ENVIRONMENTAL AND TECHNO-POLICY ANALYSIS OF AN AGRO ECO-INDUSTRIAL NETWORK IN CHACHOENGSAO PROVINCE

by

Niranchana Authayanraksa

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Environmental Engineering and Management

Examination Committee:	Prof. C. Visvanathan (Chairperson) Dr. Nowarat Coowanitwong Dr. Thammarat Koottatep Dr. Shabbir H. Gheewala
Nationality:	Thai
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Abstract

Chachoengsao Province is one of the less urbanized and industrialized zone of the Eastern region evidenced by the presence of traditional agro industries. The eastern districts of the Province, also the fringe areas of the Bangkok urban, are well irrigated by the Bang Pakong River and support paddy cultivation to a large extent. Abundant of natural resources and availability of labor promotes agriculture as a mainstream occupation.

The study considering the material flow and economic linkages in the peri-urban areas, the study focused on the five districts; Muang Chachoengsao, Bang Khla, Bang Nam Priao, Bang Pakong, and Ban Pho. Specifically, the system under consideration is the predominant agriculture sector with rice as the major product, its value chain, and the scattered livestock sectors.

The environmental setting of the sector and study region was first understood through a baseline study. The material flow starts with paddy cultivation in and proceeds as many steps until all the products and by-products are completely utilized. The livestock sectors are also connected through material flows. The quantitative material flow pattern in the region is formed; it is evident that though a near-perfect material flow occurs, pollution problems due to unrecognized value of materials still exist.

The material flow in the rice and livestock sectors of Chachoengsao indicates the potential for its transformation to an Agro Eco-industrial network. Introduction of new technologies are essential for a successful transformation. Appropriate policy reforms considering all related issues of the Eco-industrial network and rightly integrated with national and local development priorities is essential.

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Abbreviations

AEIN	Agro Eco-Industrial Network
PEA	Provincial Electricity Authority
MEA	Metropolitan Electricity Authority
EGAT	Electricity Generating Authority of Thailand
EPPO	Energy Policy and Planning Office
DIW	Department of Industrial Work
IE	Industrial Ecology
EIP	Eco-industrial park or estate
BPX	By-product exchange
EIN	Eco-industrial network
PCD	Pollution Control Department
ASEAN	Association of Southeast Asian Nations
OTOP	One Tambon, One Product
SMEs	Small and Medium Enterprises
NICs	Newly Industrialized Countries
GPP	Gross Regional and Provincial Product
NESDB	National Economic and Social Development Board
MSG	Monosodium Glutamate
UNEP	United Nations Environment Program
DTV	Daedok Techno Valley
CLA	Life-Cycle Inventory Assessment
BOI	Board of Investment
DIP	Department of Industrial Production
FAO	Food and Agriculture Organization
PRD	Public Relations Department
TISC	Thailand Investor Service Center
WHO	World Health Organization

Chapter 1

Introduction

1.1 Background

Thailand, primarily an agricultural country, has had a diversified economy since the 1960's with about 81% of the population living in rural areas. Today, agriculture constitutes the largest income generating sector followed by the manufacturing industries in the second place. While Thailand's economic prosperity has cemented the country's image as an industrial leader and development partner, the negative environmental impacts of development, rapid urbanization, and industrialization have taken their toll on the country and its people.

Chachoengsao Province, a land of agriculture depends on its natural resources, mainly land and water. Agriculture in the region has developed targeting the urban markets of Bangkok and in some cases the export markets. The proximity of the region makes it to be potentially referred as the satellite town to the economic, administrative and residential nucleus of Bangkok.

The Chachoengsao province represents a rural urban fringe area which plays a key role in the economic vitalization of the rural area by meeting the resource needs of the urban centre. With an annual output of about 2 million tons of vital agricultural products such as rice, tapioca and others, Chachoengsao steadily maintains a complex relationship between industry and agriculture. Even in the present days of industrialization and modernization, industries in the Province are characterized with agricultural products.

Industries in the province have been always consuming resources from this rural area to feed the urban centre of Bangkok's. Depleting resources, degrading environmental quality due to poor management systems, lack of awareness on environmental issues and unscientific methods of production, and waste disposal has rendered the region vulnerable.

Recently, industrialization has been accelerated in accordance with the Government's policies with the economy of the province standing a better chance through the rapid expansion of industrial sectors, development of transportation services for product and mankind, and increased investments. The scale of operation and the rate of growth indicate that the industries have been focusing more on the development of the economy than the sustenance of the environment and its resource.

The nature of agro industries tends to be highly natural resource dependent, less capital intensive, poorly integrated with the modern technologies and heavily labour dependent. However, these industrial units offer the possibility of technology transfer and opening up of markets. There is need for complementarities between large and smaller indigenous agro-processing operations. The growth of this sector also gives rise to significant environmental degradation.

Strategic environmental and economic planning is needed to keep the impacts of economic development on the environment in an acceptable level. Industrial Ecology is a tool to develop sustainable industries in an environmental friendly way to achieve the goals of economic development. Industrial ecology has been gaining momentum in the recent

years owing to its nature of solving environmental problems and resource constraints by following innovative approaches and methods.

Eco-Industrial Networking (EIN) is a relatively unexpected concept which aims at converting industries with linear consumption, production and waste handling processed into cyclic closed loop industrial systems. Eco-Industrial Clusters thus aim at reduced consumption of resources, efficient production processes and improved waste management methods.

This study seeks to find solutions and innovative ideas for development of Eco-Industrial Networking. In addition to environmental protection, economic revitalization and social upliftment are also essential for the development to be sustainable. Therefore this study attempts to understand the implications of prevailing policies and social conditions so as to integrate them with environmental and economic planning in the right level. Thus the results of the study would aid in the development of a blue print for an integrated strategic environmental and economic plan.

1.2 Objectives of the study

The general objective of the study is to analyze and assess possibilities and the potential for Eco-industrial network development of agro-based industries in Thailand, using Chachoengsao Province as the case study.

The specific objectives include the following:

1. To investigate the existing environmental, economic and technological situation of the agro-based industries in the urban fringe areas of Chachoengsao Province.
2. To study the existing role and level of integration of policies related to the development of industrial clusters and local communities.
3. To develop industrial networks (Material flow network) to identify alternative use of waste or by-product and optimize resource use thus improving the environmental and economic benefits of the industry and the community.

1.3 Scope of the study

This study needs the collection and analysis of primary and secondary data on environmental, economic, technological, and policy aspects of agro based industries in the Chachoengsao Province, especially Bangpakong, Ban Pho, Chachoengsao Muang, Bangkla and Bangnampriao districts.

A survey of the present industries and socio-economic aspects was carried out through the interviews and questionnaire during the field visit. The existing situation, management options and environmental performances of the agro based industries was investigated. Based on the response and the policy analysis, appropriate technology and policy measures were suggested.

The research looks forward to preparing and proposing for agro eco-industrial network report which is focused on findings and suggest the potential material flow network in the

macro scale of the Province. Due to the limitation of time, resources, and availability of raw data, the following data boundary was investigated:

1. Rice-based industry was the mainly focused for agro-based industrial sector for network creation. Also, the industrial sectors which are consumed the wastes and by-products from anchor were investigated.
2. Eco-industrial network was focused on the waste or non-product materials and energy exchange.
3. The present industry sectors were selected and it is sampling for data collection within 5 listed districts in Chachoengsao Province.
4. The relevant policies of the proposed eco-industrial network are mainly determined from industrial and environmental institutions so as to maximize environmental, economic and social benefits both to the industry and the community.

Chapter 2

Literature Reviews

2.1 Introduction of the Environmental Management

The goals of industry are incompatible with the preservation and enhancement of the environment (Graedel and Allenby, 1995). The more demand to provide a suitable life quality for Earth's citizens will not involve less, but more industrial activities and contribute to serious environmental problems. Thus, providing a sustainable world will require close attention to industry and environment interactions. The disregard for the protection of the environment cannot be justified by the benefits of economic development. Therefore, how to protect and improve the environmental quality has risen thinking many decades ago.

Government regulatory agencies and industry have focused their pollution reduction efforts on controlling effluents at the point where they enter the environment, since the beginning of the environmental movement in the early 1960s (Chiu and Peters, 1994). The end-of-pipe measures were added into industrial processes (Khan et al., 2001). However, the advent of strict environmental legislation in recent years, combined with the ineffectiveness and relatively high cost of several end-of-pipe treatment technologies have, in many instances, resulted in making this approach inadequate to deal with the magnitude and complexity of environmental degradation. The limitations of end-of-pipe treatment made environmental decision-makers consider replacement of end-of-pipe treatment by other alternative methods of pollution control.

Consequently, during the last decade, environmental researchers began focusing on cleaner production, waste minimization and even a new academic discipline, Industrial Ecology (IE), was born with the mission to design zero-emission industrial processes (Ayres and Simonis, 1994; Graedel and Allenby, 1995) these pollution management approaches have contributed significantly to reducing pollution, improving environmental performance, raising profitability and enhancing competitiveness. Though several successes on environmental protection have been achieved by applying these approaches, environmentalists recognize that their practical sphere is limited due to lack of unsustainable industrial system into a more environmentally sound direction.

The environmental protection approaches towards the top are usually preferred, as they are more effective in economic and environmentally; and efficient in reducing the amount of wastes; and therefore reduce present and future threats to human health and the environment.

2.1.1 Industrial Ecology (IE)

The new approach of industrial environmental management is Industrial Ecology and we accept the claim of some industrial ecologists this is "the science of sustainable development" (Allenby and Richards, 1994; Lowe et al., 1997). IE focuses on reducing the environmental impacts of goods and services, on systems-based analysis of environmental problems and on innovations that can significantly improve environmental performance.

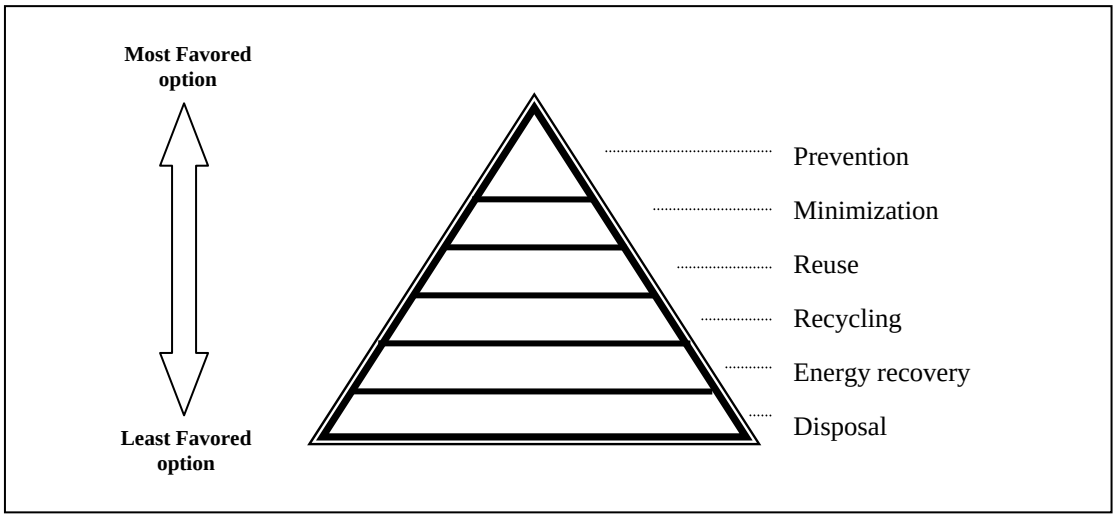


Figure 2.1 Waste management hierarchy

Robert Frosch and Gallopoulos (1989) were early drafters of the concept, For them: an industrial ecosystem is the transformation of the traditional model of industrial activity, in which individual manufacturing takes in raw materials and generates products to be sold plus wastes to be disposed of, into ma more integrated system, in which the consumption of energy and materials is optimized and the effluents of one process serve as the raw material for another process.

According to Allenby (1994), Industrial Ecology is the study of 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."

The important theme of Industrial Ecology is that design of industrial systems can, to some extent, be modeled upon ecosystem. A simple definition of an industrial ecosystem is focusing on the relations among companies in direct waste and by product exchange (Frosch and Gallopoulos, 1989). Connections with a natural ecosystem have also been made, both a interface level between man-made ecosystems with natural global ecosystem (Tibbs, 1992) as well as the application of the principles of natural systems to man-made systems (Kirchner, 1995).

Industrial ecosystem can be defined as including all types of production, processing and consumption, for instance agricultural production as well as purely industrial operation (Manahan, 1999). The four major components are shown in the figure 2.2.
Industrial Ecology is an interdisciplinary framework for designing and operating industrial systems as living systems interdependent with natural systems. On of the focus areas of IE is the networking of industries for efficient use of resources and minimizing or avoiding the material discarded as waste by finding an alternate use to it.

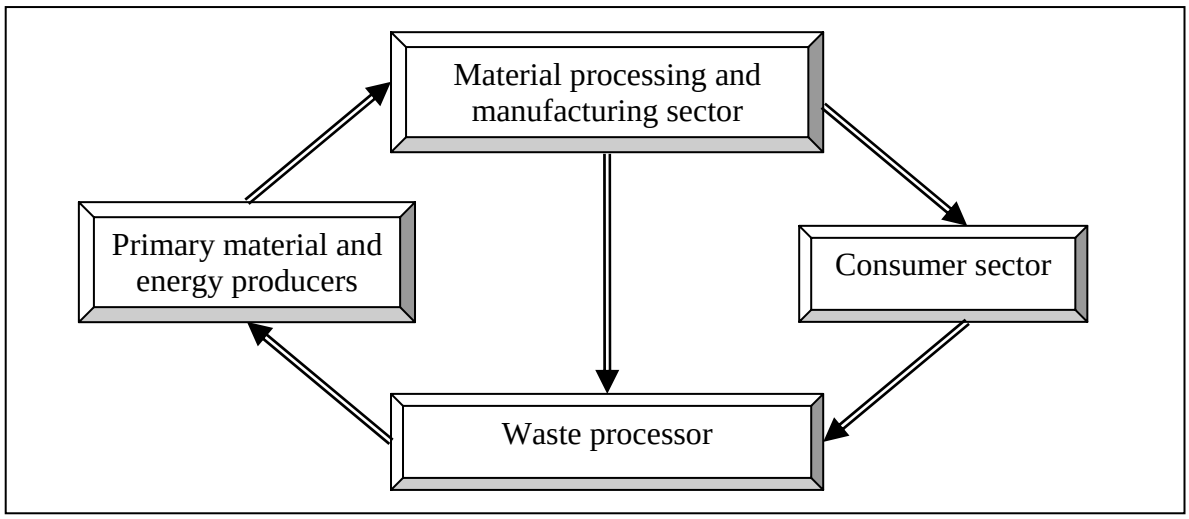


Figure 2.2 Major components of an industrial ecosystem

2.1.2 Eco-Industrial Network (EIN)

A classical definition of an Eco-industrial Park as given by Lowe (2001) is:

"An eco-industrial park or estate is a community of manufacturing and service businesses located together on a common property. Member businesses seek enhanced environmental and resource issues. By working together, the community of businesses seeks a collective benefit that is greater than the sum of individual benefits each company would realize by only optimizing its individual performance"

The Goal of an Eco-industrial Park is to improve the economic performance of the participating companies while minimizing their environmental impacts. Components of this approach include green design of park infrastructure and plants (new or retrofitted); cleaner production, pollution prevention; energy efficiency; and inter-company partnering. An EIP also seeks benefits for neighboring communities to assure that the net impact of its development is positive. To be a real EIP, a development must be more than:

- A single by-product exchange or network of exchanges;
- A recycling business cluster;
- A collection of environmental technology companies;
- A collection of companies making "green" products;
- An industrial park designed around a single environmental theme;
- A park with environmentally friendly infrastructure or construction; or
- A mixed-use development (industrial, commercial, and residential).

Although many of these concepts may be included within an eco-industrial park and should be more comprehensive. Since the terms Industrial Park and Industrial estate are in common use. Clarifying the EIP terms is important to make it clear usage for proponents and proper chosen use of many different phases to speak of the same basic strategies. Lowe (2001) distinguished three basic categories of eco-industrial projects:

- Eco-industrial park or estate (EIP)- an industrial park developed and managed as a real estate development enterprise and seeking high environmental, economic, and social benefits as well as business excellence.

- By-product exchange (BPX) - a set of companies seeking to utilize each other's by-products (energy, water, and materials) rather than disposing of them as waste.
- Eco-industrial network (EIN) - a set of companies collaborating to improve their environmental, social, and economic performance in a region.

There are various ways projects can overlap and the Figure 2.3 is shown the relations between each terms. EIPs and EINs may include by-product exchange programs. One or more EIPs may participate in either a BPX or EINs.

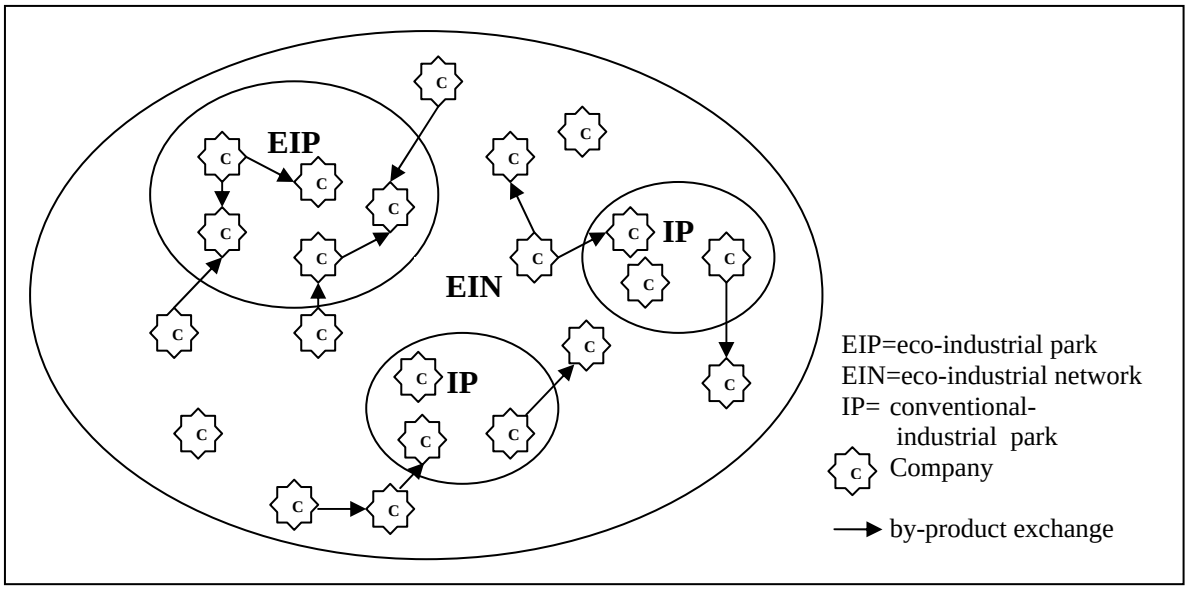


Figure 2.3 Eco-Industrial Network and relationships of between the terms

An Eco-Industrial Network may include stand-alone companies, companies in industrial parks and the park management organizations. EIN members collaborate to enhance their performance and to create shared service and facilities. One form of collaboration is to exchange by-product materials, energy, or water among companies, when feasible.

Eco-Industrial Clusters (EIC) and Eco-Industrial Networks (EIN) are synonymous in terms of nature and have been interchangeably used through out this text. Essentially, both EICs and EINs refer to a collection of industries along the value chain of the same product or similar products. EICs and EINs also collectively represent a manufacturing/service system where a symbiosis exists within and among the components of the system. Components or member industries of the system exchange raw materials and by products, share common resources, technology, information, infrastructure etc.

