CHAPTER 3

METHODOLOGY AND RESEARCH METHOD

3.1 Introduction

This chapter aims at developing a methodology how to analysis and design an integrated model of pollution prevention for industrial systems, using the various theoretical ideas, especially focusing on cleaner production, waste exchange (reuse and recycling) and industrial ecology. Detailed case studies will be carried out on three different types of palm oil enterprises in Thailand, including material balances, assessment of actual and potential technological options and actor network analyses.

3.2 Research Methodology

The objectives and research questions reveal that this study seeks to find out how to improve the environmental performance of crude palm oil industry by identifying clean technologies and the theoretical and practical assessment of these technologies and to analyze and access the possibilities and the potency for improving the environmental performance of crude palm oil industry in Thailand, based on the combination and integration of existing clean technology and industrial ecology approach. Therefore case study research offers the most relevant methodology. Within this case study, the issues to be concerned are to evaluate the environmental performance of existing production processes in Thailand, to identify cleaner technology options, to assess the feasibility of cleaner production and waste exchange application in Thailand, to analyze the implementation barriers for Cleaner Production and to develop strategies to overcome these barriers. The detailed research methods applied are the study of relevant policy documents and statistics; a secondary analysis of existing studies on cleaner technology, impact assessments, and environmental performance in crude palm oil; interviews with relevant key informants in the economic, policy and social networks surrounding the case study enterprises; and a review of best international experiences in crude palm oil processing, with a special focus on Malaysia. For each part the methodology and research methods will be introduced. The methodology of this study can be divided into 3 main parts (Figure 3.1):

- Literature review and 2nd data collection.
- Pollution prevention methodology.
- Actor network analysis.

