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ENVIRONMENTAL MANAGEMENT BY ECO-INDUSTRIAL ESTATE PRINCIPAL:

A CASE STUDY IN MAP TA PHUT INDUSTRIAL ESTATE (MTPIE)

Mrs. Sauvanee Wiriyaumpaiwong

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By	Mrs. Sauvanee Wiriyaumpaiwong
Field of Study	Environmental Management
Thesis Advisor	Ekawan Luepromchai, Ph.D.
Thesis Co-advisor	Kasemsri Homchean, MTPIE Manager

Accepted by the Graduate School, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master 's Degree

.... Dean of Graduate School

(Professor Suchada Kiranandana, Ph.D.)

THESIS COMMITTEE

.... Chairman

(Assistant Professor Sutha Khaodhiar, Ph.D.)

.... Thesis Advisor

(Ekawan Luepromchai, Ph.D.)

.... Thesis Co-advisor

(Kasemsri Homchean, MTPIE manager)

.... Member

(Somporn Kamolsiripichaiporn, Ph.D.)

.... Member

(Manaskorn Rachakornkij, Ph.D.)

เสาวนีย์ วิริยะอำไพวงศ์ : การจัดการสิ่งแวดล้อมโดยใช้หลักการของนิคมอุตสาหกรรมเชิงเศรษฐนิเวศ กรณีศึกษาโรงงานในนิคมอุตสาหกรรมมาบตาพุด (Environmental Management by Eco-Industrial Estate Principal: A Case Study in Map Ta Phut Industrial Estate (MTPIE)) อ. ที่ปรึกษา : ดร. เอกวัล ลือพร้อมชัย, อ. ที่ปรึกษาร่วม : นางเกษมศรี หอมชื่น, 76 หน้า. ISBN 974-17-1278-2.

นิคมอุตสาหกรรมหรือสวนอุตสาหกรรมเชิงเศรษฐนิเวศ เป็นกลยุทธหนึ่งในการนำหลักการของอุตสาหกรรมเชิงนิเวศ (Industrial Ecology) มาใช้ในการจัดการสิ่งแวดล้อม โดยอาศัยความร่วมมือกันระหว่างอุตสาหกรรม ซึ่ง US-EPA ได้นิยามความหมายไว้ว่า คือการรวมกลุ่มกันของธุรกิจด้านการผลิตและการบริการ เพื่อเพิ่มประสิทธิภาพทางด้านสิ่งแวดล้อม และเศรษฐศาสตร์ ด้วยการร่วมมือกันในการจัดการสิ่งแวดล้อมและทรัพยากรอันได้แก่ พลังงาน น้ำ และวัตถุดิบ ทำให้กลุ่มธุรกิจได้รับผลประโยชน์โดยรวมที่มากขึ้นกว่าการดำเนินงานเองโดยลำพัง การนิคมอุตสาหกรรมแห่งประเทศไทย ได้พิจารณานำหลักการดังกล่าวมาใช้ โดยการส่งเสริมการจัดตั้งกลุ่มนิคมอุตสาหกรรมเชิงเศรษฐนิเวศขึ้นในนิคมอุตสาหกรรม 5 แห่ง ทั่วประเทศ ซึ่งนิคมอุตสาหกรรมมาบตาพุดเป็นนิคมอุตสาหกรรมที่มีศักยภาพสูงในการพัฒนา เนื่องจากมีระบบองค์กรต่างๆ ภายในที่สามารถสนับสนุนการก่อตั้งแนวคิดดังกล่าวอยู่แล้ว การศึกษานี้จึงมีจุดมุ่งหมายในการให้การสนับสนุนโครงการพัฒนาแนวคิดของนิคมอุตสาหกรรมเชิงเศรษฐนิเวศในนิคมอุตสาหกรรมมาบตาพุด โดยการศึกษาค้นคว้าถึงกิจกรรมด้านการจัดการสิ่งแวดล้อมในปัจจุบัน แนวทางในการเชื่อมโยงความร่วมมือระหว่างภาคอุตสาหกรรม และการวิเคราะห์ผลตอบแทนทางด้านสิ่งแวดล้อมและเศรษฐศาสตร์

การศึกษานี้มุ่งเน้นในการวิเคราะห์ถึงระดับความร่วมมือกันในปัจจุบัน เสนอแนะความร่วมมือกันในส่วนที่มีศักยภาพในการพัฒนา และการประเมินผลตอบแทนทางด้านสิ่งแวดล้อมและเศรษฐศาสตร์ โดยได้ทำการศึกษาใน 6 โรงงาน ซึ่งพิจารณาจากความสมัครใจ ข้อมูลที่เพียงพอ ประเภทอุตสาหกรรม และกิจกรรมความร่วมมือระหว่างภาคอุตสาหกรรม ในการศึกษาได้ทำการวิเคราะห์ผลทางด้านเศรษฐศาสตร์ และผลทางด้านสิ่งแวดล้อม ซึ่งได้ทำการศึกษาการนำเศษเหล็กใช้แล้วจากโรงงานไปใช้เป็นวัตถุดิบของโรงงานผลิตเหล็ก และการนำหลอดไฟฟลูออเรสเซนส์ที่ใช้แล้วกลับมาใช้ใหม่ โดยส่งหลอดไฟใช้แล้วกลับไปยังบริษัทผู้ผลิตหลอดไฟ ผลการศึกษาพบว่า ทั้งสองโครงการเป็นการส่งเสริมการใช้ทรัพยากรอย่างยั่งยืน ลดผลกระทบทางด้านสิ่งแวดล้อม และลดค่าใช้จ่ายของบริษัท รวมถึงเป็นการลดการใช้พื้นที่ฝังกลบ ซึ่งเป็นการลดการเกิดมลพิษที่แหล่งกำเนิด ลดการใช้พลังงาน ลดการปล่อยก๊าซเรือนกระจก และพัฒนาคุณภาพชุมชน ระดับการประยุกต์ใช้แนวคิดของนิคมอุตสาหกรรมเชิงเศรษฐนิเวศขึ้นอยู่กับนิคมอุตสาหกรรมและกลุ่มโรงงานในนิคมอุตสาหกรรม ดังนั้นควรมีการศึกษาต่อไปเพื่อปรับปรุงประสิทธิภาพของนิคมอุตสาหกรรมเชิงเศรษฐนิเวศในนิคมอุตสาหกรรมมาบตาพุด โดยความร่วมมือของการนิคมอุตสาหกรรมแห่งประเทศไทย กลุ่มโรงงานอุตสาหกรรม และสถาบันศึกษา

สหสาขาวิชา การจัดการสิ่งแวดล้อม	ลายมือชื่อนิสิต ....
สาขาวิชา การจัดการสิ่งแวดล้อม	ลายมือชื่ออาจารย์ที่ปรึกษา ....
ปีการศึกษา 2545	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม ....

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KEY WORD: ECO-INDUSTRIAL ESTATE / ECO-INDUSTRIAL PARK / INDUSTRIAL SYNERGY LINKAGE / BY-PRODUCT EXCHANGE / MAP TA PHUT INDUSTRIAL ESTATE / ECONOMIC AND ENVIRONMENTAL BENEFIT ANALYSIS

SAUVANEE WIRIYAUMPAIWONG: ENVIRONMENTAL MANAGEMENT BY ECO-INDUSTRIAL ESTATE PRINCIPAL: A CASE STUDY IN MAP TA PHUT INDUSTRIAL ESTATE (MTPIE). THESIS ADVISOR: EKAWAN LUEPROMCHAI, Ph.D. THESIS CO-ADVISOR: KASEMSRI HOMCHEAN, MTPIE MANAGER. 76 pp. ISBN 974-17-1278-2.

Eco-Industrial Estate (EIE) or Eco-Industrial Park (EIP) is one of the strategies to implement the concept of industrial ecology for environmental management by inter-company collaboration. EIPs is defined by US-EPA as "a community of manufacturing and service business seeking enhanced environmental and economic performance through collaboration in managing environmental and resource issues including energy, water and materials. By working together, the community of business seeks a collective benefit that is greater than the sum of the individual benefits each company would realize if it optimized its individual performance only". Thailand by Industrial Estate Authority of Thailand (IEAT) has adopted EIE development concept by promoting implementation at 5 industrial estates. MTPIE has high potential for Eco-Industrial Estate Development due to the existing self-organized system that supports on establishing the EIE concept. This study aimed to assist in EIE development program at Map Ta Phut Industrial Estate (MTPIE) by investigating existing environmental management activities, identifying industrial synergy linkages and analyzing the economic and environmental benefits.

This study emphasized on existing linkage level, proposed potential linkage area, and evaluated economic and environmental benefits. Based on voluntary basis, an availability of information, type of industrial sectors, and the implementation of industrial synergy linkage activities, six factories were chosen for detailed study. Two waste recycling projects in material area were analyzed in term of economic and environmental benefits. These projects are steel scrap recycling project, which is carried out by sending steel scrap directly to steel manufacturer (SCSC), and used fluorescent lamp recycling at lamp manufacturer project. The result of this study showed that these projects would promote sustainable use of natural resources, reduce environmental impact, and save operating cost. Moreover, recycling process will decelerate the need for landfills. This will promote pollution prevention at its source, energy saving, and reducing greenhouse gas emission, and community development. A successful EIE implementation depends on the industrial estate as well as its tenants. Furthermore, future studies to improve EIE effectiveness in MTPIE can be progressively accomplished by the collaboration among IEAT, industrial estate tenants, and interested academic.

Inter-department Environmental Management	Student's Signature…………………
Field of Study: Environmental Management	Advisor's Signature…………………
Academic Year 2002	Co-advisor's Signature……………..

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ABBREVIATIONS

ATC	=	Aromatic Thailand Public Company Limited
BIG	=	Bangkok Industrial Gas Company Limited
BPE	=	Bangkok Polyethylene Public Company Limited
BPX	=	By-Product Exchange
BST	=	Bangkok Synthetics Company Limited
BSTE	=	BST Elastomers Company Limited
COCO	=	The Cogeneration Public Company Limited
BAYER	=	Bayer Thai Company Limited
EH & S	=	Environmental Health and Safety
EMAG	=	Map Ta Phut Emergency Mutual Aid Group
EIE	=	Eco-Industrial Estate
EIEN	=	Eco-Industrial Estate and Network
EIN	=	Eco-Industrial Network
EIPs	=	Eco-Industrial Parks
GENCO	=	General Environmental Conservation Public Company Limited
GSCC	=	Grand Siam Composites Company Limited
GTZ	=	German Technical Cooperation
HCST	=	H.C. Starck (Thailand) Company Limited
HMC	=	HMC Polymer Company Limited
HMT	=	HMT Polystyrene Company Limited
IE	=	Industrial Estate
IEAT	=	Industrial Estate Authority of Thailand

ABBREVIATIONS (cont.)

MFC	=	Thai MFC Company Limited (MFC)
MMA	=	Thai MMA
MTPIE	=	Map Ta Phut Industrial Estate
NFC	=	National Fertilizer Public Company Limited
NOVA	=	NOVA Steel Company Limited
NPC	=	National Petrochemical Public Company Limited
PDI	=	Padaeng Industry
RESA	=	Rayong Environmental and Safety Association
ROC	=	Rayong Olefins Company Limited
RWI	=	Rayong Wire Industry Company Limited
SCSC	=	The Siam Construction Steel Company Limited
STP	=	Siam Tinplate Company Limited
SYS	=	Siam Yamato Company Limited
TEC	=	Thai Epoxy and Allied Products Company Limited (TEC)
TOC	=	Thai Olefins Company Limited
TPA	=	Ton Per Annum
TPC	=	Thai Plastic & Chemical Public Company Limited
TPC-PEST	=	TPC Paste Resin Company Limited
TPE (1993)	=	Thai Polyethylene (1993) Company Limited
TPE	=	Thai Polyethylene Company Limited
TPM	=	Total Productive Maintenance
TPP (1994)	=	Thai Polypropylene (1994) Company Limited

ABBREVIATIONS (cont.)

TPP	=	Thai Polypropylene Company Limited
TQM	=	Total Quality Management
TSIC	=	Thai Shinkong Industry Corporation Ltd.
TTC	=	Tuntex (Thailand) Public Company Limited
UNEP	=	United Nations Environment Program
VNT	=	Vinyl Thai Public Company Limited

CHAPTER 1

INTRODUCTION

1.1 Background and Motivation

The environmental impacts of rapid industrialization and population growth have been of general public concern in the world for several decades, especially in most Western countries. Examples of the impacts are air pollution, pollution of rivers and oceans, toxic chemical contamination, deforestation and desertification. In 1975 the UNEP Industry and Environment center (UNEP IE) was established in Paris. Since then, it has helped shift the environmental debate from reaction and short-term "cure" (e.g. end-of-pipe pollution control) to prevention (e.g. cleaner production), and long-term "sustainability".

In addition to the establishment of the UNEP, the challenge of sustainability was sketched out at the Rio Earth Summit in 1992. Governments and many industries in the developed nations have attempted to define and implement sustainable economies and businesses as well as experimented with national sustainability plans, life-cycle analyses and ISO 14000 certification. However, those developed countries are still not making effective progress, and sustainable development is unlikely to emerge from a process of leadership and diffusion from North to South. The developing countries are increasingly concerned that these progresses will become *de facto* requirements for access to markets in the industrialized countries (Wallace, 1996).

In most countries, the development of environmental programs follows a similar pattern. Early efforts concentrate on direct threats to public health, such as contaminated drinking water and air pollution. Only after these problems are addressed does the issue of improving the day-to-day management of wastes deemed “hazardous” rise to the top of the nation’s environmental agenda.

In the past thirty years, many developed countries have established effective hazardous waste management programs. During the past decade, some developing countries - particularly those that have experienced rapid economic growth and industrialization - have begun to consider ways of developing and implementing programs to assure the proper disposal of hazardous waste.

Looking specifically at Thailand, Thailand’s high economic growth since the late 1980s has mostly been due to the country’s rapid industrialization. The main target of industrial output has changed from domestic consumption to export. While an industry-driven economy creates higher income opportunities for some people, it also has an undeniable impact on the country’s environment and on its natural resources. Industrialization has introduced to Thailand, as it has elsewhere, the use of hazardous substances as raw materials, and the production of hazardous wastes. The hazardous waste problem in Thailand has dramatically worsened in recent years. Thailand is now a country with a high hazardous waste potential.