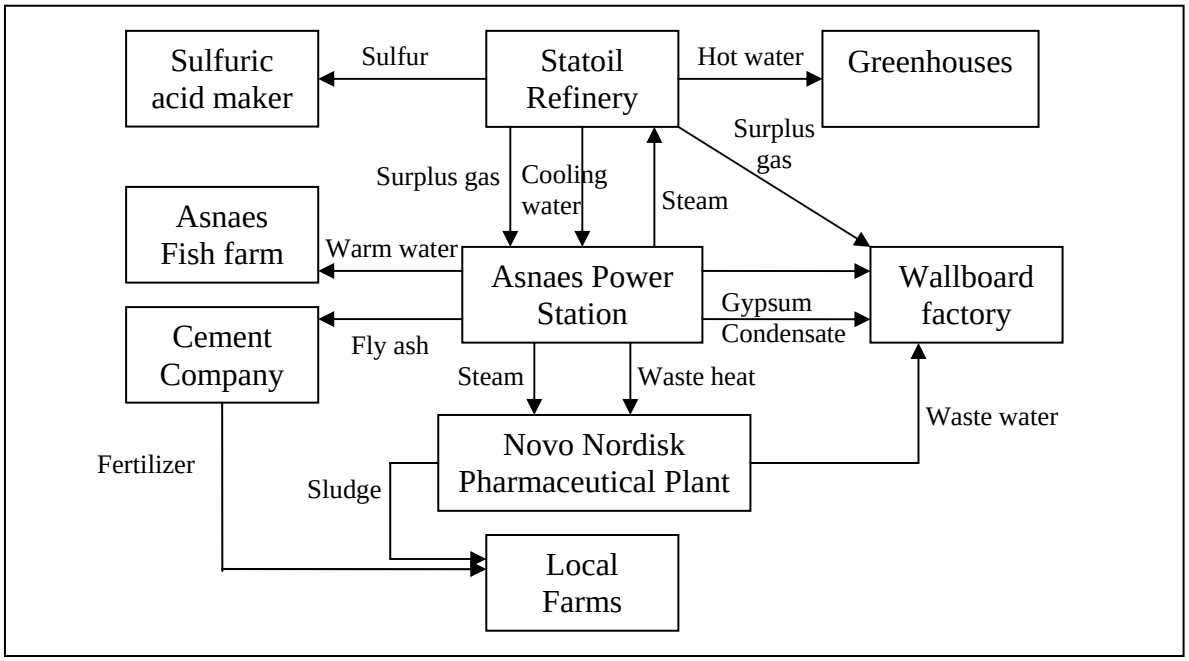
2.1.3 Eco-Industrial Project

In the literature, it can be found that most focus point commonly used for industrial ecosystem approach has been an eco-industrial park or local industrial system with the often cited example in Kalundborgin Denmark. Lowe (1997) stated that the story of it has become the premier case illustrating industry can coexist in a kindly manner while generating bottom-line benefits.

- **Kalundborg Industrial Park**

Kaludborg is a small industrial area on the Danish coast (Cohen-Rosenthal and McGalliard, 2003). The industrial symbiosis began to evolve in the 1970s, as several of the core partners, truing to reduce costs and meet regulatory goal, sought innovative way of managing waste materials and using freshwater more efficiently.

Symbiotic connections have developed between major and minor partners. The Statoil refinery distributes sulfur by-product to a sulfuric acid manufacture and hot water to local greenhouses. Waste heat and steam from the Asnaes Power Station are used by Novo Nordisk, which in turn distributes organic sludge from its manufacturing process to locals as fertilizer. The Kalundborg model goes beyond material exchanges and in a limited way towards other types of collaborations in worker training and safety (Gertler, 1995).



Source: Cohen-Rosenthal and McGalliard, (2003)

Figure 2.4 Kalundborg Industrial Symbiosis

The primary focus remained on the material and energy exchanges. The symbiotic relationships between the core partners of Kalundborg and others that operate within the system is presented in Figure 2.4. According to Novo Nordisk, one of main participants in the Kalundborg scheme, the 60 million US$ was invested in build 16 exchanges project. These projects produce surplus 10 million US$ annually.

The environmental benefits of industrial ecology schemes can be significant as well. At Kalundborg, Large savings have been achieved in consumption of raw materials; annual oil consumption was reduced by 45,000 tons, coal consumption by 15,000 tons, and water consumption by 600,000 m^3. The Carbon dioxide and Sulphur dioxide emissions have reduced by 175,000 tons and 10,200 tons per year.

Moreover, several EIP projects appeared in many developed countries in the world after Kalundborg such as;

- Burnside industrial park, Nova Scotia, Canada.
- Fairfield Eco-Industrial Park Project, Baltimore, Maryland, USA
- Port of Cape Charles Sustainable Technology Industrial Park Project, Eastville, Northampton County, Virginia
- Brownsville Eco-Industrial Park Project, Brownsville, Texas
- Riverside Eco-Park Project

In addition of these examples, every time concerns have a symbiotic relationship in which wastes from one are utilized by another, they can be regarded as a partial constitution of an industrial ecosystem, of which exist throughout the world (Tran, 2003).

2.2 Environmental Management Issues of Agro-based Industry

2.2.1 Definition of Agro-based Industry

The agro-industry is based on agricultural and forestry production, and its purpose is to preserve and refine raw produce and to extract and concentrate the valuable constituents. The food industry constitutes the most important sector of the agro-industry (World Bank, 1986).

Many agro-industries have developed from skilled manual production processes and accordingly can be carried out at varying technical levels. However, applies to small and medium-sized operations. The definition of small and medium-sized operations varies from country to country but a maximum of 100 employees can be taken as an upper limit. There are environmental briefs which focus specifically on a number of agro-industries; particularly large plants. Primary processing is basically most suited to small industrial operations, as technical input increases in line with processing complexity.

2.2.2 Impacts of Agro Processing Industry

As the agro-industry will probably increase the demand for certain commodities, or alternatively push towards different forms of land use and farming, the following environmental impacts in the area of agricultural production should be mentioned:

Problems relating to the direct expansion and intensification of resource usage include impairment of soil fertility, problems of soil losses and sedimentation, problems of desertification and irrigation problems (soil and water salination, fluctuating water table and water pollution), which in turn reduce resource productivity. The problems of fertility losses, desertification, and salination are generally greatest in countries where the population pressure on land is greatest. Here, agriculture expands most markedly in peripheral areas and marginal resources are utilized intensively (World Bank, 1986).

The economic and social parameters in place and those required are key factors in the agro-industrial sector generally. The maintenance and promotion of subsistence production and agro-industrial activities without restricting subsistence are major maxim in this respect.

Commodity processing gives rise to environmental impacts on the atmosphere (odors and dust emissions), water (quantity and wastewater), primary energy sources (mainly timber) and the soil.

- **Environmental pollution from the major Agro-based Industry**

The following comments are confined to certain branches which have been in the greatest demand in recent years;

Mills handling cereal crops; only dry milling is carried out in such plants, thus must be taken of noise and dust emissions which affect not only the specific operational area but also the area surrounding the mill. Surface water quality is impaired in cases where streams and rivers are used for waste disposal.

Processing of starch sources and root crops; If the biologically polluted wastewater from washing and processing is discharged into surface water untreated, the result can be over fertilization, reduction in the oxygen content and a general destruction of water quality, changes in the micro flora and fauna.

Processing of oil-bearing seeds and fruits; In small and medium-sized works, only pressing processes are used for oil extraction. This produces steam emissions and oil-laden wastewater.

Processing of semi-luxury goods and spices; the operations having environmental relevance in the production are fermentation and waste disposal. The pollutants thereby produced can accumulate in the soil over long periods, damaging micro flora and fauna. The biologically polluted wastewater, if discharged untreated.

2.2.3 Situation and development of Agro-based Industry

Farmers in many Asian countries, including Japan, Thailand, China, India, and the Philippines have been developing sustainable agriculture practices appropriate to their regions, often with the support of institutes such as the International Institute for Rural Reconstruction, Manila and the Food and Fertilizer Technology Center, Taipei. Often the “innovations” of sustainable farming are simply the relearning of traditional practices. A large scale field test in China in the late 1990s demonstrated that increasing the diversity of rice strains instead of growing only one strain as a monocrop, almost doubled productivity while eliminating most of destruction of crops by fungus and chemical inputs. In Thailand government policy is seeking to regain, through sustainable agriculture practices, the productivity lost to exhaustion of soil by industrialized farming on former forest land.

On the demand side, the market for organically produced grains, fruit, and vegetables is growing rapidly in Europe, the US, and Japan and beginning to open in some developing countries. Organic produce sells at premium prices, and many leading supermarkets now feature organic sections. There is growing evidence of a trend toward sustainable agriculture driven by the need to conserve soil, water, and energy in food production and pulled by consumer demand for a healthful, non-polluted food supply (Lowe, 2001).

- **Thailand**

Thailand has rich natural resources consisting of tin, rubber, natural gas, tungsten, tantalum, timber, lead, fish, gypsum, lignite, and fluorite. Roughly 49 % of Thailand's labor force is employed in agriculture with rice as the country's most important crop and a major export in the world rice market. Other agricultural commodities produced in

significant amounts include fish and fishery products, tapioca, rubber, corn, and sugar, coconuts, soybeans. Exports of processed foods such as canned tuna, pineapples, and frozen shrimp are on the rise (WHO, 2004).

Thailand's increasingly diversified manufacturing sector made the largest contribution to growth during the economic boom. Industries registering rapid increases in production included computers and electronics, garments and footwear, furniture, wood products, canned food, toys, plastic products, gems, and jewelry. High-technology products such as integrated circuits and parts, electrical appliances, and vehicles are now leading Thailand's strong growth in exports. Thailand's top ten food exports in 1998 are shown following the Table 2.1 (Tanticharoen, 2000):

Table 2.1 Thailand's top ten food exports in 1998

Products	Export Value (US$ millions)
Rice	2.17
Canned fish	1.69
Fresh chilled/frozen shrimps, prawns and lobsters	1.45
Sugar	0.66
Tapioca (cassava) products	0.57
Chilled/frozen poultry cuts	0.41
Prepared/preserved fruits in air-tight containers	0.38
Fresh chilled/frozen cuttle fish, squids and octopus	0.29
Prepared/processed foods for animal feeds	0.25
Processed poultry	0.22
Total	**8.09**

Source: Tanticharoen, (2000)

2.3 Profile of the study area: Chachoengsao Province

The province is in the Central region of Thailand and also has a short coast to the Gulf of Thailand. The area of province is 5,351 km^2 and its rank is 41^{st} with the number of population is 635,153. The west part of the province is the low river plain of the Bang Pa Kong River, which is used extensively for farming rice. To the east is more hilly terrain, with an average height of more than 100 m. above sea level.

2.3.1 General information

Chachoengsao province is a land of agriculture, counting on the favorable of rain and soil. And it also is acquiescent to serve as a "Satellite Town" of Bangkok in numerous aspects-particularly as an administrative and residential nucleus (Chachoengsao Provincial, 1996). Because of it is not too remote from existing urban centers, make it intensive expanse of the province and proximity to the economic center of the country. For these reasons, Chachoengsao province is the one to represent the Rural Urban Fringe Area of Thailand. With yielding nearly 2 million tons of agricultural output annually and being vital recipient of farming produce, Chachoengsao entertains and intimate correlation between industry and agriculture. Even now, types of industries are still determined by agricultural yields.

Recently, industrialization is being precipitated in accordance with the Government's policies and the province advancing towards the economic stance. Through the rapid

expansion of industrial varieties, the center of transportation of product and service, and development of investment. Then the industries focus on the development of the economy more than the sustenance of the environment and its resource.

2.3.2 Pollution problems in the region and Chachoengsao Province

Data on environmental problems in the Eastern region can be show in the table 2.2 revealed that pollution problems mostly complained were air and noise, water, and waste respectively. That most complaints were industrial factories, and most businesses complained were metal products, production of plant seeds or tubers such as grain milling, winnowing, grinding, flour production, peeling tubers and slicing them into round thin pieces or sticks, etc and plastic products such as production of tools, appliances, furnishings, or ornaments including parts of those products.

In the Eastern Region, The water quality in 9 main rivers, (Bangpakong River, Prachinburi River, Nakornnayok River, Rayong River, Prasae River, Pangrad River, Chantaburi River, Weru River, and Trad River), has been monitored. Among all, Bangpakong River, Nakornnayok River, Rayong River, and Prasae River had deteriorated water quality condition.

The main problem of water resources in the Eastern region was the contamination of Total Coliform Bacteria and Fecal Coliform Bacteria in crowded regions. In addition, seawater trespassing during the dry season was found at Bangpakong River up to Bangkanag Bridge in Bang Nam Priao District of Chachoengsao Province.

Table 2.2 Public Complaints on Pollution in the Eastern region of Thailand

Province	No.	Type							
		Odor	Noise	Dust/ Smoke	Wastewater	Solid waste	Hazardous waste	Other	Total
Chonburi	18	12	4	6	4	1	1	0	28
Rayong	17	9	2	6	11	0	0	0	28
Chachoengsao	12	9	2	5	3	0	1	1	21
Phrachinburi	8	3	2	1	2	1	5	1	15
Chantaburi	2	0	0	1	1	0	0	0	2
Trat	0	0	0	0	0	0	0	0	0
Sakaeo	0	0	0	0	0	0	0	0	0

Source: Public Complaints Information Center, PCD, (2004)

Chachoengsao province represented of the complex matrix of human and environmental factors that have influenced development in Thailand. Logging and agricultural settlement on the rolling uplands of east and north-east and Thailand have had major impacts on environmental quality in these regions. Therefore, too has the extensive cultivation of cash crops such as cassava. Low input cash-cropping on sandy upland soils has reduced the nutrient status of these soils and increased their susceptibility to erosion (Panyarachun, 1996).

Environmental impacts of a new trend in aquaculture in rural Thailand, the conversion of rice farms in freshwater agricultural areas to saltwater ponds for farming shrimp. This has led to the conversion of thousands of hectares of agricultural land into shrimp ponds in Thailand's fertile Central Plains, often referred to as the country's 'Rice Bowl'. The rapid

expansion of inland shrimp farming has raised serious concerns about environmental impacts, such as salinization of neighboring agricultural land and increased conflict over scarce freshwater resources.

2.4 Key role of the Rural Urban Fringe area

The rural-urban fringe is the boundary zone outside the urban area proper where rural and urban land uses intermix. It is an area of transition from agricultural and other rural land uses to urban use. Located well within the urban sphere of influence the fringe is characterized by a wide variety of land use including dormitory settlements housing middle-income commuters who work in the main urban area. Over time the characteristics of the fringe change from largely rural to largely urban. Suburbanization takes place at the urban boundary of rural-urban fringe (Nagle and Guinness, 2004).

Urban development in Asia has dramatically changed in the last four decades. There has been a shift from primary sectors such as agriculture, fishing and mining to secondary and tertiary sectors through industrial growth and service provision accompanied by rapid economic development in many of the Asian developing countries (Douglas, 1995;). In developing countries the relationship between urbanization and industrialization is not always clear. As a result the impact of urban development and industrial development on natural environment is very visible.

The vulnerability of the peri-urban region is more complicated by the fact that it includes a large number of individual authorities in term of local government and has both urban and rural characteristics. As no single authority is responsible for overall planning and management of a metropolis, an extended metropolitan area with mixed urban and rural characteristics is a complex and creates conflicts among the natural resources users of different sectors and government.

2.5 Policy Aspects

This chapter covers the currents in policies that will enable to the Agro Eco-Industrial Network. Comprehensive lists of the policies are related to the national environment, industry and development agencies in the country. The prevailing policies, regulations and Industries driven by policies and market force are given following this.

2.5.1 Environmental policy

The government of Thailand has recognized the following environmental issues and its policies and programs are geared towards addressing them: Air pollution, Water pollution, Traffic congestion, Noise pollution, Solid waste, Flooding, Hazardous waste, Deforestation, Landslides and Lack of institutions' capabilities (Thailand Health Profile, 2000).

- **Legal, Policy, and Institutional Structure**

Thailand has specific policies that are protective of health and environment (World Health Report, 2004). The three key policies are:

- Policy and Prospective Plan for National Environmental Quality Enhancement and Protection 1997-2017

- Environmental Quality Management Plan 1999-2006
- National Environment Quality Enhancement and Protection Act 1992

The 9th National Economic and Social Development Plan (2002-2006) focused on the management system that based on shared responsibility, transparency and practicality. Knowledge and information shall be disseminated to people, community, and local administrative units, so that they can actively participate in protecting natural wealth. Environmental quality shall be improved in order to promote grassroots economies and quality of life.

- **Institutional Structure for Environmental**

Administrative / organizational set-up of the country: Ministry of Environment and Natural Resources, Ministry of Public Health, Ministry of Industry, Ministry of Agriculture and Cooperatives, Ministry of Interior and Ministry of Prime Minister.

Relevant agencies and partners other than government: Foundation for Anti Air Pollution and Environmental Protection, Thai Environment and Community Development Association, Hill Area Development Foundation, Thailand Environment Foundation, Think Earth Association, Thailand Development Research Institute, Thailand Environment Institute.

Relevant International Conventions and Agreements Ratified or Signed: International Tropical Timber Agreement 1997, Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin 1995, Agreement for the Establishment of the Network Aquaculture Centers in Asia and the Pacific 1994, Biodiversity Convention at Rio de Janeiro on 12 June 1992, Montreal Protocol on Substances that deplete the ozone layer, Framework Convention on Climate Change 1995, ASEAN Agreement on the Conservation of Nature and Natural Resources, Kuala Lumpur 1985, International Plant Protection Convention 1978, Plant Protection Agreement for the Asia and Pacific Region 1956, and Agreement for the Establishment of the Asia Pacific Fishery Commission 1948 etc.

2.5.2 Industrial Policy

- **National Industrial Policy**

Thailand's Ministry of Industry has set up its policy guidelines for 2001-2006 in according to the 9th National Economic and Social Development Plan with particular emphasis on the development of the Small and Medium Size Enterprises (TISC, 2006).

Measure aimed at stimulating the grass-root industries in the near term include: initiating the "One Tambon, One Product (OTOP)" projects; speeding up the implementation of the Industrial Restructuring plan: Personnel development in modern production technology, environmental management, industrial safety and the adoption of international standards in both public and private sectors; and providing consulting services for industrial production cost reduction.

The Department of Industrial Promotion (DIP, 2006) under the Ministry of Industry acts as the lead agency of government for SMEs promotion and development and follows the

guidelines are set by Ministry of Industry and the National Plan in elaborating its own policies to support the sector.

The investment promotion policies of the past year, though successful, were implemented for a long period of time. The financial crisis in the middle of 1997 affected the Thai economy. As a result, tax collection was below target and public debts increased significantly affecting the fiscal position of the government. Moreover, the global economic climate and investment environment had undergone change. Therefore, the Board of Investment (BOI, 2006) had responsibility of the Thai Investment Promotion Polices and criteria for granting tax privileges in order to respond to the current and future economic and investment situation.

2.6 Economic Aspects

These following sections present the situation of the National economy and its trend. The existing situation of the study area can be useful for significantly describing and development the Networks for Agro Industry.

2.6.1 General economy of the country

Thailand was named one of the Asian Newly Industrialized Countries (NICs), before the economic crisis in 1997 with an average economic growth rate of 8-9 percent during 1993-95. The crisis resulted in a negative growth rate of –7.8 percent in 1998. Moreover, the impact of the economic recession in the world market has affected the country's total exports. At this stage, it is crucial for Thailand to increase the technological capability of the country, to make efficient use of its resources, and to reduce the cost of production, thereby increasing economic growth and competitiveness. Despite the country's industrialization, agriculture has remained a significant part of the economy. Thailand has been moving towards industrial-based agriculture and has focused on the development of post harvest and processing technologies that are the major problems for industry.