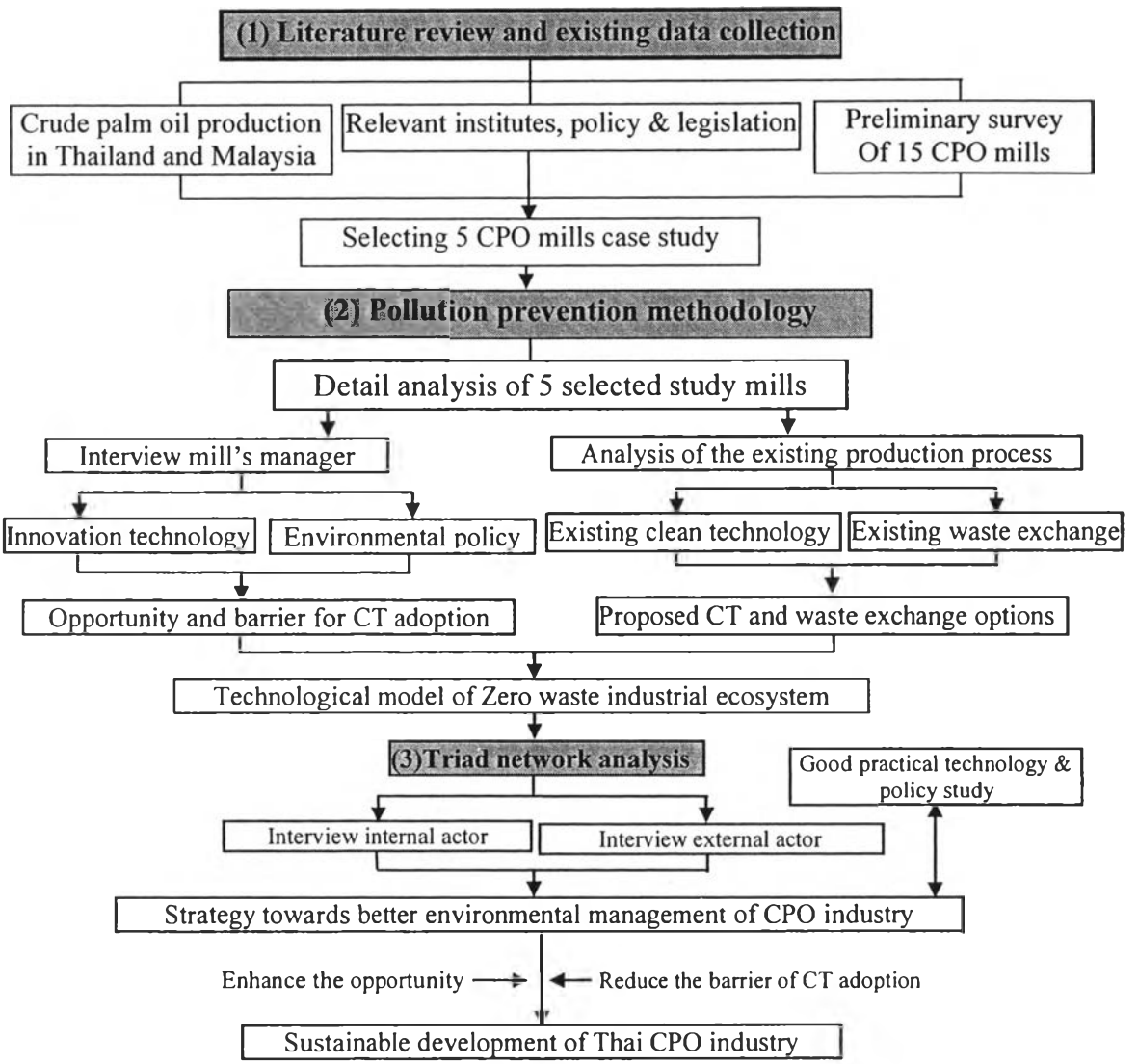

Figure 3.1 Methodology flowchart of this study.

3.3 Literature review and Existing Data Collection

The first step is to investigate the existing environmental performance of the crude palm oil production process in Thailand by gathering secondary data of relevant studies and collecting existing data. The objective is to select case studies to 'test' the developed methodology for analyzing and designing a model of an industrial ecosystem of crude palm oil mill with minimizes waste. The selected case studies have to be a representatives of such industry. They have to balance with the diversity of the industry both on size and their environmental aspects. The details of this study step is showed in Figure 3.2.

3.3.1 Literature Review

The research begins with the collection of the secondary, existing data by reviewing publications and, researches (including those that can be found at and the Internet). Previous relevant studies and survey reports on palm oil production process and their environmental aspect including clean technology and waste exchange applications and the

relevant institutes, policy and legislation are collected and reviewed both in Thailand and Malaysia. In this step, an indicative inventory of the variations in size, investment costs and production capacity of crude palm oil industry has to be made in order to classify the millers into various categories. Subsequently the state-of-the art technology, clean technology options and environmental problem in each category of palm oil industry is identified.