In examining an Industrial Estate in Thailand, it resembles an industrial town or city providing complete infrastructure necessary for industrial operations such as ample electricity, water supply, flood protection, waste water treatment, solid waste disposal, etc. It is accessible to a seaport, an airport and other transportation centers. Besides providing communication facilities and security systems, an industrial estate also contains commercial banks and a post office. Some have customs offices, schools, hospitals, shopping centers and other facilities needed for investors and workers. In fact, it is a self-contained community.

Overseeing these industrial estates in Thailand, the Industrial Estate Authority of Thailand (IEAT) is a state enterprise attached to the Ministry of Industry. It is chartered to implement the government's industrial development policy. Its objective is not only development but ensuring orderly planned industrialization of the industries concerned and the country as a whole. With problems related to various locations, for example, the control and monitoring of industrial pollution, the broad planning needed to manage all this called for a strong national authority, and so the IEAT was formed.

IEAT and private investors jointly manage a total of 21 industrial estates while the other 8 industrial estates managed solely by IEAT. They have overall employment of 400,000 employees and around 1,900 factories. The technical cooperation project is intended to improve the environmental performance of selected industrial estates and develop a policy for Eco-Industrial Development for Thailand.

According to the policy and commitment from the IEAT Board Director of Management in 1999, IEAT submitted the project “Development of Eco-Industrial Estate and Network Concept at Industrial Estate”. There are 5 industrial estates that have shown interest in participating in the project, including Amata Nakorn Industrial Estate, Northern Industrial Estate, Eastern Seaboard Industrial Estate, Bangpoo, and Map Ta Phut Industrial Estate (MTPIE).

Since June 2000, IEAT and GTZ have conducted a series of workshops, seminars and studies to start a dialogue with all major stakeholders from the industrial estate developers, entrepreneurs, government agencies and the public. The objective is to develop suitable concepts for Eco-Industrial Estate Development at industrial estates in Thailand, which would be a major policy instrument.

Of the five participating Industrial Estates, MTPIE has a high potential for Eco-Industrial Estate Development due to the existing self-organized system that supports establishing the EIE concepts, such as raw material or by- product symbiosis, common maintenance association or public relations team. Since 1999, the industrial estate management is focusing on integrated environmental management and cooperating with industrial estate enterprises, sector agencies, local government, and communities to reduce environmental effects from the estate.

MTPIE located in Rayong, on the Eastern Seaboard, is a Petrochemical Complex (with refineries, natural gas, chemical industry; upstream and downstream, steel industry). MTPIE facilities include a deep seaport, a power plant and the only hazardous waste disposal facility and landfill in Thailand (GENCO). It has been operating since 1984.

There are 58 industries in MTPIE that can be categorized into 5 industrial sectors: 52% petrochemical related downstream plants, 21% chemical and fertilizer plants, 14% steel plants, 10% utilities (electricity, stream, gas), and 3% oil refinery plants. In this proposed study, four voluntary factories were chosen from 5 diversified industrial sectors. They can be classified as one upstream petrochemical factory (ROC), two downstream petrochemical factories (HMC and Bayer Thai), one chemical and fertilizer factory (NFC), and the others are related to the iron and steel factory (SCSC) and the utility factory (COCO).

From the MTPIE waste management report year 2000, it can be summarized that overall hazardous waste generated from MTPIE is estimated at 2,500 tons per annum (TPA). Around 1,000 TPA or 40% of that is recycled mainly by applying a fuel blending process. The rest are disposed at GENCO. The amount of waste may be minimized if factories can develop symbiotic exchanges of materials as well as reusing or recycling the waste materials. Therefore, MTPIE has planed to start a waste and by-product exchange program under the Development of Eco-Industrial Estate and Network (EIEN) program, which will implement following the EIE concept. The program would integrate the environment and the economy issue together by trying to explore one aspect of industrial ecology in terms of process-oriented recycling and “cross-industry” transfer of by-product. These benefits can be used as the basis for a marketing strategy to prospective tenants, financial institutions and surrounding communities.

1.2 Objectives

From EIE concept and its current implementation in Thailand, the main objective of this study is to assist in Eco - Industrial Estate (EIE) development program at Map Ta Phut Industrial Estate (MTPIE). The immediate goal of this program is to create networking on a selected potential area among factories by identifying industrial synergy linkages between voluntary factories within Eco-Industrial Estate (EIE) Development program. The specific objectives are as follows;

1.2.1 To investigate existing environmental management activities on voluntary factories, 1.2.2 To identify industrial synergy linkages between voluntary factories that are important to the success of EIE implementation,

1.2.3 To analyze potential economic and environmental benefits of a selected industrial synergy linkage.

1.3 Scope of work

1.3.1 This study was focused on voluntary factories in MTPIE. A questionnaire on potential areas surveying was sent out to each of the 89 factories in the estate. Information about existing environmental management activities was gathered from the participating factories. According to Cohen Rosenthal (1996), there are 9 potential areas; material, transportation, human resources, information/communication systems, quality of life/community connection, energy, marketing, environmental health and safety, and the production processes.

1.3.2 Obtained data from the voluntary factories was assembled to identify the potential areas of industrial synergy linkages. After that only 6 factories were chosen to be representatives of each industrial sectors.

1.3.3 An industrial synergy linkage was chosen for potential economic and environmental analysis. In this study, the economic and environmental issues were combined together to evaluate the benefit of two recycling projects. These benefits would enable prospective tenants to improve their marketing strategy, financial situation, and image to surrounding communities.

CHAPTER 2

LITERATURE REVIEW

The major concern about concept of "Eco-Industrial Estate (EIE)" or "Eco-Industrial Parks (EIPs)" and its practical way is its advantage and disadvantage. This chapter therefore focuses on basic terms of industrial ecology (IE) as well as the applicability of this approach to industrial environmental management in Thailand and other Asian countries. The information could be used to assess new opportunities as well as impediments before adopting IE principal into practice.

2.1 Industrial Environmental Management

Over the last few decades, most environmental policies have rested on “end-of-pipe” pollution controls mandated by “command-and-control” regulations. This response was often inefficient; environmentally because pollution could have been prevented during production, and economically because companies had to comply with the regulations regardless of total costs. Furthermore, the implementation, monitoring and enforcement of these regulations were costly, sporadic, and in many case incomplete.

Many approaches to industrial environmental management have been tried and grown in complexity and coherence over time, for example, moving from end-of-pipe controls towards a life-cycle approach for products, and from local to global scale. At the same time, the design of industrial estates has been moved toward the concept of industrial ecosystem, by which industrial systems are modeled, at the global, industry sector and company levels, as a mirror of natural ecosystems. The implementation of industrial ecology has been recommended as the goal for industrial estates in environmental management (UNEP, 1996).

2.2 Industrial Ecology

Industrial ecology, the study of industrial ecosystems, focus on the flows of materials and energy in industrial and consumer activities, of the effects of these flows on the environment, and of the influences of economic, political, regulatory, and social factors on the flows, use, and transformation of resources. The objective of industrial ecology is to understand better how we can integrate environmental concerns into our economic activities. This integration, an ongoing process, is necessary if we are to address current and future environmental concerns. (Allenby et al., 1994)

Industrial ecology models industrial systems after natural systems, where the output of one organism becomes the input for another and the benefit from each process is maximized. In this way, groups of companies and industries that interact can be seen as industrial ecosystems.

Industrial Ecosystem is defined as a system in which the consumption of energy and materials is optimized, waste generation is minimized and the effluents of one process serve as the raw material for another process (Frosch & Gallopoulos 1989).

Patterns of industrial ecosystems were gradually modified from a simple linear system to the complicated system or close loop system. Three types of industrial ecosystems (Allenby et al., 1992) are shown in Figure 2.1.

Type 1: Ecosystems are linear systems with no recovery of materials (typical industrial process).

Type 2: Ecosystems include recycling and reuse of some materials, although external inputs and industrial wastes are still unavoidable (emerging process).

Type 3: Ecosystems are closed systems with complete material recovery (un-achievable with current technology).

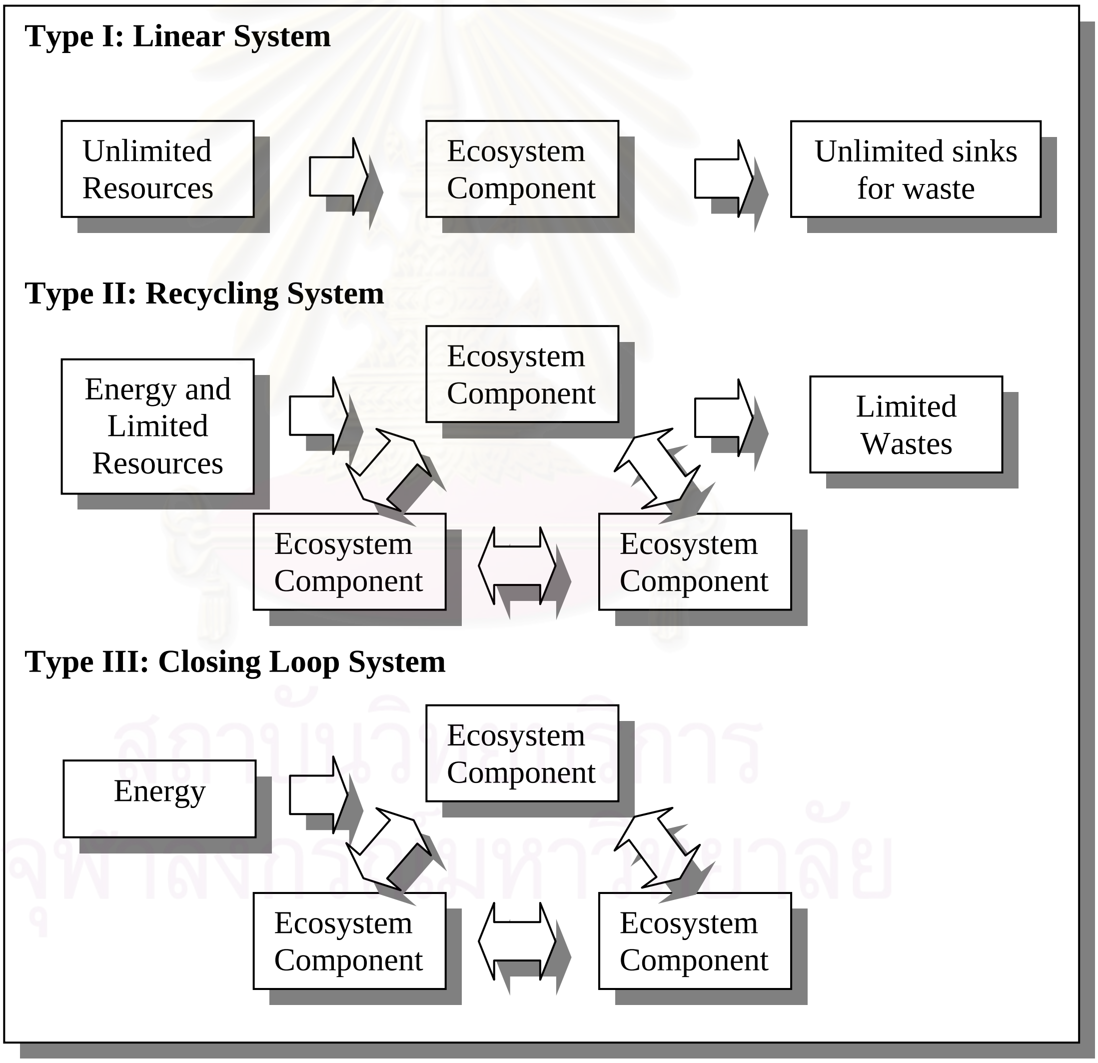

Figure 2.1 Cyclical Loop System

(Source: Braden R. Allenby, 1992)

According to Maramanos (1995), industrial ecology encourages greater environmental and economic efficiency. It provides opportunities for firms to decide whether to stress waste exchange, recycling, or material minimization based on their benefits and costs.

Industrial ecology can also yield economic and environmental benefits through its review process. It includes a thorough examination of the production process to highlight areas in which material saving and financial saving can be made. Furthermore, when end result of these saving is a lower product price, this can increase competitiveness to the firm, expand market share, and raise consumer satisfactory.

Other benefits are related to promotion of the company's reputation. This is important since many consumers increasingly consider environmental issues into their purchasing decisions. Moreover, financial and legal liabilities of a company can be minimized through industrial ecology. It can reduce payments related to higher-risk premiums and improve a firm's credibility. Waste reduction may reduce liabilities related to environmental accidents or improper disposal. In addition, since industrial ecology is a new approach to environmental problems, it may attract financial and technical support from institutions that have environmental objectives. Finally, a company might be able to induce stringent environmental regulations and become a market leader.

In a seminal article "*Industrial ecology: An Environmental Agenda for Industry*", Tibbs (1992) outlined six principal elements of industrial ecology. Those are;

1. Industrial Ecosystems,
2. Balancing industrial input and output to the constraints of natural systems,

3. Dematerialization of industrial output,
4. Improving the efficiency of the industrial processes,
5. Development of renewable energy supplies for industrial production, and
6. Adoption of new national and international economic development policies.

Creation of Eco-Industrial Parks is a practical way of applying ecological principles to industrial activities. It can be most effective when industrial systems are designed before production begins, in order to maximize materials and energy cycling (Lowe et al., 1996). Such opportunities are available in rapidly industrializing nations. Therefore, governments should put more efforts into businesses to develop industrial ecology schemes, for example by creating information systems, promoting innovative programs, and providing financial and technical support (Cohen et al., 1996).

2.3 Eco-Industrial Estate (EIE)

Concept of Eco-Industrial Estate (EIE) or Eco-Industrial Parks (EIPs), are one of the strategies introduced to implement the concept of industrial ecology by inter-company collaboration. The idea of Eco-Industrial Parks was first described during a presentation at UNCED, Rio (Carstensen 1999), and has become well know since 1993 in the USA through an introduction of Indigo Development to the US-EPA. EIP is defined by US-EPA as *"a community of manufacturing and service businesses seeking enhanced environmental and economic performance through collaboration in managing environmental and resource issues including energy, water and materials. By working together, the community of businesses seeks a collective benefit that is greater than the sum of the individual benefits each company would realize if it optimized its individual performance only."*

One of the benefits of EIPs is that they provide an opportunity for communities to foster “the best possible” industrial development. The development can range from no management to highly managed “campus” environments. In light of that, the following management range has been developed for industrial estates. A “Ladder of Environmental Management” as shown in Figure 2.2. The ladder ranges from the lowest rung – no management to the highest rung – industrial ecosystems.