The government promotion to develop agribusinesses since 1976 has greatly contributed to the expansion of agro processing. Thailand's top 10 export products in 1997 and 1998 are rice, canned foods, rubber, frozen shrimp and prawn. Export earnings for the first nine months of 1998 were US$6 and US$3.9 billion for agricultural products and agro-industry products, respectively. Combined export earnings from agriculture accounted for 23 percent of total earnings (Department of Business Economics, 2006).

2.6.2 Provincial Economy

Agricultural is prominent in the living of Chachoengsao, 70% of total population of province is farmer and Income from agriculture is 27,681 million Baht/year. The various revenue sources of Chacheongsao Province (2003) are shown in figure 2.5.

The past decade saw drastic economic rises in Chachoengsao. The province has grown into a chief exporter of agricultural yields and dominant manufacturer of industrial products. The prospect of Chachoengsao as an economic linkage and trade gateway is promising. The Province is envisioned to merge Bangkok and its vicinities with the Eastern Seaboard, be developed into a transport center for agricultural and industrial outputs in the East of Thailand. The implementation of large scale transportation projects, e.g. The

Suvannaphum Airport and efficient mass transit systems. And the province lied in the midpoint, endorsing movements of manpower and economic expansion between the two developing ends.

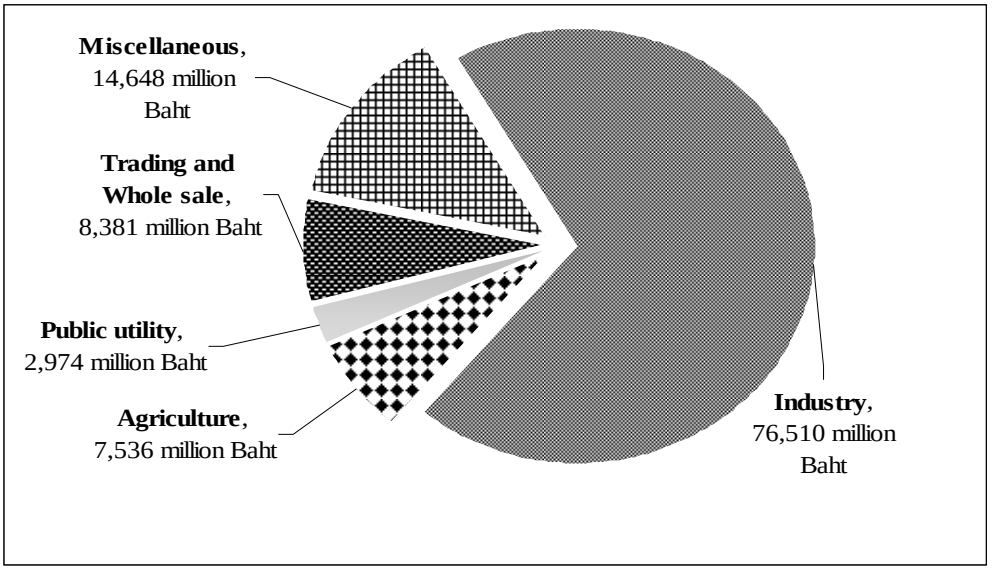


Figure 2.5 Revenue Sources of Chachoengsao Province

2.6.3 Economic project

The Government formed the Committee on the Development of Thai Food and the Kitchen of the World, chaired by Commerce Minister. The National Food Institute of Thailand, a non-profit and independent network organization of the Ministry of Industry, and the Food Sector of the Federation of Thai Industries are playing an important role in promoting (PRD, 2006). Moreover, efforts are being made to increase Thai food exports by 20% each year. At present, Thailand earns about 500 billion baht from food exports annually. Thai food products depend on 85% of local content. So, the food industry is very important to the country's economy.

2.7 Technical Aspects

Eco-Industrial Parks/Networks are expected to improve both productivity and environmental performance. Then this section presents the improving of networking of industries for material and by product exchanges, reuse/recycling and cleaner production techniques.

2.7.1 Cluster Development in Thailand

The Department of Industrial promotion (DIP) is one of core agencies in promoting SME development. Considered cluster formation as a mechanism to boost Thailand's SME competition in the world market. The cluster project is proposed to build awareness of and participation in cluster development among Thai firms and build close linkages among companies in clusters to better coordination and trust. The formal linkages in clusters include networks, alliances, and partnership and project also aimed at developing mechanism for sustainable cluster. The example projects initiatives taken up by government are OTOP and Blue sky with bio-diesel.

2.7.2 Biomass Utilization

The importance of wood/biomass fuel as an energy source for the rural areas in Thailand can not be overemphasized. It is still the cheapest fuel available and it will remain the major alternative to commercial energy sources. Many rural small-scale industries still depend on biomass-fuel for energy. It is the main source of energy of industries like agro-processing, food-processing, mineral-based industries, etc. Thus, wood energy will continue to be a major component of total energy consumption in Thailand (FAO, 1998).

In order to be able to plan the biomass-fuel demand and supply effectively, as well as to promote awareness of biomass-fuel issues, appropriate information is necessary. This would highlight the socio-economic importance of these rural based industries with a view to contributing to refining and improving prevailing policies and strategies of the sectors concerned.

2.7.3 Bioconversion of carbohydrate residues in Thailand

In the ASEAN region alone, for instance, it has been estimated that 30 million tons of rice grain are produced each year. Considering similarly large quantities of other commodities, such as cassava, maize, and sugar cane, tremendous resources of organic raw materials are potentially available for conversion into useful products - the common "F" products: food, fuel, fertilizer, and fiber (Sundhagul et al., 1983). Among many means of converting these wastes materials-mechanical, chemical, and biological-bioconversion (particularly microbiological) seems to be the most suitable for Thailand, and probably for other tropical developing countries as well.

- **Current Research and Development of Productive utilization of agricultural and agro-industrial residues throughout the world**

International Recently, the US National Academy of Sciences convened a group of experts from different parts of the world with the objective of producing a document on the current status of utilization of organic waste materials to produce foods, fuel, and fertilizer. In December 1979, UNEP convened a meeting of policy makers and administrators on the subject of waste utilization as a follow up of the previous consultative meeting of experts on this subject.

Regional An ASEAN regional co-operative project has recently been launched by the ASEAN Subcommittee on Protein aimed at better utilization of food crop wastes. The emphases are on converting food waste into acceptable food, followed by making them suitable for animal feed, and as potential alternative sources of energy.

National Several research and development programs and projects are being carried out by universities and research institutions in Thailand. Those specifically involving are as; anaerobic digestion, microbial fertilizer, high rate bio-methanation, and biomass power generation.

2.8 Applying Industrial Ecology and Research need

In most of the industrialized countries environmental protection and most preferred strategy is the pollution prevention. It has been defined as a top of environmental

management hierarchy. The concepts of pollution prevention and industrial ecology both claim similar roots. The two ideas also attempt to solve similar problems. Both concepts begin by assuming that current economic activity is increasingly harmful to the environment and conclude that changes are needed. Both concepts assert that the changes must begin with how people think between the environment and economic activity. But, when it comes to how to make the changes, pollution prevention and industrial ecology start to diverge, so much so that incompatibilities emerge. However, these differences are not so broad that there is not a reasonable potential for convergence. Then Oldenburg and Geiser (1997), identified and there are essential differences between industrial ecology and pollution prevention. Table 2.3 summarizes some of the similarities and differences between the two concepts.

Table 2.3 Primary attributes of pollution prevention and industrial ecology

Issues	Pollution Prevention	Industrial Ecology
Primary goals	Prevent pollution	Optimize resource flows
Primary focus	Reduce risk	Promote sustainability
Core concept	Individual firm	Networks of firms
Primary techniques	Planning process	Integrated system
	Life cycle assessment	Life cycle assessment
	Process characterization	Materials accounting
	Materials accounting	Design for environment
	Waste audits	
	Full cost accounting	
Role of recycling	Only in-process	In-process, off-site and between firms
Role of government	Technical assistance	Barriers removal
Economic domain	Multiple sectors	Industrial sector
Mode of evaluation	Materials tracking	Materials tracking

If industrial ecology schemes are to be made compatible with pollution prevention programs, industrial ecology should de-emphasize the current concept of firms made interdependent by linking waste streams and input needs. This is only one tenet of an ecological system and a narrow one at that. Sound ecological systems also build the health of niche organisms through careful selection and avoidance behaviors.

Instead of a narrow focus on waste recycling, industrial ecology schemes should incorporate risk reduction, target those parts of the economy that are most endangering, and assist in identifying and developing materials and technologies that fit comfortably into ecological cycles and support human and ecological health. Considered from this perspective pollution prevention programs that serve to ‘correct’ and tailor production systems could be seen as a powerful tool in an industrial ecologist’s instrument bag and industrial ecology could become a source of vision for the detailed operations of pollution prevention programs at the firm level.

Eco-industrial parks (EIPs) provide a basis for applying the concept of industrial ecology. Roberts (2004) undertaken to investigate the application of industrial ecology to ensure more sustainable industry development in the State of Queensland. In Australia, eco-industrial parks are new and are being considered by state governments as a way of achieving more sustainable industrial development. However, for many firms, local

government and communities, industrial ecology is a concept that is misunderstood and treated with suspicion.

Then, there was attempted to development a set of principles and planning guidelines for use by governments to facilitate the development of eco-industrial parks. The planning and development of this eco-industrial park was a significant challenge to the developer and public agencies concerned with this project. The case study presented provides useful lessons and advice for planners and developers involved with the planning and development of eco-industrial parks.

For the Asian country, Deog-Seong et al. (2005) attempted to draw out transferable lessons for future Eco-Industrial Park (EIP) development by analyzing the Daedok Technovalley (DTV) Development Project, the first Korean attempt to design EIP by restructuring a conventional industrial estate development plan. DTV development plan's progress towards sustainability through in-depth analysis of the planning and design strategies, and technologies adopted. The development could achieve a higher level of sustainability progress in most of the evaluation criteria when compared to conventional industrial estate development practices in Korea. However, some limitations are still apparent in the aspect of symbiotic industrial network construction, cultural identity creation and material flow planning.

Despite recent efforts by a variety of industrial organizations to apply Industrial Ecology concepts to the management of materials produced by industries, several constraints to its widespread applications still exist. Among these constraints is the lack of easily implemental decision-making support systems that include significant externalities.

In decision-making processes about materials management, recycling costs need to be compared with disposal costs. In some cases, it may be advantageous to provide the byproducts for use as raw materials outside the plant or industry that produce those (Inyang et al., 2003).
Lack of enabling technology and regulatory support can pose significant constraints with respect to large-scale material substitution and recycling. Some factors that are needed for comprehensive analysis of materials and energy management options are still not easily quantifiable. For example, valuation of natural resources is an important issue on which research advances need to be made in order to expand the application of Industrial Ecology in materials management.

Approaches, techniques and programs such as material and energy flow studies, environmental cost accounting, life-cycle inventory assessment and design (CLA), and design for environment, need to be better interlinked to provide an effective decision-making tool on material and process substitutions.

Chapter 3

Methodology

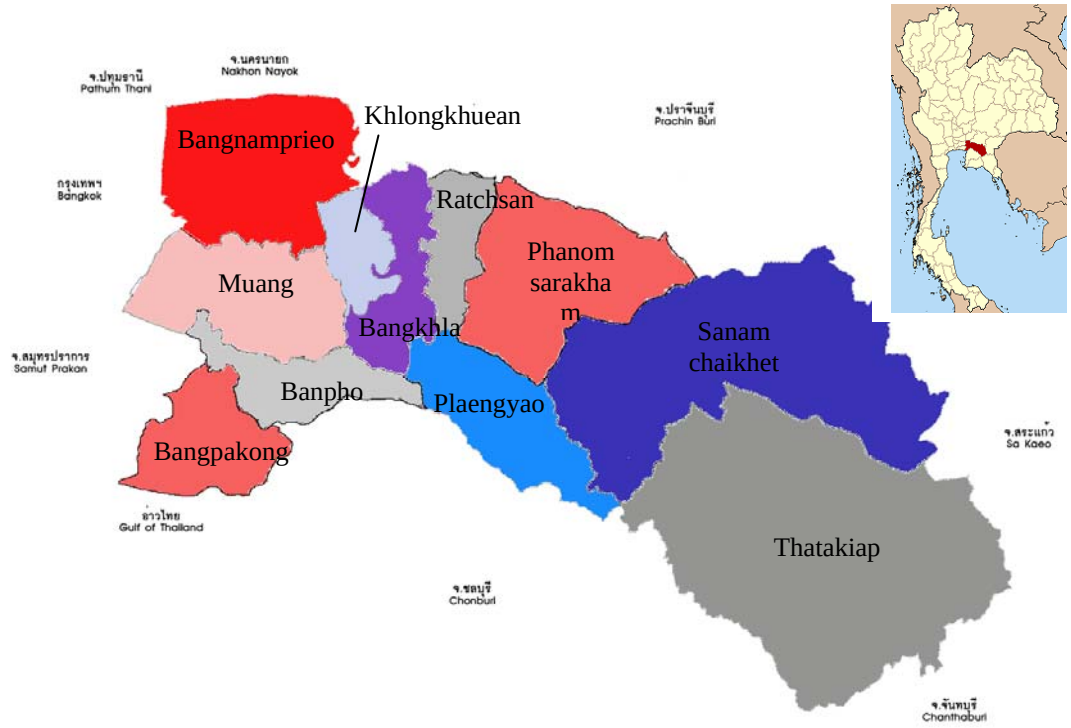
3.1 Introduction

Agro industries, especially rice, cassava and livestock have been the main feeding source of the economy in the Chachoengsao Province. In the recent years, the industries have rapidly grown in such a way that they have been causing several significant environmental problems in the region. A transition of these industries into eco-industrial network is essential to preserve the natural resources of the region. The study focuses on the environmental management of these agro eco-industrial clusters by forming material flow linkages to other industries in industrial system so as to reduce resource consumption and waste generation.

The study was carried out in Chachoengsao Province, Thailand. Currently, the industries have an unprompted development and imply a need for comprehensive planning. Therefore, this chapter presents the methodology of this study aims to develop an eco-industrial network which can benefit both environmental and economic development in the Province.

3.1.1 Study area

This study was carried out in the districts of Bang Pakong, Ban Pho, Chachoengsao Muang, Bangnampreo and Bang Khla in the Chachoengsao Province. The primary focus of the study is the agro industrial clusters of the region, especially rice-based industry.



Source: Chachoengsao Provincial Operation Center, 2006

Figure 3.1 Administration Map of Chachoengsao Province

3.1.2 Methods Adopted for the Study

The study method designed to with a view to develop the Eco-industrial network. Therefore, the appropriate data collection instruments need to be applied and suitable to the respondents and the research needs. Combinations of several standard methods were used, to realize the objectives set for the study.

- Field Study

Observation, is applied when the researcher observes an occurrence in the field situation. *Interview*, the questions (a structured or an unstructured manner) from researcher arks to the respondents and record their responses. *Questionnaire*, the participants are responded to the structure question sets, or through the communication as mail. These techniques were carried out to get acquainted with and collection of data on environmental problems and economic performance with special reference of rice-based industry problems.

- Secondary Data Review

The secondary data such as records, census, documents and indices are used for the analysis of scientific data and information on the existing actors and policies in rice-based industry. The data related with groups involved in rice-based industry was collected to check its reliability and also gather information for material flow network creation.

3.2 Research Methodology

The nature of the study requires direct interactions with the enterprises for obtaining first hand information on the industry, understanding the production processes, technologies, waste generation, and treatment methods. In addition, information on the driving forces, such as actors and institutional, policy support market forces, trade and legal requirements for the formation of the network are also essential for a better understanding. In view of the above requirements of the research the following methodology was used in this study as outlined in Figure 3.2.

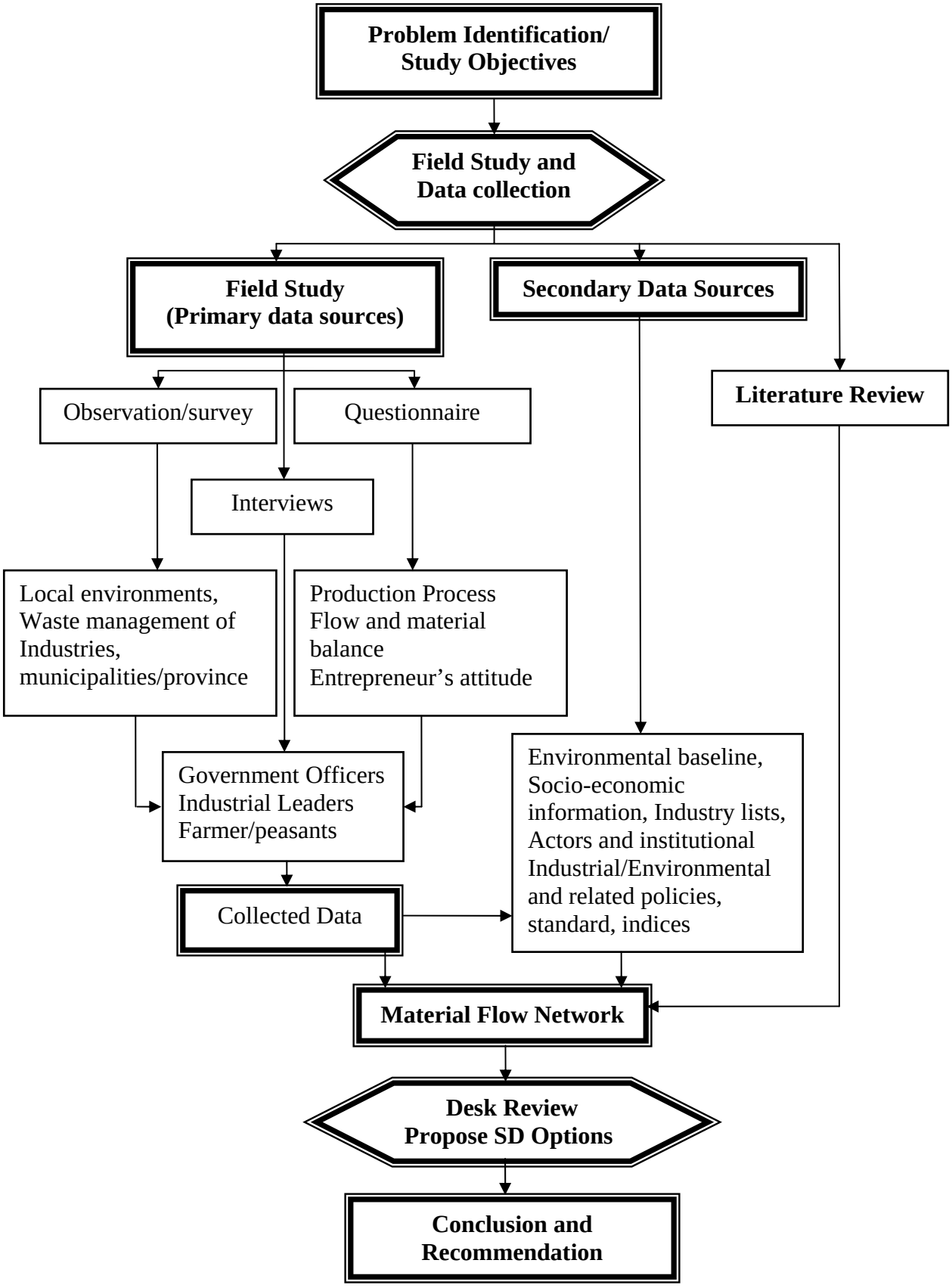


Figure 3.2 Research Methodology

3.2.1 Secondary Data Collection

The study begins with the collection of required data from secondary sources such as the libraries, journals, feature articles, indigenous magazines, and publications from relevant government departments, NGOs, regional academic/research, institutes and business associations. Typical information was collected from these sources is shown in Figure 3.3:

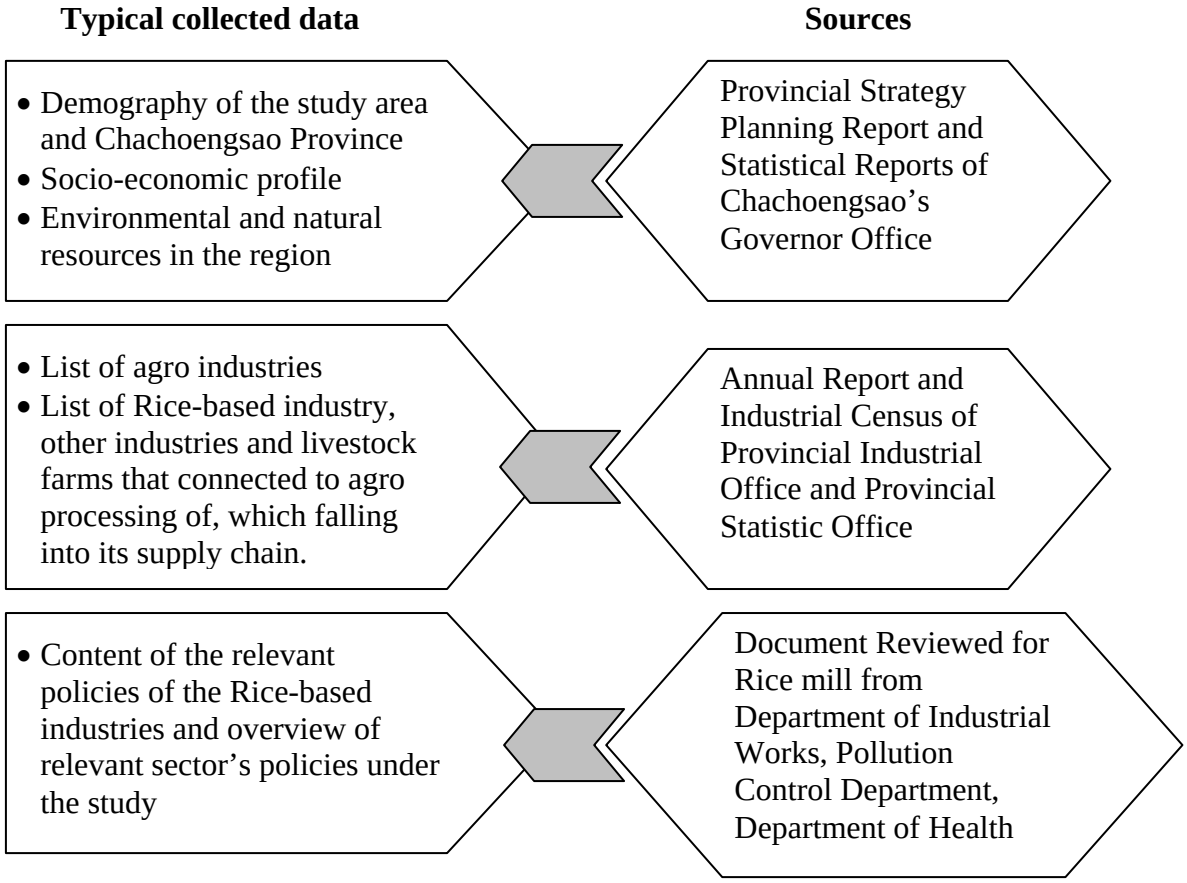


Figure 3.3 Typical information collected from secondary source

3.2.2 Environmental Baseline

In addition to the above, information on the following environmental aspects, particularly in the study area, were collected from several organizations so as to develop an environmental baseline.

- The data were obtained from Provincial Profile and Statistical Reports of Chachoengsao's Governor Office:
    - Water resources, rainfall
    - Water quality, pollution loads and sources
    - Water consumption; both industrial and domestic
    - Wastewater generation and treatment; both industrial and domestic

- The data reports from Pollution Control Department (PCD) were contained of;
    - Air quality from Regional Air Quality Report 2005

    - Sources of air pollution from Summary of State of Thailand's Pollution in Year 2005
    - Solid waste generation; both industrial and municipal, and
    - Solid waste management practices; both industrial and municipal from Regional solid waste survey report 2005, Municipalities and Provincial Sanitary Office.
- The data of Land use, forest cover, sources of land degradation were collected from the Report of Environmental and Natural Resource Evaluation and Monitoring in Eastern Coastal Area (Phase II), under Office of Natural Resource and Environmental Policy and Planning (ONEP).
- Any other location specific environmental problems as observed during the field survey.

3.3 Field Study

The field study focused on obtaining the physical and technological of the industry and locality specific information. Interviews and interactions with the entrepreneurs and communities aimed at local development are absolutely essential for getting reliable information. In addition, municipalities and local offices of government departments provide valuable information on the region. Thus, the field study was an opportunity to obtain location specific information.

3.3.1 Collecting data on agro industry from the local administration

The information was collected by interviews and interaction with the officials of local government departments. The main organization directly related to the industrial development is Ministry of Industry and its Provincial Department of Local (Chachoengsao Provincial Industrial Office, 2006).

The type of information each level obtained from the relevant departments such Provincial Environmental and Natural Resource Office, Provincial Livestock Office and the study focused to see how the actors and policies can push the existing industrial system of agro-industry in Chachoengsao Province towards an eco-industrial network.

For this study, information on the following was collected at the Regional and local level.

- Information on socio-economic profile of the region
- Contribution of industries to local development
- Share of the industries in the national market
- Data on export/import trade activities

Whereas, in the case of policy documents, those that are implemented or awaiting implementation were collected irrespective of their origin, Ministry, Province, District and Sub-district (Tambon). Thus, the following policies were collected for analysis.

- Industrial Policy
- Environmental Protection
- Social Development Policies
- Technology Transfer
- Policy on agriculture, aquaculture, livestock etc
- Export/Import, Business and Trade Promotions portfolios,

- Marketing facilities, Infrastructure Development and Conflict Resolution
- Energy Policy

3.3.2 Designed Questionnaire and Size Selection of Typical Enterprises

The rice mills in 5 districts were selected to the field study and use the structure manner for interviewed. The selected rice mills were distributed in the size of industry and also the mixing of the 4 groups of product; Sticky rice, Hom mali rice, White rice, and Parboiled rice. Then, the other rice-base industries in supply chain were selected to survey in order to fulfill the linkages and network. The list of surveyed industries is showed following this:

- 8 Rice Mills in Muang, Bangnamprieo, Bangpakong, and Banpho
- 2 Rice Noodle industries, which used Broken Rice (Product of Rice mill)
- 1 Rice Bran Oil Extraction Industry
- 1 Small Power Plant (Biomass from rice husk and wood chips)
- 1 Solid Waste Recycling Firm
- 1 Animal feed industry
- 4 Livestock Farms

The questionnaire was designed to gather the information from Rice mill and the other industries in the supply chain, which following the including sections:

- General Information of Enterprise
- Production process and flow data
- Waste generation and waste management
- Perspectives and comments of the entrepreneur on the relevant actors and policies

3.3.3 Interview with the entrepreneurs

The fundamental premise of interviews with entrepreneurs is to obtain industry specific information on the environment and technological framework. The objective of this is to establish a material balance to ascertain the environmental performance of the industry with respect to resource use/conservation, practices and techniques, skill level of employees etc. In essence, the following data were collected to evaluate the environmental performance:

- Types and amount of materials i.e. raw materials, product, by product
- Production Process
- Energy consumption
- Water consumption
- Packaging and transportation of products and by products
- Wastewater and solid waste; generation and treatment
- Technology use and needs assessment
- Occupation health and safety aspects

Developing a basic mass balance of material and energy within the process, as in the case of rice mill industry (Parboiled Mill) is shown in example below, Figure 3.4 aids in the process of evaluating the environmental performance of the industry.

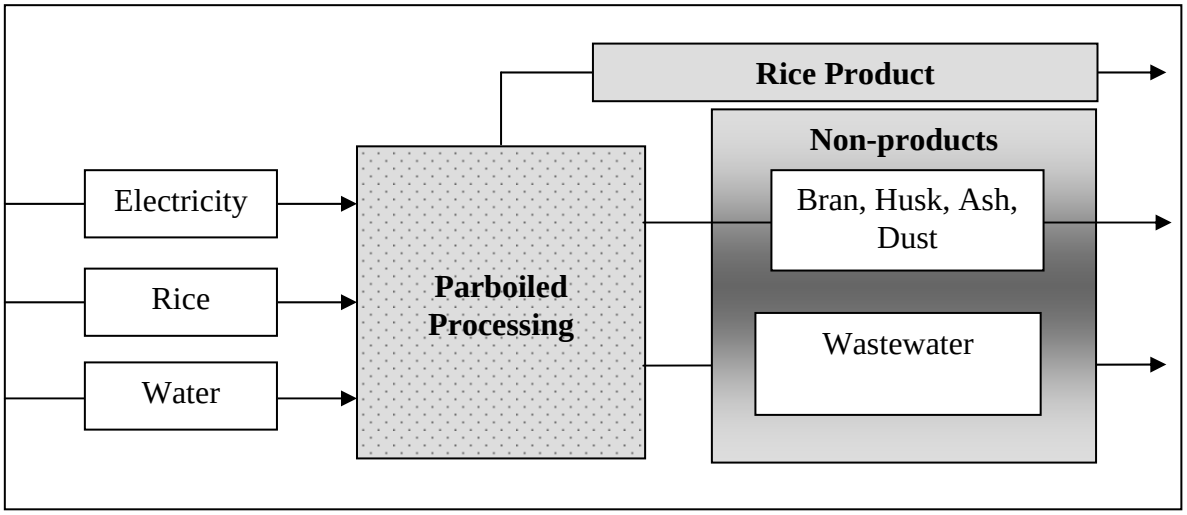


Figure 3.4 Example of Material Balance in a Rice Mill Processing

In this example, quantification of all raw materials, products, non-products are essential to evaluate the environmental performance of the industry. Appropriate data to establish such a material balance was collected. The efficiency of the process can be resulted when the material balance is complete. The energy process is also considered and evaluated in order to rate the performance of the process. The waste stream and by-products are also identified in this stage. The by-products and wastes are analyzed and make it marketable with alternative treatments.

3.3.4 Evaluation of financial performance of the industry

In the course of the study, it is proposed that the financial status of the industries also be evaluated. This is done to understand the financial performance of the industry in terms of raw materials, energy costs, waste treatment and disposal costs, value of products and by products. This process aids in comparing the financial baseline of the industry with that after applying by-products and waste exchanges.

3.3.5 Comprehend the perspectives of entrepreneurs on the relevant policies

The collected data of the typical surveyed industries such Rice-mill and the connected of rice-based industries were formed in the questionnaire and interviewed from the field study. Because legal systems reflect the desire of society so we need to investigate from many point of views about what they expect on policy and policy-maker are developed a more effective and stringent policy base. Understanding the perspective of manufactures on the relevant policy are helped policy-maker having suitable decision and reforming the policy in order to create better management work.

3.4 Material Flow Network Creation

The Formation of Material Flow Network is a key component of the study as it helps to draw strategic inferences about potential material, product, by product and waste exchanges focused at closing the material cycle. A sustainable supply chain with a closed material loop, results in improved environmental and economic performance in addition to augmenting the product quality.

The distribution of Rice mill and other rice-base industry in 5 districts of study area were analyzed. Then, the questionnaire and interviewed in the field study were applied to the typical industry. First, to the rice mill sector was selected to evaluation of material and energy flows in the industrial system. Then, the production process was analyzing the various possibilities to reduce the pollution and natural resources use. The rice mill was identified as the original waste generator.

The niche sectors (industries following the supply chain, waste recycler and livestock farm) also identified the material flow, current waste management, prevention and minimization of wastes generation and waste treatment also considered. Based on the field data collection, a material flow among all industries in the region was developed. The material flow network is completed by considering all possible linkages in the existing industrial setup.

Though the central theme of the study is the rice mill sector, an analysis of all agriculture based industries falling in its supply chain would be done. An example of a potential material flow is presented in Figure 3.5.

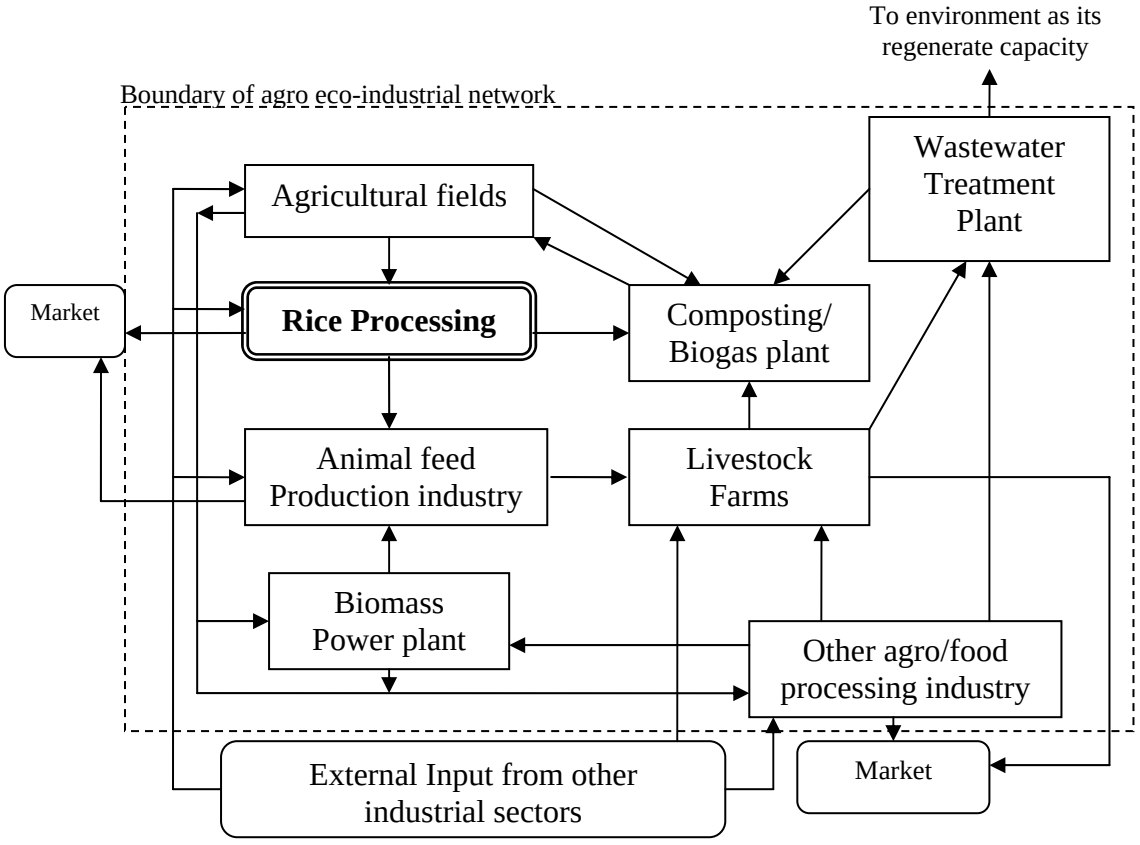


Figure 3.5 Potential Material Flows Network of Agro-Eco Industrial Network

3.5 Desk review

Field Study and Material Flow Analysis, though described as different components, were carried out simultaneously, based on the experiences obtained in each industry. Thereby, all industries in the supply chain of the agricultural sector were under the light of the study. Thus all required information to develop a sustainable supply chain was available.

The desk review performed considering technological and environmental aspects of agro eco-industrial network, policy networks, and socio-economic networks in the region of the study.

3.5.1 Technology and Environmental aspects

From the Field Study and Material Flow Analysis a broader picture of the material cycle in the region could be obtained. This thoroughly analyzed to identify potential sources of discarded waste. In addition to this, where material exchanges take place the strength of the linkage was evaluated in terms of quantity and quality of material exchanges. Options of strengthening these links could be explored in addition to establishing new links.
Technological plays a major role to strengthen the existing link or establish new links. The prevailing technology in the industries is compared with the recent ones and options of introducing new technologies are suggested. In addition to suggesting new technologies, application of simple Cleaner Production concepts also suggested to improve productivity, product quality and profitability.

3.5.2 Policy Analysis

This task implemented after all data are collected which need to analyzed. Following the objective of the thesis the policies were analyzed and base on the current condition of the province to suggest an effective management system. So the present related policies were understood all of its envisaged aspects and its effect on the industry in order to find out the several conditions for applying those policies on agro industry not only on the government role but also on the industry.

The study the policy networks which are related with the eco-industry networking were done following steps mentioned below;

- Identify the relevant actors and institutions, which determine industrial and environmental policy, reviewed from the reports; 1) Survey and study for an establishment of Nuisance Standard from Rice Mill Factories, and 2) Summary report of industrial sector codes of practice for cleaner technology.
- Identify and group all policies applicable to the major industrial sectors under the material flow network.
- Understand the objectives of the policy; mainly of Industrial Policy and Environmental Protection Policy
- List the industrial sectors to which the policy is applicable
- Tabulate the factors of the policy which favor/ hamper the growth of the target sectors
- Mapping the favoring/hampering aspects of the policies cutting across sector boundaries of all industries in the supply chain

The key source of roles, actors, and policies were used in policy analysis of industrial development. The majority of them were collected from Ministry of Industry and its supervised organizations; Department of Industrial Works, Office of Industrial Economics, Board of Investment, SMEs.

Policies of each industry based on its properties were analyzed. Such as Joint Venture Company and self employed company; large scale companies and the small and medium size of company. The economic loans policies for each type of industry also are different.

The priorities of local and national policies on development of agro based industries also examined and analyzed.

3.5.3 Commonalities and conflicting condition between and within policies

The commonalities and the conflicts of policies between the government levels or offices were identified and analyzed such Ministry of Industry, Ministry of Natural Resource and Environment, Ministry of Agriculture and Cooperatives. Thus the gaps in policies and missing aspects also identified. From this analyzed result, the study suggested some solutions to overcome these problems and filling the missing aspects of the related policies for better management and sustainable development.

The result of this task is suggested some measures that aims using policy tool to develop an eco-industrial network in the province and effective management system which is suitable with the long term and short term economic–environment development of both national and regional strategies.

Given that eco-industrial network are a means of parallel environmental and economic development, and possibilities of material flows and inter-firm networks exist, the study also attempted to identify environmental, social, technical, and policy barriers to their existence.

Chapter 4

Results and Discussion

4.1 Situation of Chachoengsao Province

4.1.1 Topography and Physical Setting

The area of Chachoengsao Province is 5,351 km^2, engrossing the second biggest area of Eastern Thailand next only to Chanthaburi Province. It reaches Nakhon Nayok and Prachinburi in the North, Chonburi and Chantaburi Province in the South, Bangkok Metropolis, Samutprakarn and Pathumthani in the West.

The terrain of Chachoengsao is predominantly wet, with corrugated plains, highlands and low hills recurring alternately. There are abundant flatland for cultivation, and at the eastern of province along the ridge is covered by forests with a number of rare and endangered species are found. The Bangpakong River, considered as the vein of Chachoengsao Province passing through the region enriching it with fertile soil before moving seaward into the Gulf of Thailand.