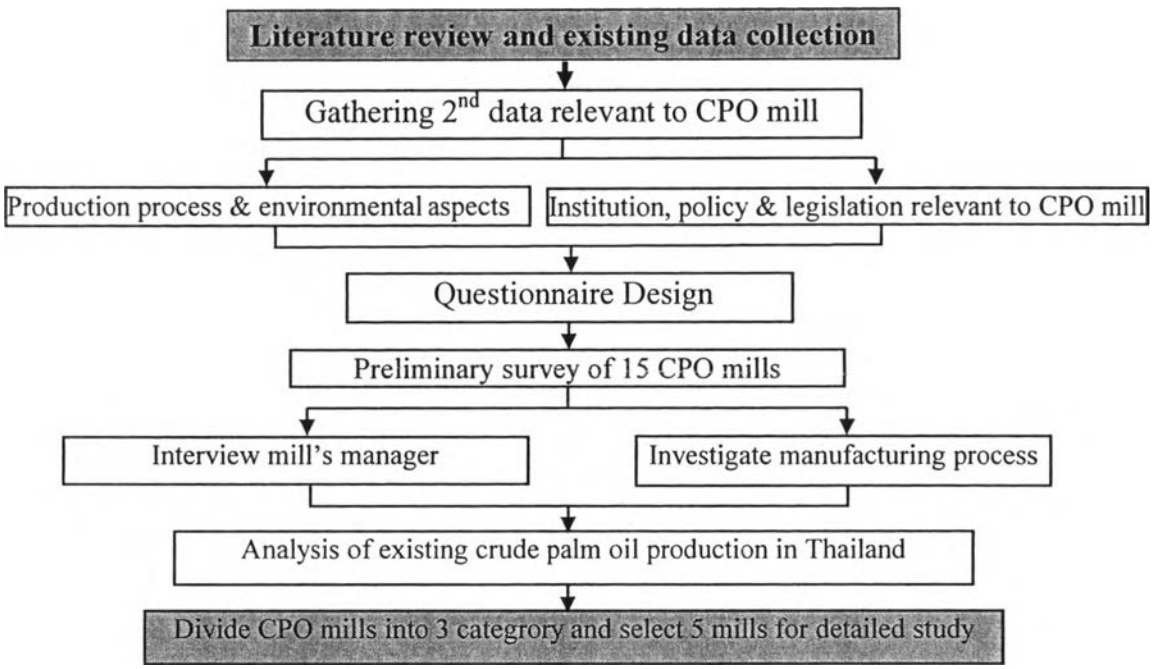

Figure 3.2 Literature review and existing data collection flowchart of this study.

In this study, Malaysia is the representative of the best international experiences in crude palm oil processing, with a special focus on research and development on clean technology and waste exchange. Malaysia is the world's largest producer and exporter of palm oil product since 1989 (Yusoff, 2000). This industry was the worst source of water pollution in the country. Malaysian government has experience in overcome the pollution generated form such industry by passed the regulatory package such as licensing system and pollution charge system (World Bank, 2001). Moreover the government sets up a specific government agency together with palm oil industry associations that have brought about enhanced the industry environmental performance.

3.3.2 Existing Data Collection

To evaluate the existing data on production process and environmental performance of crude palm oil industry, preliminary survey of the millers are done. From appointment via telephone, the responses from factories allowed only 15 factories possible for field surveys and interviews. However, the field surveys had covers all provinces that CPO factory located in the southern region of Thailand. The fifteen factories out of 25 wet process palm oil mill factories were implanted surveyed and interviewed during May 9, 2002 to June 29, 2002. Table 3.1 shows variation of Thai crude palm oil factories and the detailed results of management's interviewee of the 15 factories are shown in Appendix A.

Table 3.1 Number of CPO factories in various size.

Size (Investment cost, million Baht)	**Big** (>200)	**Medium** (50-200)	**Small** (< 50)
- Investment cost, million Baht	260-859*	60-181	38-46
- No. of Employee	136-385*	21-92	22-103
- Production capacity, ton CPO/ hr	55-60	25-60	20-25
- No. of mills in 2002	2	20	3
- No. of factory involved in preliminary survey	1	12	2
- No of selected case studies	-	5	-

Note: * = palm oil industry complex (a miller and a refinery)

Questionnaire is a major tool of this step for collecting actual data from industry. The reviewed secondary data were used to design an appropriate questionnaire. The questionnaire is divided into 5 parts such as: general information, production process data, waste generator and management data, environmental policy data and clean technology implementation data. The design questionnaire is shown in Appendix C.

3.3.3 Data Analysis.

The analysis of the existing data on production process, clean technologies application and location of the factories are used to select representative factories for detailed on material and energy flow analysis.

3.3.4 Selecting Case Study.

After an overall study of the palm oil processing industry in Thailand, five companies have been selected for more detailed analyses on the dynamics of clean technology development and introduction. Besides more practical criteria (such as availability of data and access to companies) the differences in production processes and locations are taken as core selection criteria. Factories are classified into 3 groups depending on their production technologies:

1) Improved processes, such as the use of decanter and separator in oil extraction. These will represent the best practice in clean technology options at present in Thailand.
2) Standard processes: such as a decanter only used in oil extraction.
3) Standard process, where for instance a separator is only used in oil extraction. This will represent the poor practices in cleaner production approach.

For the locational factors important considerations are distance to communities and location within palm plantations, as from the literature these prove to be relevant for cleaner production practices. Of course other factors are also relevant but will not be used initially for case selection. The result of selected case studies is shown in Figure 3.2.

Table 3.2 Factories represent for different technology and location.

