiation, the multiplicity of production stages within the two industrial clusters is worthy of notice. All firms located in the Banwol-Sihwa dyeing cluster are engaged in the same production stage in the garment value chain, dyeing and printing. Firms engaged in the same production stage tend to use similar raw material inputs with similar equipment and manufacturing techniques. Accordingly, firms working at the same production stage can easily adopt new environment-friendly manufacturing practices together. This, in the Banwol-Sihwa dyeing cluster, newly invented dyeing equipment and dyestuffs have been quickly disseminated across the cluster. However, a single production stage cluster has greater difficulty in developing industrial symbioses initiatives at the intra-cluster level because the variety of by-products from one production stage is limited. Due to the low heterogeneity of by-products, single production stage clusters like the Banwol-Sihwa dyeing cluster do not need to create many by-product exchange networks with other industrial sectors.

In contrast, an industrial cluster composed of multiple production stages has limited opportunities to adopt the same types of manufacturing practices. Instead, firms engaged in different production stages tend to have more opportunities to exchange by-products within their value chains because different production stages require different sorts of material inputs and discard different by-products. In the Yeosu petrochemical cluster, the petrochemical and chemical firms are in operation at different production stages within the

same sectoral boundary. This has firstly resulted in their collective adoption of the industry-specific initiatives like Responsible Care (Interview YO-F1, YO-F2, YO-F3). Furthermore, thanks to the heterogeneity of by-products generated from multiple production stages, some self-organising industrial symbioses had already germinated from the petrochemical value chains before the EIP programme was formally launched in Yeosu: for instance, the nascent by-product hydrogen exchange networks within the boundaries of affiliate firm groups (Interview YO-I3), the exchange of hydrochloric acid between Hanhwa Chemical and Kumho Mitsui Chemicals (Interview YO-I3) and the stem exchange among the affiliate firms of the Kumho company group (Interview YO-F3).

The Second Phase of Environmental Upgrading: Vertical Collective Eco-efficiency

The characteristics of value chains significantly affect clusters' environmental upgrading. In the case of the Banwol-Sihwa textiles dyeing cluster, it is noticeable that backward vertical linkages play an integral role in terms of bringing about cleaner production. Traditionally, most studies on the garment value chain have focused on the role of global retailers, due to the industry's overall characteristics as a buyer-driven value chain (Gereffi, 1999; Mayer and Pickles, 2010). However, innovation has been conducted through cooperation between the textiles dyeing business and its raw material and equipment suppliers. Moreover, innovation support institutions have been actively involved in this environmental innovation process. This implies that some less discovered parts of vertical linkages in the apparel value chain deserve special consideration together with the increasing concerns over environmental degradation. In the case of the Yeosu petrochemical cluster, the value chains consist of multiple production stages within a limited geographical area as well as having the nature of material flows. These characteristics of the petrochemical value chains have obviously worked as an advantage in establishing self-organising industrial symbioses.

The environmental upgrading that has emerged from the value chain governance has two features. Firstly, the environmental joint actions are not only reactive but also proactive. The dyeing cluster's project to invent a new energy and water efficient type of dyeing equipment was voluntarily initiated at the local level with little involvement or pressure from global buyers and garment retailers. Similarly, the petrochemical sector's self-organising industrial symbioses was built through by-product exchange networks as part of

their own business strategy. The other feature is that the environmental upgrading in the vertical dimension is between the pollution control approach and the industrial ecology approach. The cleaner production practices triggered by global lead firms and developed by local producers in the Banwol-Sihwa dyeing cluster are more advanced than end-of-pipe measures and less holistic than EIPs. The establishment of self-organising industrial symbioses in the Yeosu petrochemical cluster has served as the stepping-stone to a full-fledged EIP. In this regard, it can be seen a ‘vertical’ form of collective eco-efficiency.

[Table 7-2] Comparative Analysis: Global Value Chains versus Local Value Chains

	Banwol-Sihwa	Yeosu	Common Patterns
Structural Difference	Globalised buyer-driven value chains	Localised producer-driven value chains	Lead firms’ environmental standards trigger environmental upgrading of local producers via value chain governance
Passive gains	Effective knowledge spillover between similar production stages	Heterogeneous by-products due to multiplicity of production stages	
Organisational Changes	R&D consortia with related industries	Knowledge exchanges among affiliate firms	Vertical inter-firm ties are the main dimension in which environmental innovation takes place as a business strategy.
Types of joint actions	Toxicity reduction, equipment substitution & resource efficiency	Self-organising industrial symbioses	Firms tend to undertake <i>ex ante</i> measures from cleaner production to self-organising industrial symbiosis

*Source: Author

7.2.3. Government Intervention versus Community Involvement: Environmental Upgrading through Regional Linkages

The final major difference between the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster relates to their institutional support systems. The dyeing cluster’s institutional support system has been built by strong government intervention as a part of Banwol-Sihwa’s RIS, while the institutional support system surrounding the Yeosu

petrochemical cluster is a regional consultative committee which is designed to allow active community involvement. The comparison between these two different institutional support systems is crucial in implementing the EIP programmes in the two clusters.

Organisational Changes for Environmental Performance

In the Banwol-Sihwa region, it is obvious that all cooperative interactions between the dyeing cluster and the innovation support organisations for environmental upgrading are directly related to state initiatives. The two university-based environmental technology centres, AGECE and SHGEC, have provided engineering consulting services to the dyeing and printing firms with public funds from central and local government. KITECH is a government research institute that has carried out various R&D projects aimed at applying cleaner production practices to the dyeing process by using national R&D funds. In fact, there have been “countless visits from various public agencies” to suggest and discuss potential R&D activities related to environmental issues, and such R&D projects are “a major part of everyday work” (Interview AN-I1, AN-I2). In addition to technical and financial support, public non-firm institutions, especially KITECH and KICOX, have served as coordinators that promote inter-sector cooperation in the Banwol-Sihwa region. KITECH has organised various R&D consortia by inviting the dyeing sector, the dyestuff and chemical additives suppliers and the dyeing equipment manufacturers. KICOX has mediated between the dyeing sector and its by-product exchange counterparts in the EIP programme.

One is reminded of South Korea’s characteristics as the classic ‘developmental state’ in reviewing the active involvement of public institutions in the dyeing cluster’s environmental upgrading. Clearly, the dyeing cluster’s environmental upgrading has heavily relied on government intervention. The EIP programme is also a state initiative. However, state interventions to improve environmental performance of clustered firms in the Banwol-Sihwa region have been implemented through cooperative networks of local actors. Instead of the central government, local (or localised) public agencies take the leadership in implementing state initiatives at the local level. In contrast to the conventional belief that the Korean developmental state model is a top-down approach with *chaebol*-centric industrial policies, innovation support policy measures for SMEs and inter-firm networks are much more strongly developed by the central government (Hassink,

2002). Therefore, it should be argued that such a traditional viewpoint on the Korean developmental state model needs to be updated. The case study on the Banwol-Sihwa region shows that the Korean government has changed its focus of industrial policy measures toward the SME-oriented qualitative development at the local level.

In Yeosu, a very different story has unfolded. The EIP programme was initiated and has been implemented through the industry-community cooperation. Although some external research groups and local universities have been engaged in Yeosu's EIP programme, especially in the initial stage, the contribution from innovation support organisations is much less significant than in the Banwol-Sihwa region. This is, first of all, because a large part of the innovation capacity in Yeosu relies on the large firms' research departments and high-tech chemical engineering companies working in the backward vertical linkages of the cluster. More importantly, the industrial sector and the civil society have directly confronted and collaborated with each other since the oil-spill accident in 1995. As a result, the petrochemical and chemical firms have been embedded in a relationship with local civil society. The regional consultative Co-development Committee, consisting of the industrial sector, the public sector and the NGO sector, is the empirical evidence showing that the embeddedness of the petrochemical and chemical firms is structured. As firms are strongly embedded in relationships with local stakeholders, the industry-led knowledge development system reflects local community interests.

Environmental Joint Actions from Cleaner Production to EIP

In both the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster, interaction between clustered firms and non-firm actors has propelled environmental upgrading from cleaner production to EIP. However, the difference between the two clusters' institutional support systems has led to specific pathways to EIP developments. While the EIP development in the Banwol-Sihwa dyeing cluster has been promoted by industry-academy-public cooperation at the local level, industry-community cooperation has propelled EIP development in the Yeosu petrochemical cluster.

In the Banwol-Sihwa region, the main function of the dyeing cluster's institutional support system is knowledge generation. The textile dyeing sector is conventionally based on tacit knowledge related to know-how and craft rather than scientific knowledge. However, a variety of changes in the textile business, such as diversification of fabric materials,

expansion of textile use in various industries and shortage of experienced workers have brought about the need for more scientific knowledge in the Banwol-Sihwa dyeing cluster. Environmental pressure is one of these changes. Cleaner production practices such as toxicity reduction and equipment substitution have led to the conversion of the dyeing and printing process from a low-tech to a more high-tech based manufacturing process. In terms of the EIP programme, although the industrial ecology approach seeks the best available technologies rather than cutting-edge technologies, by-product reuse and energy cascading is less relevant to traditional dyeing and printing techniques. As a result, the dyeing and printing firms have increasingly relied on collaboration with local innovation support organisations and public R&D funds. In response, the Gyeonggi EIP Centre has concentrated on coordinating industry-academy-public cooperation by using public R&D funds from the central government.

The institutional support system surrounding the Yeosu petrochemical cluster is far less focused on generating and disseminating scientific knowledge, as compared with the Banwol-Sihwa region. Given that the petrochemical and chemical firms had already realised the industrial ecology approach in the form of self-organising industrial symbioses beyond the cleaner production approach and the pollution control approach, the Yeosu-based NGOs played an integral role in moving the petrochemical cluster forward from the stage of self-organising industrial symbiosis to the stage of EIP by organising a national-scale movement. At the local level, the EIP programme was launched with consent between the industrial sector, the public sector and the NGO sector in the form of a common enterprise. A few EIP projects were practically discussed and planned at meetings of the Co-development Committee before the Jeonnam EIP Centre was established.

The Third Phase of Environmental Upgrading: Region-wide Collective Eco-efficiency

The EIP programme is without doubt a state initiative in South Korea. However, this national-level decision does not take the form of a command-and-control measure but of an industrial policy framework through which local firms can improve their environmental performance in a flexible and autonomous manner. In the Banwol-Sihwa region, the realisation that there were opportunities to convert waste outputs into recycled inputs has motivated BDEC and SDEC to create by-product exchange and energy-cascading networks beyond the sectoral boundary of the textiles dyeing business. The innovation support

institutions like KICOX and KITECH have also been actively involved in establishing the industrial symbioses. In Yeosu, the large petrochemical and chemical firms have used the EIP programme as a chance to pursue economic benefits and social benefits at the same time. In addition, the engineering service companies working in the backward linkages of the Yeosu petrochemical cluster have created new business and/or expanded existing business. From the point of view of the Yeosu-based NGOs, the EIP programme has functioned as a direct measure by which they can encourage local firms to make contributions to regional environmental improvement. In short, the EIP developments being promoted and implemented through the region-wide linkages in both the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster represent a proactive type of inter-firm joint action and involvement of non-firm local actors. Therefore, I term this most pro-active phase of environmental upgrading as a region-wide collective eco-efficiency.

[Table 7-3] Comparative Analysis: Government Intervention versus Community Involvement

	Banwol-Sihwa	Yeosu	Common Patterns
Structural Difference	State-led RIS	Industry-led RIS	The EIP programme was launched as a policy measure with local actors in cooperative relationships can improve environmental performance in an autonomous and flexible manner.
Passive gains	Sufficient knowledge source given by state initiatives	Strong grassroots movement	
Organisational Changes	Industry-academy-public cooperation networks	Regional consultative committee between the industrial sector, the public sector and the NGO sector	Region-wide institutional linkages are the main dimension in which firms and other actors interact and collaborate for environmental performance.
Types of joint actions	EIP development	EIP development	Firms tend to attain a full-fledged EIP.

*Source: Author

7.2.4. Summary: Cluster's Environmental Upgrading Pattern

This section compares the two clusters' environmental upgrading by considering the three different characters of the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster; SME cluster versus large firm cluster in the horizontal dimension; global buyer-driven value chain versus local producer-driven value chain in the vertical dimension; and government intervention versus community involvement in the region-wide dimension.

The first comparative analysis focused on the environmental upgrading that has emerged from the two clusters' horizontal linkages reveals that clustered firms tend to realise economies of scale in environmental management by organising a local enterprise association. Due to the disparity in financial and technical competence between the SMEs and the large firms, the environmental joint actions based on the horizontal inter-firm ties in the Banwol-Sihwa dyeing cluster have placed emphasis on technical solutions like

facility-sharing while the petrochemical and chemical firms have focused on non-technical measures. The main environmental management strategies that have emerged from the horizontal inter-firm linkages in both industrial clusters are, regardless of the difference in their specific types of joint actions, categorised as the pollution control approach. I term this reactive environmental upgrading pattern as a horizontal form of collective eco-efficiency.