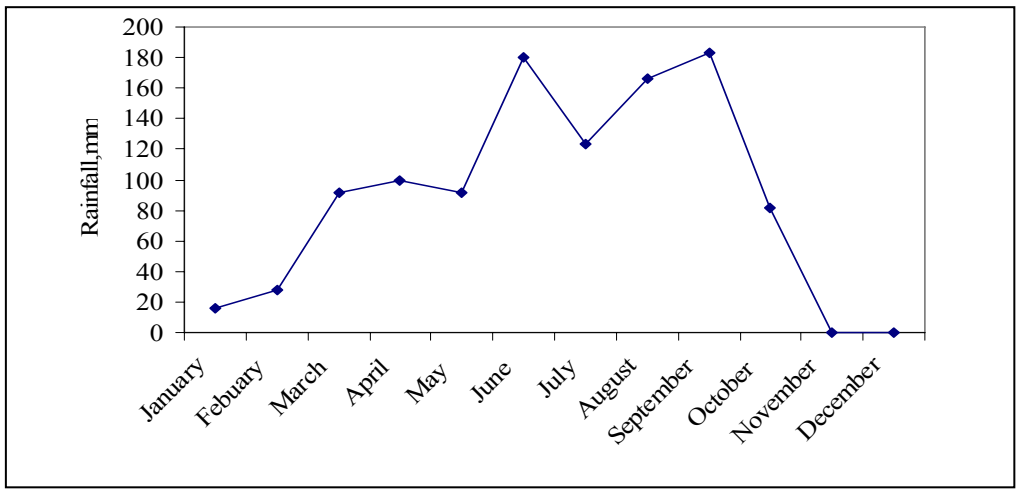
Figure 4.1 Key Map of Chachoengsao

The River, flows into the sea at the estuary of Bangpakong district, which has a coast of 12 km. long hold by rich mangrove forests. In close proximity to the sea, the city is influenced by land and sea breezes, and moistened by northeast and southwest monsoons, which carry with them seasonal rainfall and hence fertility.

4.1.2 Meteorology

The Eastern region of the gulf of Thailand is influenced by seasonal monsoon winds such as the South-west monsoon, North-east monsoon and occasional cyclones. Time series data on the rainfall of the region is presented in Figure 4.2.

The South-West monsoon brings rain through out this region from May to October. In addition to this, tropical cyclones, low pressure depressions, tropical storms and typhoons bring in heavy rain during the month of October. The North-East monsoon brings with it cold and drought weather from China from November to February. However, this region has a less cold weather than the North-east region of Thailand because the landscape of the Sankhampang and Phanomdongrak Mountain and the province's proximity to the sea.



Source: Provincial Statistical Report (2005)

Figure 4.2 Meteorology of the Chachoengsao Province

4.1.3 Administration

The province is subdivided into 10 districts and 1 minor-district, 93 sub-districts, 870 villages, 22 municipalities with one provincial administrative organization and 91 district administrative organizations. Figure 4.3 presents the administrative map of the Province. Table 4.1 presents the demography of the various districts. The districts of Chachoengsao are:

1. Mueang Chachoengsao
2. Bang Khla
3. Bang Nam Priao
4. Bang Pakong
5. Ban Pho
6. Phanom Sarakham
7. Ratchasan
8. Sanam Chai Khet
9. Plaeng Yao
10. Tha Takiap
11. Khlong Khuean

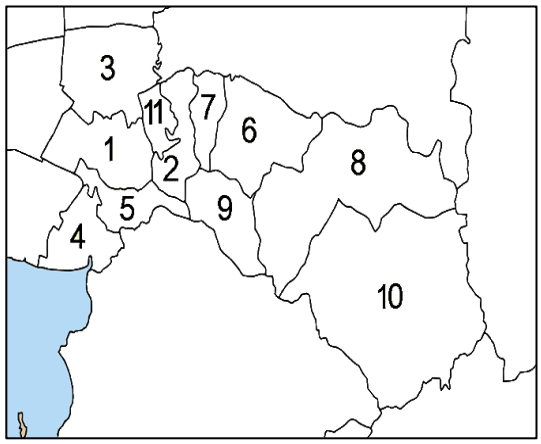


Figure 4.3 Administrative Map

4.1.4 Population

It could be observed from Figure 4.4 that the population growth in the recent years (2003 and 2004) has followed a negative trend, meaning that the population has decreased. In a developing country like Thailand, especially in rural areas, population always tend to increase. Decreasing population trends are subject to thought with two possible reasons either the spread of epidemics or population migration. No serious life-threatening epidemic has been reported in the region during the recent years and hence it could be concluded that migration of the population to other parts of the province (or country) in search of employment opportunities and other amenities is the foremost reason for the decrease in population.

Table 4.1 Demography of the region

District	Population				Change in population (%)				Population density (per km^2)
	2001	2002	2003	2004	2001	2002	2003	2004	
Mueang Chachoengsao	144,085	145,239	145,181	140,908	0.67	0.79	-0.04	-3.03	372
Bangkhla	46,809	47,029	46,837	45,199	0.88	0.47	-0.41	-3.62	198
Bang Nam Prieo	81,537	81,844	81,730	80,699	0.46	0.38	-0.14	-1.28	162
Bang Pakong	79,082	79,821	80,211	78,415	0.17	0.93	0.49	-2.24	304
Ban Pho	46,115	46,550	46,984	47,891	0.93	0.94	0.92	1.89	220
Phanom Sarakham	76,080	76,862	77,505	77,542	0.49	1.02	0.83	0.05	141
Ratchasan	12,475	12,547	12,518	12,363	0	0.58	-0.23	-1.25	92
Sanam Chai Khet	69,403	69,798	70,252	68,818	1.06	0.57	0.65	-2.08	41
Plaeng Yao	35,373	35,943	36,390	35,974	0.73	1.59	1.23	-1.16	152
Tha Takiap	39,527	40,590	41,357	42,008	1.7	2.62	1.85	1.55	40
Khlong Khuean	13,510	13,535	13,536	13,615	-0.89	0.18	0.01	0.58	107
Total	643,996	649,758	652,501	643,432	0.66	0.89	0.42	-1.41	120

Source: Chachoengsao Provincial Administration Office (2005)

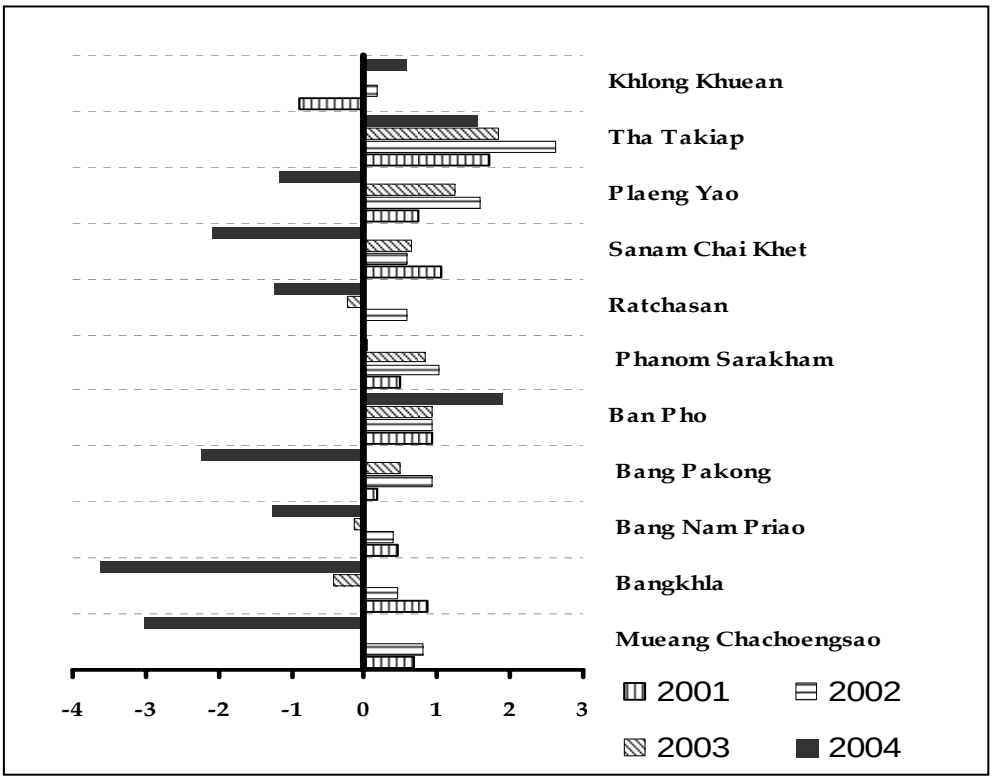


Figure 4.4 Yearly population growth rates in Chachoengsao Province

4.1.5 Infrastructure

- **Transportation**

Chachoengsao Province is situated beside the Bangkok, the center of economy of the country. The Province is important as the entrance to the Eastern Seaboard, which will be the focus of new development. Therefore, this region has completed facilities-services and infrastructure projects to support the part of development. Moreover, the efficiently of communication networks are also makes the region quite accessible and convenient.

Motorized transportation:

The province has developed several route of motorized transportation to serve the mega project development in the region as the central of transport and logistic. Several roads are connecting the region to Bangkok and its vicinity area such motor way (eastern outer ring) by pass the metropolis by mostly transporters from North and North-east region of Thailand. Highway number 304, 3, 34, 315, 23 and sub-highway are the major routes from Bangkok to the Eastern region and major port of country such Map tha put industrial estate and Laem Chabang Port.

Rail Transportation:

The railway passes Chachoengsao Province connecting other destinations with 4 pathways: Chachoengsao-Bangkok, Chachoengsao-Arunyaprated (Srakaew Province), Chachoengsao-Kangkoi (Nakhonratchasima Province), and Chachoengsao-Map Ta Put (Rayong Province) by dividing into Laem Chabang, Sattaheap Port, and Map Ta Put Industrial Estate. This railway from Eastern region is important for transportation of goods and petroleum products. The railway effectively transports these supplies to other regions. The major products such as LPG, Cement powder, sugar, gravel, sand etc.

Waterway Transportation:

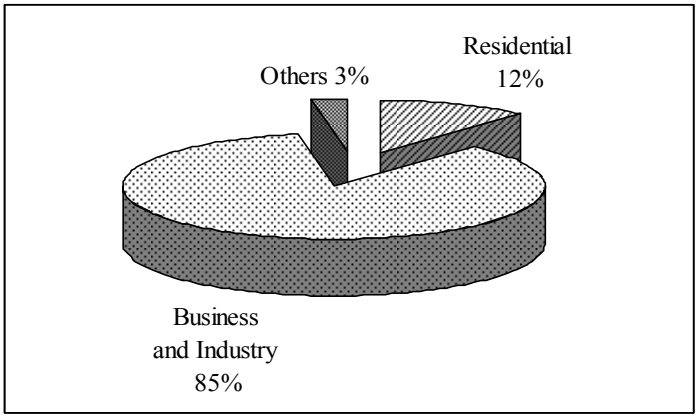
Bangpakong River is the major waterway and is the main mean of local communication and transportation of agricultural products to the river mouth for oversea transportation. The River supports in transportation to oversea by two mega-projects of wharf, which are Laem Chabang (Chonburi Province) and Map Ta Put (Rayong Province). More over, the local communication between Chachoengsao, Samutprakarn, and Bangkok becomes far more easy. The major branches such as Sansab, Sumrong, Tha Khai, Bang Khanag and Pravetburirom Canals are used for local people since long.

- **Water supply production and distribution**

The Provincial Office of Water Supply operates through 4 offices under Chachoengsao area as following: Chachoengsao Waterworks Office, Bangpakong Waterworks Office, Bangkhla Waterworks Office, and Phanom Sarakham Waterworks Office. The total no of consumers is 46,000 in the water supply accessed area and most of them are located in the municipality areas. The total water production capacity is 23 million m^3; with the percentage of water loss is about 13.30. Water is supplied in 19 municipal areas and 27 Sub-district Administration areas, so supplied totally area about 460 km^2.

- **Electricity and energy supply**

In the year 2005, Chachoengsao Province has 14 electricity service office and 12 main power stations. Total consumption of Province is 2,600 GWh supplied to 201,400 consumers with the entirely supply to the whole 883 villages in the Province. The highest electricity consumer is business and industrial sector by 85%, and the second is residential about 12% and others 3%, as shown in Figure 4.5.



Source: Chachoengsao Provincial Electricity Authority (2006)

Figure 4.5 Electricity Sales by Type of Consumers and Districts

Three high consumption areas are Muang with 43,000 consumers, Bangpakong with 23,000 consumers, and Phanomsarakham District with 20,000 consumers, with a consumption of approximately 560 GWh, 1,000 GWh, and 128 GWh of electricity respectively. The development of industries and enterprises in Bangpakong consumed high electricity for their production.

PEA, the organization was responsible for generating and selling electrical power in the provincial area of the state (MEA: Bangkok, Nonthaburi, Samutprakarn). PEA regulates the electricity rates and the collection of the fees.

4.1.6 Provincial economy development

- **Gross Provincial Product (GPP)**

Gross Provincial Product of the Chachoengsao Province is about 110,149 million Baht. The GPP ranking is in the 10th of Central region and the 12th of in the whole country. The economic growth rate has been estimated at 4.17% in 2004. In the year 2003, Average population income of Chachoengsao Province is 91,363 Baht/capita/year and the ranking is in the 3rd of Central region and the 9th of the whole country. The GPP of agricultural sector is 7,800 million Baht, while the non-agriculture sector is 87,000 million Baht with the three highest rank of GPP is from the manufacturing 64,000 million Baht, wholesale and retail trading 6,000 million Baht, and transportation service 3,000 million Baht.

The information clearly indicates the role played by the agricultural sector in the region. The manufacturing sector contributes to a higher degree in the economy of the region, by

good worth of the nature of the products which have more market value. The agriculture stands second only to the manufacturing sector.

- **Agriculture**

The topography of the region is such that well irrigated plain lands of Muang Chachoengsao, Bangkhla, Bang Namprieo, Banpho and Bangpakong district are used for paddy cultivation, plantations and animal raising while the undulated lands of Phanomsarakham and Plaengyao district support for farm plantations and ranches.

Presently, the cultivation land exceeds 60% of the whole province, half of which is rice. Due to the efficient irrigation, Chachoengsao's paddy fields are productive, supporting 5 harvests within 2 years. Others economic crops are tapioca, mango, betel nut, coconut, sugar cane, maize, rubber, cashew nut, pineapple and eucalyptus. Chachoengsao gives best yields of mangoes; especially in Bangkhla district and tapioca here make the 2nd highest output of the whole country. Coconuts and betel nuts are mostly produced in Muang and Bangkhla district. The Figure 4.6 is shown the percentage of each cultivation and comparing the land use changed.

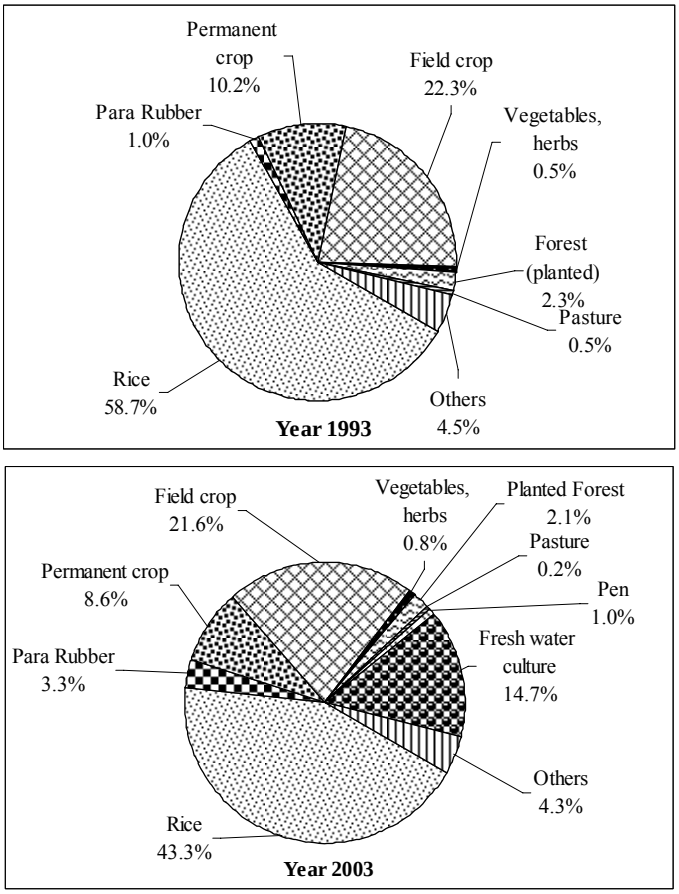


Figure 4.6 Agricultural land use of the Province between 1993 and 2003

The agricultural land has changed from 1993 to 2003, the rice field are reduced due to the promotion of aquaculture, such as shrimp farming, fresh and brackish water fish farming. However, the rice yield can be increased by using technology, fertilizer, and adaptation of farmers.

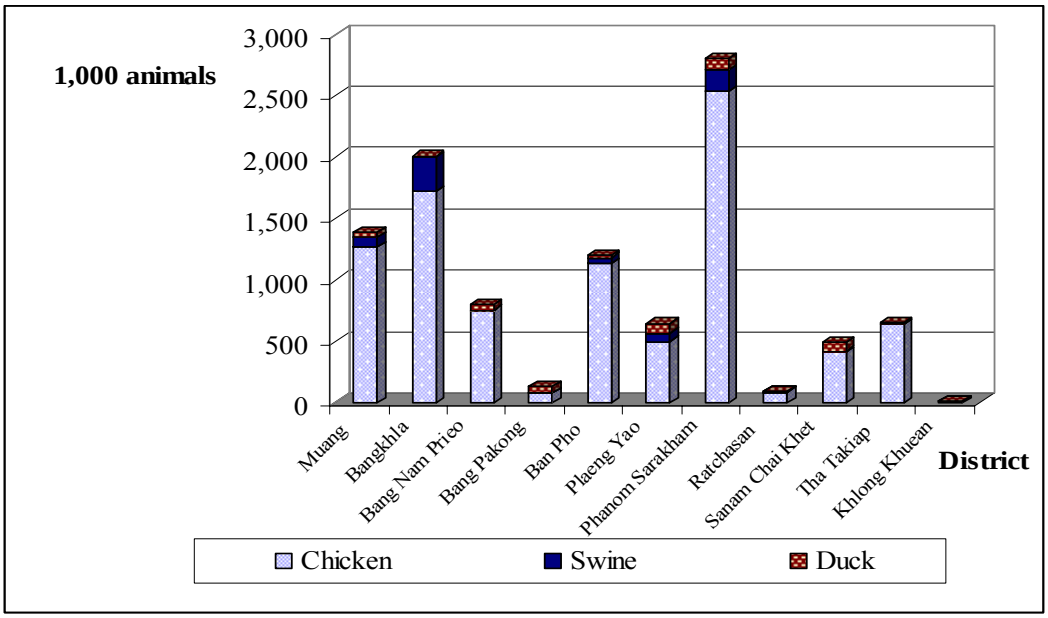
Though agricultural system of the Province has improved regularly, the local farmer faces a number of problems. The area of province is situated beside the shore and the estuary of Bangpakong River to the Thai Bay. First problem is the salinity of Bangpakong River because the water intrusion during November-June. The Second problem is flooding in the rainy season of Bangpakong River Basin areas around September to October every year. However, technological adaptation can solve these issues.