Location / Oil recovery Machine	Closed to community	Far from community
Modify decanter	Factory A	Factory B
Decanter	Factory C	Factory D
Separator	-	Factory E

3.4 Pollution Prevention Methodology

The objective of this methodological step is to assess production processes and waste generations that cause environmental impacts in order to be able to redesign the production process and waste exchange in the next step. The goal is to minimize waste and impact to the environment. A systematic methodology to achieve better environmental performance of crude palm oil industry consists of 6 steps (Figure 3.3) :

Step 1 : Analysis of the existing production process.
Step 2 : Analysis of material and energy flow.
Step 3 : Selection of appropriate possibility for prevention and minimization of waste generation.
Step 4 : Identifying and designing potential clean technology options and waste exchanges, including recycling and re-use option.
Step 5 : Analysis of appropriate waste treatment.
Step 6 : Develop a physical-technological model for an industrial system to move towards a zero waste industrial system.

3.4.1 Analysis of the Existing Production Process

The objective of this step is mapping the technological profile of the production process. The analysis usually starts at individual factory. In this study data on state-of - art of technology and clean technology application, source of waste generation, environmental impact and barrier for clean technology implementation were collected.

3.4.2 Analysis of Material and Energy Flow

The second step is the analysis of material and energy flows that run through the industrial system. This assessment will start with an inventory of the process flow data to identify the flows of material and energy, sources of waste generation and quality and generation of waste from each production process. For each case study companies the following steps are being concluded.