The second comparative analysis pays attention to the environmental upgrading that has emerged from the two clusters' vertical linkages. In the case of the Banwol-Sihwa dyeing cluster, global buyers' environmental standards have encouraged cooperative R&D activities between the textiles dyeing business, its related industrial sectors like dyeing equipment manufacturers, dyestuff manufacturers and chemical additives suppliers, and local innovation support institutions. The dyeing cluster's environmental joint actions in this phase have concentrated on participating in various R&D consortia and thus introducing cleaner production technologies into their manufacturing process. In Yeosu, it is noticeable that the environmental upgrading through the petrochemical value chains has attained self-organising industrial symbioses thanks to the multiplicity of production stages and the industry-specific character as a material processing sector. Technically speaking, cleaner production and self-organising industrial symbiosis are an intermediate stage between pollution control and EIP. In addition, the environmental joint actions undertaken via the vertical inter-firm linkages in both the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster are not simply reactive responses to the requests from lead firms but also proactive business strategies. I term the environmental upgrading from cleaner production to self-organising industrial symbiosis through the vertical inter-firm linkages as a vertical form of collective eco-efficiency.

The final comparative analysis focused on the two clusters' environmental upgrading in the region-wide context exposes two different pathways toward EIP development. In Banwol-Sihwa, the industry-academy-public cooperation was one of the keys to success in establishing and implementing the EIP. In the case of the Yeosu petrochemical cluster, the community involvement in encouraging the large firms to participate in the EIP programme, and the Jeonnam EIP Centre's role in supporting engineering service companies to access the large petrochemical and chemical firms, were critical for the establishment of EIP. The environmental joint actions to establish the EIPs in both the Banwol-Sihwa region and the Yeosu region are proactive, in that local firms have

voluntarily created by-product exchange and energy-cascading networks in order to generate economic benefits as well as environmental benefits. This third phase of an industrial cluster's environmental upgrading can be seen as a region-wide form of collective eco-efficiency.

7.3. Comparative Analysis on the Social Dimension of EIP Developments

As identified in the previous section, an industrial cluster tends to go through three phases of environmental upgrading toward EIP development. This is a meaningful finding for both the industrial cluster literature, given that the studies addressing environmental issues in the industrial cluster literature have paid limited attention to pollution control measures. However, this still raises a question: what elements move an industrial cluster from one phase of environmental upgrading to the next phase of environmental upgrading? In this regard, the industrial ecology literature suggests four social factors influence EIP development: mental distance, role of champion, institutional setting and planning. Although these four social factors are not well-established theoretical framework, they can be instrumental to explore key determinants in environmental upgrading. In this line of thinking, this section compare the influence of mental distance, role of champion, institutional setting and planning on the environmental upgrading patterns in the Banwol-Sihwa textiles dyeing cluster and the Yeosu petrochemical cluster. Through this analysis the four social factors are re-sharpened as three key determinants that promote the two clusters' environmental upgrading.

7.3.1. Mental Distances

The first social factor that is employed in order to understand the social dimension of the EIP developments in the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster is mental distance. Industrial ecologists define 'mental distance' as psychological intimacy between neighbouring potential symbiosis partner firms (Ehrenfeld and Gertler, 1997; Chertow, 2000). Many authors in the field of industrial ecology insist that short mental distance is highly relevant to cooperative business culture and existing social

networks (Lowe and Evans, 1995; Ehrenfeld and Gerter, 1997; Gibbs et al., 2004; Gibbs and Deutz, 2007; Asthon, 2008; Paquin and Howard-Greville, 2009). In both the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster, short mental distance has clearly existed and affected the clusters' environmental upgrading toward EIP developments. More interestingly, when comparing the influence of mental distances between the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster, it becomes clear that there are three levels of mental distance.

Three Distinct Levels of Mental Distance

Intra-sectoral Inter-firm Level: The first level where short mental distance is observed is the intra-sectoral inter-firm relations. In Banwol-Sihwa, the dyeing and printing firms open and exchange internal information on pollution with each other and entrust environmental management to BDEC and SDEC. This trust, openness and collective representation is a clear sign of short mental distance among the dyeing and printing firms. In fact, the short mental distance among the dyeing and printing firms is not only related to environmental issues. They have developed their social ties since the mid-1950s and a variety of joint actions have been conducted through these social ties since the 1970s. This means that the inter-firm relations have been embedded among the dyeing and printing firms for a long time and, therefore, the environmental joint actions from sharing the common effluent treatment plants to establishing the industrial symbioses were easily organised through the embedded relations. In Yeosu, the petrochemical and chemical firms have developed and maintained their close inter-firm relationships as the member firms of YIEA, while they were commonly confronted with a series of strong civil society actions and government regulations. In addition, affiliated firms under the same corporate governance regularly meet to build relationships and share exemplary environmental management practices with each other. The Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster shows that such cooperative inter-firm relationships have materialised in the form of local industrial association and collective decision-making on environmental joint actions. Therefore, it can be said that the persistence of systematically organised joint actions within both single-industry clusters clearly proves the short mental distance at intra-sectoral inter-firm level.

Inter-sectoral Inter-firm Level: Theoretically, it is supposed that short mental distance exists or should exist to some extent when an EIP is established between heterogeneous industries. This is practically true in the Kalundborg Symbiosis (Grann, 1997), which is known as the ideal model in the industrial ecology literature. However, the case studies on the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster issue a strong counterargument. The six industrial symbioses investigated in this doctoral study prove that the inter-sectoral inter-firm mental distance had little influence in building the by-product exchange and energy cascading networks. In Banwol-Sihwa, the textiles dyeing cluster and the cogeneration plant that engaged in the wastewater heat exchange network together were not co-operative when the EIP project was underway (Interview AN-I7). The cement manufacturer using sludge from the dyeing sector and the chemical firm importing oil ingredients extracted from the dyeing sector's air pollution did not have any relationship with the dyeing business before the EIP programme. In Yeosu, the hydrogen recycling network and the effluent sludge recycling network had not emerged from inter-sectoral but from intra-sectoral inter-firm relationships. The network to recycle waste platinum catalyst is not relevant to short mental distance. Rather, this was a case where the public agency helped a SME shorten its long mental distance with large firms.

Regional Firm-Institution Level: The comparative analysis on the influence of mental distance between the two clusters' EIP development uncovers one more relationship in which short mental distance has formed and through which short mental distance affects clusters' environmental upgrading. In both the Banwol-Sihwa region and the Yeosu region, clustered firms and non-firm actors have routinely interacted with each other and developed certain types of partnerships in order to improve the environmental performance of clustered firms. Due to the characteristics of the Banwol-Sihwa region as a dirigiste RIS, the short mental distance between clustered firms and non-firm actors has been expressed in continuous and routinized learning-by-interaction through industry-academy-public cooperation. On the other hand, the Yeosu region is a more explicit example showing that the short mental distance between clustered firms and non-firm actors influence an industrial cluster's environmental upgrading. Most of all, the Yeosu region has a regional consultative body, the Co-Development Committee between Yeosu City and Yeosu Industrial Complex, through which the industrial sector, the public sector and the NGO sector discuss common regional issues, share information and make collective-decisions.

Considering that all three sectors have adhered to agreements as well as having seldom refused requests from the others (Interview YO-R2), it is evident that the short mental distance between industry and community takes the form of structural embeddedness. Moreover, the petrochemical and chemical firms have strong attachment to the region (Interview YO-F1, YO-F2, YO-F3). Due to this sense of belongingness, the large firms have recognised the EIP programme as a part of social contribution to community development and the involvement from local NGOs in the EIP programme is much more highly acceptable than in the other regions.

The First Key Determinant: Scope of Cooperative Relationship

All the empirical evidence expressing mental distance, such as the openness in sharing information on pollutions, the collective representation in environmental management, the partnerships with innovation support institutions and the firms' attachment to local communities can be summarised as cooperative relationships. The case studies on the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster prove that the mental distances among actors involved in environmental performance of clustered firms are not just psychologically close. Their real behaviour is practically interdependent so that clustered firms and non-firm institutions have made collective decisions and conducted joint actions. A state where behaviour and institutions are dependent on social relations is defined as embeddedness (Granovetter, 1985). In this regard, short mental distance refers to cooperative relationships connoting embeddedness.

The first comparative analysis on the social dimension of clusters' EIP development focusing on the mental distance factor shows that cooperative relationships matter at three different levels of relationship; intra-sector inter-firm level, inter-sector inter-firm level and regional firm-institution level. The cooperative relationships at the intra-sector inter-firm level are highly developed in both clusters. However, at the inter-sector inter-firm level, cooperative relationships have hardly existed and have not greatly affected building an industrial symbiosis. At the regional level, while cooperative relationships take the form of industry-academy-public partnerships in the Banwol-Sihwa region, the relationship between the petrochemical sector and the other local actors in Yeosu has been structured as a regional consultative committee.

In the industrial ecology literature, it is traditionally supposed that mental distance exists between firm managers who perceive opportunities for materials reuse/exchange (Chertow and Ashton, 2009). However, the finding from the comparative analysis on the influence of mental distance is that this traditional view is too narrowly focused on inter-sectoral inter-firm relationships. In reality, firms are strongly embedded in the intra-sectoral inter-firm relations and regional relations with a variety of stakeholders such as public agencies, R&D centres and NGOs. In both the Banwol-Sihwa textiles dyeing cluster and the Yeosu petrochemical cluster, the intra-sectoral inter-firm relationships facilitated joint actions to adopt end-of-pipe measures. As cooperative relationships have gradually expanded beyond sectoral boundaries and embraced a variety of actors, the two clusters have advanced toward EIP developments. Therefore, it can be supposed that scope of cooperative relationship is a key determinant to explain an industrial cluster's environmental upgrading.

7.3.2. Role of Champions

Role of champions is proposed as the second social factor that influences the two clusters' EIP development in this doctoral study. In the industrial cluster literature, the term 'champion' conventionally refers to lead firms that govern value chains inside or outside industrial clusters. As for the industrial ecology literature, champion connotes more than the notion of lead firm. Hewes and Lyons (2008) define champions as organisations or persons who induce firms to become involved in the establishment of an EIP. The case studies on the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster shows that there are three types of champions who have contributed to the two clusters' environmental upgrading in practice: lead firms; anchor; and network broker.

Roles of Champions as Lead Firm: It is confirmed that lead firms play integral roles as environmental rule setters in the apparel value chains and the petrochemical value chains. In the Banwol-Sihwa dyeing cluster, as international environmental standards and global buyers' codes of conduct are recognised as "trade barriers" (Interview AN-F3, AN-I2), these private rules have stimulated the local producers' cooperation for survival together with the government regulations and, consequently, the dyeing and printing firms have enlarged their pollution control facilities and improved their technical knowledge of pro-

environment manufacturing processes and the environment-friendly quality of their products. Similarly but more directly, the lead firms located at the centre of the petrochemical value chains in Yeosu have introduced a variety of environmental compliance programmes and the other firms have adapted to these private rules and environmental management practices.

Roles of Champions as Anchor Tenant: However, the lead firms' role is somewhat limited in the EIP programme. In the Banwol-Sihwa dyeing cluster in particular, it turns out that the two industrial associations, BDEC and SDEC, have functioned as champions in managing pollution control systems and building by-product exchange networks. In other words, BDEC and SDEC play the role of champion as an anchor tenant by operating common effluent treatment plants. The existence of such anchor tenants is required because there is a discrepancy between value chains and material flows in the garment industry. As the global value chain perspective has mainly investigated flows of components and raw materials as a sequence of value creation activities (Sturgeon 2009), the processes of production, distribution and consumption in the value chain context are not closely associated with environmental issues (Coe, et al, 2008). This implies that a value chain does not necessarily match a flow of materials including by-products, wastes, energy and water. Especially with regard to globalised value chains like the fashion industry, it is normal that only commercially valuable components and raw materials are transferred from one production stage to another production stage across a border. However, at the local level, an environmental management system to care for the whole range of material flows is necessarily required in order to maintain environmental sustainability. Because BDEC and SDEC are in charge of operating common effluent treatment plants that treat all wastewater from individual production units and send useful by-products to other industries, they can function as one of the private hubs within the web of material flows in the Banwol-Sihwa region.