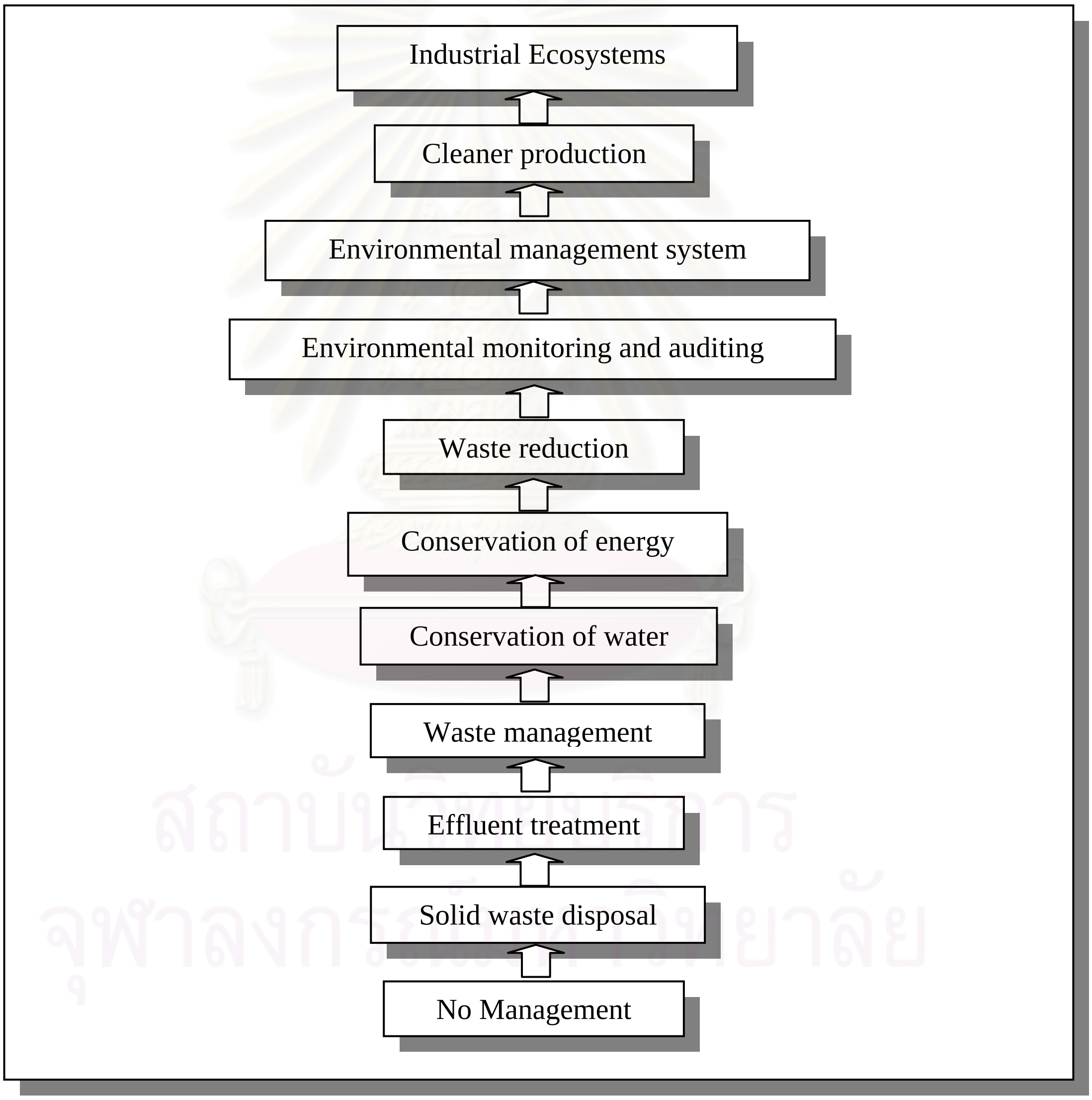

Figure 2.2 Ladder of Environmental Management
(Source: UNEP, 1996)

EIPs also provide a unique opportunity to simulate new technologies to fit the need of a particular location. Martin et al., (1995) suggested that EIPs can provide the incentive and the opportunity to think more systematically about technology and how it can best be applied. Moreover, the development of EIPs can create good jobs, strong companies, sustainable communities, and improved regional environments (Cohen et al., 1996). Cohen-Rosenthal mentions a more systematic approach may be necessary to consciously frame a wide range of possibilities, across a number of functional and thematic layers. Within key areas familiar to business, numerous possibilities for collaboration might emerge such as joint marketing and green labeling; ride sharing; shared processing equipment; flexible employee assignments; joint purchasing and shared services; and of course materials exchanges and energy cascading. A potential model of collaborative opportunities is illustrated as shown in Figure 2.3.

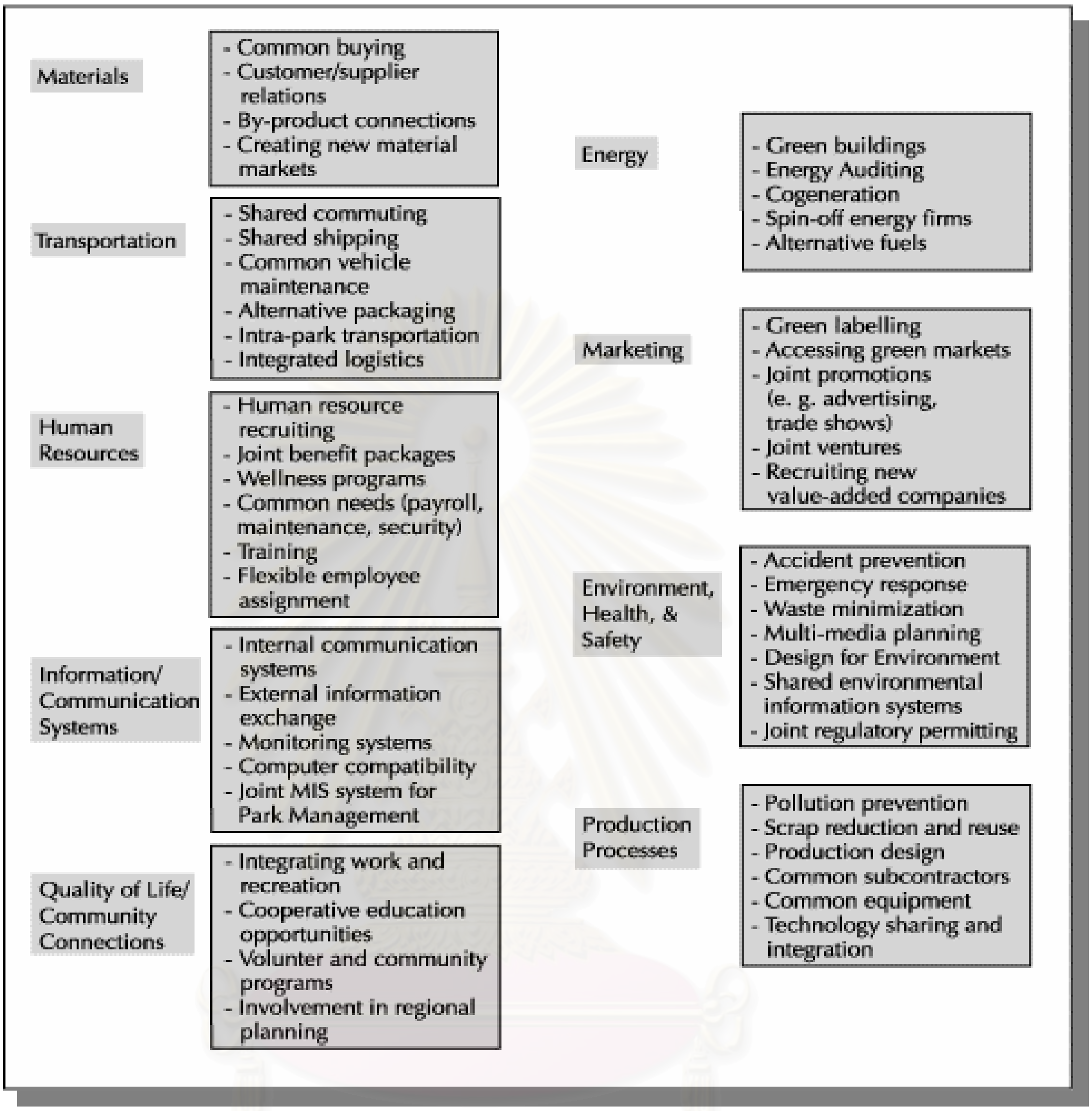

Figure 2.3 Potential Areas of Eco-Industrial Networking

(Source: Cohen-Rosenthal 1996)

The final key benefit of EIPs is that they mirror natural systems. They are sites where companies with compatible wastes operate and can easily exchange materials and energy. In ecological terms, the businesses that exchange used materials have entered into *a symbiotic relationship*. Symbiosis is an arrangement where two or more industries collaborate in ways that are beneficial for both. Symbiotic relationships among businesses are often referred to as industrial symbiosis (Reid, 1995). Industrial symbiosis is therefore a highly inter-dependent relationship between two firms, exchanging materials and energy in a mutually advantageous manner, each contributing to the welfare of the other (Manahan, 1999).

One key to transforming an existing industrial park into an industrial ecosystem is to first link the existing businesses at the site and then fill critical niches with new businesses that will enable or increase the effectiveness of exchange (Lowe, 1998). Some degree of consensus must be achieved among the tenants regarding the mutual benefits of developing symbiotic exchanges of materials, energy, and information (Lowe. et al., 1996). There is a great opportunity for state-of-the-art advancement that can be aided through increased identification of transfer both between and within industries. The research and development costs, and some of the fixed and operational costs, can be shared among the participating firms (Karamanos, 1995).

2.4 Industrial Symbiosis in Kalundborg Estate, Denmark

The best example of EIPs concept application is in Kalundborg Industrial Estate, Denmark. The history of Kalundborg began in 1961 with a project to use surface water from Lake Tissø for a new oil refinery in order to save the limited supplies of ground water (Christensen, 1999). The city of Kalundborg took the responsibility for building the pipeline while the refinery financed it. Starting from this initial collaboration, a number of other collaborative projects were subsequently introduced and the number of partners gradually increased. By the end of the 1980's, the partners realized that they had effectively "self-organized" into what is probably the best-known example of a working industrial ecosystem, or an industrial symbiosis.

Kalundborg's industrial symbiosis, as shown in Figure 2.4, is the world's most well known example of industrial ecology in practice. The industrial symbiosis in the Kalundborg district was built as a network cooperation between five industrial enterprises and the municipality of Kalundborg for mutual economic and environmental benefit. It is based on a series of bilateral commercial agreements on three different kinds of projects: recycling water, exchanging energy at different levels, and recycling waste products.

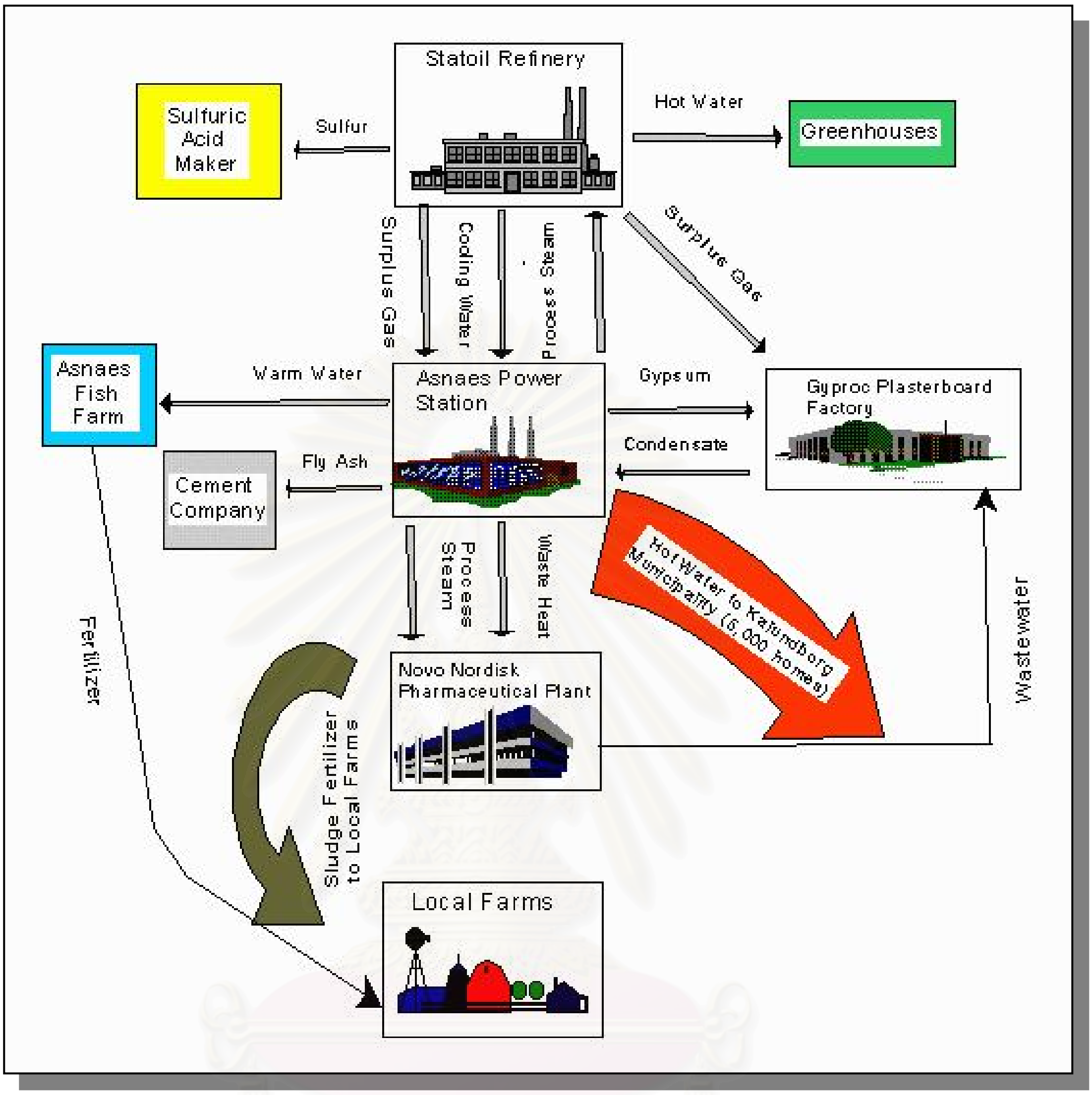

Figure 2.4 Kalundborg's Industrial Symbiosis

(Source: http://www.cfe.cornell.edu/wei/br97_fin.htm)

In this symbiosis, the five enterprises; Asnaes Power Station, the plasterboard manufacturer GYPROC, the pharmaceutical and biotechnology company Novo Nordisk/Novozymes, the soil remediating company A/S Bioteknisk Jordrens and the STATOIL refinery, trade their by-products as a valuable raw material to one or more of the others. For example, the STATOIL refinery distributes sulfur by-products to a sulfuric acid manufacturer and hot water to local greenhouses. Waste heat and steam from the Asnaes are used by Novo Nordisk. Where the Novo Nordisk distributes sludge from its manufacturing process to local farmers to fertilizer. These result in the reduction of both resource consumption and environmental impacts. The six business partners also gain financially benefits from their cooperation. All contracts within the symbiosis are based on sound commercial principles.