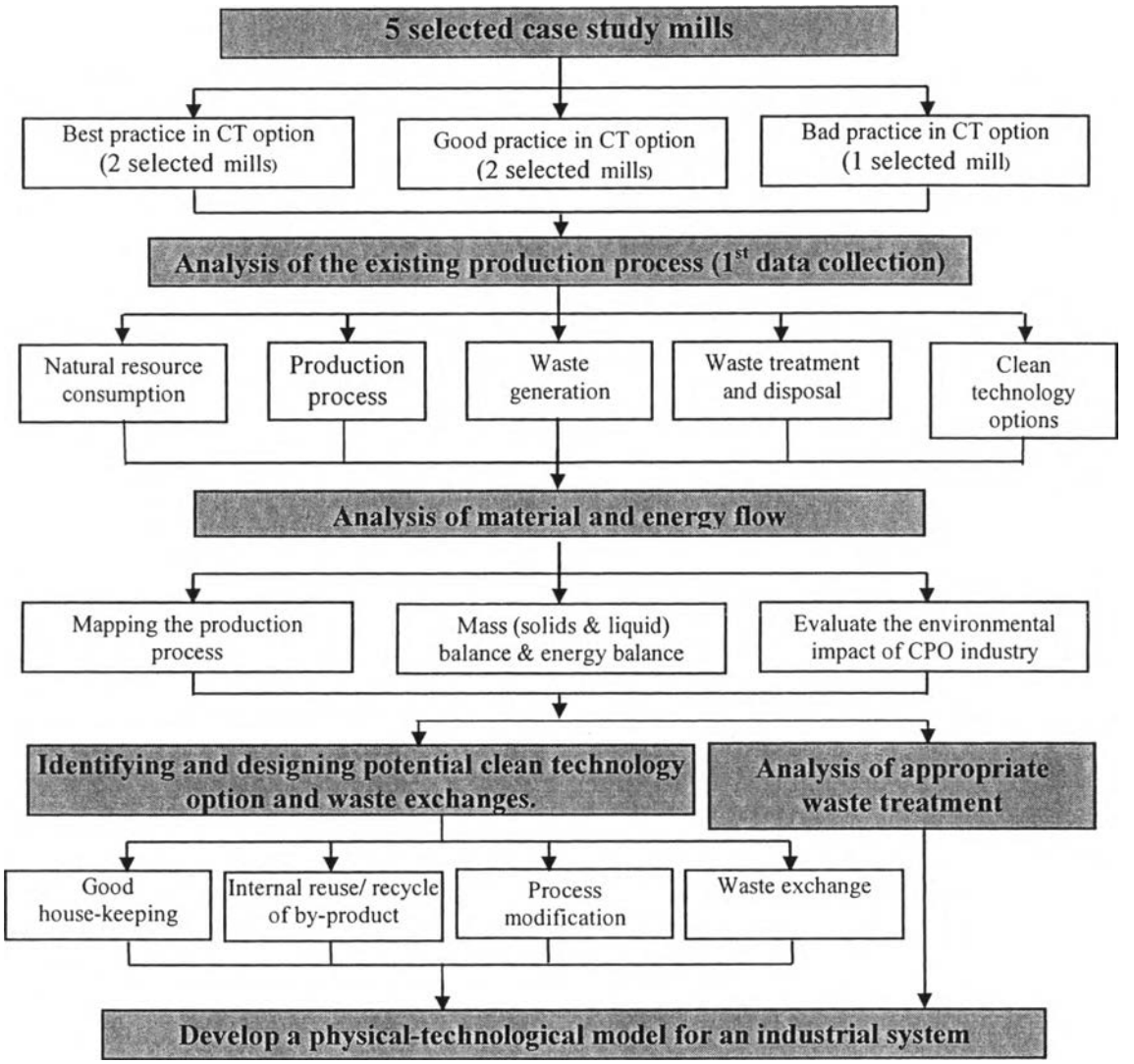

Figure 3.3 Flowchart of pollution prevention methodology.

- **Investigating manufacturing process of the selected factories**

General information about the factory and the way it deal with various waste streams (water solid, air) handling method are compiled during the field visit through discussion and interview with the industry's management. Information is collected about general factory description, management of factory, attitude on cleaner production concept and pollution problem.

- **Mapping the production process and the organizational structure of the management**.

The process description started with drafting lists of unit operation. Identification of raw material inputs, waste generation from each important processing step as indicated in the done to cooperate with oil extraction process flow diagram.

- **Water use identification.**

This section looks into various sections of water usage in the process and their required quality and quantification. Water requirement is either in the form of steam or hot water.

- **Wastewater generation in each processing step.**

This phase focuses on various sections of wastewater generation and including their quantification and qualification. Data are collected from company recording systems and direct measurement. Wastewater are sampled from various source in production process and in wastewater treatment plant.

- **Energy consumed in production process.**

Define source of energy utilization and electricity consumption rate by the industry for the manufacturing process.

- **Material and energy balance.**

The purpose of undertaking of material balance is to account for the consumption of raw materials during the process, and the losses via waste emission resulting from the process. From the process description, the varieties of waste generation rate, energy input, power and process steam requirements are compiled in a material balance. Identify environmental problems related to the processing activities.

- **Evaluate the environmental impact of CPO Industry in Thailand.**

The impact of crude palm oil industrial development on environment will be assessed both natural resource used and industrial pollution.

3.4.3 Identifying and Designing Potential Clean Technology Options, Waste Exchanges and Including Recycling and Re-use Option.

The third step focus on the prevention of waste generation, minimization of waste and waste exchange. All data collected in the first and second step are used as guidelines and inspiration to select appropriate possibility for presentation and minimization of waste generation within crude palm oil industry. The detail of this study step consists of the following steps.

- **Clean Technology Options**

This step concentrates on identifying, analyzing and designing potential internal recovery, recycling and re-uses option.

Comparison of environmental performance of each category. Data from analyzing natural resource used and pollution loading are used to determine the key indicator of production efficiency of crude palm oil industry, environmental performance indicators are identified and used to determine excessive consumption of resource and excessive waste generation by comparing then with other case study companies.

Identification of clean technology option. Data on clean technology option adapted in each factory are collected and identified and assess the theoretical and practical assessment of these technologies of cleaner production in each factory.

Evaluate the optimal clean technology option. All previous data on environmental performance indicator and clean technology available within industry will be use of to assess the select appropriate possibilities for prevention and minimization of waste generation within crude palm oil industry in Thailand.

- **Waste exchange**

This step is study on convert waste to more valuated product. For waste, which cannot be recovered internally (within the original production units), recycling and reuse in other plants or economic activities play a vital role in solving the industrial waste problem (Wei and Huang, 2001). This option ranks in the environmental management hierarchy often as the second most preferable method, following prevention of wastes. It is considered advantageous because, among others, natural resources are conserved, treatment and disposal is avoided, and the need for raw materials is reduced, thereby lowering cost (Chieu and Peters, 1994). Besides, many businesses benefit from the proximity or co-location of functions that are closely related to, or rely upon, the production process (ULI, 1988). The creation of a (waste) material flow network or waste exchange practices is part of this third step.