In the Yeosu region, the petrochemical sectors a material processing industry. In addition, there is no clear separation between products and by-products in the petrochemical and chemical business. This means that the value chains of the Yeosu petrochemical cluster itself are a set of material flows. In this business circumstance, the lead firms such as the petroleum refinery and the three naphtha cracking units play the role of anchor tenant as well. The hydrogen recycling network is a typical example. The three naphtha cracking

units generate by-product hydrogen, and fifteen petrochemical and chemical firms in this network use this material. The project was initially suggested by the petroleum refinery. The most influential lead firm in the Yeosu region identified this material exchange network and the other three lead firms generate by-products useful to their neighbouring firms. In this regard, the lead firms are anchor tenants at least within the hydrogen recycling network.

Roles of Champions as Network Broker: In both the Banwol-Sihwa region and the Yeosu region, the clustered firms alone cannot entrench EIPs because their communication channels are limited within their industrial boundaries. The dyeing cluster's three industrial symbioses are material exchanges with the three different industries: the energy sector, the cement manufacturing sector and the chemical sector. In addition, three research institutes have participated in building the three industrial symbioses respectively. Although BDEC and SDEC have strong coordination power among their member firms, their influence is slight beyond the industrial boundary. Accordingly, there should be someone who can coordinate role-setting for all participants. In the case of Yeosu, although industrial symbioses can be established within same industry in Yeosu, the establishment of EIP is a peripheral issue in the industrial community. YIEA's influence is also limited among its 29 member firms. As an increasing number of SMEs that are not members of YIEA have participated in the EIP programme, in order to use by-products from the large petrochemical and chemical firms, someone who can mediate the large firms and the SMEs has been needed.

This has brought about the necessity for involvement from the public sector. The Gyeonggi EIP Centre in the Banwol-Sihwa region and the Jeonnam EIP Centre in the Yeosu region are the empirical evidence showing that a champion can be deliberately created. Both centres are KICOX's regional implementation agencies specialising in the EIP programme. The case studies on the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster show that local industrial associations and public agencies play the role of champion as network brokers in establishing and implementing EIPs. While BDEC, SDEC and YIEA have used their confidential relationships with the local firms, Gyeonggi EIP Centre and Jeonnam EIP Centre have served as an authoritative government agency in the EIP programme. The private institutions have facilitated intra-sector communication, while the public institutions have organised inter-sector communication. This can be seen from

observing the roles of the three local industrial associations and the two regional EIP centres. Non-firm institutions can be eligible to be a champion in establishing EIPs and the main condition of eligibility as a non-firm champion is providing coordination as a network broker.

The Second Key Determinant: Diversity of Coordination Power

The second comparative analysis on the social dimension of clusters' EIP development focusing on the roles of champions shows that there are three different types of champions: lead firm, anchor tenant and network broker. These three types of champions are basically the source of coordination power for environmental performance of clustered firms. Lead firms set the private rules such as international environmental standards, codes of conduct and environmental compliance programmes through their value chains. These aim to coordinate behaviour of local producers who are engaged in value chains in more environment-friendly ways. The role of anchor tenant should be highlighted with regard to material flows at the local level. While BDEC and SDED manage the flows of materials within the cluster as an anchor tenant, the lead firms hold an additional post of anchor tenants in the Yeosu petrochemical cluster due to the characteristics of its value chains as a system of material flows. In any case, an anchor tenant basically serves to coordinate material flows at the local level. The Third type of champion, network broker, is originally committed to coordination. Especially in terms of the EIP programme, the case studies on the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster show that the two public network brokers, the Gyeonggi EIP Centre and the Jeonnam EIP Centre, have played integral roles in coordinating a variety of actors such as firms, innovation centres, universities, governments and NGOs. Therefore, it is arguable that the sources of coordination power are diverse in clusters' environmental upgrading.

7.3.3. Institutional Setting and Planning

Institutional setting is the third social factor that is supposed to influence the social dimension of clusters' EIP development. In fact, the notion of institutional setting has been used in ambiguous manners in the industrial ecology literature. Moreover, the last social factor that is employed from the industrial ecology perspective, planning, is closely related

to institutional setting, given that EIPs are, in many cases, a target programme designed by governments (Ronch *et al.*, 2013). Accordingly, it can be argued that institutional setting and planning are more interconnected with each other in practice than in theory. The case studies on the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster show that the two factors have influenced the EIP developments in interconnected ways. Through the comparative analysis focused on institutional setting and planning between the two clusters' EIP development, the two social factors can be reframed in two different types of institutional structures: programme implementation system and RIS.

Programme Implementation System: When it comes to the EIP programme, it is certain that both the Banwol-Sihwa region and the Yeosu region have the same type of institutional settings, consisting of an EIP centre and a local steering committee, a group of local environmental practitioners called 'coordinators' and several meetings of local business people and experts called 'forums' respectively (See the details on page 163-164). This arrangement of institutional settings is provided by the state in order to implement the EIP programme (Behera *et al.*, 2012). The reason that central government has demanded to set up this programme implementation system in all the regions designated as EIP areas is obvious. Given that the financial aid from central government accounts for 70 percent of the total budget to implement the EIP programme, it is essential to establish a platform through which resources are distributed from the national level to the local level, as well as performance being reported from the local level to the national level. Accordingly, the primary function of the EIP implementation system organised in accordance with the central government's guidelines is the financial support and its attendant administrative management.

However, the financial dependence on central government does not necessarily mean a restriction on local actors' discretion. On the contrary, the programme implementation system is designed to maximise local actors' discretion in implementing the programme. To understand this aspect, it is useful to explore role assignments pertaining to the EIP centres, the local steering committees, the coordinator groups and the forums in the Banwol-Sihwa region and the Yeosu region. The Gyeonggi EIP Centre is a department of the Gyeonggi Regional Headquarter of KICOX, and the Jeonnam EIP Centre is a department of the Honam Regional Headquarter of KICOX. That is to say, the two EIP centres have been derived from the localised institution. In both Banwol-Sihwa and Yeosu,

members of the steering committees are invited from local firms, public agencies and research institutes that are located within the regions (Interview AN-I3, YO-I2), not from outside. The group of practitioners called coordinators are from local innovation centres like AGECE and SHGEC in Banwol-Sihwa, while the same group in Yeosu consists of retired engineers from local firms. Forums are meetings between local firm managers and university-based researchers in both the Banwol-Sihwa region and the Yeosu region. This human and institutional formation ensures that the state initiative can be implemented through cooperative networks between local actors while the role of central bureaucracies is limited to financial support and performance assessment.

Regional Innovation System: The EIP programme is one of various joint enterprises at the local level. Aside from the EIPs, firms and other local actors have collaborated in various programmes in both the Banwol-Sihwa region and the Yeosu region. Broadening one's view from the EIP programme to the clusters' environmental upgrading as a whole, it is observed that both the textiles dyeing cluster and the petrochemical cluster have learnt new environmental engineering solutions and updated their environmental management strategies through learning-by-interaction based on their institutional support systems. The Banwol-Sihwa textiles dyeing cluster is in close partnerships with various innovation support organisations such as KITECH and the local universities, so that such non-firm institutions are the main sources of scientific knowledge related to environmental management. The dyeing cluster's three EIP projects also emerged from the interaction between the textiles dyeing sector and the innovation support institutions. In the Yeosu region, a large part of innovation capacity in Yeosu relies on the petrochemical and chemical firms' research departments and chemical engineering companies working in the backward vertical linkages of the cluster. The petrochemical and chemical firms have developed pollution control technologies and cleaner production technologies using their own innovation capacity as well as employing new solutions from engineering service units. In short, while the dyeing cluster's environmental upgrading has been accelerated by the learning-by-interaction based in the Banwol-Sihwa's dirigiste RIS, the petrochemical and chemical firms have employed environmental engineering solutions from chemical engineering service units based in Yeosu's industry-led knowledge generation and dissemination system.

Knowledge generation and dissemination pertaining to the two clusters' environmental upgrading is more than simple technical changes. A closer investigation of the interaction between firms, non-firm institutions and other stakeholders to improve clustered firms' environmental performance in the Banwol-Sihwa region reveals that a unique function of the RIS has been activated in the dyeing cluster's environmental upgrading. It is notable that the knowledge generation and dissemination systems have functioned as a *buffer zone* to absorb external environmental impacts. For example, KITECH carried out various R&D projects related to developing eco-labels, inventing new dyeing equipment and reducing toxicity of chemical additives during the 2000s. All these projects aimed to help the dyeing sector to respond to government regulations and global buyer's demands. Meanwhile, the two university-based R&D centres, AGECE and SHGEC, have assisted the dyeing and printing firms to reduce air pollution in response to the pressures from the local community. The cluster's EIP development can be understood in the same vein. The wastewater heat exchange network was deliberately initiated by KITECH, because KITECH knew that energy price was a pending issue for the dyeing and printing firms. The project to collect and reuse oil ingredients from air pollution suggested by SHGEC seeks to mitigate odour, which is the most serious environmental concern of Banwol-Sihwa's residential communities. This EIP project was intentionally designed to improve the dyeing cluster's reputation, as SHGEC has cooperated with the dyeing cluster in terms of the odour problem. In order to understand this buffer zone effect in RIS, it is critical to remember that Banwol-Sihwa's knowledge generation and dissemination system is a dirigiste RIS. Given that most innovation support institutions located in the Banwol-Sihwa region are directly owned or financially supported by the government, almost all R&D consortia have the character of public policy networks in Banwol-Sihwa. Due to the public nature of Banwol-Sihwa's RIS, the tier of non-firm institutions surrounding the dyeing cluster not only supports the business but also regulates clustered firms' behaviour. A KITECH researcher interviewed said that they should "force" firms to adopt new technologies to address the issues relevant to public interest such as environmental concerns (Interview AN-I6). This testifies that the dirigiste RIS can function to encourage firms highly reliant on the knowledge generation and dissemination system to balance private benefits and social benefits.

Compared to the Banwol-Sihwa region, Yeosu's RIS is much less influenced by the public sector. The petrochemical and chemical firms can conduct innovation without considerable

support from central and local governments thanks to its well-developed industry-led knowledge generation and dissemination system. Notwithstanding this, Yeosu's RIS has the adjustment ability to balance private benefits and social benefits. This ability is based on the high degree of interaction between the industrial community and the local civil society. During the late 1990s when a series of environmental disputes were current in Yeosu, NGOs and local residents remained protesters encountering the petrochemical business and supplicants filing petitions to the government. However, it seems that, while organising a national movement to solve environmental problems in industrial regions and interacting with the petrochemical business through the regional consultative committee, the local civil society has significantly improved its capacity to deal with environmental issues. The fact that the NGO-led initiative, so-called 'Environment-friendly Industrial Complex', became a rough sketch of the EIP programme shows that the local civil society is qualified to form part of the Yeosu region's knowledge generation and dissemination system. The Yeosu-based NGOs have directly participated in establishing the local steering committee of Yeosu's EIP programme and even in a few feasibility studies on potential industrial symbioses (Interview YO-F2, YO-I2, YO-R1). Moreover, the regional consultative Co-development Committee, consisting of the industrial sector, the public sector and the NGO sector, serves to make collective decisions between these three sectors, especially with regard to environmental concerns and CSR issues. Under this institutional structure, the interaction between the industry and the civil society tends to induce the industry-led knowledge generation and dissemination to give priority to social benefits and, thereby, to continue innovation for environmental performance.

The Third Determinant: Institutional Ability to Balance Private Benefits and Social Benefits

The comparative analysis on the social dimension of clusters' EIP development focused on institutional setting and planning reveals that there are two different types of institutional structures underpinning a cluster's environmental upgrading toward EIP development; programme implementation system and RIS. The former is an institutional setting that is specifically designed to carry out the EIP programme. This mainly functions as a platform through which the central government provides financial support to local actors and local actors report their performance to the government. The latter is the regional dynamics of

learning-by-interaction between firms and non-firm institutions that generate innovative changes. A cluster's environmental upgrading including EIPs is one of various innovative changes resulting from inter-organisational interaction within a RIS.

The main finding from the comparative analysis focused on institutional setting and planning between the two industrial clusters is that the two RISs have worked, although the specific context is unique to each case, as a mechanism to adjust balance between private benefits and social benefits. Banwol-Sihwa's RIS remains strongly public, because most innovation support institutions are sponsored by the state. Accordingly, the tier of non-firm institutions surrounding clustered firms have sensitively responded to public concerns together with local firms and thus have driven local firms to balance private benefits and social benefits by technical and financial assistance. Although this mechanism takes the form of R&D activity, there seems to be a power asymmetry between SMEs and innovation support institutions, especially localised public agencies like KICOX and KITECH, behind the scenes. In the Yeosu region, there is relatively little room for public intervention with regard to knowledge generation and dissemination because of firms' high technical and financial competence. Instead, the high degree of interaction between the petrochemical industry and the local civil society functions to balance private benefits and social benefits. Despite the different characteristics of institutional contexts, the case studies on the Banwol-Sihwa region and the Yeosu region commonly show the importance of institutional ability to balance private benefits and social benefits.