- **Livestock**

Livestock and domestic animals such as cattle, buffalo, swine, duck, chicken, etc. in the province are abundantly used for consumption and other farming use Recently, livestock is the second major occupation in the region follows the agriculture and the farmers always couple it with the agriculture. Because of some advantage such as close proximity of the market and easy access to the sources of feeding livestock raising has seen a good growth. The number of swine mostly farmed in Bangkhla district, and chicken mostly presented in Phanomsarakham and Bangkha. Total animal numbers of the Province are 667,000 swine, 9 million chickens, 4,000 ducts, and 37,000 cattle along the districts as showed in Figure 4.7.

- **Aquaculture**

The Province has both fresh water and brine water aquaculture due to the geological favors. That is Bangpakong River and canals are the major sources of fresh water. The brine water aquaculture is settled in Muang, Banpho and Bangpakong districts and mostly is shrimp farm. In addition, fishery is practiced along the seaside and estuary of Bangpakong.



Source: Chachoengsao Provincial Livestock Office, (2006)

Figure 4.7 Number of livestock by district in Chachoengsao Province

- **Industry**

In the year 2006, Chachoengsao Province has total 1,300 (exclude the industries in industrial estate) industries with a total investment of 162,000 Million Baht employing 93,600 people. The Province also has 2 industrial estates with about 193 industries with an investment of around 133,000 Million Baht generating 38,540 employments. The number of major industrial establishment, capital and employee are shown in Table 4.2. The numbers of employment and capital values are high in the modern type of industrial production process and hi-technology. Although, the agro and food industries performed the major part and its most number of entrepreneurs in the province.

Table 4.2 Number of 8 Majors Industrial establishment, capital and employees

Type of industries	Number of industrial establishments	Capital (Million Baht)	Number of employees
Agro-industry	200	3,722	3,400
Food industry	108	4,432	4,371
Chemical products	41	1,878	1,066
Plastic products	94	6,720	8,730
Metallic products	163	7,525	7,974
Machinery	71	26,141	2,578
Electric devices and appliances	58	15,095	15,546
Automobile products	104	24,695	11,616

Remark: The data exclude the industry of industrial estate

Source: Chachoengsao Provincial Industrial Office (2006)

Recently, the number of industrial establishment in the Province has increasing sharply. Number of new industries in 2002 is about 83, in 2003 about 105, in 2004 about 125 and in 2005 about 164 industries. The increasing rate is 25.3% in comparison to the 5-10 years ago. Agro-industry is ranked 1st (about 200 industries), metal production industries are the second highest category with about 163 industries, and food industry is the third (about 108 industries) and 4th is automobile and transport production (104 industries).

The industrial areas are distributed to several districts in the Province. However, the crowded areas are Muang, Bangpakong, Phanomsarakham, and Banpho districts. These districts are attracted because the investors interest in the location of market and raw material source. The transportation accessibility and near by the Suvanbhumi Airport where is the large transfer station of goods and products.

Considering the investment cost of industrial establishment, the Province categorized the industries with high potential development following this: Electronics industry, Electric devices production, Automobile and compartment manufacture, Plastic production, Furniture from wood production, Metal and steel production, Concrete and Cement, Chemical product, Food and agro-industry, and Wearing apparel.

Chacheongsao Province has 2 industrial estates, 2 industrial enterprise areas, and 1 industrial park:

Industrial Estate:

1) *Well grow Industrial Estate*: It is situated in Bangpakong district has totally about 153 industries. The major sectors are electric appliance, electronic devices, automobile parts, paint products, instant foods, stainless kitchen utensil etc.
2) *Gateway City Industrial Estate*: It is situated in Plaeng Yao district. About 40 industries are operated. The major productions are electronic devices, automobile parts, paint products, instant foods, stainless kitchen utensil etc.

Industrial enterprise area:

1) *Alfa Techno-Polis* is situated in Muang district, has 1 industry operation.
2) *Sunyo* is in Muang district with 4 electricity appliance industries.

Industrial park: 304 Industrial Park is situated at Phanomsarakham district

The Province has promoted for the investment following these sectors;

1) Agro-industry and agricultural products
2) Technology and human development enterprises
3) Infrastructure and common facilities enterprises i.e. transportation, water supply, power production
4) Environmental prevention enterprises i.e. green-industrial estate, wastewater treatment company, solid waste management company
5) Target industrial sector which using high-technology i.e. foundry of steel and induction furnace, machinery production, automobile parts assembly, electronic devices production and software, warehouse.

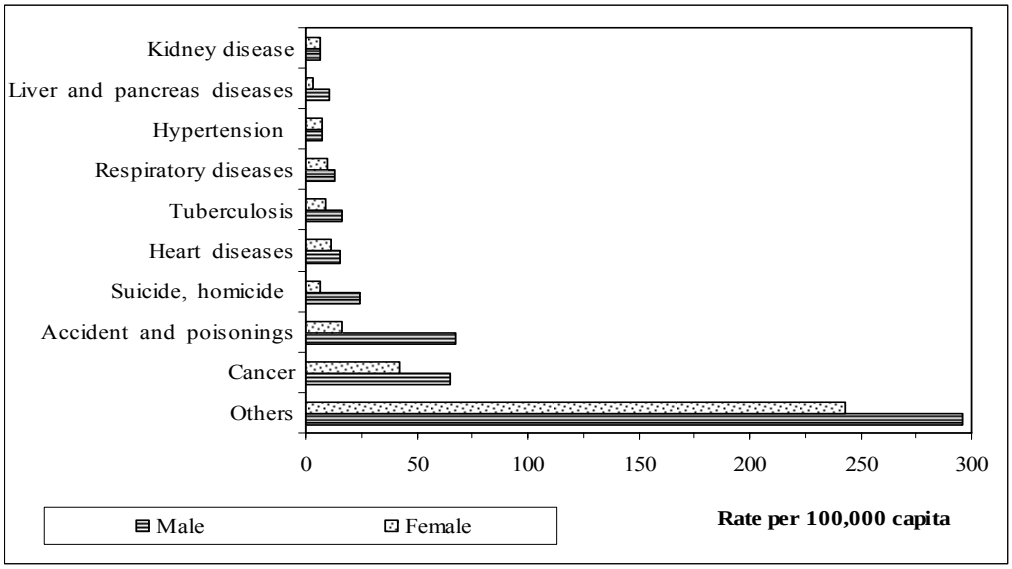
The Organizations promote the industrial sector development are following this;

1) Chachoengsao Governor
2) Chachoengsao Provincial Industrial Office
3) Chachoengsao Provincial Commercial Office
4) Chachoengsao Provincial Public Relation Office
5) Chachoengsao Provincial Urban Planning Office
6) Chachoengsao Local Administration Promotion Group
7) Chachoengsao Federation of Thai Industry Office
8) Chachoengsao Chamber of Commerce
9) Chachoengsao Commercial Bank Association
11) Plaeng Yao Industrial Estate Authority of Thailand
12) Chachoengsao Provincial Administration Office

4.1.7 Social, public health and sanitation

- **Public health and disease**

In the year 2004, the provincial birth rate is 12.42 per 1,000 capita and death rate is 6.49 per 1,000 capita. Since 2001, the birth rate has decreased and death rate has increased. The natural of population growing rate is about 0.59% which it also has decreasing trend.



Source: Chachoengsao Provincial Statistical Office, 2005

Figure 4.8 Disease prevalence in Chachoengsao Province

From the Figure 4.8, the first recognized prevalence rank is the accident and poisoning is high in males. This may be related to occupational health and safety of man worker having the risk of poisoning and accident. These causes vary from car accidents, accident in working places and industries. The remaining are of chronic disease, such cancers, heart disease and respiratory issues related to environment degradation and poor air quality.

4.1.8 Natural resources and environmental issues

- **Surface Water Sources**

The Bangpakong River flowing across a distance of 122 km is the main source for about 10 districts of Chachoengsao Province, including six districts of Chonburi Province, one district of Prachinburi Province and one district of Saraburi Province. The Bangpakong River Basin is divided into 4 sub-basins as Bangpakong River, Nakhonnayok River, Klong-Thalad and Klong-Luang. On an average, about 5,700 million m^3 flows in the river every year. About 1,800 million m^3 of water from the river is used for domestic consumption, agriculture and industrial purposes. Water source from swamps/reservoirs are 167 of which 166 are used in dry season. About 9 springs provide water even in the dry season. About 180 lakes and ponds also act as local water sources.

- **Water Quality Issues**

Bangpakong river water quality is periodically monitored and has been categorized under Class 3 and 4 of the standards as shown in Appendix (Class 3: This type of water can be used for agriculture and domestic consumption, but needs to be treated before using, Class 4: Not appropriate for consumption unless other sources are available. However, adequate treatment and quality control is required before supply). Bangpakong River has a Dissolved Oxygen of 2.4-3.5 mg/L. Such water resources are categorized as Class-4.

Biochemical Oxygen Demand (BOD) fall in the class 4 standard except in Bangkla and Bangnamprieo district which are in Class 3 which (<1.0-1.9 mg/l) and the Fecal Coliform Bacteria (FCB) contamination was between 40-2,400 MPN/100 ml which falls under class 3. Lead Concentration (Heavy Metal) has been reported higher than the water quality standards at Banpho district and Muang district with 0.059 and 0.089 mg/L.

Moreover, Bangpakong River faces sea water intrusion in the dry season, especially in the months of February to June when the Bangpakong river basin needs high amount of water for domestic, industry and agriculture purposes.

- **Water demand**

A study performed by the Kasetsart University for the Eastern Region Water Resources Management and Development, estimates a requirement of about 125 million m^3 for domestic consumption alone by 2006. This water required is compared with the other purpose used about 170 million m^3/year or 73% of the total water requirement in the area, the water crisis are showed in the Table 4.3.

Table 4.3 Water demand in the Province

Bangpakong River Basin	
Problem areas (Districts)	Bangnampreo, Chachoengsao Muang, Banpho, Bangpakong, Plangyao and Klongkaeon subdistrict
River volume	2,290 million m^3
Water consumption ▪ 1996 ▪ 2006	 1,028 million m^3 1,057 million m^3
Water supply capacity	848 million m^3
Additional quantity needed ▪ 1996 ▪ 2006	 179 million m^3 208 million m^3

Source: NESDB and Department of irrigation (1999)

Industrial use

In the recent years water consumption has increased due to the rapid growth of industries. Demand projections indicate a requirement of about 50 million m^3 in 2006 and 70 million m^3 in 2016 (Kasetsart University, 1999) for the Province.

Tourism use

Thailand is known for its tourism which has obviously resulted in an increased demand for water. Hotels, restaurants, recreation, cultural and heritage centers alone are estimated to consume about 1 million m^3 of water in 2006 while in 2016 it is projected at 2 million m^3.

Agriculture use

Water consumption for agriculture has increased to 387 million m^3 in the 2004. Of the total water demand rice cultivation constitutes a huge 42% while permanent crops consume 29%, field crop 24%, aquaculture 4% and others 1%.

- **Ground water source**

The quality and quantity of ground water is different in each area and are subject to several factors such as meteorology, geology and hydrogeology. Multiple aquifers are more common in the Chachoengsao province especially in Bangnamprieo, Klongkhaun, Ratchasarn, Bangkla, Muang, Banpho and Bangpakong. This aquifer has low capacity to carry water at less than 0.07 m^3 per minute. There are found in Phanomsarakham, Sanamchaiket and Plangyao. Groundwater levels change following the seasons. Though not steady an average of change of not more than 2-3 m has been observed.

- **Bangpakong Irrigation Dam (Bangpakong Barrage)**

The Dam was constructed in 1996 and is situated at Banpaisawek, Bangkeaw district, Chachoengsao Muang. The reservoir is about 70 km upstream of the estuary and has a capacity of 30 million m^3. This project from the government was aimed at solving the problem of sea water intrusion into the river and to store for water consumption, agriculture and irrigation in this region.

However, the operation by gate-closing caused the 2 major problems are 1) destruction of the bank of the river during ebb tide period and 2) sea water intrusion during flood tide. Therefore, the dam has been stop working due to keeping for problem resolve.

- **Source of Water Pollution**

Chachoengsao Muang municipality contributes the highest BOD of 1,100 kg/day discharged to Bangpakong River. The second is the Bangpakong District municipality (180 kg/day) and Bangkhanak District Municipality (50 kg/day). The Chachoengsao Muang Municipality is in the process of constructing a sewage treatment plant with a capacity of wastewater 24,000 m^3/day.

Rice cultivation areas of the province normally settle near the river or canal. Bangpakong, Banpho, Chachoengsao Muang, Bangnamprieo and Klongkhaun districts are largely paddy fields. Water pollution problems are mostly observed in the post harvesting period. The paddy stubble left after harvesting are flooded with the runoff water discharged in to the local water course.

The highest concentration of shrimp farms is seen in the Banpho district and Chachoengsao Muang. Almost 80% of the farms are small scale family owned, which have not been standard acceptable by the Department of Fisheries due to inadequate environmental management practices such as: feeding with an open system and absence of clarifying ponds, sludge pits, improper treatment of wastewater and sludge discharge into water sources.

Pig farms play a key role in water quality degradation (Muang Chachoengsao, Bangkhla district), especially in the upstream areas of the Bangpakong stream. About 900,000 pigs are grown in 1,751 farms in these districts. Waste generation from pig farms is about 5kg/pig/day of which pig manure (70%) is sold. About 75% of the total pig farm has composting pit, but in the real case they discharge the waste into the water sources.

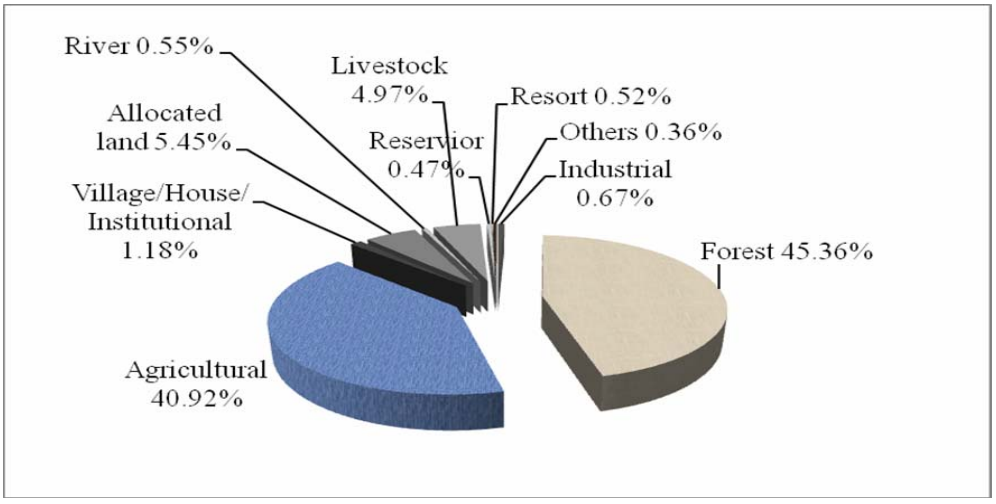
Chachoengsao Muang, Bangpakong and Bangkhla district are the centers of industrial activities. Almost all industries requiring water for the production process are located near water sources. Lack of sound environmental management practices and discharge of wastewater to natural resources without appropriate treatment have given rise pollution problems.

- **Soil and Land use**

Soil resource of the Province mostly is categorized in clay soil and founded in the flat land area. Previously, land formed by the estuary sedimentation, has awful water drainage quality. However, this soil properly used for paddy field in Muang, Phanomsarakharm, and Sanamchaikhet districts. The problem in this type of soil area is flooding in rainy season due to poor drainage.

However, the drainage is high because some clay soil area has inserted with gravel. This type is properly for crop field such as cassava in Thatakiap and Bangkhla districts, while the high slope can cause the soil erosion as Phanomsarakham and Sanamchaikhet districts. The soil type in Chachoengsao Province can be categorized following the origin materials; Tidal Flat, Former Tidal Flat, River mouth and estuaries, Hills and Mountain, Erosion Surfaces and Local Washes.

Chachoengsao Province has total area about 5,351 Km^2 and most of land use is the forest area about 45% of the whole province. The second is agriculture area 41% and the third is allocated land about 5.5% and livestock and aquaculture area with 5%. The provincial landuse are shown in Figure 4.9:



Source: Department of Environmental Quality Promotion (2004)

Figure 4.9 Landuse area of Chachoengsao Province

- **Forestry**

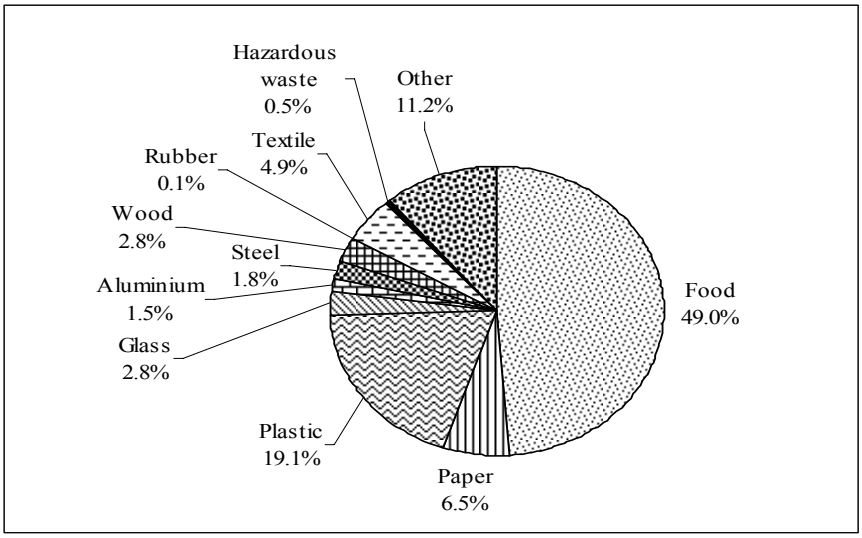
Half of the forest in the Eastern region is located in the connection area of 5 provinces are Chonburi, Chantaburi, Rayong, Prachinburi and Chachoengsao. Name of largest forest in this junction area is Khwai Rabom-Seeyad, where the most of forest located in Sanamchaikhet and Thatakiap districts of Chachoengsao Province. In the year 2000, the

forest area in the Province is 2,400 Km^2 which is about 45% of the whole Provincial area. The forest is the origin of many water courses and it has abundant of flora and wildlife diversity, so the Forestry Ministry has kept the forest to be national park. In the year 2004, the conservation area of land forest is about 845 Km^2 and mangrove forest is 12 Km^2. The total area of both forests in the Province is 16%.

- **Solid waste**

Solid waste management is the responsibility of the each local administration such as municipality and the Sub-district administration (Tambon). Total solid waste generation in the Province is about 400 tons/day of which 170 tons/day is from the municipality and 200 tons/day in the district. The waste characteristic and composition is showed in the Figure 4.10.

Chachoengsao Muang (53 tons/day), Bangkhla (18 tons/day) and Phanom Sarakham (15 tons/day) are the municipalities which generate the highest volume of waste in the Province. Tambon Bangwua (in Bangpakong district) generates 20 tons/day, Tambon Sanphudad (in Banpho district) 12 tons/day, and Khoh khanoon (in Phanomsarakham district) 11 tons/day are the sub-districts which generate the maximum quantity of waste.



Source: Pollution Control Department (2006)

Figure 4.10 Solid waste composition of Muang Municipality

Solid waste management in the municipality is done by collection and transportation using trucks with a capacity of 8-11 m^3. The trucks make about 2-3 roundtrips per day and collect the waste from both commercial and residential areas. The efficiency of the collection system has bee reported to be between 70-90% of the total waste generation. In some places the quantity of waste generation from Sub-district administration areas is small about 2-3 tons/day. In such places solid wastes are disposed and managed by the household in small open dumps or through open burning. The Table 4.4 is showed the solid waste generation and management.