Following lists of material transfers in the system indicated flow of energy and materials between nodes in the symbiosis (Gertler 1995). Moreover, reduction of gaseous emission was also taken into account.

For Material and energy

- 225,000 tons of steam was provided by Asnaes to the district heating system equivalent to 19,000 tons of oil.
- The Asnaes plant made use of its own excess heat to run a fish farm.
- The sludge from the fishponds was recovered and sold as fertilizer.
- 14,000 tons of steam a year was sold by Asnaes to the Statoil refinery, accounting for 40% of its steam for pipe and tank heating.
- 215,000 tons of steam per year was supplied by Asnaes to Novo Nordisk.
- 80,000 tons per year of gypsum (calcium sulfate) recovered from the Asnaes power station's sulfur dioxide scrubber, was supplied to Gyproc.
- The power station also sold 170,000 tons per year of fly ash and clinker residues from coal burning for using in construction and road building.
- Ethane and Methane from the Statoil refinery were supplied for Gyproc's drying ovens and for the power station's boilers. Gyproc consumed 900 kilograms per hour and the power station is able to avoid burning 30,000 tons of coal a year.
- Novo Nordisk shipped 400 tons of phosphorus to farmers in the form of biosludge fertilizer.

For Emissions reduction

- CO_2 emissions have been reduced by 130,000 tons per year or about 3%.
- SO_2 emissions have declined 25,000 tons a year or roughly 58%.

2.5 By-product exchange (BPX)

Within the Eco - Industrial network one of the key program that can be imitated is By-Product Exchange (BPX). It is a relatively easy strategy to communicate, it requires active business leadership to achieve, and it offers relatively quick returns in cost saving and revenues (Gertler, 1995). This makes the BPX a logical choice as a part of an industrial ecology strategy. The basic concept here is that the by-products of one process can be an input for another. This can create more value to the by-products, normally regarded as "wastes", through reduced disposal & raw material costs.

BPX naturally connects to waste minimization and pollution prevention programs, designed for the environment, environmental management systems, and other industry initiatives to improve environmental performance.

Below are some examples of waste exchanges grouped by industry or waste type, which would be useful for identification of EIPs recruitment candidates (Lowe et al., 1996).

- Contra Costa Water District (Concord, CA) sends dried sludge to Port Costa Materials where it will be used in lightweight concrete bricks. About 700 tons of sludge will be exchanged annually.

- Dupont and Waste Management recycle plastics and produce resins to be used by Dupont as feedstock.

- Horsehead Resource Development Co. (PA), buys waste from steel foundries, metal finishers, electroplaters, and zinc die-casters for use in its metal recovery kilns.

- Paker Hannifan Corp. (Cleveland, OH) ships 8,800 gallons of sludge every 90 days to Encycle Texas, Inc., a metal waste recycling company in Corpus Cristi, TX. This saves Parker Hannifan about $80,000 each year.

- British Steel sends leaded steel by-products to a secondary lead smelter about 50 miles away. They break even on the deal.

- Burnside Industrial Park is located in the Halifax Regional Municipality, Nova Scotia, Canada. It is designated primarily for light manufacturing, distribution, and commercial activities. Burnside Industrial Park has served as an eco-industrial laboratory. While the stakeholders investigated the application of eco-industrial development strategies, they collaborated with the municipality in attempting to transform the existing infrastructure and companies while influencing the nature of the new infrastructure. The main success factor in this case has come from a continuing commitment by a group of partners from government, industry, academia, and community organizations (Cote, 2001).

- Eric Schwarz, and Austrian researcher, discovered a large industrial recycling network in the Austrian province of Styria. Materials traded in the Styrian network include familiar recyclables like paper, power plant gypsum, iron scrap, used oil, and tires, as well as a wide range of other byproducts. The plant managers in Styria were not aware of the larger pattern of exchange as it evolved. They were motivated purely by the revenues from byproducts they could sell and the savings in landfill disposal costs for either sold or free outputs. In some cases the byproducts were less expensive or higher quality than primary materials would be. (Schwarz & Steininger, 1997)

- Sarnia, Ontario, Canada, carried out an industrial symbiosis between oil refineries, a synthetic rubber plant, petrochemical facilities and a steam electrical generation station. (Cote & Cohen-Rosenthal, 1998)

- Resource Recovery Park Project, Arecibo, Puerto Rico. This Eco-Industrial Park project includes an advanced waste-to-energy and materials recovery plant as its anchor, but its still in the planning stage. (Lowe, 2000)

2.6 EIE development in Asian countries

At present, the trend towards industrial estates is continuing in both developed and developing countries, but it is far stronger where there is rapid industrialization. In Asian, industrial development began much later, however, industrial estates are growing rapidly. There was rapid and widespread development in Asian during the 1960s and 1970s, as exports of manufactured goods grew. In 1993, there were 19 estates in Indonesia, more than 150 in Malaysia and more than 600 in Japan. A more recent figure shows in Indonesia there are about 80 estates in the process of development or already operating, and more than 20 estates in Thailand (UNEP, 1996).

Environmental Management System (EMS) is applied in a few estates in Asian countries. However, such systems still generally view economic activity as an open system in which raw materials are drawn in from the environment and large amounts of unwanted by-products are discharged in the form of waste. Alternative models are now being proposed from the field of industrial ecology. The challenge of this transformation is in the need for radical changes in the organization of industries, institutions and the production (UNEP, 1996).

The Asian cases below depict some successful forms of EIPs:

- Fujisawa Factory Eco-Industrial Park, Japan is a combination of industrial, commercial, agricultural, residential and recreational components. An EIP development program included technologies and features in energy conservation and cascading, renewable energies, solar greenhouses, waste water treatment using wetlands and reuse of treated water, conversion of waste into cement and ceramics, reuse and recycling of materials, etc. (Cote & Cohen-Rosenthal, 1998)

- Five CALABARZON industrial estates in Philippines located geographically close to each other entered into partnership on two programs. The first is to have by-product exchange (BPX) among the locators within the estate; and then among the estates and its communities. This program has gone through the awareness team building, mutual trust, planning, by-product matching, and commitment of some proactive locators. The second program is an integrated resource recovery system (IRRS). The main player is petrochemical complex, the naphtha cracker, which generate various by-product options at its upstream and downstream industries. The estate management together with the locators is currently in the in the stage of programmatic EMS planning and greening the supply chain. Two projects process some good environmental management at estate level, such as common effluent treatment plants, hazardous waste treatment plan, emergency response system, secure landfills, shared facility program, etc. (Georginia Pascual-Sison, 2001)

- Industrial estate in Indonesia mainly for small firms considers an estate-wide biowaste treatment project and good housekeeping program. It is still in the planning stage for Eco-Industrial Network (EIN) motive, there are scavengers currently performing the traditional waste recovery by manual segregation. Some useful recyclable materials were sold or re-processed. A good potential of the estate is that the management provides showroom for shared marketing called Graha Pariwara. This can be the future venue for further EIN activities such as information exchange of by-products, enhanced government-industry cooperation, or setting up of a Cleaner Production advisory center, etc.(PT Tananh Makmure, Firman Istiawan, 2001)

- Three cases in Gujarat, India were reported; they are Naroda (NIE1), Ankleshwari (AIE), and Nadeseri Industrial Estate (NIE2). In one of these industrial estates, an initial attempt to survey by-product through questionnaires generated the list of five major areas and one significant waste stream. These areas are chemical gypsum, biologically degradable waste, mild steel scrap, spent sulfuric acid, and iron sludge. These partnerships are presently being developed with the injection of cleaner production strategy. In all three cases, Common Effluent treatment Plant (CETM) plays a very important role. Furthermore, in the AIE and NIE2 cases, locators are using clean energy (e.g. natural gas), estates conduct shared human resources training (e.g. post-graduate programs on CP and Industrial Safety). Among these Indian cases, some authors claimed that strengthened judiciary, total commitments of the corporate management, and information drives are the main supporting software the EIN sustainability needs in the future. (Khanna; Patel et al., 2001)

CHAPTER 3

RESEARCH METHODOLOGY

According to Cohen and Rosenthal (1996), EIE development strategies attempt to establish networking among companies so they can work together on potential areas. This can be achieved by framing a wide range of possibilities from voluntary factories at the early stage of EIE development. This research therefore intended to gather information and identify a potential area in the first phase. Then, the acquired information was used to analyze economic and environmental benefits of selected industrial synergy linkage. It is expected that the research procedure will be applied with other potential area, which does help to sustain eco-industrial practices within the MTPIE.

3.1 Gathering information on industrial synergy linkage

Nine potential areas for industrial synergy linkage according to Cohen Rosenthal (1996), covers material, transportation, human resource, information/ communication systems, quality of life/community connection, energy, marketing, environmental health and safety, and production processes areas. Detailed definition of each area is provided in Appendix A. Some of these areas have been practiced in several factories. However, information was known only within the participated factories. The following types of techniques and tools are used to collect existing industrial synergy activities in Map Ta Phut Industrial Estate (MTPIE).

3.1.1 Meetings

The first meeting was conducted by MTPIE in January 2001 aiming to inform information about the project to all concerned parties. Afterward, monthly meetings were regularly held to gather preliminary information of tenants, and encourage them to join the program and acquaint with other factories. The meeting was organized by a secretariat team, which consisted of Ms. Sauvanee Wiriyaumpaiwong (Chulalongkorn University student) and Ms. Oranush Pewruangnont (MTPIE officer). The detail of each meeting contains 3 following steps.

3.1.1.1 The secretariat team sent the letter of invitation to all participating factories via e-mail, facsimile, and mail two weeks before the meeting. At the same time, the team inquired the voluntary factories whether they would like to present the detail of activities and process flow diagram that related to Eco-Industrial Estate concept. A meeting agenda and supplementary document for distributing to participants were prepared.

3.1.1.2 The team conducted the meeting according to the agenda. The meeting included reporting the progress of this project, presenting information from volunteered factories, brainstorming, drawing conclusion, and making appointment for next meeting. Discussion among the factories was encouraged in order to share information as well as to accelerate networking activities.

3.1.1.3 The team wrote a minute of meeting and distributed it to participants before next meeting via e-mail, facsimile, and mail.

3.1.2 Questionnaire

To have further detailed data, a questionnaire was designed according to Cohen Rosenthal (1996). The prepared questionnaire is based on all of nine potential areas. Total forty-eight environmental management activities in nine potential areas were determined their implementation status; no implementation, during implementation, and implemented intra or inter factories. The questionnaire was sent to all eighty-nine factories located in 3 Industrial Estates including Map Ta Phut, Padaeng, and Eastern Industry Estate. After received the questionnaires back, the team checked and categorized all of their activities into nine potential areas. The questionnaire was shown in Appendix B.

3.1.3 Interviewing and Field Surveying

Objective of the interview process was to describe the definition of the nine industrial synergy areas as well as to ensure that the factory understood and filled up corrected information. Benefit of this process is two-way communication method that can double-check the information of each factory and also provide clear understanding about EIE project. The team used this opportunity to ask representative from each factory to present general factory information, production process (process flow diagram) and other activities such as TQM, TPM, 5S, balance score card, and cleaner production.

3.2 Assembling information and identifying the potential areas of industrial synergy linkage

Questions in the questionnaire were arranged in a metric form between each activity in the potential areas and participated factories. Information from voluntary factories was assembled and put into the metric. Only implemented activities were checked in the metric.

3.2.1 Identifying the potential areas of industrial synergy linkage

Information of each factory obtained from interviewing was converted to percentage for each activity. Based on the averaged percentage of activity in each area, the minimum percentage was used as a criterion to identify the potential areas interested for further study. Since the minimum percentage was assumed to imply the minimum synergy linkage area.

3.2.2 Selecting representative factories of industrial synergy linkages

Interviewed factories in Map Ta Phut Industrial Estate were categorized into five industrial sectors; petrochemicals, chemicals and fertilizer, utility, iron and steel, and refinery. The representative factories for this study were chosen from each industrial sector on voluntary basis, and then used to identify the potential areas.

3.3 Evaluating potential benefits of interested area

Economic and environmental benefits are now becoming required components for decision-making. Activities within a selected area, i.e. material, were analyzed not only in potential economic but also significant environmental benefits.

3.3.1 Economic benefit analysis

Economic benefit analysis, in term of financial benefit analysis, is one of economics tools for evaluation of natural resource management. Benefit-cost ratio was employed to assess cost and benefit from implemented activities. Where the ratio is greater than 1, it means an implementation is profitable. On the other hand, the ratio lowers than 1 means loss of profit.

In this study, financial benefit was analyzed from recycling activity. Recycling generates significant financial benefits for communities. Driven for proper handling and use of recyclable materials can accelerate recycling which will be innovation a key for long-term economic profit. The evaluated financial analysis was compared in term of the benefit-cost ratio of each factory as follows;

$$\text{Benefit-Cost ratio} = \frac{\text{Benefit}}{\text{Cost}}$$

Where,

Benefit	= Avoided disposal cost (Baht/year)
	+ Recycled material sell price (Baht/year)
Avoided disposal cost	= [Quantity of waste (ton/year) x Disposal Charge (Baht/ton)]
Recycled material sell price	= [Quantity of waste (ton/year) x Retail Price (Baht/ton)]
Cost	= Transportation Charge (Baht/year)
	= Recycling cost (Baht/year)
	= Disposal cost (Baht/year)

3.3.2 Environmental benefit analysis

Activities in material area would enable factory to reduce cost, toxicity considered waste and by-products to increase value of waste and by-products. Environmental benefit analysis could be determined in term of reduction of resource consumption, emission, and waste generation. These obtained benefits will be a tool to promote sustainable development.