7.3.4. Summary: Three Key Determinants in EIP Development

This section compares the two industrial clusters' EIP development with regard to the influence of mental distance, champion roles, institutional setting and planning on the EIP developments between the Banwol-Sihwa textiles dyeing cluster and the Yeosu petrochemical cluster.

The first comparative analysis focused on mental distance shows that close mental distance actually refers to cooperative relationships connoting embeddedness. The conventional idea of mental distance in the industrial ecology literature is that some extent of cooperative relationship between traditionally separated industries is desired for EIP development as in the case of Kalundborg Symbiosis. In contrast to this theoretical

expectation, the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster generally show that there has been little cooperative relationship at the inter-sectoral inter-firm level. Rather, firms are strongly embedded in the intra-sectoral inter-firm relations and the regional firm-institution relations. This finding means the notion of short mental distance in the industrial ecology literature is too narrowly focused on inter-sectoral inter-firm relationships. Rather, the empirical evidence from the Banwol-Sihwa textiles dyeing cluster and the Yeosu petrochemical cluster shows that EIP development requires much broader cooperative relationships at various levels. This finding leads to the first key determinant in clusters' environmental upgrading: scope of cooperative relationship.

The second comparative analysis pertaining to role of champion reveals that there are three different types of coordination power: lead firm, anchor tenant and network broker. Lead firms coordinate other firms' behaviour in pro-environment ways by setting up private rules such as environmental standards, codes of conduct and CSR compliance programmes. However, a lead firm's environmental coordination based on value chain governance does not necessarily include all aspects of environmental management. Except for a few industries whose value chains are equal to material flows, as in the petrochemical and chemical sector in the Yeosu region, another coordination power, the anchor tenant, is required in order to manage material flows, including by-products, wastes and energy, at the local level. In the case of the Banwol-Sihwa textiles dyeing cluster, the position of anchor tenant is occupied by the two business cooperatives, because they operate common effluent treatment plants. In addition, if an environmental management practice makes it necessary to coordinate relationships that are beyond the influence of lead firms and/or anchor tenants, there would be a need of involvement from a non-firm institution which is specifically committed to coordination, a network broker. The Gyeonggi EIP Centre and the Jeonnam EIP Centre have served as network brokers in the two clusters' EIP programmes. The findings from the comparative analysis focusing on the role of champion can be expressed as a diversity of coordination power, the second key determinant in clusters' environmental upgrading.

In the third comparative analysis, I simplify the complicated and overlapping notions of institutional setting and planning into two types of institutional structures: programme implementation system and regional innovation system. Programme implementation system refers to an institutional structure that is designed to conduct a specific joint enterprise. The EIP implementation systems in the Banwol-Sihwa region and the Yeosu

region are a typical example. The dynamics through which local actors can form various types of coalitions to conduct their joint enterprises is learning-by-interaction based on RIS. The critical finding from the comparative analysis concerning institutional setting and planning is that RIS functions to strike a balance between private benefits and social benefits. In the Banwol-Sihwa region, innovation support institutions have been significantly concerned with public issues and thus driven local firms to continuously update environmental management practices, given that a large part of Banwol-Sihwa's RIS consists of public and quasi-public institutions. As for the Yeosu region, the strong and structured interaction between the industry and the civil society has encouraged firms to seek social benefits as well as private benefits. I term this function of RIS the institutional ability to balance private benefits and social benefits, the third key determinant in clusters' environmental upgrading.

[Table 7-4] Comparative Analysis of the social dimension of EIP development between Banwol-Sihwa and Yeosu: Three key determinants

		Banwol-Sihwa	Yeosu	Key Determinants
Mental Distance	Intra-sectoral inter-firm	A high degree of trust and openness among the dyeing and printing firms has been built through a long history of joint actions. Collective representation is based on the two enterprise associations, BDEC and SDEC.	A high degree of trust and openness among affiliate firms has been built through corporate governance. Collective representativeness is based on the enterprise association, YIEA.	<i>Scope of Cooperative Relationship</i> Both cases show that EIP development is based on a variety of relations in which firms' behaviours are embedded. Short mental distance is materialised as cooperative relationship in practice.
	Inter-sectoral inter-firms	Market-based relations	Market-based relations	
	Regional firm-institution	A high degree of partnership between the clustered firms and innovation support institutions has developed, taking forms of R&D consortia.	A high degree of interaction between the industry and the local civil society has developed through cooperation in a series of disputes, taking the form of a regional consultative committee.	
Role of Champion	Lead firms	Lead firms have set private rules like environmental standards and compliance programmes in order to coordinate local producers' behaviours through their value chains.	Lead firms have set private rules like environmental standards and compliance programmes in order to coordinate affiliate firms and subcontractors' behaviours through their value chains.	<i>Diversity of coordination power</i> Both cases show coordination power varies according to the

	Anchor Tenants	The two local enterprise associations, BDEC and SDEC, play the role of anchor tenant by operating common effluent treatment plants.	Lead firms play the role as anchor tenant given that the petrochemical value chains have the characteristics as a set of material flows.	characteristics of value chains, material flows and institutional context.
	Network Brokers	The enterprise associations serve as a private network broker to coordinate joint actions within the sectoral boundary. Gyeonggi EIP Centre serves as a public network broker to coordinate inter-sectoral relations.	The enterprise association serves as a private network broker to coordinate joint actions within the sectoral boundary. Jeonnam EIP Centre serves as a public network broker to coordinate relations between large firms and SMEs.	
Institutional Setting & Planning	Programme Implementation System	There is an EIP implementation system which functions as a platform through which the central government provides financial support.	There is an EIP implementation system which functions as a platform through which the central government provides financial support.	<i>Institutional ability to balance private benefits and social benefits</i>
	Regional Innovation System	Based on the strong public nature of the dirigiste RIS, innovation support institutions have driven firms to adopt advanced environmental management practices.	Due to the high degree of interaction between the industry and the civil society, firms tend to seek social benefits as well as private benefits.	Both cases show that learning-by-interaction between firms and other actors has induced firms to pursue social benefits in promoting EIP development.

*Source: Author

7.4. Conclusion: Collective Eco-Efficiency Mechanism

This chapter seeks to answer the last research question: “what are the comparative lessons from the different environmental upgrading strategies between the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster?” The comparative analysis of the two clusters’ EIP development identifies the clusters’ environmental upgrading patterns that are affected by three key determinants.

Section 7.2 discloses three types of environmental upgrading: a horizontal form of collective eco-efficiency, a vertical form of collective eco-efficiency and a region-wide form of collective eco-efficiency. These three types of collective eco-efficiency are not mutually exclusive. Rather, the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster have generally shown that these three types of collective eco-efficiency tend to take place in sequence from a horizontal form to a region-wide form. In this regard, EIP development should be understood as the process of a cluster’s environmental upgrading which tends to pass through the three statuses of collective eco-efficiency. Furthermore, as identified in section 7.3, it is obvious that the three key determinants, scope of cooperative relationship, diversity of coordination power and institutional ability to balance private benefits and social benefits, are associated with all three phases of environmental upgrading.

First, cooperative networks aiming at environmental performance have increasingly widened, as both the Banwol-Sihwa textiles dyeing cluster and the Yeosu petrochemical cluster evolved from horizontal collective eco-efficiency region-wide collective eco-efficiency. At the first phase of environmental upgrading, firms working in the same industry were mainly embedded in the intra-sectoral inter-firm relations that take the form of local enterprise associations like BDEC, SDCE and YIEA. While the two clusters advanced to the vertical collective eco-efficiency, firms began to collaborate with related industries like material and equipment suppliers as well as non-firm institutions. This tendency is especially conspicuous in the Banwol-Sihwa textiles dyeing cluster. The dyeing and printing firms have formed various R&D consortia with their suppliers working in the cluster’s backward linkages and local innovation support institutions during the second phase of environmental upgrading. The two clusters’ region-wide forms of collective eco-efficiency have been realised, when cooperative relationships are full-

fledged so that clustered firms, innovation support institutions, public agencies and NGOs can control opportunistic behaviour harmful to common public interests and conduct local-level joint enterprises. By reviewing the two clusters' environmental upgrading patterns, it is arguable that an industrial cluster's environmental performance evolves toward EIP development in direct proportion to scope of cooperative relationship.

Second, the two clusters have advanced from the first phase of environmental upgrading to the third phase of environmental upgrading in accordance with the increase in diversity of coordination power. When end-of-pipe measures were dominating, the local business associations like BDEC, SDEC and YIEA were the main source of coordination power in environmental management. During this first phase of environmental upgrading, they were not qualified as an anchor tenant or a private network broker because their functions were not strongly associated with coordinating flows of materials and energy. During the second phase of environmental upgrading, lead firms presented coordination powers in both the garment value chains and the petrochemical value chains. In the case of the Banwol-Sihwa region, innovation support institutions like KITECH also began to serve as a coordination power in order to organise R&D consortia. During the third phase of environmental upgrading from cleaner production to EIP, all types of coordination power such as lead firm, anchor tenant, private network broker and public network broker have been activated in both the Banwol-Sihwa region and the Yeosu region.

Finally, as a region's institutional ability to balance private benefits and social benefit grows, industrial clusters based in the region tend to go forward from the basic phase to an advanced phase of environmental upgrading. In both the Banwol-Sihwa region and the Yeosu region, clustered firms adopted pollution control methods in response to the state's command-and-control measures. Non-firm actors had hardly made a contribution to building the clusters' horizontal forms of collective eco-efficiency. However, in the Banwol-Sihwa region the dyeing cluster has increasingly relied on innovation support institutions for environmental upgrading with the gradual refinement of non-firm actors' competence. The dyeing cluster's institutional support system dominated by public agencies like KICOX and KITECH has substituted for the state's command-and-control framework by providing technical and financial assistance with which local firms can improve environmental performance in a more autonomous way. In Yeosu, the cooperative interaction between clustered firms and civil society groups has been structured in the form of a regional consultative committee so that firms and other stakeholders can make

collective decisions on their common issues. Given that the petrochemical cluster has high technical and financial competence, this institutional structure functions to encourage clustered firms to consider social benefits as well as private benefits in improving environmental management systems. Therefore, it can be said that the two case study regions' institutional ability to balance private benefits and social benefits is yet another determinant that has propelled both the textiles dyeing cluster and the petrochemical cluster into gradual environmental upgrading.

VIII. CONCLUSION

8.1. Introduction

The conventional type of material flows in modern economic activities is a linear process. Raw materials are extracted, used and dumped into nature. However, it is more and more apparent that the era of the “throw it away and get a new one” economy is being eclipsed. As environmental concerns like pollution, resource depletion and energy crisis continue to grow, it is inevitable that we need to reconsider the environmental sustainability of the conventional industrial structure based on linear material flows. Industrial ecology is one new approach that seeks to convert the industrial landscape from linear material flows into a system of circulatory flows. This research studies eco-industrial parks (EIP), one of the practical models suggested by industrial ecology, through the theoretical lens of the industrial cluster literature, and draws on evidence from the Banwol-Sihwa textiles dyeing cluster and the Yeosu petrochemical cluster in South Korea. The case studies on the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster show that the EIPs have been developed through a gradual environmental upgrading of clustered firms, reflecting the nature of local production systems and institutional support systems.

This concluding chapter is structured as follows: Section 8.2 summarises the findings from the case studies on the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster. Section 8.3 is dedicated to linking the industrial ecology literature and the industrial cluster literature with the theoretical lessons that are exposed in the two clusters’ environmental upgrading patterns. In section 8.4, I provide recommendations for further research.

8.2. Summary of Main Findings

This doctoral study poses the core research question, “how do clustered firms draw on inter-firm collaboration and institutional linkages to undertake holistic environmental upgrading strategies?” In order to answer this question, this research draws on empirical evidence from the Banwol-Sihwa textiles dyeing cluster and the Yeosu petrochemical cluster in South Korea. The two industrial clusters have experienced a series of pollution

crises and environmental disputes. The Banwol-Sihwa dyeing cluster has suffered from the water pollution in Han River during the late 1970s, the Sihwa Lake pollution scandal in 1996 and the odour issue in the early 2000s. Each of these pollution crises provoked government regulations and community pressures. In addition, international environmental standards and increasing energy prices have driven the dyeing and printing firms to improve their environmental performance. In response, the Banwol-Sihwa dyeing cluster has taken various forms of environmental joint action. In Yeosu, a string of environmental disputes was triggered in 1995 when an oil tanker ran aground off the coast of Yeosu. The serious environmental struggles between the petrochemical cluster and the local civil society that lasted for a decade in the Yeosu region resulted in the establishment of a regional consultative committee, the Co-development Committee, to provide a platform to collectively address environmental concerns. EIP was suggested as a national policy agenda by the environmental movement led by Yeosu-based NGOs. The narratives from the Banwol-Sihwa region and the Yeosu region tell us that collective environmental failure can be redirected toward collective eco-efficiency. Both the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster were in a status of external diseconomies and collective failures. A series of societal interactions surrounding environmental concerns has driven clustered firms to take environmental joint action and thus facilitated environmental upgrading in the two industrial clusters.