Table 4.4 Solid Waste Generation in Muang Municipality

Amount of Solid waste generation Waste generation rate Disposal method Disposal place area Disposal Location	53 Ton/day 1.2 Kg/person/day Open dumping 5 hectare Bangkwan sub-district (Muang District)
Type of Community/Town	Industrial, Commercial and Agricultural

Source: Pollution Control Department (2006)

- **Air quality**

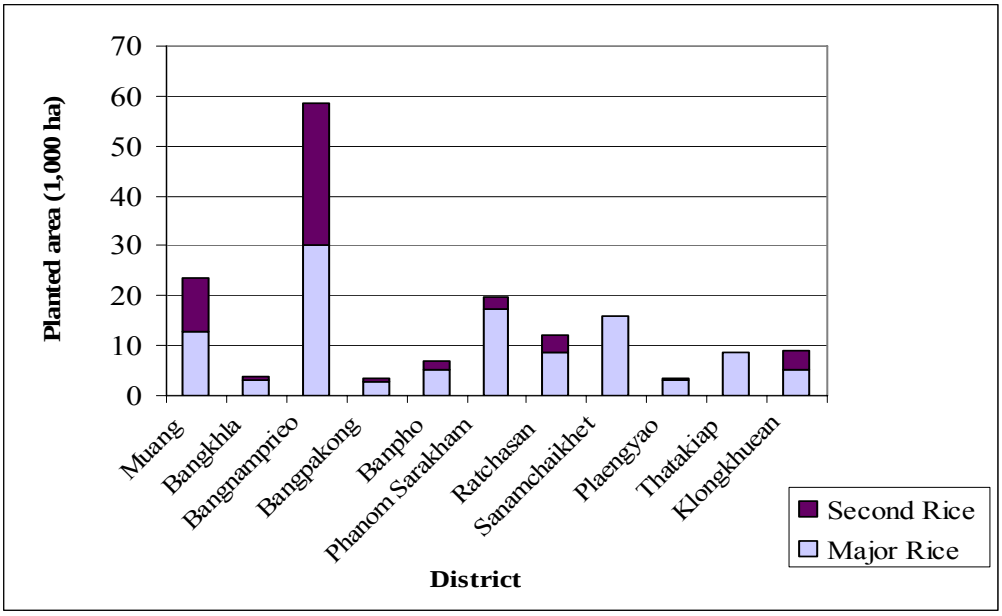
Ambient air quality has monitoring yearly by Pollution Control Department, which the air monitoring station in the Province is situated in Plaeng Yao District. Most of the parameter results are settling in the standard limitation and quite low. However, the results also show the parameters that exceed than the standard only O_3 and PM_{10}. This may occur in the post-harvesting season, where farmer operate open burning at their agriculture field.

4.2 Major Economic Activities in Chachoengsao Province

From the collected data, the major economic activities in the province and study area have been focused. Rice cultivation, the started point is the original sector of rice-based industry. Then, this part focused on the rice mill as the key point of rice-based processing industry. Focusing on the group of sample rice-based industry in the production process, material input, output by-product and waste of each industry and it environmental means. Data in this part are used to develop the material flow of rice-based industry in the Agro Eco-Industrial Network and final part of analyzed the policy network.

4.2.1 Rice cultivation

Rice cultivation is the major agricultural economy of Chachoengsao Province. In the middle region, the topography of prominence land is favor to grow both major rice cultivation and second rice cultivation. Especially, Jasmine rice is originated from this province and well-known in the rice market. The total rice planted area in the province is 166,000 hectare and planted in 660 villages. The highest rice planted is in Muang District. However, the major rice cultivation is the most plentiful in the whole Province which 113,000 hectare and the cultivation present in every district. The second major rice cultivation is the second in the province with 53,000 hectare and the main sources are from Bangnamprieo, Muang, Khlongkhuen, and Bangkhla districts. The two system cultivations are planting in both types of rice and sticky rice. The rice cultivation of each district in Chachoengsao Province is shown in the Figure 4.11.



Source: Chachoengsao Provincial Statistical Office (2005)

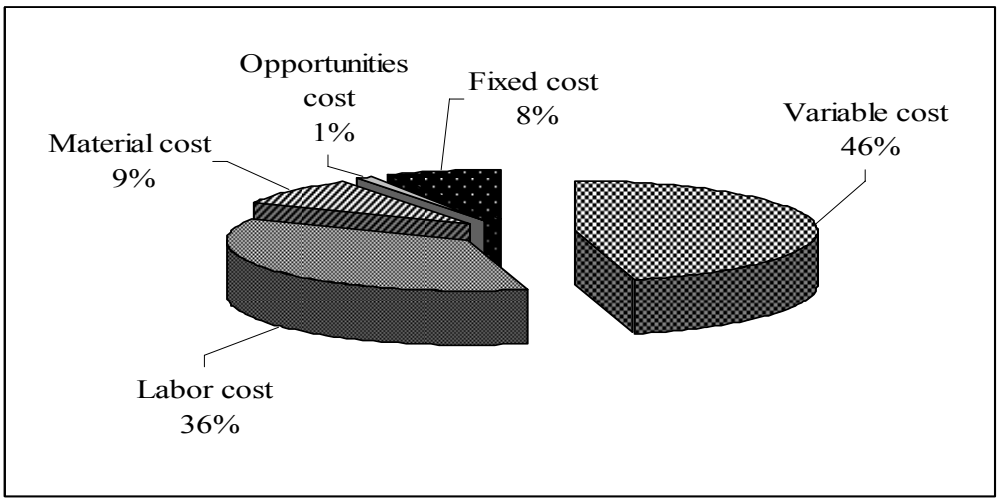
Figure 4.11 Rice Cultivation in Chachoengsao Province

The paddy field of lowland and plain in the central part such as Chachoengsao Province, are popularly planting the non-glutinous rice. The depth of water level in farmland during September and November is 1-3 m. Then, the farmer in some area have to use type of floating rice, otherwise most of the area is the type of lowland rice. The rice characteristic depends on the growing factors; high yield, resistant to environment variability, and rice quality. The quality of rice considering on several factors such as seed dormancy, sensitivity photoperiod, floating ability and tolerance to deep water, grain quality, plant type, resistance to diseases and insects.

- **Production cost and rice trading**

The rice cultivation price and production cost of farmer is the basic consideration point of value chain of rice based industry. The rice at farm price can be varied in each month and year. The variation of price depends on the market price and several factors such as water resource, oil price, planted area etc. The example of producing jasmine rice can be categorized for a cost analysis. (Mentioned in Figure 4.12) Total cost of paddy cultivation is average for one farm is 240 Baht/hectare, then equal to total cost 5,400 Baht/ton with the yield 4,788 kg/hectare. The paddy sale at farm price is 7,070 Baht/ton, so the net benefit to the farmer is 1,630 Baht/ton.

The rice cultivation area is fit to use the large machinery in production e.g. pushcart, tractor to land preparation. The farmer can save the cost for labor and shorter time to harvest, but the material cost is increasing. In the area of deficient land and less nutrient, the farmers need to prepare the farm by using lot of chemical fertilizer.



Source: Office of Agricultural Economics, Ministry of Agriculture and Co-operatives (2006)

Figure 4.12 Cost in the investment of major rice cultivation

In the central region, the fresh paddies are required and purchased from the local rice trader or rice mill agent at the farm. Some farmers sell the paddy to the nearby rice mill directly, so the farmers have not to reduce or maintain the moisture content by themselves. However, the rice mill or paddy trading market has to check the moisture content before purchase for setting the price concerning the quality of paddy. The local paddy trader loads the rice to send the medium size of rice mill.

The rice after milling is distributed to; 1) the local consumer in the province and 2) sells through the agent to the Bangkok market. Because the rice market is the major role of rice distributor to the other regions which deficient of rice production e.g. South of Thailand. The medium size of rice mills in Chacheongsao province usually sells the rice to the wholesaler, retailer or large enterprises. Otherwise, the large rice mills are trading to the exporter by passing through the agent.

Trader and agent play as a key role in paddy and rice market. They purchase and collect the paddy from high yield of rice region such as North and Central part and stock at their bran/warehouse. Then, they sell the paddy to the rice mills (medium and large size) or rice trading market at Bangkok and vicinity. Moreover, the trader and agent give the loan to farmer for invest the rice cultivation such as rice seed, fertilizer, and pest control chemicals. Especially at the beginning of season, the farmers raise a loan from them and return with interest after production.

- **Resource constraints and environmental issues**

Chachoengsao Province has several soil problems, with the major face to high content of gravel and sand in soil in Plaengyao, Sanamchaikhet and Phanomsarakham. The acid soil concentrated in Banpho, Bangnamprieo, Plaengyao, and Phanomsarakham. The saline soil problems occurred in Bangpakong district. However, the rice cultivation mostly in the acid soil (pH 3.5-5) is effected with high composition of sulfur in soil, especially in dry season of irrigation area faced to the sea intrusion from Bangpakong River. The salinity is

exceeding than standard highly in November-December and depends on rainfall quantity of each year. The rice yield and net income of farmer is quite low but the capital cost high.

The land without acid soil problem is suitable for rice cultivation. This area obtained higher yield and the farmer can obtained more net income. The area is divided into 2 areas of water sources consumption; the irrigation accessed area with the loam quality is quite good in Bangnamprieo, Muang, Klongkhuen, Panomsarakham and in the west of Bangkhla. However, the water is lacked during dry season because the irrigation gate was closed to prevent sea intrusion. The rain fed area; Bangpakong, Banpho, Bangkhla, Ratchasarn have most of the major rice cultivation due to depending on the rain fall. The rainfall is quite low during planting season (May-July), so the water source from canal is used to fulfill this period.

In Chachoengsao province the area treated by inorganic fertilizers is totally about 174,000 hectare; the paddy field is treated about 112,000 hectares or 63% of the treated area in the province. The total quantity used in the province is 59,179 kg and the rice cultivation consume the fertilizer about 40,743 kg or 68% of the total crops used fertilizer in the province.

The post harvest period of rice, the presented of farmer managed the rice residue in their field such rice straw and paddy stubbles left after harvesting. This is the one cause of air pollution, nuisance and risk of car accident due to closely the transportation route. Water resource is very important to rice cultivation; the water demand for irrigation of rice cultivation is 42% of total agricultural water demand. Chachoengsao has rage of agricultural water consumption is 387 million m^3/year. Therefore, the water demands in agricultural purposed also competitive to the other demand purposed due to river and canal water resource.

The soil quality in the area is increasingly deficient due to long lasting period of cultivation, intensive use of chemical fertilizer and pesticide, degradation of soil and nutrient loss. Therefore, several projects are developed from government organization to support the farmer livelihood. For example; encouraging the farmer to plow the agricultural residue after harvesting, promote the organic fertilizer and adopt to the farm land, soil improvement techniques promotion.

4.2.2 Rice mill

Chachoengsao province has abundant of rice production and it distributed mostly in the study area of 5 districts. Rice milling process is the one kind of agro-industry, which is purposed to processing the paddy for foodstuff. In the past, the rice mills are served at small scale and local area. Thus, the scale and technology is quite low. However, the rice mill developed following the rice production for last 30 years due to the enhancement policies to increasing capacity of rice supply inside the country and export. The number of rice mills in Chachoengsao also presented plentiful for last 10 years following the country statistical number as showed in the Figure 4.13. Last 5 years, it seems the amount of rice mill is stable developed in this area (MOI, 2005).

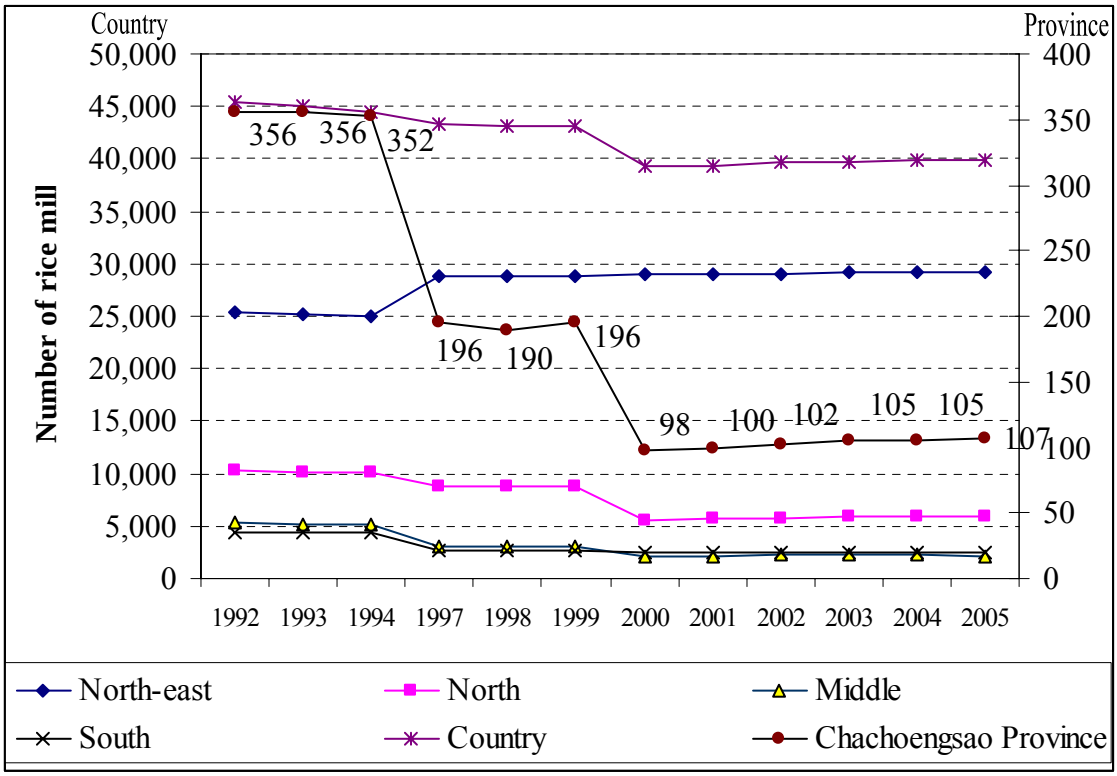


Figure 4.13 Trend of rice mills established in the province, regions and country

This status of rice mill is caused from the changed number of traditional rice mills was turn into modern rice mill production with higher capacity. Also, it is caused from the change of rice cultivation land use into the other types of development. However, the rice mill still is the first rank of industrial establishment in the Province.

Statistical information from the Department of Industrial Works, 2005 indicated that 39,834 rice mill factories are operating in Thailand. A highest number of factories are in the north-eastern part. The north, south and middle are accordingly to the rank. It was found that there were 107 rice mills in Chachoengsao Province and the distribution of rice mills are as following the Table 4.5. Criteria of factory classification are defined as follows:

- Small size: maximum production are less than 18 tons/day
- Medium size: maximum production are 18 to 30 tons/day
- Large size: maximum production are more than 30 tons/day

Chachoengsao Province has totally 107 rice mills operated in 10 districts. Bangnamprieo is the first rank by 29 rice mills. The rice mill has been categorized in the different scales are small, medium, and large; 44, 15, and 48 by the mills size accordingly.

Regarding of rice mill establishment is regulated in the list of factory type and classification No. 00901, which is based on the Ministerial Regulation 1992 (B.E. 2535) issued pursuant to the Factory Act 1992 (B.E. 2535). The type of all industry establishments in the regulation has totally 107 code numbers and each of types of factory is divided into several series number. Moreover, the rice mill can be set in the No. 00201 in case of the entrepreneurs registered and produce other factories of their business. Some

parboiled mill also import and produce the drying and roasting rice, additional from their in-line rice production.

Table 4.5 Distribution of Rice Mill in Chachoengsao Province

District	Size of Mill			Total
	Small	Medium	Large	
Muang Chachoengsao	5	3	11	19
Bangkhla	2	2	3	7
Bangnamprieo	8	4	17	29
Bangpakong	4	1	7	12
Banpho	8	3	4	15
Phanom Sarakham	9	2	5	16
Ratchasan	1	-	-	1
Sanamchaikhet	2	-	-	2
Plaengyao	3	-	1	4
Thatakiap	-	-	-	0
Klongkhuean Minor-district	2	-	-	2
Total	44	15	48	107

Unit: Number of Rice Mill

The code number 009: Factories engaging in any kind or several kinds of the following business related to plant seeds or plant bulbs. Issued in the sub-code number 00901: milling, winnowing or scouring grains;

Classification No.1: Machinery is not more than 20 horsepower and there have not boiler

Classification No.2: Machinery is not more than 50 horsepower. There have not boiler and it is not classified as Group 1

Classification No.3: Machinery is more than 50 horsepower or every size of factory with a boiler

The code number 002: Factory engaged in any kind or several kinds of the following agricultural produce. Issued in the sub-code number 00201: boiling, steaming or roasting plants or plant seeds;

Classification No.1: Not classify

Classification No.2: Machinery is not more than 50 Horsepower

Classification No.3: Machinery is more than 50 Horsepower

- **Rice mill production process**

This part of the study analyzed the rice mill process in Chachoengsao Province, so as the rice mill established in the study area of 5 districts. The 5 sample of rice mills are selected to study the processing. However, the rice mill production efficiency of each industry is diverged and depended on the industrial management. The rice mills production process are different in terms of production technology, machinery, quality of raw materials, the target quality of product, energy consumption, and production capacity. The rice mill can be categorized by production process and products in 2 groups; Rice mill (Sticky rice, White rice, and Hom mali rice) and Parboiled rice mill.

Rice mill A; it is established in Bangnamprieo District for 12 years. The mill is managed by the family owned. The production capacity is 150 tons/day with the 24 operation hours and 25 day working. The paddy is weigh during contained in the truck and also quality checking in the heap such moisture, temperature and % head rice. Then, it is loaded from the truck to process unit. Mostly, the quality is accepted by inspector due to the purchase system of raw material is procured by conversant retailer.

The processes of rice mill are composed of de-husking, whitening and separation of head rice and broken rice. Rice quality and rice mill efficiency is major considering from head rice grain because the head rice is the major product with top price. The quantity of head rice production from rice mill also depends on rice variety, cultivation method, harvesting method, moisture reduction of rice, paddy storage and rice milling. The production process of this typical rice mill is showed in the Figure 4.14. Therefore, the key point of each processes are described below;

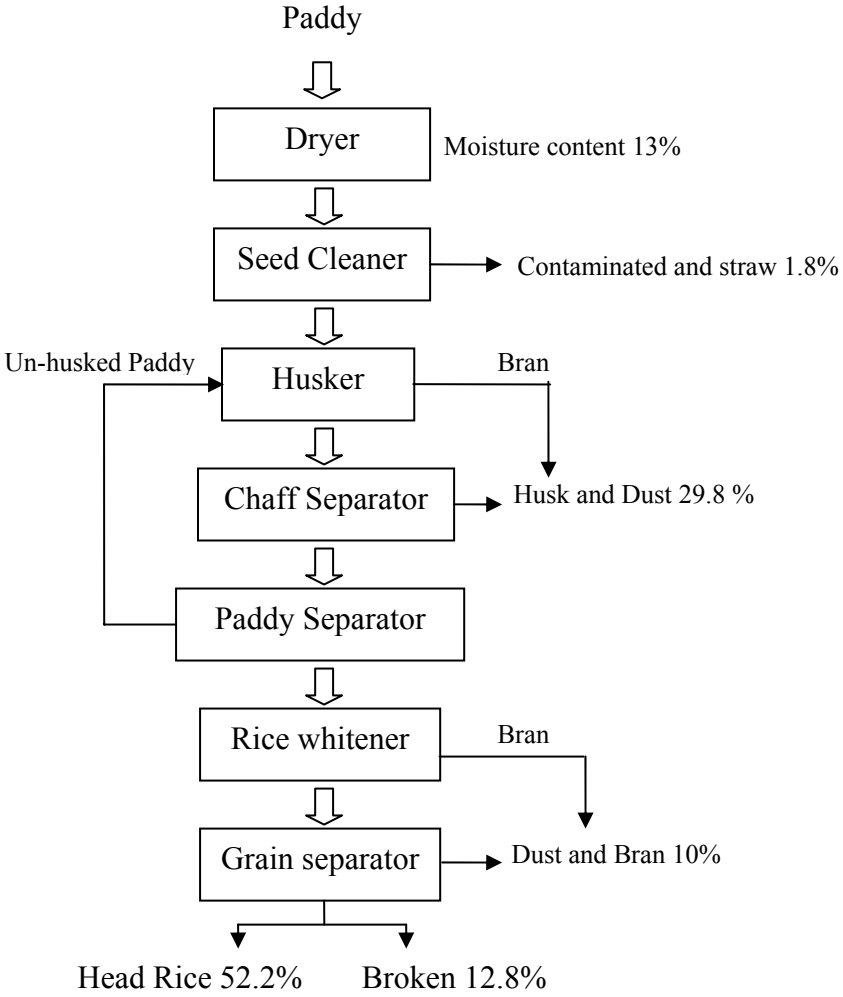


Figure 4.14 Rice milling process flow diagram

Paddy drying; The principle is moisture decreasing of paddy and prepare to mill process. The proper moisture before milling is affected to the higher percentage of rice. The proper of moisture content of paddy dryer is set at 13% by used mechanical dryer in the mill.