3.4.4 Analysis of Appropriate Waste Treatment

The fifth step is waste treatment. This entails the identification of remaining wastes that need to be treated properly before discharging into the environment. End-of-pipe treatment technologies are usually helpful for a complete removal of remaining contaminants. To be able to select proper waste treatment technology, it should be noted that knowing the quantity and quality of the waste is important. The appropriate treatment technology should be selected based on emission standard requirements, final targets, available technologies and economic efficiency.

3.4.5 Develop a Physical-technological Model for an Industrial Ecosystem

Combinations of previous study, step 3.3 and 3.4, are used to develop a physical-technological model for an industrial system of crude palm oil industry. Technical options to approach an almost zero waste industrial ecosystem will be select based on the considerations of environmental protection target, available technology and economic feasibility.

3.5 Actor network Analysis: Analysis the Implementation Barrier for cleaner Production and Develop Strategies to Overcome these Barrier

The last step is entailing the actor network analysis. Results from above study are used to form a systematic methodology that leads us towards the environmentally balance crude palm oil industry solution model for an almost zero waste in industrial ecosystem. However, actual application of the physical-technological model might face severe difficulties and barriers since the industrial system as a whole and the various constituting subsystems might have conflicting interest, they are often confronted with a lack of coordination and are not isolated entity but related to and embedded in complex social-economic conditions. No matter how innovative, original and closed the designed industrial system is in terms of its substance flows, this does not guarantee any success in

terms of application and implementation of the whole model or even of few parts. To transform the developed, the model for an industrial system from the design table to reality, it is essential that the complex social, economic and political relations and institutions between the industrial system and actors outside are analyzed in depth. Only by understanding the existing relations of the industrial systems with, among others, government agencies, other economic entities and social actors, we are able to (i) identify the existing barriers that hamper the implementation and introduction of some or all of the alternatives of the physical-technological model, and (ii) to design the necessary transformation and changes in these social, political and economic relations and institutions in order to facilitate, support and enhance the possibilities of implementing some or all of the physical-technological options. In other words, we are in need of an analytical tool that provides us with the concepts to analyze existing interactions and relations between actors within and outside the industrial system, as well as the institutions that govern and structure these interactions and relations.

Mol (1995) developed also a methodology to analyze the changing interactions within the institutional environment of an industrial sector in an era in which environmental consideration push for major industrial transformations. This so call 'triad-network'-approach encompasses a study of the policy networks, economic networks and societal networks in which a industrial sector is embedded. The triad network approach is an instrument for studying the role of several stakeholders and institutions in bringing about environmental improvements of industrial firms via technological and organizational change. To understand the interactions between a company, the authorities and other stakeholders, we use the network model. From a company's point of view, there are three networks (Figure 3.4):

Policy network: focuses on the relationship between government and industry from a political-administration point of view. Studying policy network involve the main policy processes and dynamics, the (institutionalized) interaction patterns and power relations, the division of task among governmental agencies, the role of intermediary organizations, innovative private-public partnership constructions, etc.