8.2.1. EIP Development in the Banwol-Sihwa Textiles Dyeing Cluster

The Banwol-Sihwa dyeing cluster shows gradual environmental upgrading through a sequence from pollution control to cleaner production and eventually to an EIP. At the initial stage, the dyeing and printing firms established two local business cooperatives specialised in environmental management. Under the leadership of the two business cooperatives, the dyeing and printing firms shared common effluent treatment plants and purchased air pollution control equipment. Furthermore, the dyeing cluster has carried out various R&D projects aiming at developing cleaner production technologies. In cooperation with local innovation support organizations and related industries, the dyeing and printing firms have successfully adopted cleaner production practices such as equipment substitution and toxicity reduction. Since the EIP programme was launched in the Banwol-Sihwa region in 2006, the dyeing cluster has established three industrial

symbioses: the wastewater heat recycling network with the energy sector, the sludge reuse network with a cement manufacturer and the project to collect and reuse oil ingredients from air pollutants with a chemical firm.

The Banwol-Sihwa dyeing cluster's EIP development has resulted most of all from the short mental distance among the dyeing and printing firms. The dyeing and printing firms have a shared purpose: addressing environmental sustainability, exchanging internal information on industrial pollution and entrusting collective environmental management to their two business cooperatives. Second, as the two business cooperatives represent the dyeing and printing firms in terms of environmental issues, the business cooperatives have taken the role of champion in the EIP programme. In addition, some non-firm institutions that are in cooperative relationship with the dyeing cluster have served as network brokers and knowledge providers forming an institutional setting for the EIP programme. Last but not least, all activities for the EIP development have been supported by the national planning system to implement the EIP programme.

The EIP development in the Banwol-Sihwa dyeing cluster is underpinned by three environmental upgrading dynamics of collective efficiency, value chain governance and regional innovation system. The dyeing and printing firms are engaged in the same production process and thus emit similar types of by-products. As their by-products are collected into the common effluent treatment plants, the amount of by-product is large enough to assure the economic feasibility of an industrial symbiosis. Based on these agglomeration gains, the clustered firms have taken proactive joint action to create new supply chains specialising in by-product exchanges with other industrial sectors. This is clearly understood as a collective efficiency. It turns out that the dynamics of value chain governance has not directly contributed to EIP development. Global buyers' requests have triggered R&D activities to develop cleaner production technology, rather than industrial ecology practices. However, the dyeing cluster has built partnerships with local innovation support institutions, like public research organisations and local universities, to carry out such R&D activities. These cooperative relationships became the institutional setting for EIP development. In this context, it is crucial to understand the regional innovation system surrounding the Banwol-Sihwa dyeing cluster. Banwol-Sihwa's regional innovation system can be characterized as a well-developed knowledge generation system that has been deliberately built by the government. All non-firm institutions involved in the Banwol-Sihwa dyeing cluster's EIP development have already functioned to support SMEs

under other state initiatives in Banwol-Sihwa. Accordingly, the EIP programme should be understood as one of various state initiatives in the Banwol-Sihwa's regional innovation system.

8.2.2. EIP Development in the Yeosu Petrochemical Cluster

In the Yeosu petrochemical cluster, technical engineering solutions based on the pollution control approach and the cleaner production approach have been developed and adopted individually. Instead, the environmental joint actions had been focused on collective negotiation with local communities and compensation for environmental damage caused by industrial activities. In addition, the petrochemical and chemical firms have placed great emphasis on environmental CSR compliance and social contribution in the value chain dimension. This tendency shows that the petrochemical and chemical firms are particularly bothered by the relationship with the local civil society. Interestingly, the EIP programme in Yeosu was launched with consent between the industrial sector, the public sector and the NGO sector at their regional consultative body, Co-development Committee. Currently, eleven industrial symbioses are in operation in the Yeosu petrochemical cluster.

The EIP development in the Yeosu petrochemical cluster also reflects the four social factors of industrial ecology: mental distance, roles of champion, institutional setting and planning. Short mental distance has emerged in two different contexts in Yeosu. First, in terms of inter-firm relationships, 29 large firms regularly meet and discuss their common environmental issues through their local industrial association specialising in environmental management, YIEA. The other, and more important, context of mental distance is relevant to the relationship between the industry and the local civil society. The firms interviewed expressed a strong sense of belongingness to the Yeosu region and solidarity with other local actors. Due to this embeddedness, the firms tend to regard their participation in the EIP programme as a part of their social contribution to the local community. In implementing the EIP programme, the lead firm of the petrochemical cluster, the monopolistic petroleum refinery, has played the role of an anchor tenant to attract by-product users. However, the real coordinators in the EIP are YIEA and Jeonnam EIP Centre. In the initial stage of the EIP programme, YIEA became an effective channel through which industrial ecology principles were disseminated across the cluster. Jeonnam EIP Centre was deliberately set up as a part of the national EIP planning system. As for

knowledge providers, it turns out that chemical engineering companies working in the backward vertical linkages of the petrochemical cluster are the main knowledge generation source. Many SMEs constituting the backward vertical linkages are technologically advanced firms specialising in providing ancillary engineering services. They can expand their business areas or create new business opportunities by using by-products generated by the large petrochemical and chemical firms. For this reason, an increasing number of SMEs have participated in the EIP programme with new ideas and technology.

The EIP development in the Yeosu petrochemical cluster is also explained with the three dynamics of industrial cluster upgrading. The petrochemical and chemical sector is a material processing industry. As various materials are processed in gas and liquid state at high temperature and high pressure, firms should be agglomerated within a limited space in accordance with material flows. This industry-specific feature provides high potentiality to establish by-product exchange networks. Due to this agglomeration gain, the petrochemical and chemical firms have relatively easily built various industrial symbioses. Once industrial ecology principles were disseminated in the Yeosu petrochemical cluster, more and more SMEs participated in the EIP programme in order to use by-products generated from the core petrochemical and chemical firms. In consequence, the backward vertical linkages of the petrochemical cluster have been expanded and improved. This shows how modular value chain governance can underpin EIP development. Lastly, it should be remembered that civil society actions have accelerated the EIP development in the Yeosu petrochemical cluster. Although the role of the local civil society is little relevant to the conventional types of regional innovation systems, the empirical evidence from the Yeosu region highlights the importance of civil society actions in a cluster's environmental upgrading.

8.2.3. Industrial Cluster's Environmental Upgrading Mechanism

Three Impetuses for Cluster's Environmental Performance

This study identifies three different types of impetus that drive an industrial cluster to environmental upgrading. Within an industrial cluster, environmental external diseconomies come about when unintended environmental damage is not internalised by clustered firms. In the terminology of the industrial cluster literature, environmental

concerns like pollution are a collective failure of clustered firms in undertaking appropriate joint action (Nadvi, 1999). In response to this collective failure, other actors make efforts to adjust the imbalance between private cost and social cost. In the cases of the Banwol-Sihwa region and the Yeosu region, petitions from local residents and NGO movements have encouraged clustered firms to undertake environmental joint actions. These civil society actions can be categorised as the social impetus to a cluster's environmental upgrading. In addition, the South Korean government has strengthened the environmental regulatory framework, as well as introducing strong command-and-control measures, such as the administrative order to re-locate pollution-emitting industries in 1976, and the prohibition of sea dumping in 2012. These government actions can be seen as the political impetus to a cluster's environmental upgrading. In addition, firms can face resource depletion or green barriers to trade, such as international environmental standards and buyers' codes of conduct. Especially in the case of the Banwol-Sihwa textiles dyeing cluster, these economic impetuses have motivated the clustered firms to improve their environmental performance. The social, political and economic impetuses trigger environmental joint actions of clustered firms, through which environmental external diseconomies can be re-routed toward an external economy.

Collective Eco-Efficiency: Three Phases of Environmental Upgrading

The case studies on the Banwol-Sihwa textiles dyeing cluster and the Yeosu petrochemical cluster show that clustered firms can convert negative environmental externalities to positive externalities leading to enhanced resource productivity, cost saving and social responsibility. Using a simile with the notion of collective efficiency in the industrial cluster literature, the environmental upgrading dynamics towards EIP development can result in what is termed 'collective eco-efficiency'. The comparative analysis on the two clusters' environmental performance reveals that three different types of environmental upgrading patterns have emerged in sequence: the first phase of environmental upgrading connoting the collective eco-efficiency emerging from horizontal inter-firm linkages; the second phase of environmental upgrading connoting the collective eco-efficiency emerging vertical inter-firm linkages; and the third phase of environmental upgrading connoting collective eco-efficiency emerging region-wide institutional linkages. A concern is that we cannot take these three phases of environmental upgrading for granted. Rather, it seems

that clusters' collective failure in environmental management is a more common situation than collective eco-efficiency in reality. If so, what sorts of conditions are required for an industrial cluster to be upgraded in pro-environment ways? The comparative analysis focused on the four social factors of the two clusters' EIP developments explores three key determinants of environmental upgrading: scope of cooperative relationship; diversity of coordination power; and institutional ability to balance private benefits and social benefits. As these three determinants gradually strengthen, a cluster's environmental performance tends to pass through the three phases of environmental upgrading in sequence.

Horizontal collective eco-efficiency: When the scope of cooperative networks is limited to within intra-sectoral inter-firm level, and institutional coalition between firms and non-firm actors is little developed, clustered firms tend to take *ex post* environmental management measures based on the pollution control approach via horizontal inter-firm ties like local enterprise associations. During this phase of environmental upgrading, environmental joint actions are re-active in that they are normally undertaken as a passive response to external pressures like government regulations.

Vertical collective eco-efficiency: In line with lead firms' codes of conduct, environmental compliance programmes and international environmental standards, clustered firms tend to take *ex ante* environmental management measures, from cleaner production technologies to self-organising industrial symbioses, based on vertical inter-firm relations. This means that lead firms emerge as an additional coordination power that is exerted over the environmental management system of value chains. Furthermore, firms begin to be embedded in partnerships with related industries and/or innovation support institutions. This is because, in contrast to end-of-pipe measures, cleaner production and industrial symbioses require innovation to promote quality of raw materials, resource efficiency in manufacturing processes and improved reputation in customer markets.

Region-wide collective eco-efficiency: When the scope of cooperative relationships expanded beyond sectoral boundaries, the source of coordination power is so diversified that lead firms, anchor tenants and public/private network broker all serve as coordination powers, and the institutional ability to balance private benefits and social benefits is structured to some extent, an industrial cluster realizes a region-wide form of collective eco-efficiency. During this phase of environmental upgrading, clustered firms are equipped with holistic environmental management systems such as an EIP. Complex interactions between firms and non-firm actors underpinned by the RIS dynamics become the source of

scientific knowledge, financial assistance and social motivation, with which clustered firms take proactive environmental joint actions such as the creation of inter-sectoral by-product and energy exchange.

[Table 8-1] Collective Eco-efficiency Mechanism

	Scope of Cooperative Relationship	Diversity of Coordination Power	Institutional Ability to Balance private Benefits and Social Benefits
Horizontal Collective Eco-efficiency	Low	Low	Low
Vertical Collective Eco-efficiency	↕	↕	↕
Region-wide Collective Eco-efficiency	High	High	High

*Source: Author

8.3. Theoretical links between Industrial Ecology and Industrial Clusters

The theoretical aim of this doctoral study is to identify links between the industrial ecology literature and the industrial cluster literature. Industrial ecology has rapidly developed with its rigid basis of natural science and industrial engineering discipline. In practice, the application of industrial ecology requires the social science perspectives on how firms employ industrial ecology principles in industrial sites. On the other hand, the industrial cluster literature has provided substantial explanations on the dynamics underlying clustered firms' joint actions. However, environmental issues caused by clustering are a relatively under-studied area. Accordingly, the gaps in the industrial ecology literature and the industrial cluster literature can be mutually filled by developing an integrated framework that investigates the cluster dynamics underlying firms' joint action towards EIP development.