Normally, factories generate waste from their production processes and other activities. The waste can be in several forms including hazardous, non-hazardous, and domestic waste. In this study, emission of carbon dioxide (CO_2), sulfur dioxide (SO_2), and waste generation reduction are investigated as a result of the reduction of resource consumption. The emission and waste depend on consumption of coal, and sulfur and ash contents in each type of and coal. Reduction of resource consumption is determined based on amount of natural resources used to generate the materials. It implied that factories those use more material recycled, they also reduce gaseous emission generated, waste, other environmental burdens.

On the other hand, other environmental performance indicators could be considered in order to determine benchmark amount of waste generation, hazard of waste, and waste management method. The advantage of these indicators used for benchmark with their factories and also compared between before and after EIE implementation or could be used for the same industrial businesses.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Gathering information on industrial synergy linkage

4.1.1 Factories volunteered in the EIE development program

At the beginning of this project, there were fifteen factories, out of total eighty-nine factories in MTPIE, participated in the EIE development program. However, the number of participants increased up to fifty-two factories as shown in Figure 4.1. The increasing gradually occurs after the industry meetings, the Managing Director Club meetings and several EIE workshops, which led to a better understanding of Eco-Industrial Estate concept and its benefits by the factory administrators and their environment officers.

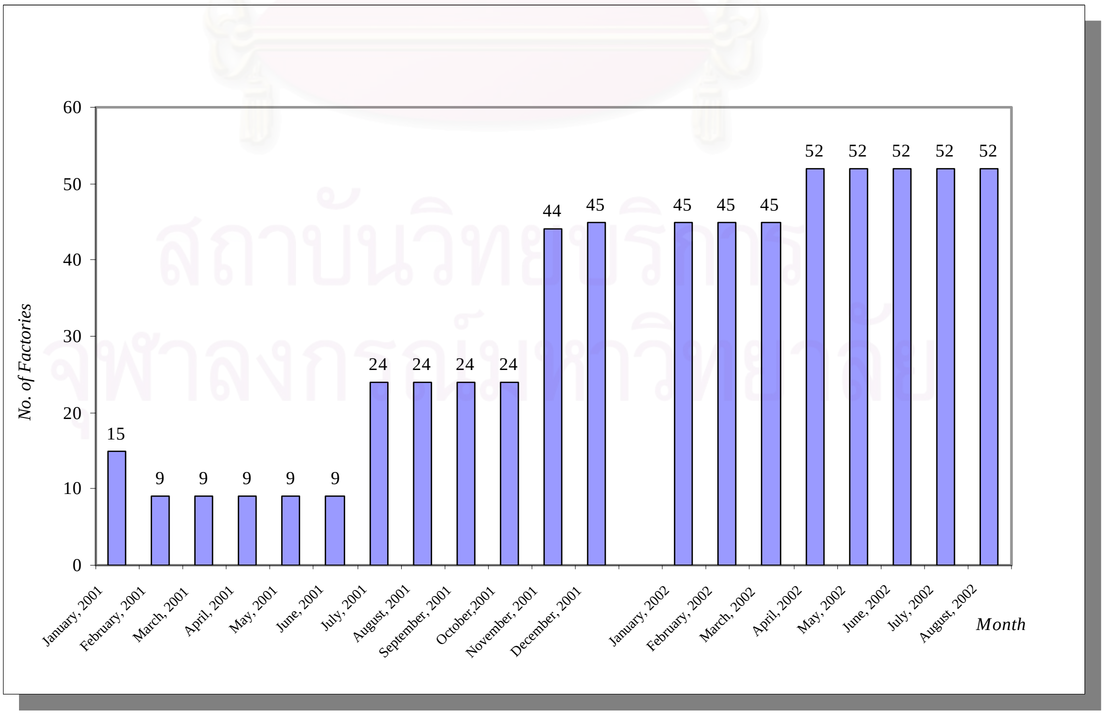

Figure 4.1 Number of Participated Factories attended the EIE Meeting

Questionnaires were sent out to 89 factories for gathering detailed information on industrial synergy linkage activities practiced in factories after several meetings. Only 23 factories responded to the questionnaire and provided relevant information, i.e., provision of detailed activities and process flow diagram. List of these participants is shown in Table 4.1.

Table 4.1 List of Voluntary Participants

Industrial Sectors	**Participated Factory (52 factories)**		**Responded (23 factories)**	**Interviewed (13 factories)**
Petrochemical *(Upstream)*	1.	ROC	✓	✓
	2.	NPC	✓	
Petrochemical *(Midstream)*	3.	TPC		
	4.	VNT	✓	✓
	5.	ATC	✓	✓
Petrochemical *(Downstream)*	6.	Bayer	✓	✓
	7.	HMC	✓	✓
	8.	TEC		✓
	9.	MMA		
	10	GSCC	✓	
	11.	MFC	✓	
	12.	BPE	✓	
	13.	HMT		
	14-17.	Siam Olefins (4)		
	18.	BST	✓	
	19.	BSTE	✓	
	20.	TPC-PEST		
	21.	TTC	✓	
	22.	TSIC		
	23.	Crompton		

Table 4.1 List of Voluntary Participants (Cont.)

Industrial Sectors	Participated Factory (52 factories)	Responded (23 factories)	Interviewed (13 factories)
Chemicals & Fertilizer	24. NFC	✓	✓
	25. Peroxy Thai	✓	
	26. Pornpat Chemicals		✓
	27. Sakchaisidhi		
	28. Padaeng *(PDI)*	✓	✓
Utility	29-35. Glow Group (7)	✓	✓
	36. BIG		
Iron & Steel	37. SCSC	✓	✓
	38. NOVA		
	39. SYS	✓	✓
	40. HCST	✓	
	41. STP		
	42. RWI		✓
Business Industry	43. Genco	✓	
Port	44. MTT		
	45. RBT		
	46. TTT	✓	
Easter IE	47. THASCO		
	48. Solutia		
	49. Wanachai		
Easter IE	50. Clariant	✓	
	51. Rohm & Hass		
	52. SUS	✓	

Thirteen factories from four industrial sectors were chosen for interview after receiving responded questionnaire. The criterion for factory selection included availability of factory officers and variety of industrial sectors. The interviewed process can crosscheck information with responsible representative in each EIE potential area in the questionnaire. Those factories consist of 6 from petrochemical, 3 from chemical and fertilizer, 3 from iron and steel, and one from utility industrial sector.

4.1.1 Existing synergy linkage areas in volunteered factories

Based on the interviewed data obtained from 13 factories, environmental management activities of EIE areas had been implemented inter and intra factories. Table 4.2.1 and Table 4.2.2 showed activities from petrochemical industry; and iron and steel, chemical and fertilizer, and utility industry, respectively.

Table 4.2.1 EIE Potential Area Activities Metric of Petrochemical Industry

Industrial Sector / EIE Potential Area	Petrochemicals					
	Upstream	Midstream		Downstream		
	ROC	VNT	ATC	Bayer	HMC	TEC
1. Material						
- Common Buying	✓	✗	✗	✗	✗	✓
- Customer/ Supplier Relations	✓	✓	✓	✓	✓	✓
- By-product Connections	✓	✓	✓	✓	✗	✗
- Creating new materials markets	✗	✗	✗	✗	✓	✗
Total Activities (4)	3	2	2	2	2	2
2. Transportation						
- Shared Commuting/ Carpool	✓	✓	✓	✓	✓	✓
- Shared Shipping	✓	✓	✓	✗	✗	✓
- Common Vehicle Maintenance	✓	✗	✗	✗	✓	✓
- Alternative Packing	✗	✓	✗	✗	✓	✗
- Intra – Park Transportation	✓	✗	✗	✓	✓	✗
- Integrated Logistics	✗	✗	✗	✗	✗	✗

Table 4.2.1 EIE Potential Area Activities Metric of Petrochemical Industry (cont.)

EIE Potential Area \ Industrial Sector	Petrochemicals					
	Upstream	Midstream		Downstream		
	ROC	VNT	ATC	Bayer	HMC	TEC
Total Activities (6)	4	3	2	2	4	3
3. Humans Resources						
- Human Resources Recruiting	✓	✓	✓	✓	✓	✓
- Joint Benefit Packages	✓	✓	✗	✓	✓	✓
- Wellness Programs	✓	✓	✓	✓	✓	✓
- Common Needs	✓	✓	✗	✓	✓	✓
- Training	✓	✓	✓	✓	✓	✓
- Flexible Employee Assignment	✓	✗	✓	✗	✗	✗
Total Activities (6)	6	5	4	5	5	5
4. Information Communication Systems						
- Internal Communication Systems	✓	✓	✓	✓	✓	✓
- External Information Exchange	✓	✓	✓	✓	✓	✓
- Monitoring Systems	✗	✓	✗	✓	✗	✓
- Computer Compatibility	✓	✓	✓	✓	✓	✓
- Joint MIS System for Park-management	✗	✗	✗	✗	✗	✗
Total Activities (5)	3	4	3	4	3	4
5. Quality of Life/Community Connections						
- Integration Work and Recreation	✓	✓	✓	✓	✓	✓
- Cooperative Education Opportunities	✓	✓	✓	✓	✓	✓
- Volunteer and Community Programs	✓	✓	✓	✓	✓	✓
- Involvement in Regional Planning	✓	✓	✓	✓	✓	✓
Total Activities (4)	4	4	4	4	4	4
6. Energy						
- Green Building	✗	✗	✗	✗	✗	✗
- Energy Auditing	✓	✓	✓	✓	✓	✓
- Co-generation	✓	✓	✓	✗	✗	✗
- Spin - Off Energy Firms	✗	✗	✗	✗	✗	✗
- Alternative Fuels	✓	✗	✗	✓	✗	✓
Total Activities (5)	3	2	2	2	1	2
7. Marketing						
- Green Labeling	✗	✗	✗	✗	✗	✗
- Accessing Green Markets	✗	✗	✗	✗	✗	✗
- Joint Promotion (e.g. Advertising, Trade Shows)	✗	✓	✓	✗	✓	✓

Table 4.2.1 EIE Potential Area Activities Metric of Petrochemical Industry (cont.)

EIE Potential Area \ Industrial Sector	Petrochemicals					
	Upstream	Midstream		Downstream		
	ROC	VNT	ATC	Bayer	HMC	TEC
- Joint Ventures						
- Recruiting New value-added companies	✗	✓	✓	✗	✓	✓
Total Activities (5)	0	2	2	0	2	2
8. Environmental Health & Safety						
- Accident Prevention	✓	✓	✓	✓	✓	✓
- Emergency Response	✓	✓	✓	✓	✓	✓
- Waste Minimization	✓	✓	✓	✓	✗	✓
- Multimedia Planning	✓	✓	✓	✓	✓	✓
- Design for Environment	✓	✓	✓	✓	✓	✓
- Shared Environmental Information Systems	✓	✓	✓	✓	✓	✓
- Joint Regulatory Permitting	✓	✓	✓	✓	✓	✓
Total Activities (7)	7	7	7	7	6	7
9. Production Processes						
- Pollution Prevention	✓	✓	✓	✓	✓	✓
- Scrap Reduction and Reuse	✓	✓	✓	✓	✗	✓
- Production Design	✗	✓	✓	✓	✓	✓
- Common Subcontractors	✓	✗	✗	✗	✗	✓
- Common Equipment	✗	✗	✗	✗	✗	✓
- Technology Sharing & Integration	✓	✗	✓	✓	✓	✓
Total Activities (6)	4	3	4	4	3	6
Total EIE Potential Area Activities (48)	34	32	30	30	30	35

Key: □, Implemented.

□, During implementation or No implementation.

From Table 4.2.1, the interviewed voluntary petrochemical factories were defined into 3 classes. These are upstream (Rayong Olefins Co., Ltd. *(ROC)*); midstream (Vinyl Thai Public CO., Ltd. *(VNT)* and Aromatic (Thailand) Public Co., Ltd. *(ATC)*); and downstream factories (Bayer Thai Co., Ltd. *(Bayer)*, HMC Polymer Co., Ltd. *(HMC)*, and Thai Epoxy and Allied Products Co., Ltd. *(TEC)*). The industrial synergy activities practiced by ROC, VNT, ATC, Bayer, HMC, and TEC were 34, 32, 30, 30, 30, and 35 activities, respectively. Implemented activities were quite similar in these interviewed factories since they are in the same business sector.

Table 4.2.2 EIE Potential Area Activities Metric of Chemical & Fertilizer, Utility, Iron & Steel Industry

Industrial Sector / EIE Potential Area	Chemical & Fertilizer			Utility	Iron & Steel		
	NFC	PCC	PDI	COCO	SCSC	SYS	RWI
1. Material							
- Common Buying	✗	✗	✓	✓	✗	✗	✗
- Customer/ Supplier Relations	✗	✓	✓	✓	✓	✓	✓
- By-product Connections	✓	✗	✓	✓	✓	✓	✗
- Creating new materials markets	✗	✗	✗	✗	✗	✓	✗
Total Activities (4)	1	1	3	3	2	3	1
2. Transportation							
- Shared Commuting/ Carpool	✓	✗	✗	✓	✓	✓	✓
- Shared Shipping	✗	✓	✓	✓	✗	✗	✓
- Common Vehicle Maintenance	✗	✗	✗	✓	✗	✗	✗
- Alternative Packing	✗	✗	✗	✗	✗	✗	✗
- Intra - Park Transportation	✓	✗	✗	✓	✗	✗	✗
- Integrated Logistics	✗	✗	✗	✗	✗	✗	✗
Total Activities (6)	2	1	1	4	1	1	2
3. Humans Resources							
- Human Resources Recruiting	✓	✓	✓	✓	✓	✓	✓
- Joint Benefit Packages	✓	✓	✓	✓	✓	✓	✗
- Wellness Programs	✓	✓	✓	✓	✗	✓	✗
- Common Needs	✗	✓	✓	✓	✓	✓	✗
- Training	✓	✓	✓	✓	✓	✓	✓
- Flexible Employee Assignment	✗	✗	✓	✗	✗	✓	✗
Total Activities (6)	4	5	6	5	4	6	2
4. Information Communication Systems							
- Internal Communication Systems	✓	✓	✓	✓	✓	✓	✓
- External Information Exchange	✓	✗	✓	✓	✓	✓	✗
- Monitoring Systems	✗	✓	✓	✗	✗	✓	✗

Table 4.2.2 EIE Potential Area Activities Metric of Chemical & Fertilizer, Utility, Iron & Steel Industry (cont.)