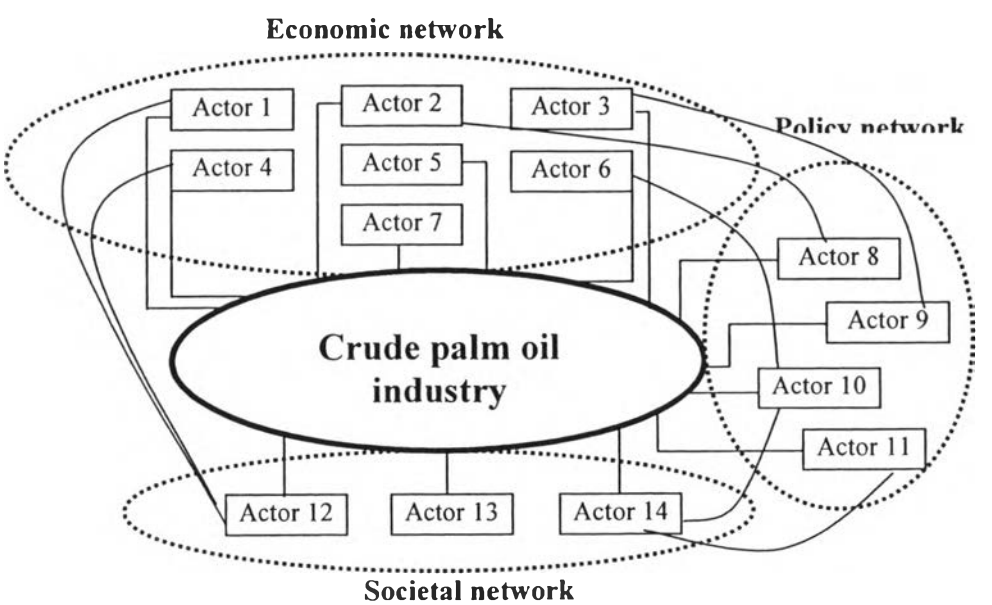

Figure 3.4 Triad networks relevant to crude palm oil factory.

Economic network: This network consists of interacting organizations, which have economic goals and rationality as their principal motive for interactions. There is a vertical connection and integration between them: from raw materials to products. Horizontal relations and integration refer to competition from other firms and interaction via branches. Economic actors are business and their representative organizations, other competing firms, utility suppliers, equipment suppliers, credit organization such as bank, consumers and customers, etc.

Societal network: The societal networks deal with industry-civil society interactions. These can consist of NGOs, communities, research and training institutions, employees association, labour organizations, etc.

The network model will be useful in understanding the institutions involving and interactions between a company and its social environment. Such network analyses can be used to identify both the main mechanisms and dynamics in pushing environmental reform, as well as the implementation barriers that hinder cleaner production implementation in industry. Following such analyses we can develop a strategy to improve the diffusion and implementation of options by taking away these barriers.

In all these three networks, globalization plays an increasing important role. Factors to be taken into account are international competitors, international environmental policies, home-country-less companies, etc. They have only marginally affected national societal networks. Nevertheless, interdependence between ecological restructuring and globalization is increasing (Mol, 1995).

As well as investment in new technologies, companies can also improve their environmental performance through organizational change and the introduction of new managerial techniques. Organizational innovation can not only bring economic and environmental gains but it can also have a positive impact on the environment into which technologies must be introduced, thereby enhancing the potential for clean technologies to be integrated into existing system. Finally, companies can explore the potential for improving their environmental performance by integrating environmental concerns into their strategic as well as their operational management process.

In this step, the crude palm oil industry's management and enterprise's environmental manager in each case study are interviewed to assess the feasibility of implementing the various options, the attitudes within the company on cleaner production options, the organization fitting of these options, and the various barriers that these options might meet. Then the internal implementation barriers of cleaner production can be identified.

3.5.1 Triad Network Analysis

This method is used for analyzing the interactions among actors or stakeholders, who have an influence on the environmental performance of the palm oil companies. This model offers the way to analyse the relationship between industry and other actors in the networks in shaping improved environmental performance of industry. Examination on the interaction among and between stakeholders in the policy, economic and societal arenas lead to the main push and pull factors and the enabling and constraining social environment. This analysis will identify the external and internal

implementation barriers. Table 3.3 illustrates various key informants, which will be interviewed.

Table 3.3 Number of the relevant actors are interviewed.

Network	Key informants	Number of persons
Policy	- Central level: DIW; PCD	2
	- Provincial level: PIA;	1-2 / province
	- Local Level: TAO; PAO	1/ sub-district
	- Company level	1-2/ mill
Economic	- Planters; recyclers;	1-3
	- Refinery	2
	- University; CPO association; Bank	1-2
Societal	- Surrounding community	3-5 /mill
	- NGOs	2 persons

This study also interview the crude palm oil industry's management and enterprise's environmental manager in each case study to assess the feasibility of implementing the various options, the attitudes within the company on cleaner production options, the organization fitting of these options, and the various barriers that these options might meet. Then the internal implementation barriers of cleaner production can be identified.

3.5.2 Development of Strategy towards Better Environmental Management

Development of strategy to improve the diffusion of potential improvement options is as a result from combination of this study and lessons from other relevant studies. Special focus will be put on the implementation barriers and the opportunities to take away these barriers, both internally within the factory and externally.