8.3.1. Theoretical Contributions to the Industrial Ecology Literature

A concern in the field of industrial ecology is that, due to the nature of an EIP as an inter-firm network, it is necessary to understand the influences of social factors on establishing by-product exchanges and energy cascading (Cohen-Rosenthal, 2000; Ehrenfeld 2000; Boons and Roome, 2001). In this regard, the studies in the social science line of industrial ecology provide four major factors that affect EIP development: mental distance, roles of champion, institutional setting and planning. However, these four social factors are still not well-established as a theoretical framework. With the empirical evidence from the EIP developments in the Banwol-Sihwa region and the Yeosu region, this doctoral study re-sharpens these four social factors as three key determinants in the environmental upgrading of an industrial cluster.

Firstly, this study magnifies and deepens understanding about the narrowly focused notion of mental distance. The traditional argument in industrial ecology is that collaborative networks are significant in the relations between traditionally separated industries (Chertow, 2000; Ashton, 2008; Chertow and Ashton, 2009; Berent, 2011). In other words, industrial ecology has placed much emphasis on embeddedness at inter-sectoral inter-firm

level. However, the case studies on the Banwol-Sihwa textiles dyeing cluster and the Yeosu petrochemical cluster put forward empirical evidence with which the conventional idea about inter-firm relationships in industrial ecology can be supplemented. It is obvious that firms in the relationship of industrial symbiosis have had few connections before they participated in the industrial symbioses, especially in the case of by-product exchanges between traditionally separated industries. Instead, firms in both the dyeing cluster and petrochemical cluster are strongly embedded in relationships at the intra-sectoral inter-firm level as well as at the regional firm-institution level. In reality, an enterprise association that represents the intra-sectoral inter-firm cooperative networks takes charge of negotiation with other industries in establishing resource exchanges, and/or non-firm institutions that have relationships with several industrial sectors facilitate industrial symbiosis partnerships between separated industries. Therefore, it is arguable that, except for a few idealistic cases like the Kalundborg Symbiosis, collaborative networks between traditionally separated industries are based in a much broader range of cooperative relationships. This implies that the notion of mental distance can be resharpened as a more instrumental theoretical concept by paying more attentions to intra-sectoral inter-firm relations and cooperation between firms and non-firm institutions on which the industrial cluster literature has placed a lot of emphases.

Secondly, the case studies on the Banwol-Sihwa textiles dyeing cluster and the Yeosu petrochemical cluster identify three different types of coordination power in environmental upgrading toward EIP development: lead firm, anchor tenant and network broker. Lead firms coordinate local producers' behaviour through value chain governance. Although the industrial symbiosis literature has largely ignored the roles of lead firms in establishing an EIP, both case studies show that lead firms also make direct and indirect contributions to EIP development. In Banwol-Sihwa, a variety of R&D consortia have been formed in response to global buyers' environmental standards, and this knowledge generation system became the institutional base for developing and disseminating industrial ecology practices. In Yeosu, lead firms like the petroleum refinery directly function as by-product suppliers. Another champion in establishing an EIP is the anchor tenant. A group of industrial ecologists use the term 'anchor tenant' in order to denote a firm that generates by-products useful for other neighbouring firms, identifies potential resource exchange networks and attracts other firms into an EIP (Lowe, 1997; Chertow, 2000; Gibbs and Deutz, 2005; Gibbs, 2008). The investigation of the EIP developments in the Banwol-Sihwa textiles dyeing

cluster and the Yeosu petrochemical cluster reveals that the intrinsic attribute of anchor tenants is their coordination power over material flows at the local level. Yet another champion in establishing an EIP is the network broker. 'Network broker' refers to non-firm actors that serve to discover potential industrial symbioses and mediate between by-product exchange partners. In both the Banwol-Sihwa region and the Yeosu region, local enterprise associations like BDEC, SDEC and YIEA serve as private coordination powers, and EIP centres serve as a public coordination power. In short, this study identifies three different types of champion and their specific roles in an industrial cluster's environmental upgrading.

Another theoretical lesson is that the multiplicity of production stages within an industrial cluster is essential in environmental upgrading. The industrial ecology literature has conventionally focused on industrial symbioses between traditionally separate industries (Chertow, 2004; Geng *et al.*, 2010; Brent *et al.*, 2011). This is a reasonable insight because different industries generate different by-products and thus by-product exchanges easily emerge from the inter-sector dimension. The case studies on the Banwol-Sihwa dyeing cluster and the Yeosu petrochemical cluster show that this traditional insight in industrial ecology can be reinforced by paying attention to production stages. A single industry cluster can establish by-product exchanges if the industrial cluster consists of multiple production stages, as in the Yeosu petrochemical cluster. Furthermore, even in a single production stage cluster, firms can generate inter-firm synergy effects for environmental performance by taking actions like facility sharing and joint R&D activities, based on their homogeneity.

Finally, this study reframes the two ambiguous and overlapping notions of institutional setting and planning. In the industrial ecology literature, 'institutional setting' firstly refers to the involvement of non-firm actors such as financial bodies, research institutes and public agencies (Heeres, 2004; Deutz and Gibbs, 2008; Lombardi and Laybourn, 2012). Second, as von Malmborg (2004) points out, the systems of information-sharing and decision-making are also categorised as 'institutional setting' in industrial ecology. Finally, the environmental regulatory framework can be also understood under the notion of institutional setting as well. Moreover, planning basically denotes public intervention in EIPs (Chertow, 2007). This public intervention includes the state's role in ensuring favourable regulations, providing financial sources and facilitating knowledge transfer (Weinburg *et al.*, 1994; Gibbs, 2003; von Malmborg, 2004). All these debates on

institutional setting and planning show that the two notions have been used in significantly overlapping ways. Through the case studies on the EIP developments in the Banwol-Sihwa region and the Yeosu region, this doctoral study reveals that the essence of institutional setting and planning is RIS. The EIP development has resulted from long-term learning-by-interaction between clustered firms and other local actors in both regions. It is not surprising that the non-firm institutions located in Banwol-Sihwa have provided knowledge and information on environmental management to the dyeing and printing firms. The finding related to the roles of non-firm institutions in Banwol-Sihwa also resonates with industrial ecologist notions of institutional setting (Heeres *et al.*, 2004; Deutz and Gibbs, 2008) and planning (Weinburge *et al.*, 1994; Gibbs 2003; Behera *et al.*, 2012; Lombardi and Laybourn, 2012). Rather, a striking point is that the state has localised a few government research institutions in the Banwol-Sihwa region and encouraged local actors to interact with each other through state initiatives. Chertow (2007) points out that the Korean EIP model has been understood as a totally planned industrial symbiosis. However, the central government has played only limited roles as a fund resource and a remote supervisor, promising local actors' autonomy. Therefore, it can be said that Banwol-Sihwa's EIP development is a result of new state initiatives to build regional innovation systems. Furthermore, this study shows how local civil society can be involved in EIP development, by drawing on the evidence from the Yeosu region. Although the industrial ecology literature has repeatedly pointed out the importance of involving stakeholders and local community (Bass and Boons, 2004; Heeres *et al.*, 2004; Kim, 2007; Taddeo *et al.*, 2012), there have been few empirical studies on the ways in which local stakeholders and local communities can support and encourage EIP development. In Yeosu, the local civil society and the local industrial community established a regional consultative committee, through which the industrial sector, the public sector and the NGO sector can make collective decisions on their common issues.

8.3.2. Theoretical Contributions to the Industrial Cluster Literature

In the industrial cluster literature, it is not clear yet what is the dynamics underlying industrial clusters' environmental upgrading. This dissertation addresses this theoretical gap by importing some theoretical perspectives from industrial ecology as well as investigating the EIP developments in the two industrial clusters. In consequence, the three

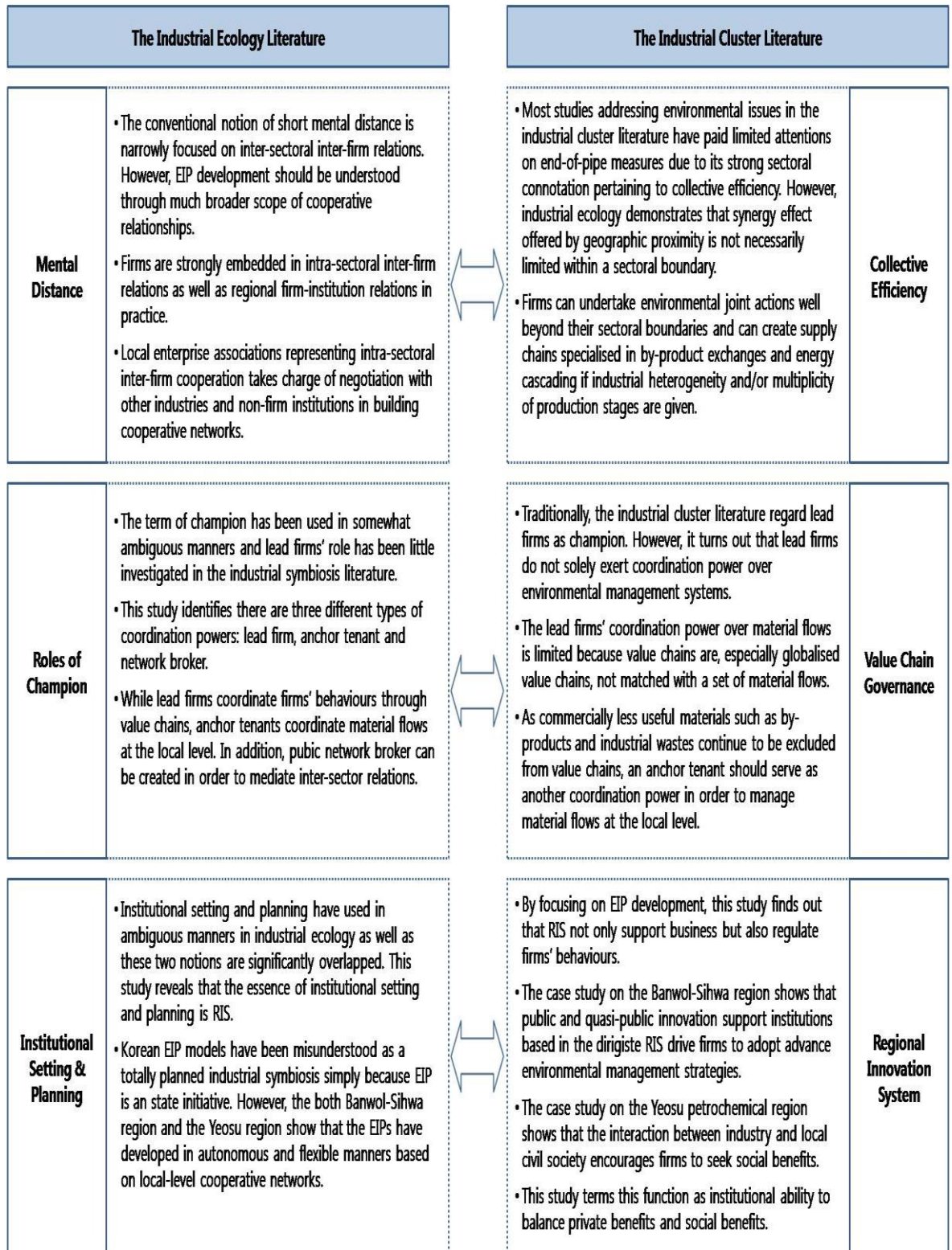
theoretical frameworks of collective efficiency, value chain governance and RIS are reinforced with regard to understanding of an industrial cluster's environmental upgrading. First of all, this study shows that an industrial cluster's joint action can go far beyond the pollution control approach. An increasing number of studies addressing the environmental issues of clustered firms have been reported in the industrial cluster literature (Kennedy, 1999; Montini and Zoboli, 2004; Crow and Batz, 2006; Almeida, 2008; Konstadkopulos, 2008; Lund-Thomsen, 2009; Jabbour and Puppim-de-oliveira, 2011; Ronch *et al.*, 2013). However, most studies addressing environmental joint actions of clustered firms in the industrial cluster literature only focus on pollution control practices. This is partly because the industrial cluster literature has largely ignored the inter-sectoral dimension due to its strong sectoral focus, although the dynamics of collective efficiency that is expressed as "collaboration and the synergistic possibilities offered by geographic proximity" in the industrial ecology literature (Chertow, 2000: 314) has been substantially studied. The case studies in this research prove that, as argued in industrial ecology, inter-sectoral cooperative networks can be built if clustered firms are embedded in not only intra-sectoral relations but also regional firm-institution relations. Therefore, with regard to environmental upgrading, the dynamics of collective efficiency is not necessarily limited within a sectoral boundary. When opportunities for by-product exchanges generated from clustering of heterogeneous industries or multiple production stages are given as a passive gain, firms can undertake joint action to establish industrial symbioses regardless of their sectoral origin.