Industrial Sector / EIE Potential Area	Chemical & Fertilizer			Utility	Iron & Steel		
	NFC	PCC	PDI	COCO	SCSC	SYS	RWI
- Computer Compatibility	✓	✗	✓	✓	✓	✓	✗
- Joint MIS System for Park-management	✗	✗	✗	✗	✗	✗	✗
Total Activities (5)	3	2	4	3	3	4	2
5. Quality of Life/Community Connections							
- Integration Work and Recreation	✓	✓	✓	✓	✓	✓	✗
- Cooperative Education Opportunities	✓	✓	✓	✓	✓	✓	✗
- Volunteer and Community Programs	✓	✓	✓	✓	✗	✓	✗
- Involvement in Regional Planning	✗	✗	✓	✓	✗	✗	✗
Total Activities (4)	3	3	4	4	2	3	0
6. Energy							
- Green Building	✗	✗	✓	✗	✗	✗	✗
- Energy Auditing	✓	✓	✓	✓	✓	✓	✓
- Co-generation	✓	✗	✗	✓	✗	✗	✗
- Spin - Off Energy Firms	✗	✗	✗	✗	✗	✗	✗
- Alternative Fuels	✗	✗	✓	✗	✗	✗	✗
Total Activities (5)	2	1	3	2	1	1	1
7. Marketing							
- Green Labeling	✗	✗	✓	✗	✗	✗	✗
- Accessing Green Markets	✓	✓	✓	✗	✗	✗	✗
- Joint Promotion (e.g. Advertising, Trade Shows)	✓	✗	✓	✗	✗	✗	✗
- Joint Ventures	✗	✗	✗	✗	✗	✗	✗
- Recruiting New value-added companies	✓	✓	✓	✗	✗	✓	✗
Total Activities (5)	3	2	4	0	0	1	0
8. Environmental Health & Safety							
- Accident Prevention	✓	✓	✓	✓	✓	✓	✓
- Emergency Response	✓	✓	✓	✓	✓	✓	✓
- Waste Minimization	✓	✓	✗	✓	✓	✗	✗
- Multimedia Planning	✓	✓	✗	✓	✗	✓	✗
- Design for Environment	✗	✗	✗	✓	✗	✗	✗
- Shared Environmental Information Systems	✓	✓	✓	✓	✓	✗	✗
- Joint Regulatory Permitting	✓	✓	✓	✓	✓	✓	✓
Total Activities (7)	6	6	4	7	5	4	3

Table 4.2.2 EIE Potential Area Activities Metric of Chemical & Fertilizer, Utility, Iron & Steel Industry (cont.)

Industrial Sector / EIE Potential Area	Chemical & Fertilizer			Utility	Iron & Steel		
	NFC	PCC	PDI	COCO	SCSC	SYS	RWI
9. Production Processes							
- Pollution Prevention	✓	✓	✓	✓	✗	✓	✓
- Scrap Reduction and Reuse	✓	✓	✓	✓	✓	✓	✗
- Production Design	✓	✗	✗	✓	✓	✓	✗
- Common Subcontractors	✗	✓	✗	✓	✗	✓	✗
- Common Equipment	✗	✓	✓	✓	✗	✓	✗
- Technology Sharing & Integration	✗	✗	✓	✗	✓	✓	✗
Total Activities (6)	3	4	4	5	3	6	1
Total EIE Potential Area Activities (48)	27	25	33	33	21	29	11

Key: □, Implemented.

□, During implementation or No implementation.

From Table 4.2.2, the representatives of chemical & fertilizer industrial are National Fertilizer Public Co., Ltd. *(NFC)*, Pornpat Chemicals Co., Ltd. *(PCC)*, and Padaeng Industry Public Co., Ltd. *(PDI)*. Representative from utility industry is The Cogeneration Public Co., Ltd. *(COCO)*. Whereas representatives from iron & steel industrial, are The Siam Construction Steel Co., Ltd. *(SCSC)*, Siam Yamato Co., Ltd. *(SYS)*, and Rayong Wire Industry Co., Ltd. *(RWI)*. The synergy linkage activities practiced by NFC, PCC, PDI, COCO, SCSC, SYS, and RWI were 27, 25, 33, 33, 21, 29, and 11 activities, respectively. Similar to petrochemical industry, these 3 sectors indicated similar activities within the sector. However, PDI had total activities were higher than the other 2 factories in chemical & fertilizer sector; NFC and PCC, since PDI material and human resources areas were conducted with the acid trader and other factories on I3A road.

At the same time, SYS and SCSC had higher activities than RWI due to their businesses are owned by belong to the Cementhai Holding. Some of their activities could be linked with each other factory such as human resources area and quality of life/community connection.

4.2 Identifying EIE Potential Area of Industrial Synergy Linkage

4.2.1 Selecting potential industrial synergy linkage area

In order to compare implementation of activities in each area, numbers of activities were converted to percentage and averaged from all 13 factories as shown in Table 4.3. The priority ranking of implemented areas could be arranged from lowest to highest. Those areas are marketing, energy, transportation, material, information/communication systems, production processes, human resources, quality of life/community connection, and environmental health & safety area respectively.

Table 4.3 Percentage of Potential Area Activities Practiced in the Interviewed Factories

Areas (No. of activities) / Factories	Material (4)	Transportation (6)	Human Resources (6)	Information/ Communication Systems (5)	Quality of life/ Community Connection (4)	Energy (5)	Marketing (5)	Environmental Health and Safety (7)	Production Processes (6)	Total (48)
ROC	75%	67%	100%	60%	100%	60%	0%	100%	67%	71%
VNT	50%	50%	83%	80%	100%	40%	40%	100%	50%	67%
ATC	50%	33%	67%	60%	100%	40%	40%	100%	67%	62%
Bayer	50%	33%	83%	80%	100%	40%	0%	100%	67%	62%
HMC	50%	67%	83%	60%	100%	20%	40%	86%	50%	62%
TEC	50%	50%	83%	80%	100%	40%	40%	100%	100%	73%
NFC	25%	33%	67%	60%	75%	40%	60%	86%	50%	56%
PCC	25%	17%	83%	40%	75%	20%	40%	86%	67%	52%
PDI	75%	17%	100%	80%	100%	60%	80%	57%	67%	69%
COCO	75%	67%	83%	60%	100%	40%	0%	100%	83%	69%
SCCS	50%	17%	67%	60%	50%	20%	0%	71%	50%	44%
SYS	75%	17%	100%	80%	75%	20%	20%	57%	100%	60%
RWI	25%	33%	33%	40%	0%	20%	0%	43%	17%	23%
Total (100%)	**52 (%)**	**38 (%)**	**79 (%)**	**63 (%)**	**83 (%)**	**35 (%)**	**28 (%)**	**84 (%)**	**64 (%)**	**59 (%)**

EIE potential areas that provide the highest percentage of 84 and 83 were Environmental Health & Safety and Quality of Life/Community Connection, respectively. These areas have already well implemented in MTPIE. ISO14001 in Environmental Health & Safety area was already performed in almost all factories. The factories also carry out several Environmental Health & Safety activities together such as responsible care, EMAG, RESA, and etc. Quality of Life/Community

Connection, e.g., plant manager club, public relation club, visit neighbor programs, industry meeting, mobile medical clinic, and other activities initiated by their mother companies were another area, which have many channels of linkage.

Since, the marketing area gave a minimum percentage in all factories. It should be the highest potential to be recommended as industrial synergy linkage activity. However, it is difficult to link marketing area between or within industrial sectors because of various nature of businesses in MTPIE.

According to the reasons mentioned above, the most interested potential area is material area. Even though, this area has 52% of implemented activities. Materials area is a core of Eco-Industrial Estate. It is a way to reduce cost, toxicity and net volume of wastes within business operations. The material that was once considered waste or a by-product with little value could become a valued input in a new process. The channels of linkage in material area were four activities including common buying, customer/supplier relations, by-product connections, and creating new material markets. Improvements in cost, inventory, quality or quantity flexibility can be affected by common buying, setting supplier specifications (including environmental), and materials exchange connections of products and by-products among different organizations. In addition, Eco-Industrial Estate and networks have the potential to create new material markets. Material area has challenged all participating enterprises since the area does not only enable them to improve environmental performance but also gain more financial benefits.

4.2.2 Selecting representatives from voluntary factories

There were fifty-two factories volunteered to participate in this program. However, only six of them were chosen as the representatives of MTPIE factories according to the availability of information from volunteer factories, type of industrial sectors, and opportunities for industrial synergy linkage implementation between each other. List of factories were showed in Table 4.4.

The six voluntary factories were one from upstream, two from downstream petrochemical industry, one from chemical and fertilizer industry, one from utility service, and one from steel industry.

Table 4.4 Representative Factories

Industry Sectors	**Representative Factories**
Upstream Petrochemicals	ROC
Downstream Petrochemicals	Bayer and HMC
Chemicals & Fertilizer	NFC
Utility	COCO
Iron & Steel	SCSC
Total Factories	**6**

4.2.3 Representative factories information

Brief details of each factory are as follows:

4.2.3.1 Rayong Olefins Co., Ltd. (ROC)

Rayong Olefins Co., Ltd. is a producer of upstream petrochemicals mainly used as feedstock for Polyethylene (PE) and Polypropylene (PP) resins. Production start-up was commenced in 1999. This upstream manufacturing has turned Siam Cement Group to become one of the leading petrochemical players in Thailand and in Asia-Pacific.

Production Capacity is Ethylene 800,000 tons/ year, Propylene 400,000 tons/ year, Benzene 160,000 tons/ year, and Toluene 70,000 tons/ year.

4.2.3.2 Bayer Thai Co., Ltd. (Bayer)

Bayer Thai Co., Ltd., the fully owned subsidiary of Bayer AG in Leverkusen, Germany and a core company of the Bayer Group in Thailand, was established in 1962. The company's structure consists of four business segments following the international organizational pattern: Polymers, Chemicals, Health Care and CropScience, comprising all operating business groups and marketing more than 3,000 products in various categories. Bayer Thai manufactures crop protection, household hygiene and animal health products at the production plant in Bangpoo Industrial Estate to supply local and Asian markets. At the same time, plastic manufacturing plant in Map Ta Phut Industrial Estate produces and exports engineering thermoplastics to the region with world scale capacities.

4.2.3.3 HMC Polymer Co., Ltd. (HMC)

HMC is a joint venture company between Basell Polyolefins and a group of leading Thai companies including Bangkok Bank and Hua Kee Group. HMC established the first polypropylene manufacturing facility in Thailand in 1987. Since that time it has continued to expand and modernize its facilities. Today it has the most modern technology in Thailand and with capacity of 450,000 tons which make it one of largest and most advanced facilities in Asia.

4.2.3.4 National Fertilizer Public Co., Ltd. (NFC)

National Fertilizer Public Co., Ltd. (NFC) receives investment promotion from the Board of Investment for the manufacture of fertilizer base and aggregate fertilizer ready for direct application by farmer. Direct application is possible because ready-made fertilizer contains all the nutrients that crops need namely nitrogen (N), phosphorous (P), and potassium (K). The company plant, which is located in Map Ta Phut Industrial Estate, Rayong Province, has a production capacity of approximately a million tons of aggregate fertilizer per year, 462,000 tons of sulfuric acid, and 180,840 tons of phosphoric acid. Ships of up to 60,000 metric tons deadweight are able to dock at the company's own port, which can handle about 1.5 million tons of raw materials per year.

4.2.3.5 The Cogeneration Public Co., Ltd. (COCO)

COCO is an investment joint venture between Banpu Public Co., Ltd. and other leading global energy companies. The group was formed to supply electricity, steam, as well as clarified and demineralized water to industrial operators. Target customers are mainly petrochemical factories in Map Ta Phut Industrial Estate. The group is also a supplier to Electricity Generation Authority of Thailand (EGAT) under the Small Power Producer program.

4.2.3.6 The Siam Construction Steel CO., Ltd. (SCSC)

The Siam Construction Steel Co., Ltd. is a holding company of the Cementhai Holding Group, produces steel bars for concrete reinforcement-deformed bars and round bars, and machine structural steel. Its production capacity is 500,000 tons/ year. The products are deformed bars for reinforced concrete that used for medium and large-scale construction such as high buildings, dams and bridges, round bars for reinforced concrete that used for small and medium scale construction, and steel bars for machine structural use and steel bar.

4.3 Evaluating potential benefits of the selected EIE potential area

Material area was identified as the potential industrial synergy linkage for implementation within six factories. Detailed of material area covers common buying, customer/supplier relations, by-product connections, and creating new materials markets. Wastes are the concerned materials in factories. The amount of waste generation in each factory per year represents the efficiency of material usage and can be used as an indicator for material area.

Wastes in MTPIE are classified into three types. Under this classification, 72% of waste are hazardous waste, 21% are non-hazardous waste, and 7% are domestic waste (Figure 4.2). Management process for each waste type was showed in Table 4.5 where the data was obtained from MTPIE waste permit (2001).

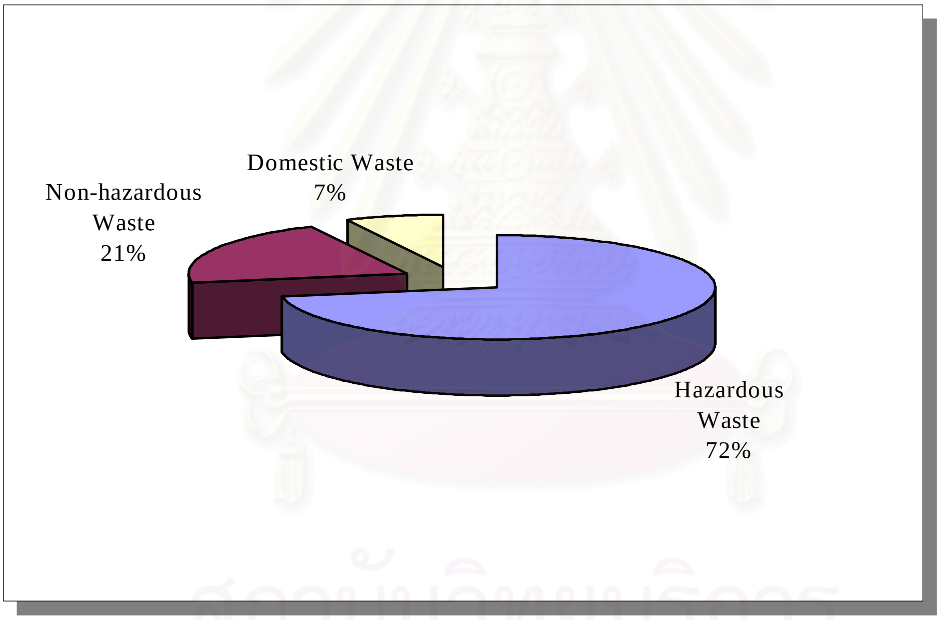

Figure 4.2 Percentage of waste classification

(Source: Industrial Pollution Control Section, MTPIE)

Table 4.5 Waste Management Process in Map Ta Phut Industrial Estate

Type of Waste	Waste Management	Total amount (ton/ year)	Ratio (%)
Hazardous Waste	1. Combustion	24,162	3
	1.1 Rotary kiln	24,040	3
	1.2 Infectious Incinerator	122	0
	2. Secure Landfill	10,623	1
	3. Recycle	819,204	96
	Total	853,989	100
Non-Hazardous Waste	1. Sanitary Landfill	54,103	22
	2. Land reclamation	743	0
	3. Recycle	187,831	77
	3.1 Recycled Store	42,355	17
	3.2 Raw material to cement industrial	3,405	1
	3.2 Raw material to other industrial	38,728	16
	3.3 Other	103,343	43
	4. Fertilizer	10.5	0
	Total	242,687.5	100
Domestic Waste	Sanitary Landfill (Municipal Map Ta Phut)	85,325	100
	Total	85,325	100

Source: Industrial Pollution Control Section, MTPIE

From Table 4.5, recycle process was practiced the most, by which the ratio of recycling hazardous waste and non-hazardous waste are 96% and 77%, respectively. Nonetheless, recycle opportunities should be encouraged further since recycle materials have apparent economic and environmental value both by the market and social perception.