In addition, this study identifies an essential point pertaining to value chain dynamics in environmental upgrading. Traditionally, lead firms are recognised as champions in the industrial cluster literature. However, with more focus on the EIP developments, it seems that lead firms are relatively less influential on building industrial symbioses than the other champions, anchor tenants and network brokers. In the Banwol-Sihwa dyeing cluster in particular, the leadership in identifying potential material exchange networks and establishing industrial symbioses has been taken by the two anchor tenants, BDEC and SDEC. In other words, while the global lead firms play the role of champion in the value chain dimension, the anchor tenants take the position of champion in the local-level material flows. The reason why two different coordination powers, lead firm and anchor tenant, respectively work in the same production system is that value chains do not necessarily match material flows. As in the globalised garment value chains, only

commercially valuable materials like components and raw materials are transferred along value chains. It seems that less valuable materials like by-products, industrial wastes and extra energy continue to be excluded from value chains or remain at the local level. Given that EIP development is necessarily grounded on material flows including by-products and energy, an anchor tenant who coordinates material flows at the local level is required. In the case of the Yeosu petrochemical cluster, lead firms can serve as an anchor tenant because the petrochemical value chains are basically a set of material flows.

Finally, this study identifies a distinctive feature of RIS that has been neglected in the industrial cluster literature as well as the innovation system literature. The case studies on the Banwol-Sihwa region and the Yeosu region show that RIS function to mitigate environmental pressures by the interaction between clustered firms, innovation support institutions and local civil society. I term this function as institutional ability to balance private benefits and social benefits. In terms of SMEs' environmental upgrading, lack of information and knowledge on environmental management is one of the biggest barriers for SMEs to environmental upgrading (Jabbour and Puppim-de-oliveira, 2011). The innovation support institutions based in the Banwol-Sihwa region have served as knowledge providers to overcome this barrier. The critical point in this knowledge generation and dissemination process is that non-firm actors not only support but also regulate firms' behaviour. As Banwol-Sihwa's RIS has been intentionally built and sponsored by the state, most innovation support institutions located in Banwol-Sihwa retain a strongly public nature. Some institutions like KICOX and KITECH have authority as localised government agencies. Due to the public nature of the dirigiste RIS, innovation support institutions in the Banwol-Sihwa region have forced local firms to adopt a more environmentally sustainable business strategy. In the Yeosu region, the participation of civil society groups in generating and disseminating knowledge is institutionalised in the form of a regional consultative committee. As civil society groups directly confront and collaborate with the industry, Yeosu's industry-led RIS tends to prioritise the needs of residential communities to some extent.

[Figure 8-1] Interlinking between Industrial Ecology and Industrial Cluster



*Source: Author

8.4. Concluding Observations

The main framework of this study is the regional approach of industrial ecology which is focused on territorial dimensions of industrial ecology practices. As briefly discussed in chapter 2, industrial ecology takes the other approach, addressing vertical dimensions of material flows, called the production chain approach of industrial ecology. As the industrial cluster literature and the value chain literature are highly interlinked with each other and thus provide integrated perspectives on the horizontal dimension and the vertical dimension of production systems, the regional approach and the production chain approach together provide two-dimensional perspectives on environmental upgrading of production systems. Accordingly, an industry's environmental performance will be better addressed if the two horizontal approaches and the two vertical approaches can be developed as an integrated theoretical framework. This study is mainly concentrated on suggesting an integrated framework between the two horizontal approaches at the local level, the industrial cluster literature and the regional approach of industrial ecology. Therefore, building bridges between the value chain literature and the production chain approach of industrial ecology at the global level suggests one important avenue for further research.

This doctoral study has limitations as a case study. In contrast to sampling, cases are deliberately selected. Therefore, the findings from this study need to be reinforced with more case studies. I have investigated two different types of industrial clusters. The Banwol-Sihwa dyeing cluster is a SME agglomeration. There are few case studies on EIP development in SME clusters so far. In this sense, this thesis can be regarded as an initial step for the study of EIP development in SME clusters. In addition, the industrial cluster literature and the global value chain literature have paid relatively limited attention to environmental issues in the resource extraction and processing industries. This doctoral study has made a small contribution by investigating a petrochemical cluster. Considering the importance of resource extraction and processing industries pertaining to environmental concerns, more empirical evidence is required to develop knowledge on the environmental performance of the resource extraction and processing industries.

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APPENDIX 1. Example Research Note

Research Note in December 2011 and January 2012

The Findings in Yeosu Industrial District

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This paper is written to report what was found in the Yeosu industrial district during December 2011 and January 2012 and to discuss what the findings mean and how to deal with them. This research note is the last report from the Yeosu area.

I. Chain Reactions on Environmental Disputes in Yeosu

- 1.1. The petrochemical industry retains many possible hazards, because it deals with sensitive materials at high temperature and under high pressure in the form of compressed gas or liquid status. Accordingly, even a small leakage could cause a very serious industrial disaster or pollution accident. There have been 212 industrial accidents and pollution accidents over the last four decades, according to the Yeosu city government.

- 1.2. There are three types of damage which can be caused by the petrochemical industry. First of all, establishing a petrochemical complex demands an extensive area of land. This inevitably leads to native people being evacuated to other areas. Second, there is always a risk of accidental explosion in the petrochemical business. This is a direct threat to workers and neighbouring residents. Finally, the petrochemical industry can generate environmental degradation at local level. The Yeosu industrial district is one of two regions²³ that the central government has designated as Special Air-pollution Prevention Areas in South Korea. In addition, numerous cases of health problems and damage to crops have been reported in Yeosu.

²³The other one is the Ulsan industrial district.

The environmental dispute in Yeosu is not a simple problem but the result of complex social struggles. The native local people feel they have been continually marginalised in Yeosu. Their hometown was designated as an industrial district by the military regime's unilateral decision. The large petrochemical firms have continued to send profits gained in Yeosu to their headquarters in Seoul. Contrary to initial expectation, the firms have not created many job opportunities or contributed to developing the local community. The income gap between the local people and the petrochemical employees has dramatically increased. This situation is described with the expression, "Profit goes to the large firms, tax goes to the government, environmental damage goes to the local community" (Interview with Yeosu YMCA). Therefore, the environmental dispute is one phenomenon representing the deep-rooted complaint. One informant reported that there were many rumours about health problems. Most rumours might not be true. However, from a social science viewpoint, the rumours are also evidence of the complaints from the local community.

- 1.3. In July 1995, LG-Caltex's oil tanker, *Seaprince*, ran aground off Yeosu, spilling 9,000 tons of crude oil and 1,000 tons of bunker-C oil. Even before the anger on this accident cooled down, one more oil-spill was caused by another LG-Caltex oil tanker, *Sapphire* in November 1995. The local residents and NGOs organised a strong movement against LG-Caltex and a series of actions including protests and boycotts continued. In this serious struggle, KIST's report on the environmental condition of the Yeosu area was released, announcing "Yeosu is the land where human beings cannot live". The report poured oil over the flames of environmental disputes. The Ministry of Environment scrutinised the environmental conditions in the area and the central government designated it as a Special Air-pollution Prevention Area. LG-Caltex promised to make a social contribution to the local community including compensation. Furthermore, the firms together launched an independent body to perform their joint actions on local environmental concerns, Yeosu Industry Environment Association (YIEA). As one of the efforts to end the unceasing environmental disputes at the local level, the Committee for Co-development of Yeosu City and Yeosu Industrial Complex was established in 2000.

A string of events surrounding the environmental issues in the Yeosu area during the late 1990s can be regarded as the first round of the chain reactions. This phase started

from the *Seaprince* Oil-spill and finished with the establishment of the local governance. Most institutional channels through which the co-operating firms can carry out joint actions and cooperate with the local community were set up in this period. However, the firms' attitude in this period was actually "defensive" rather than cooperative. (Interview with GS-Caltex).

- 1.4. At the end of 2000, BASF Korea planned to build a BTI/MDT plant to produce phosgene gas.²⁴ The local community, NGOs, and labour unions strongly opposed the plan and, furthermore, demanded the right to participate in the decision-making on how to use the petrochemical cluster. The NGOs suggested setting up a consultative body, in which the local community, the government, the business society and the academic society could discuss local environmental issues. Although this plan foundered, the newly elected mayor in 2002 reactivated the existing local governance, the Committee for Co-development of Yeosu City and Yeosu Industrial Complex. The subcommittee on environment and safety was established and the local governance began to function in a proper manner in this period.

The early 2000s was the second phase of the chain reactions in the Yeosu industrial district. During this period, there appeared to be no significant changes and the firms' attitude was still passive. However, the business people sat on the negotiating table in the governance. Theoretically speaking, this implies that the economic territory and socio-political territory of the Yeosu industrial district started to interact in terms of external diseconomies through institutional solidarity.

- 1.5. The Yeosu-based NGO activists felt "the movement at the local level is limited" and thought "other areas where an industrial district is located must have the same problems as us" (Interview with Yeosu YMCA). They suggested a national level movement to improve the environment of industrial districts and the NGOs from 22 industrial areas launched the National Solidarity to Improve Environment in National Industrial Complexes and Reform Policy.²⁵ This solidarity organisation held repeated

²⁴ Phosgene gas is a very toxic material which is used as a military weapon. Yeosu had already experienced a phosgene gas pollution accident in 1994. The gas leak caused 57 casualties in the petrochemical cluster.

²⁵ This is generally called Solidarity for Environmental Improvement in Industrial Complexes for short.

conferences on the environmental issues in industrial districts with national assembly members. The eighth national workshop in 2003 was the milestone toward EIP. The NGOs suggested their idea of an environmentally friendly industrial district and KITECH introduced the notion of industrial ecosystem in the meeting. The central government also formally disclosed their plan on EIP at this workshop. From this time, the EIP project has been accelerated by the central government and the Yeosu industrial district was designated as EIP in 2005.

The fieldwork in the Yeosu industrial district reverses my thinking that EIP is a top-down decision. In contrast to my previous judgment, EIP is also the result of the social chain reactions. This fact is the missing link without which I could not answer the question of how co-operating firms' joint action can evolve to an industrial ecosystem beyond end-of-pipe and clean production.

II. EIP in the Yeosu Petrochemical Cluster

Numerous EIP projects are going on in the Yeosu petrochemical cluster, because exchanging materials is a fundamental activity of the petrochemical industry. The largest EIP project in the Yeosu petrochemical cluster, hydrogen recycling network, was reported in the previous report. I would like to add two more projects in this report.

2.1. Optimised Recycling of Waste Catalyst: Catalysts are materials to accelerate chemical reactions in petrochemical processes. Catalysts should be discarded because they cannot function properly after a certain operation time. The average annual amount of waste catalysts generated from the Yeosu petrochemical cluster is 12,810 tons, which accounts for 41 percent of the whole amount of discarded catalysts in Korea (The Ministry of Knowledge Economy and KICOX, 2011). In many cases, precious metals are used as catalysts. To reuse the precious metal catalysts, a group of firms located in the Yeosu petrochemical cluster has tested a new physic-chemical recycling technology and several firms are currently participating in this new business. For example, Kumho Petrochemical has used platinum in its production process of rubber antioxidant (Interview with Kumho). The firms using platinum as a catalyst

have exported the waste catalyst to Australia and the US, which have a high level of metal refining technique. However, the refining inevitably causes some loss of platinum in the burning process. A small firm, G&M, has suggested a new dissolution method with which platinum can be selectively refined. The Yeosu EIP office has supported G&M by networking platinum catalyst users and this technology is commercialised now in the Yeosu petrochemical cluster.

This example proves the formula commonly mentioned by the interviewees, “Network should be expanded”. The decisive problem in this project was not developing technology but economic feasibility. Because the amount of precious metals is basically small, G&M could not make a profit with one provider. Currently four companies in the Yeosu petrochemical cluster join in the waste catalyst recycling network as suppliers. The other interesting point is that the technology provider, G&M, is a venture business established by a retiree who worked in the petrochemical cluster for a long time. This is a case where an idea from an individual person is realised via socio-economic networks.

- 2.2. **Effluent Sludge Recycling as Energy Source:** Effluent sludge accounts for 65 percent of the total amount of sludge, 83,470 tons, generated from the Yeosu industrial district. As the ocean disposal of sludge will be prohibited shortly, the petrochemical firms must find other ways to treat their sludge on land. The affiliate firms of Kumho Group in the Yeosu industrial district have succeeded in using sludge as an auxiliary fuel for their affiliate cogeneration plant. Kumho petrochemical, Kumho P&B Chemical and Kumho Polychem generate organic sludge, while Kumho Cogeneration Plant emits inorganic sludge. The cogeneration plant is equipped with fluidized incinerators that use sand as the material to improve thermal efficiency. Organic sludge can be reused as auxiliary fuel and inorganic sludge can substitute for sand.