In this study, potential economic and environmental benefits of the selected EIE potential area was evaluated from two wastes recycle projects. These are steel scrap recycling (hazardous and non-hazardous waste) project, and fluorescent lamp recycling (hazardous waste) project. Analysis of environmental benefits was represented in term of reduction of resource consumption, emission, and waste generation.

4.3.1 Economic benefit Analysis

Economic benefit analysis in term of financial benefit is one of tools that can be used for economic evaluation. Benefit-cost ratio was employed to assess cost and benefit from two opportunity projects. The benefit cost ratio for both projects can be calculated by the following benefit cost ratio (B/C) equation.

$$\text{Benefit-Cost ratio} = \frac{\text{Benefit}}{\text{Cost}}$$

Where,

Benefit	= Avoided disposal cost (Baht/year) + Recycled material sell price (Baht/year)
Avoided disposal cost	= [Quantity of waste (ton/year) x Disposal Charge (Baht/ton)]
Recycled material sell price	= [Quantity of waste (ton/year) x Retail Price (Baht/ton)]
Cost	= Transportation Charge (Baht/year) = Recycling cost (Baht/year) = Disposal cost (Baht/year)

4.3.1a The steel scrap recycling project

Nowadays, the existing steel recycling activities of all factories in MTPIE are managed by the third party since factories are complicated with responded staff assignment and hazardous waste transportation permission.

In this study, we explored the steel scrap recycling alternative by sending steel scrap directly to SCSC located in MTPIE. It was proposed for only four voluntary factories based on available steel scrap consumption of each factory per year. The data were obtained from MTPIE waste permission, 2001. The comparison of B/C ratio calculation from above equation was summarized in Table 4.6.1 and Table 4.6.2.

Table 4.6.1 Financial benefit analysis of existing steel scrap recycling project

Item	ROC	Bayer	HMC	NFC
Benefit (Baht/year)	0	0	0	0
Cost (Baht/year)				
• Transportation charge	5,980	58,075	23,230	92,920
• Disposal cost	12,000	309,960	66,000	280,000
Benefit-cost ratio (B/C)	**0**	**0**	**0**	**0**

Existing steel scrap recycling was managed by third party, by which the factories paid a third party to take the steel scraps from their factories. Then, the scraps were sent to waste management company or steel manufacturer who will use it as raw material. Therefore, B/C of all factories equals to zero since they paid money for recycled management, benefit is intangible.

Table 4.6.2 Financial benefit analysis of alternative steel scrap recycling project

Item	ROC	Bayer	HMC	NFC
Benefit (Baht/year)				
• Avoided disposal cost	12,000	309,960	66,000	280,000
• Recycled Steel sell price	6,000	154,980	66,000	280,000
Cost (Baht/year)				
• Transportation charge	5,980	58,075	23,230	92,920
Benefit-cost ratio (B/C)	**3.0**	**8.0**	**5.7**	**6.0**

Alternative steel scrap recycling project means their steel scrap was sent directly to SCSC or steel manufacturer. The benefit came from the money that factories would save from not paying the disposal cost.

The B/C ratio calculation indicated that B/C ratio for all factories are greater than 1. Therefore, it is profitable for all factories to implement this recycling project.

4.3.1b The fluorescent lamp recycling project

Approximately 100% of used fluorescent lamps are disposed to landfill. This study proposes an alternative to manage used lamp in MTPIE by recycling process. Fluorescent lamp recycling project has just initiated by collaboration between factories and Phillips (Thailand) Co., Ltd.

Recycling process description is started from end cutting process by using compressed air and spot heating until lamp scratched. After that, the power-removing process operated by using high-speed compressed air and captured by vacuum head. Then, the wiping process is operated.

Lamp constituent consists of glass, phosphor power, inert gas, mercury, barrier ring, emitter, wire, glass stem, cement, cap and leg of lamp. Glass is the main components of lamp. Glass content of long fluorescent lamp is 180 grams out of total 200 grams. It means 71.3% of total waste can be recycled .The remaining 28.7% is normally sent to secure landfill.

According to the B/C ratio equation mentioned earlier, used lamp consumption of six factories per year obtained from responded questionnaire surveying was used to evaluate B/C ratio for decision-making implemented recycling method in comparison to landfill disposal. The questionnaire was showed in Appendix C. The benefit of lamp recycling project came from the money that factories would save from not paying the disposal cost. The actual cost will be included transportation, collection, and used lamp rest areas cost. However, there is some recycling cost charged by Phillips (Thailand) Co., Ltd. but the cost of recycling process is lower than disposal cost as shown in Table 4.7. Thus, recycling process should be implemented.

Table 4.7 Financial benefit analysis of lamp recycling project.

Item	ROC	Bayer	HMC	NFC	COCO	SCSC
Benefit (Baht/year)						
• Avoided disposal cost	1,350	540	1,350	2,700	1,350	540
Cost (Baht/year)						
• Recycling Cost	1,125	450	1,125	2,250	1,125	450
Benefit-Cost ratio (B/C)	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**

Even though, lamp recycling project gain benefit less than steel scrap project recycling project, it is designed to help factories to comply with the regulations and reduce their environmental risks. Furthermore, reduce raw material would also reduce natural resources.

4.3.2 Environmental benefit analysis

Environmental benefit analysis of six representative factories was represented in term of reduction of resource consumption, emission, and waste generation in both projects as mentioned above.

4.3.2a The steel scrap recycling project

The benefit of steel recycling project comes from the reduction of import-recycled material and solid waste stream. Besides saving landfill space, steel recycling also saves valuable energy and natural resources. In this study three reduction scenarios, i.e. reduced resource consumption, reduced emission, and reduced waste, were evaluated from an environmental perspective. The analysis was summarized in Table 4.8.

Table 4.8 Environmental benefit analysis of steel scrap recycling project

Item (kg/ year)	ROC	Bayer	HMC	NFC
Quantity of recycled steel	3,000	77,490	33,000	140,000
Reduced resource consumption				
• Iron ore[1]	3,390	87,560	37,290	158,200
• Coal[1]	1,920	49,590	21,120	89,600
Reduced emission [2]				
• CO_2[3]	1,152	29,756	12,672	53,760
• SO_2	5	129	55	233
Reduced waste				
• Ash[2]	70	1,800	760	3,240

Sources of reference data:

[1] from steel manufacturing in United States,

[2] from Ban Pu Public Co., Ltd., January to August 2002,

[3] from National Air Emission Inventory, UK Greenhouse Gas Inventory, Digest of UK Energy Statistics DTI 1998, Greenhouse Gas Inventory Reference Manual IPCC 1997.

The analysis based on essential assumptions as follows:

- One thousand kilograms of recycled steel could save [1]
  - 2,500 pounds or 1,130 kg of iron ore
  - 1,400 pounds or 640 kg of coal
- Clean coal 1,000 kilograms could be used to generate 2,000 kW-hr of electricity [2]
- Clean coal 1,000 kilograms has sulfur content of 2.6 kg [2]

- Clean coal 1,000 kilograms has ash content of 2.6 kg [(2)]
- CO_2 emission from clean coal is 0.3 kg CO_2/kW-hr [(3)]

4.3.2b The fluorescent lamp recycling project

Disposal of large quantities of fluorescent lamps in landfills is a concern due to potential risk to human health and the environmental caused by mercury leaching. Mercury is toxic to the human nervous system. Chronic breathing of mercury vapors can cause a range of physical symptoms, including inability to coordinate body movement and impairment of hearing, speech and vision. Exposure to mercury in other forms can lead to skin rashes and kidney damage.

Under certain conditions, fluorescent lamps burned in waste-to-energy plants can release mercury to the air and water. Not even the best pollution control devices can capture all of the mercury all of the time.

Mercury in the water can bioaccumulate, its concentration is increased over time in the tissue of fish, making them less healthful to eat frequently. Pregnant women who eat contaminated fish can pass mercury to their unborn children.

According to environmental perspective evaluation, reduction analysis scenarios were summarized as shown in Table 4.9. Each factory can also use the calculation to benchmark their waste management process or compare with other factories.

Table 4.9 Environmental benefit analysis of fluorescent lamp recycling project

Item	ROC	Bayer	HMC	NFC	COCO	SCSC
Quantity of used lamp						
• Unit per year	750	300	750	1,500	750	300
• Kg per year	150	60	150	300	150	60
Reduced resource consumption (kg/year)						
• Sand/ Silica	150	60	150	300	150	60
Reduced used lamp						
• Unit per year	535	214	535	1,070	535	214
• Kg per year	107	43	107	214	107	43

The analysis based on essential assumptions as follows:

- Approximately weight of fluorescent lamp is 200 grams per unit,
- One kilogram of fluorescent lamp is produced from one kilogram of silica,
- The energy required in recycling of fluorescent lamp equals to that required in production of lamp.

Since, fluorescent lamp waste causes more mercury contamination of the environment than any other consumer product, we found urgent need to encourage all factories to participate in this project as well as to safely handle this mercury-bearing waste and do not contribute to mercury pollution through improper lamp recycling.

Moreover, maximum amount of mercury was being reclaimed to protect the environment and helped avoid potential environmental liability risks. The additional opportunity of lamp recycling project are to recovery and recycle mercury from lamp parts and therefore preventing mercury releases to the environment especially an airborne release, which is the major cause of mercury contamination in lakes and rivers.

The opportunity for mercury management of lamps' end part is mercury recovery or recycles with the ultra-high temperature by high vacuum retort distillation technology to remove 99.9% of the mercury. This technology is an alternative of existing waste management by secure landfill. The benefit is to reduce material including glass tube and mercury, reduce environmental risk, reduce energy and operating cost for glass processing, and create a new job, i.e., mercury distillation company.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Eco-Industrial Estate (EIE) Development Program has been implemented at the Map Ta Phut Industrial Estate (MTPIE) under the "Development of Eco-Industrial Estate and Network (EIEN)" project carried out by the Industrial Estate Authority of Thailand (IEAT) - Ministry of Industry.

During the study, monthly meetings were conducted by MTPIE to provide information on EIE concept, gather preliminary information of tenants, and encourage tenants to joint the program, and acquaint with other factories. Number of factories volunteered in the EIE development program were increased from fifteen to fifty-two factories at the end of this study. Interview and field survey, covering nine EIE potential areas according to Cohen Rosenthal (1996) for the EIE Development, was done to investigate environmental management activities in participated factories. The EIE potential areas consist of material, transportation, human resources, information/communication systems, quality of life/community connection, energy, marketing, environmental health and safety, and production processes. After collecting the existing information, the study focused on a waste and by-product connection program, an important activity in material area. We found that waste materials generated in MTPIE could be further minimized by recycling projects.

An implementation of EIE program was evaluated in term of economic, i.e., benefit-cost ratio and environmental benefits, i.e., emission of carbon dioxide (CO_2), sulfur dioxide (SO_2), and waste generation reduction. Of the fifty-two participated factories, six industries had been chosen as the representatives for the project analysis. Those are one upstream petrochemical factory (ROC), two downstream petrochemical factories (HMC and Bayer Thai), and others relating to steel plant (SCSC) and utilities (COCO). It was found that steel scrap and lamp recycling project would promote sustainable use of natural resources, reduce environmental impact, and save operating cost. In addition, recycling activities in MTPIE will decelerate the need for landfills. This will promote the prevention of pollution at its source, save energy, and reduce greenhouse gas emissions, community development. At the same time, factories implemented EIE will gain a competitive advantage in the industrial market.

5.2 Recommendations for further study

From the results, EIE program is required for a success environmental management in industrial estates. Implementation of this program depends on the industrial estate as well as its tenants. Further studies are recommended to perform in order to improve effectiveness of EIE implementation. Those studies are summarized into 3 groups as follows:

5.2.1 Industrial Estate Authority of Thailand (IEAT)

5.2.1.1 Maintain a leadership and encouraging public participation

As a leader in this program, IEAT has created and maintained EIE association to continue building networks of present industrial synergy linkage and expanding other potential EIE areas. Moreover, IEAT should provide technical support, and develop outreach to businesses and the financial community.

5.2.1.2 Establish a clearinghouse for information

The clearinghouse could be a central location for literature and a World Wide Web Site. It would be important for IEAT to help start the clearinghouse, but may not be necessary to host the clearinghouse.

5.2.2 Factories in Map Ta Phut Industrial Estate

5.2.2.1 Maintain a representative of each factory

Representative is a major key of EIE success. Activities or information need to contribute among top management to all employees in their factories and the EIE team.

5.2.2.2 Collect existing relevant data

Complete data is useful for comparison and evaluation in term of economic and environmental benefits, which later will facilitate a decision-making process. The more precise data in each project will improve validity of the data.

5.2.2.3 Encourage their employee to understand EIE concept

EIE development needs to continue implementation and improvement. Therefore, encouraging employee to understand EIE concept is a way to maintain and increase more industrial synergy linkage.

5.2.3 Academic

Academic should conduct research to promote new technology and substitute material. New technology is essential for EIE implementation. It can be changed from one to another technology that has a value-added. For example, mercury refinery technology is required in mercury recovery process.

Alternative substitute materials should be long lasting and ease to destroy. For example, alternative pallets to wooden pallets are reusable pallets.

wooden pallets are only pallets made from material that meet 4R criteria such as reusable, repairable, recycle, and is generated from a renewable resource.

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APPENDICES

Appendix A

Definition of nine EIE potential areas

According to Cohen-Rosenthal (1996), under the Eco-Industrial Development, business and environmental performance can simultaneously improve through a comprehensive networking structure designed to fit with the local mix of companies. All resources are beneficially integrated to develop an industrial ecosystem including working with a number of the following areas that are considered core business issues.

1. Materials

Materials flow is at the core of industrial ecology as a way to reduce cost, toxicity and net volume within business operations. Improvements in cost, inventory, quality or quantity flexibility can be affected by common buying, setting supplier specifications (including environmental), and materials exchange connections of products and by-products among different organizations. At the simplest level cooperating companies could jointly order products to get volume pricing and to reduce shipping costs incurred with separate deliveries.

The use of environmentally preferred products is another area of market development. Increasingly companies are shifting their purchasing requirements to include sourcing products with demonstrably lower environmental impact than comparable items. This strategy not only contributes directly to cumulative environmental improvement but directly supports the companies active in those areas.

Eco-industrial networks have the potential to create new material markets. A material that was once considered waste or a by-product with little value could become a valued input in a new process. However, there is a need to examine intermediate strategies to facilitate a larger range of materials connections that meet time, quality and quantity requirements. The overall goal of this aspect of business networking is the safest and most effective use of materials.

2. Transportation

The ability to move people and goods in a timely and efficient manner is one of the keys to business success. Employee transportation issues include commuting and use of company vehicles for business. Car pools, company vans, walking or bicycling are strategies for reducing energy used in employee commuting. Support for a responsive local mass transit system is also important with regard to minimizing the environmental impact of commuting and supporting workforce flexibility. Transportation of goods and services represents another category of potential cooperation. Bulk buying could result in lower costs by outsourcing vehicle maintenance services to a local firm. Intra-park transportation, from bicycles to electric vehicles could be explored between firms located on a contiguous piece of land. Reduction, recycling, and/or management of packaging materials could also be a focus of cooperation.

The use of alternatively fueled vehicles represents a further step in eco-industrial development. Selecting alternatively fueled vehicles moves towards changing the basic approach to resource use. In addition, the evaluation of the methods used to ship products from place to place, the overall efficiency of distribution, also represents another level in the transportation area. Improved evaluation of production requirements and shipping needs can make better use of the transportation needed to move products between producers as well as on to customers.

3. Human Resources

In a networking environment, synergies can be created that recruit and build competence, increase organizational flexibility, and manage costs. Each firm needs to be sure that it has the people with the right skills and attitudes to be able to do their jobs well. To get to this, each firm goes through screening and training to develop the best employees. By working across companies broader recruitment and screening efforts can be accomplished and thus raise the quality of the employees hired. Special skills can also be shared more broadly and common training needs can be accommodated more easily.

Employee benefits are taking a larger share of payroll. Pooling of employers can lead to cost savings and/or expansion of benefits for more leverage with suppliers. The cost of employee benefits and services could be spread over a number of businesses in the network. Multi-company health plans could be negotiated. Employee wellness programs could be initiated across multiple companies to reduce the startup costs and provide more options by including a broader population of workers.

At the next level could be the creation of a common services pool. Companies that make different products may still use similar skills. There are many possible sets of services that could be maintained and scheduled by several companies to minimize overhead for any one and to provide flexibility for all.

Another possible example includes cross company training options, the costs of which could be born by the group of companies or with government training assistance. This would serve to enhance the flexibility and skill level of the overall workforce. It would be aimed at increasing worker productivity and performance for participating employees. A common training center could be designated.

With interchangeable skills, employees could shift between companies, as they would between tasks within one company. In unionized facilities, a cooperative union-management relationship leading to high performance organizations could be developed with contractual flexibility for assignments in other parts of the network. Labor could also play a role in the broader planning and management of the eco-industrial network.

4. Information and Communication Systems

In the modern world access to and ease of use of information is a critical element of success. This includes making sure that best available technologies are used in a cost-effective way to assure speed, accessibility and interpretive capability.

Information and communication systems are areas that have taken on increased importance in today's business planning and can benefit from business networking. Various management information system (MIS) managers can examine ways to measure, analyze and report key data valuable within and between organizations. There is also technical integration possibilities that result in more productive external connections such as fast and accurate electronic communications between customers and suppliers, access to useful databases, and new and creative uses of World Wide Web resources.

The next step in the development of information and communications systems is to take advantage of the connections between companies and the beneficial sharing of resources. As communications abilities are shared and the improvements in environmental performance throughout the park are recognized, standards for measuring and evaluating environmental performance could be coordinated among the networked companies. Information related to enhanced environmental performance could be shared over a network or on a web site that would allow broader participation by member firms.

5. Quality of Life/Community Connections

A well functioning business network will recognize the importance of its relation to the surrounding community. The network's ability to function efficiently and move forward with business improvements and expansion may be based on the quality of this relationship. On a practical level, community issues and concerns are important to maintaining the link between the conceptualization of the eco-industrial park and its sanction by the larger community.

There is the link between business and the community that promotes quality of life issues. Most communities are strongly committed to the idea that companies should contribute to the local quality of life.

At another level, businesses can work with the educational community to develop cooperative educational opportunities. Cooperative education benefits both the company and the community by building the skills base and providing school to work transitions for participating students. At this level, firms are interacting with local educational institutions creating a standard for participation in sustainable businesses in the community.

6. Energy

Energy is a cost of production for all individual firms as well as a global environmental consideration. Access to an adequate energy supply is a prerequisite for accomplishing the goals of any organization. Networking of energy supply can increase overall energy efficiency, adjust for peak load variations and drive down costs by connecting efficiencies between various companies. When energy is being cascaded, it requires integration of measurement and delivery systems. As an environmental system, the net effect is to lower overall emissions, which results from energy production, transfer and use.

Green buildings and green retrofits are a next step. These include energy saving designs and technologies as well as planning for employee efficiency and comfort in the space. Green designs represent greater overall savings but they have a longer payback due to their greater capital cost.

Energy auditing represents another area of potential collaboration. An eco-industrial network could collectively contract with energy auditing firms for their services or jointly develop internal capacity within the network.

Cogeneration represents an opportunity for an energy user to sell excess or waste energy in the same way that companies have looked for ways to market by-products of production. Nevertheless, the important part of making these connections is that a network of companies be maintained with a level of information that can promote the possibility of energy sharing and cascading between the participating companies.

Another area of energy cooperation, based on sustainable development strategies, could promote the use of alternative or renewable energy sources. Solar, hydrogen, and wind are possible technological areas. This goal for energy production can also provide fertile ground for the development of spin-off companies or new divisions to market energy efficient technologies or processes.

7. Marketing

Markets are a primary driver of company success. Based on this, Eco-Industrial Development should promote enhanced market access, presence, and penetration. Joint marketing efforts allow small and medium sized firms to get greater recognition of their products and services from a broader audience than they could do alone. An environmental focus provides a special advantage for developing and exploiting green markets at the retail and wholesale and in the private or public sectors.

Marketing strategies have focused on both green labeling and expansion of markets in the initial stages of eco-industrial development. Individual companies have used green labeling as a marketing strategy. It is also possible for a network of companies to use green labeling based on their eco-industrial connections. This broader strategy can lead to joint promotions among firms and an increased credibility that the activities are more than just claims. A group of companies can market themselves and their products under the umbrella of eco-industrial strategies that reduce waste and thus bring higher value to the products. They can also stress the reduced impact of their products over their entire life-cycle. These goals will help focus participating companies on the value of implementing these strategies as well as attracting customers.

Joint ventures between participating firms are likely to occur. As marketing strengths are shared in a growing atmosphere of cooperative problem solving, joint solutions might be created that will enhance all of the participating businesses. This could include joint ventures between participants or the recruitment of new value added partners that could bring further capacity to the group.

8. Environmental, Health and Safety

Ecological Industrial Parks make the promise that excellent environmental performance not only has value in itself but contributes to overall business success. It does so by reducing compliance costs, reducing waste, improving hazardous waste management, and providing consolidated emergency management plans, among others. Cross-media (air, water and soil) emissions monitoring allows for real improvements without shifting pollution and its management costs from one waste stream to another.

One goal of eco-industrial activity is environmental excellence demonstrated by documenting full compliance with applicable regulations, a beyond compliance mentality and real contributions to overall corporate performance. A systematic approach to environmental protection also means a safety and health systems approach that reduces occupational exposure and sets an expectation of zero accidents.

Accident prevention is many times the first area of focus and may include managers, process engineers and supervisors as well as line employees. Companies that show success in accident prevention have made it a major focus for all of their employees. Across the business network, there are opportunities for common safety inspection teams as well as process safety groups that provide services to all participating companies.

Emergency response strategies include coordinating with the surrounding community, fire and police departments. This is an opportunity for the companies to reassure the community about their commitment to safety and to inform them of the positive steps taken in this area.

Hazardous waste minimization programs have become more and more prevalent in order to limit potential liabilities as well as to reduce the possibility of workforce and community exposure. This process is closely linked to issues discussed earlier about materials use and changing production processes. One of the long term goals of companies looking into compliance management is to perform multi-media emissions planning. This strategy would allow the company, or group of companies acting in concert, to minimize their overall emissions, across air, land, and water.

The field of "design for the environment" (DfE), has developed out of a broad view of minimizing the environmental impact of production. Its goal is to review the materials, process, use, and finally the recycling or disposal of the product with and approach called life cycle analysis. It can have the effect of combining all of the progress made before into superior product design and thus superior marketability and reduced operational cost. Products or processes can be designed for reduced waste, lower costs of production, increased customer value, and maximum reuse or recyclability.

9. Production/Service Processes

Eco-industrial networks can explore comprehensive improvement of production processes and the delivery of services. The goal is different within and between firms. Within firms it is to assure an optimal connection between design, technology, skills requirements, work flow, and quality management that leads to reduction of unnecessary steps while increasing operational flexibility, cost control and quality outcomes. Quality focus can be inculcated within and between firms. In order to maximize interaction between firms, process integration or alignment would also be required based on mutual interest

Between the partners as a whole, utilization of resources, technology, and people can be optimized still further in mutually beneficial ways that reduce cost, increase flexibility and enhance capability. Common maintenance capability with an emphasis on process and preventative approaches will help better manage peak or seasonal loads as well as dealing with operational emergencies.

A very basic type of business networking is the use of common subcontractors. If the service is specialized or the volume large enough, a subcontractor network develops. These and other opportunities to share underutilized assets represent a level of business networking based on common aspects of the production process. The savings from shared equipment could be financial or could provide the opportunity to purchase better equipment that would also contribute to positive environmental impact.

Shared skills are another area in which improvements could be realized as a result of networking. With developed networking between companies, the application of that skill base could be spread over more than one company and yield both more productivity from the skills and higher job satisfaction for the worker.

As networking develops, more information can be transferred between companies and the potential for interaction, technology sharing and integration of product lines increases. The implementation of modern computer networking can also enhance this process.

Rather than attachment to any one quality technique, a commitment to a systemic process based approach to quality can be a shared goal and various quality processes, training and techniques can be shared among all or some of the companies. The development of coordinated and measurable quality systems within a company has been a successful step in improving productivity. In many cases the environmental standards of the company have shown improvement through these programs.

Appendix B

EIE potential area activities questionnaire

Area	Detail of Activities	Present Status		Implemented	During Implementation	No Implementation	Problem/ Obstacle
		Intra-Factory	Inter-Factory				

Detail of existing activities	Name of Factory	Development of Work Plan	Problem/ Obstacle

Appendix C

Questionnaire of Lamp Recycling Project

Please mark x in the box.

1. Do you interest in this project?

   1.1 ☐ Yes   1.2 ☐ No (If no, please go to no. 8)

2. What kind of lamp do your business usually use? (You may select more than one choice)

   2.1 ☐ Fluorescent lamp   2.2 ☐ Halogen

   2.3 ☐ HID   2.4 ☐ Compact fluorescent lamp

   2.5 ☐ Others (Please specify)

3. Which brand of lamps do you usually use? (You may select more than one choice)

   3.1 ☐ Phillips   3.2 ☐ Toshiba

   3.3 ☐ Osram   3.4 ☐ Daiichi

   3.5 ☐ Others (Please specify)

4. How many lamps do your business has? (Please estimate)

   4.1 ☐ Less than 500   4.2 ☐ 501-1,000

   4.3 ☐ 1,001-2,500   4.4 ☐ 2,501-5,000

   4.5 ☐ 5,001-10,000   4.6 ☐ More than 10,001

5. How many lamps do you use per year? (Please estimate)

   5.1 ☐ Less than 100   5.2 ☐ 100-500

   5.3 ☐ 501-1,000   5.4 ☐ 1,001-2,000

   5.5 ☐ 2,001-5,000   5.6 ☐ More than 5,001

6. How many lamps do you use per year? (Please estimate)

   6.1 ☐ Dispose in general garbage can

   6.2 ☐ Send to licensed waste treatment firm

   6.3 ☐ Collect for future appropriate treatment

   6.4 ☐ Others (Please specify)

7. To return the expired lamps, which method do you prefer? (You may select more than one choice)

   7.1 ☐ To have a service car to collect the lamps and charge depend on the distant from the company

   7.2 ☐ To send the lamps to the service center in your region

   7.3 ☐ To send the lamps directly to Phillips Company at Bang Poo yourself

   7.4 ☐ Others (Please recommend)

8. If there is any charge from this project, what kinds of charge do you prefer?

   8.1 ☐ Free of charge, if buy Phillips lamps at certain amount

   8.2 ☐ Charge less than 1.5 baht/ lamp (not included transportation cost)

   8.3 ☐ Total charge (service and collect) depend on distance

   8.4 ☐ Others (Please recommend)

9. Would you have any further comments or recommendations for this project? Please let us know.

   ....

   ....

10. Please tell us about yourself (or environmental personnel).

    Name- Last name .... Position ....

    Office .... Telephone .... E-mail address ....

BIOGRAPHY

Mrs. Sauvanee Wiriyaumpaiwong was born on 8th September, 1973 in Bangkok. She completed her higher secondary course from Benjamarachanusorn School, Nonthaburi in March, 1991. Four years later, in March, 1995, she graduated from Faculty of Engineer at Rangsit University in the major of Chemical Engineering. After that, she performed excellent works as a chemical engineer specifically in Air Pollution Control System (APCS) and Environmental Management System (EMS) with consultant firms. In order to improve her capability, she decided to further her study for Master' s Degree in Environmental Management (International Program) at Chulalongkorn University where she achieved her Master' s Degree in October, 2002.