The participant firms have three advantages in the sludge recycling network. First of all, the number of sludge providers is sufficient. As explained in the case of waste catalysts, the more providers the better, to obtain economic feasibility and stable supply of resources. Secondly, the characters of their industrial wastes are physically complementary. Last but not least, they are under the same corporation governance.

The informant pointed out this fact as one of keys to success: “The project is not only relevant to us. However, our affiliate firms become active in cooperation because we are affiliated. We already have our own cooperative relationship.”

III. Cluster-wide Resources: Social Capital in Yeosu

The Ansan industrial district has a variety of well-developed networks among the clustered firms, the government agents and the local research institutes. As described in many previous reports, the networks have formed according to the state’s plan to build a regional innovation system through which SMEs can improve their competitiveness. In contrast, my judgment during the fieldwork in Yeosu is that there has been less government intervention in the Yeosu industrial district. This appears to be true at least at the local level. Instead, various types of autonomous network have been developed in the Yeosu area. The Yeosu industrial district clearly has a meaningful degree of social capital.

- 3.1. Is it possible to argue that externally owned firms are firmly embedded in a local society? As for the petrochemical firms located in the Yeosu industrial district, the answer is “maybe yes”. Most of all, the petrochemical firms are *physically* embedded in the area because of the specific character of the petrochemical industry. Secondly, the local governance functions to induce the petrochemical firms to commit to the local society. The executive secretary of the governance evaluates this as follows: “As the petitions from the business society have been solved and the firms have gained credit for their contribution to the local community in this formal framework, now they are underway to settle down in the governance so as to demand and negotiate in a natural way.” Third, several petrochemical firms have a strong regional identity. For example, GS-Caltex “drove the pipe into Yeosu in 1967. GS-Caltex put down its roots in this land. The matrix of GS-Caltex’s manufacturing base originated here” (Interview with GS-Caltex). The interviewee working for Kumho Petrochemical also made a similar comment: “Kumho is the company of this local society. We are the native firm here, Jeonnam”. Both GS-Caltex and Kumho Petrochemical point out that their regional identity is one of the reasons why they make efforts to solve the

environment problems and contribute to the local community.

The results from interviewing a few firms cannot be generalised. A large proportion of the petrochemical firms probably do not have such a regional identity. GS and Kumbo might be an exception. Even then, it is interesting that giant multinational corporations have a sense of belonging to their birthplace.

- 3.2. CSR (Corporate Social Responsibility) was rarely mentioned during the interview process in the Ansan industrial district. In contrast, CSR is one of main issues in the Yeosu industrial district. Roughly speaking, CSR activities of the petrochemical firms can be divided into two categories; the CSR in production networks and the CSR in social contribution. This implies that a firm's CSR management is a multi-faceted system through which all stakeholders are considered, including trade counterparts, subcontractors and local community.
- 3.3. Especially on the environment and safety issues, CSR or SR is a crucial framework to understand the environmental performance in the Yeosu petrochemical cluster. However, CSR or SR is not a concept which I have reviewed in my theoretical body.
- 3.4. The local NGOs like Yeosu YMCA and Yeosu Federation for Environmental Movement are very active on the local environmental issues. The Yeosu industrial district is the starting point of the national-scale movement to improve the environment in industrial regions, and the only industrial district where the local NGOs are participating in EIP as one of the principal agents. The local NGOs have developed through various struggles against "strong counterparts, corporate giants". Interestingly, despite the long list of hostile strife between the local NGOs and the business community, the current relationship between the local NGOs and the petrochemical firms in the Yeosu industrial district is fairly amicable. Both sides have collaborated in a variety of formal and informal local projects. The role of local NGOs in the Yeosu area is far more than a simple observer or surveillant.

The interviewees working in the business sector reveal their positive attitude to the local NGOs. Frequent contacts, collaboration experience, the same regional identity

and the shared perception of the common aim are mentioned in terms of the cooperative interrelationship.

- 3.5. It seems clear that the local actors are in an intimate relationship in the Yeosu industrial district. Most informants take pride in their cooperative and reciprocal interactions. They are working in an effective formal and informal network through which “just one bridge is enough” to access someone.

This was the most impressive finding during the fieldwork in the Yeosu area. While the public, private and social sector of the Yeosu industrial district has their own close ties respectively, they are linked with each other via formal institutionalized relations as well as personal networks. This looks like the strength of weak ties described by Granovetter (1973), although it is slightly off the point in my research.

IV. Others

- 4.1. The government regulation is the most decisive element to drive the petrochemical firms to improve their environmental performance. All three interviewed firms put top priority on the government regulation rather than any other elements.
- 4.2. The petrochemical firms regard EIP as problem-solving. This viewpoint is distinguished from the textile dyeing cluster which focuses on cost-saving through its environmental performance.
- 4.3. The quantitative data about the environmental performance is unreliable because of the firms’ defensive attitude on sensitive environmental issues and trade secrets.

APPENDIX 2. Example Preview Report

SORT: Fieldwork Preview No.13

DATE: 30/08/2011

WRITER: Sukjin Yoon (IDPM, Manchester)

This paper is written to review the history of Yeosu briefly. In contrast to the Ansan area, Yeosu was a populated rural area even before the petrochemical cluster was established. This historical feature has caused the continuing struggle between the clustered firms and the native local people.

The History of Yeosu

In the Pre-modern Time

Yeosu was a rural area where communities depended on agriculture and fishery for their livelihood. Even in pre-modern times, Yeosu was a populated area because it was abundant in agricultural products and marine products. In addition, its urban function was developed to a certain extent because one of the major naval bases in the Joseon Dynasty²⁶ was located in Yeosu. During the war with Japan between 1592 and 1598, Yeosu was the central base of the Joseon fleet.



Jin-Nam Gwan, Navy Command Centre of the Joseon Dynasty in Yeosu

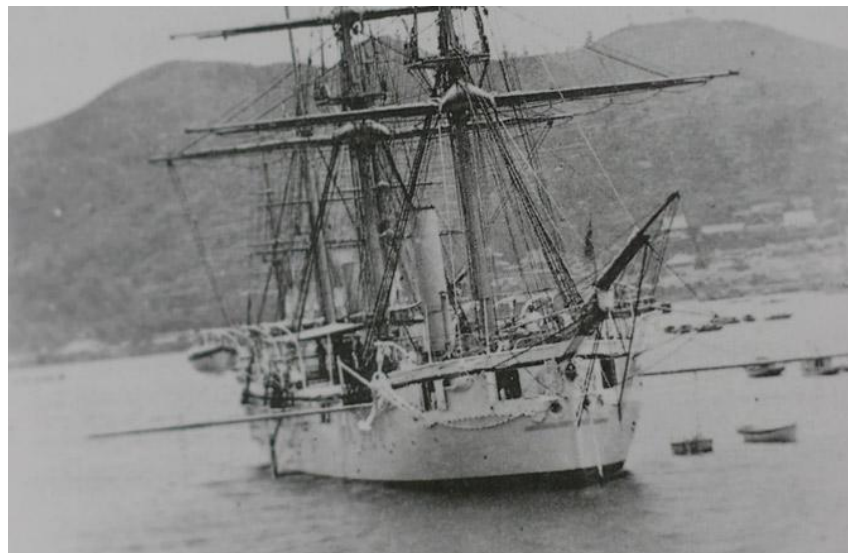
²⁶ The Joseon Dynasty is the last kingdom in Korean Peninsula.



The map of the old castle in Yeosu

Between the Japanese Colonisation Period and the Korean War

Yeosu experienced a series of bitter historical events in the modernisation period. In 1885, the English fleet invaded Geomun Island²⁷, an off-lying island of Yeosu, and illegally occupied the island for three years. This military action aimed to restrict the increasing influence of Russia in the Far East. From the Korean viewpoint, this was a signal showing that the Korean Peninsula had begun to be threatened by western imperialism.



The English warship anchored in front of Geomun Island in 1885

²⁷ The English navy called it Port Hamilton.

When the Donghak Peasant War occurred in 1894²⁸, Yeosu became one of the major battlefields through which Japanese imperialism invaded Korea. The peasant army marched to Yeosu from the neighbouring city of Suncheon in 1894 and the royal force stationed at the navy base in Yeosu asked for military assistance from the Japanese fleet which was anchored off the coast of Yeosu. As a result, the strategic place to defend Korea from the Japanese invasion in the sixteenth century became the shortcut to the colonisation of Korea by Japan in the twentieth century.

After Japan was defeated in the Second World War, the Korean Peninsula was divided into two different political regimes, and South Korea under the control of the US Army experienced extreme political struggle in the late 1940s. The military rebellion in Yeosu and Suncheon in 1848 was one representative event caused by the ideological civil war. A group of soldiers refused to be dispatched to Jeju Island where a communist-led guerrilla movement against the Korean police and the US military government had operated and occupied Yeosu, Suncheon and other five areas in Jeollanam-do. Many innocent people were scarified in Yeosu via this tragic historical event.

During the Rapid Economic Growth Period

The petrochemical cluster's history began with the settlement of Honam Oil Refinery (GS Caltex at present), the first refinery in South Korea, in Yeosu in 1967. To meet the increasing demand for oil during the rapid economic growth in South Korea, the government decided to designate Yeosu as one of the national industrial complexes specialised in the petrochemical business. Now the Yeosu industrial district has become one of the three main petrochemical clusters.

The government has forced the local people to evacuate from their hometowns so as to prepare the industrial estate. There has been continuous environmental degradation, and pollution accidents such as explosions in chemical process facilities. In addition, the income gap between the local firms and local communities has expanded. As a result, the inbuilt complaint and distrust have been accumulated for over thirty years. In July 1995, oil products tanker ship, *Seaprince*, ran aground off Yeosu, spilling a large amount of crude oil. This sea pollution accident ignited the explosion of the suppressed complaints from the

²⁸ This is the peasant rebellion based on anti-feudalism and anti-imperialism.

local society in Yeosu. To make matters worse, KIST's report on the environmental conditions in Yeosu in 1996 announced "Yeosu is the land where human beings cannot live". With the *Seaprince* marine pollution accident, this report triggered a series of chain reactions to deal with the environmental concerns among the stakeholders surrounding the petrochemical cluster.



Seaprince Marine Pollution Accident in 1995

APPENDIX 3. Interview Questionnaire (Firm)

Environmental Issues at the Firm Level
Could you introduce your firms? (Main products, number of employees, total sales, main market and brief history)
What are the main pollutants / environmental concerns from your activities?
Has there been a negative effect on your activities from environmental impact?
What is your main strategy to deal with environmental impacts?
Environmental Issues in Vertical Tie
Who are your main buyers and suppliers?
Describe the features of the business relationships with your buyers and suppliers.
Are you responsible for the environmental impacts of your suppliers or buyers?
Has there been a change in your business relationships with your suppliers or buyers because of environmental issues?
Do you assist your suppliers or buyers to improve environmental performance?
Do your suppliers or buyers assist you to improve environmental performance?
Could you describe your experience of cooperation with your suppliers or buyers for environmental performance? (benefits, barriers, and expectations)
Environmental Issues in Horizontal Ties
In what way do you cooperate and/or compete with other firms in the cluster?
What are the main issues for cooperation and for competition?
How do you cooperate with other firms in the cluster for environmental issues?
If there is a facilitator between you and your partner, who is it?
Do you have a plan to continue the cooperative relationship on another issue?
Could you describe your experience of cooperation with other firms in the cluster for environmental issues? (benefits, barriers, and expectations)

Environmental Issues at the Inter-Sectoral Level
Do you have a partner firm operating in the other sectors on environmental issues?
How did you find the partner firm operating in the other sectors?
If there is a facilitator between you and your partner, who is it?
Have you any previous experience of cooperating with your partner?
Do you have a plan to continue the cooperative relationship on another issue?
Could you describe your experience of cooperation with other firms in the cluster for environmental issues? (benefits, barriers, and expectations)
Cooperation with Non-firm Institutions
Have you ever cooperated with any non-firm institutions?
How did your firm find the non-firm institutions? If there is a facilitator, who is it?
In what ways have your firm and the non-firm institutions cooperated and what are the main areas of your cooperation?
Have you ever cooperated with the non-firm institutions for environmental performance?
In what way did you cooperate with them to improve environmental performance?
Could you describe your experience of cooperation with other firms in the cluster for environmental issues? (benefits, barriers, and expectations)
Participation in the EIP Programme
Could you introduce the industrial symbioses in which your firm is involved?
How did your firm find the information about the EIP programme?
How did your firm find the by-product exchange counterparts?
Have you ever had support from any non-firm institutions for the industrial symbioses? What sorts of support have you received from them?
In what way did you negotiate with your symbiosis counterparts in terms of investments and price-setting?
What are the benefits, barriers, and expectations in the EIP programme?