Cleaning Process; Paddy from storage bin goes to a separator for separating straw chaffs, stones and dust particles. The *Screening cleaner*: The cleaning set is two screens, on the top screen particle greater than the size of paddy is retained, while paddy is retained on the second screen. The dust particles pass through and collected together with straw to dispose.

De-husking process; Due to the reciprocating motion of the separator, the cleaned paddy falls to a chamber and by pneumatic conveying to the husker machine. The outputs from this process are brawn rice, course bran and husk. *Rubber Roll Husker*: popular used in rice mill due to it decreases the broken rice problem.

Paddy Storage and conveyer

De-husker

Paddy Separator and Rice Whitener

Figure 4.15 Unit operations of Rice mill production process

Chaff Separator; The paddy from husker still mixed with the straw chaffs and leaves, and then it goes to the chaff separator for separate the husk and bran from brown rice. The Air Brower is used with the flinging screens. The husk aspirator chamber collected the husk and course bran in this process.

Paddy Separator; The brown rice and some small paddy go to the paddy separator (tray type) by another conveyor belt which retains the small paddy which is sent back to a rubber huller again. After de-husking, the brown rice and husks are sent to the husk separator for husk separation and storage.

Rice Whitening; The whitening process has 3 stages. The brown rice from the paddy separator goes to a distributor which has different outlets to send the brown rice to different polishers where the brown rice is polished for the first time to give rise to rice and coarse bran. The rice and coarse bran go to a bran separator for separation. The rice is sent to another whitener. The White rice polisher is Vertical cone-shape polisher.

Rice Polishing; The major purpose of this process is to eliminate the fine bran at the grain surface and the rice grain is shined and smooth. The whole rice is collected to *Grain Separation*; in order to separate the broken rice from head rice. The Trieur cylinders is used, also rectangle strainer is used in separation of fine bran.

The rice mill just installed the machine of color separator for the need of rice export. It is adapted the automatic color sorter (Photoelectric principal). Normally, the grain length of whole rice is set at the proportion 10 following the Thai Rice Standard. The main components of the product are Head rice, Big broken rice, Small broken rice and Brokens.

- **Parboiling Rice Mill**

Parboiled rice mill B; it is established in Bangnamprieo District for 20 years. The mill is managed by the family owned. The production capacity is 600 tons/day with the 24 operation hours and 25 days working. The number of employee is 100 workers working in 3 shifts. Parboiling process is operated the same as rice milling process but the parboiling has adding the processes. The process of paddy cooking is using the Hydrothermal Process.

- **Parboiled rice production process**

The typical of sample parboiled rice industry is analyzed the production process. The production process of one typical rice mill is showed in the Figure 4.16. The parboiling process has major unit operations are as following described;

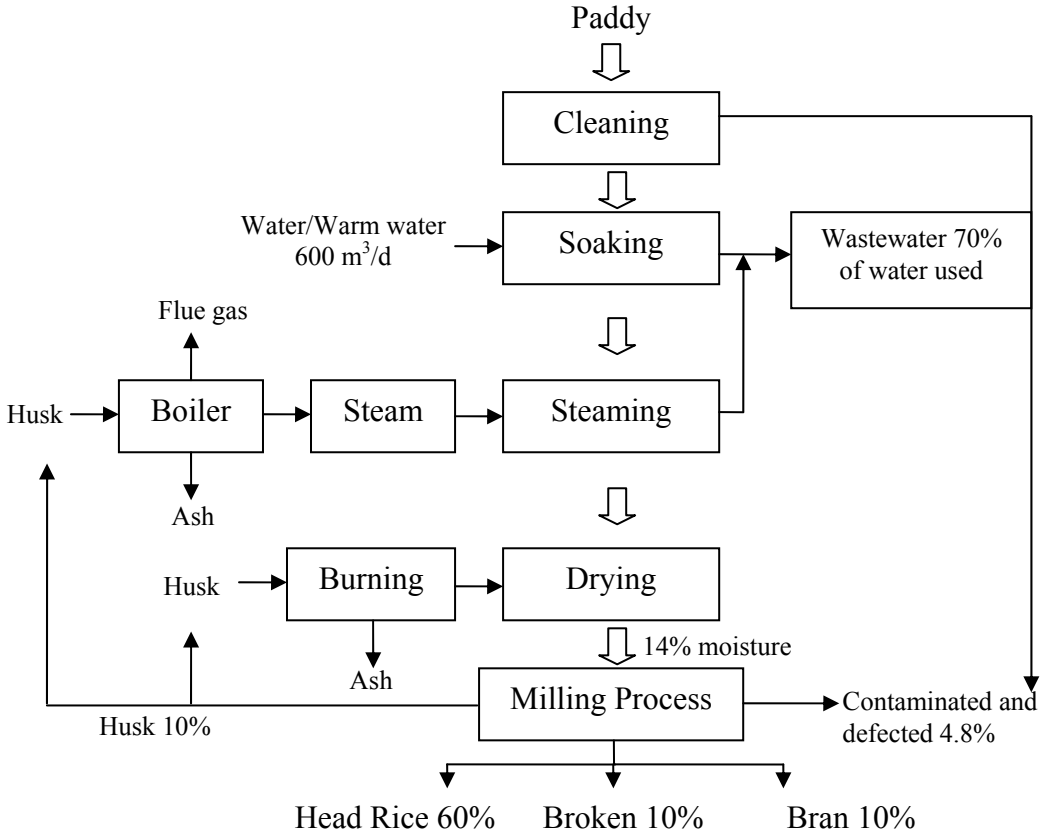


Figure 4.16 Parboiled rice process flow diagram

Soaking; To prevent the darker color change of parboiled rice (over the starch gelatinized temperature limit), the temperature using should less than 70 ^{o}C, the 6 tanks are used and soaking time about 4 hrs and pH 5 is suitable in soaking water.

Steaming; The tanks with rice after soaking are fulfilled with the steam, the pressure is about 100 psi with 3 tons of paddy is required time of parboiling about 15-20 minutes for each tanks. Purposing of this process is the improvement of rice quality, increasing head rice yield, increasing time of rice preservation and obtain higher nutrition value of parboiled rice. However, this process is the major source of wastewater due to it is the main environmental issues of parboiled rice mill.

Parboiled drying; Drying of parboiled paddy is purposing to the reduction of moisture content for proper milling and storage. The drying process of parboiled paddy is different and more special than raw rice milling due to high moisture content and texture changing of the starch from gelatinized. Then, the temperature is required about 100 ^{o}C and keeping time is 5 hours with 6 dryer units. *The parboiled rice milling;* to de-husking of parboiled paddy and polishing the brown rice, to get the rice product are done by the similar processes of rice milling.

- **Material balance (Input, Output, Waste)**

The mass balance is a major tool to identify the efficiency of rice production, percentage of head rice and percentage of total rice is the one important to the rice mill. The major raw material cost of rice production is paddy, which is about 95% of the total cost. The cost of electricity, transportation, labor and material is about 5%. The mass balance is established to check the problem of the rice milling process and find out the major problems through the milling unit operation.

From the study of typical rice mill information, the rice mill A produced sticky rice 98 tons/day in plastic pack (49 kg/pack), sack (99 kg/sack) and bulk (jumbo pack=1 ton/pack). The input used paddy 150 tons/day as raw materials. Fuel oil used about 200 L/month and packaging materials such as plastic bag. The specific mass balance of one rice mill is showed following the Figure 4.17.

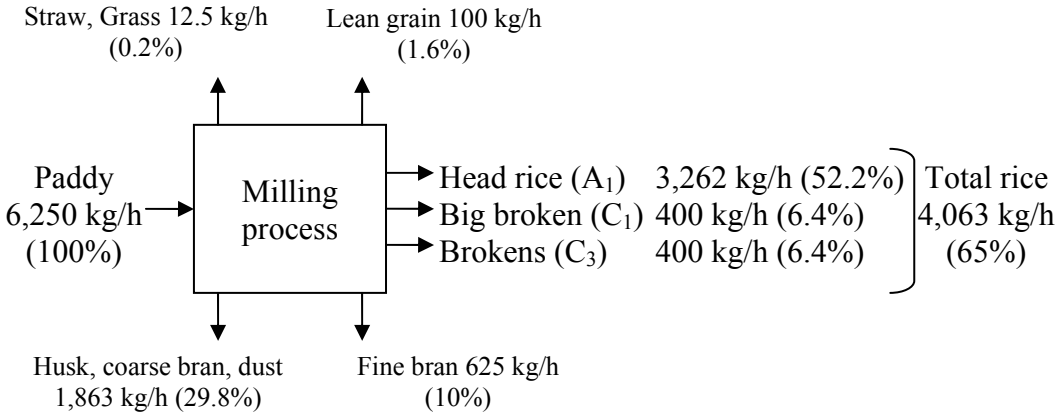


Figure 4.17 Mass balance of typical rice mill process

The output of rice also is the by-product of 29.8 % of husk including dust waste due to the industry has to dispose by mixing it to the husk. Rice bran is produced about 10% of paddy and contaminated things such straw and defected grain is about 2.7 tons/day. All the by-products are sold to the dealer or distributed to other industry.

Capital investment of Rice Mill A is 14,000,000 Baht, it established since 1995. The total cost of rice mill production is approximately about 10,080 Baht/ton of paddy. The paddy purchasing cost is about 7,000 Baht (The purchased price is varied following the market price which is set by rice trader and exporter). The minor cost is about 380 Baht/ton of paddy; it is the additional cost from:

- Labor cost 50 Baht/ton
- Electricity cost 100 Baht/ton (for milling),
  100 Baht/ton (for drying paddy to 14% moisture)
- Transportation cost 130 Baht/ton

From the studied of typical parboiled rice mill B information, the production capacity is 600 tons/day with the 24 operation hours and 25 days working. The paddy is from the supply market inside the Province but depend on the sufficient requirement and production capacity in local area, unless the industry will buy from other regions. Water source in production process from canal, it is pump and restore in their pond (1.28 hectare); water used in the process is 600 m^3.

The outputs are parboiled rice and broken rice about 420 tons/day (70% of paddy). Husk about 60 tons/day (10% of paddy) are used in process for boiling and some of that sale to the farm and ash is sale to the farmer in truck. Bran is obtained about 60 tons/day (10% of paddy), the parboiled rice bran has higher quality than white rice bran, and then the rice mill can sell with the higher price to the rice bran oil extraction industry at Bangpakong District. The specific mass balance of parboiled rice mill is showed following the Figure 4.18.

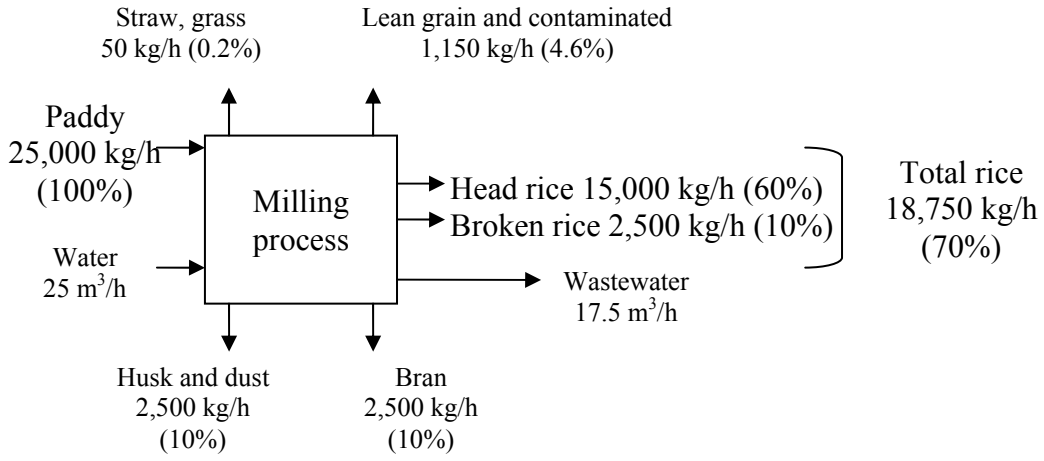


Figure 4.18 Mass balance of typical parboiled rice mill process

Normally, the transitional standard of total rice percentage and its by-product is around 75% (Department of Health, 2000), and the number could be varied due to many factors such as; amount of contaminated thing mixed with paddy, seed cleaning and separation

process, loss of paddy in the cleaning process and chaff separation process, over polishing of rice, maintenance, and experiences of operator.

Some conclusions from the mass balance of rice mill process were drawn as follows;

- The rice mills achieved the reference standard of total rice and by-product (75%). The total rice percentage is the parboiled rice mill is higher, due to this mill needs less polishing of rice and the starch content could obtained more than other kind.
- The head rice percentage also difference on each mill, there is no benchmark of the accurate values. It is varied due to several factors such as; harvested paddy to rice processing, variety, origin areas of paddy, paddy quality, harvesting period, moisture content reduction process, transportation, de-husking process and polishing.
- The products and by-products from the rice mill are mostly recycled either at on-site recycle or at off-site recycle. The management method of the 5 sample rice mills are summarized in the Table 4.6. The alternative options and value of product, by-products and waste are different for each rice mill. It depends on the amount and quality of rice product, cost saving of rice mill, purpose of customer industries need.

Table 4.6 Scheme of Product, By-products and Wastes of Rice mill and Parboiled mill

Output	Rice mill			Parboiled rice mill		
	kg/ton paddy	Customer/ disposed method	Sale price (Baht/ton)	kg/ton paddy	Customer	Sale price (Baht/ton)
Head rice	522	Dealer (market)	12,000	600	Dealer(market)	10,400
Broken rice	128	Dealer (market)	7,500	100	Dealer(market)	7,500
Bran -Fine -Coarse	 100 -	 Animal feed Mixed in husk	 6,500 -	100	Rice bran oil industry	8,250
Husk	298	Power plant	650	100	In plant used, Sale as fuel, Chicken farm	800
Dust	-	Mixed in husk	-	-	Mixed in husk	-
Contaminant things	16	Dump their land	-	46	Dump their land, Give to agriculture	-
Straw	2	Agriculture	1,000	2	Agriculture	1,200
Ash	-	-	-	25% of husk	Planting and cultivation	500

Remark: Surveyed data from questionnaires and field study

- **Energy consumption**

The energy utilization in rice mill can categorize into 2 major types are: 1) Electricity, mostly is the new establishment rice mill or unused boiler in rice mill. 2) Combine of electricity and husk fuel, the rice mills set up the boiler by using the husk as a fuel to produce the steam and supply to driving the motor's machinery. The steam also feeding to the soaking and steaming in parboiled mill. However, recently the price of husk for fuel are keep on increasing, the rice mills tend to change and use the electricity motor for machinery driving.

The typical rice mill has measured the energy consumption and reported in the following Figure 4.19. Therefore, the average of electricity energy utilization in the rice mill processing and cost of electricity are summarized in the following Table 4.7.

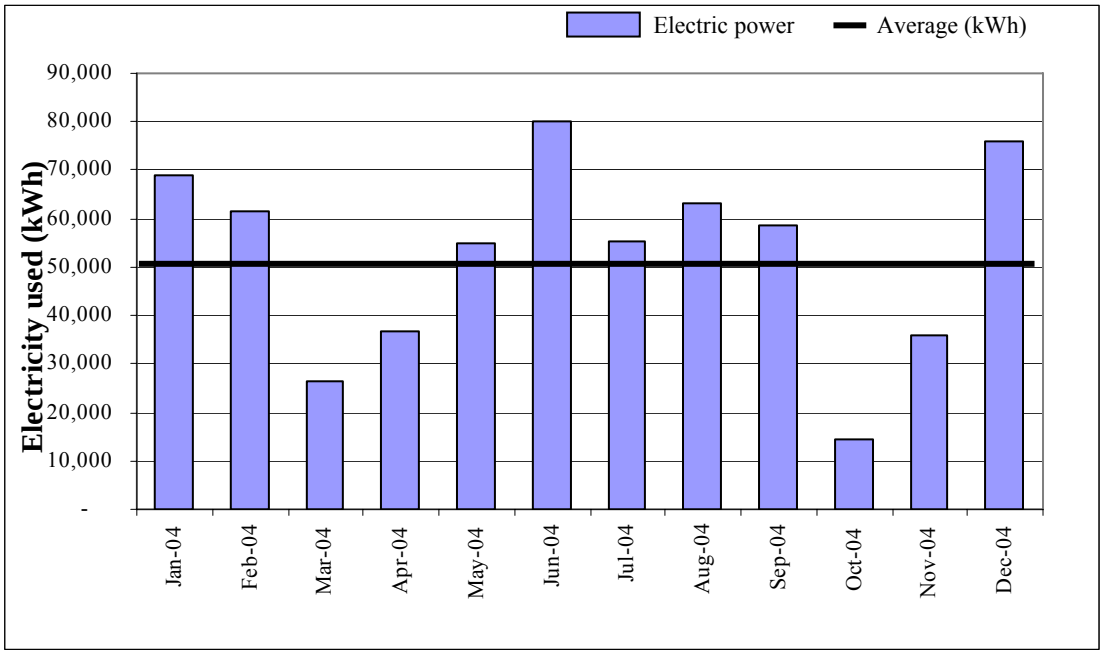


Figure 4.19 Electricity consumption of rice mill production

The average electricity consumption for rice processing of rice mill is 52,700 Baht/month. And the maximum consumption is settling in December and June because the rice mill production increasing the capacity following the high production of paddy from agricultural sector during October to December and May to June periods.

Table 4.7 Energy utilization of Rice mill and Parboiled mill production process

Rice mill	Unit per Ton of paddy		
	kWh	Ton of husk	Total cost (Baht)
Rice mill A	17.8	-	53.4
Parboiled mill B	44.4	0.04	154.2

Remark: The husk feeding for boiler is about 700 tons/day and husk price is 600 Baht/ton;
Surveyed data from questionnaires and field study and electricity bill

The quantity of combined of electricity and husk fuel used in rice mill is separated in 2 processes: Milling process (Electricity and Fuel) and Soaking-steaming process (Steam is used in soaking-steaming and electricity is used in conveying system). From the Table 4.7, the parboiled rice mill consumed electricity and energy higher than rice mill because the process is more complicated and higher production capacity. The electricity price is lower than normal period due to rice mill did not operate the drying unit. Energy consumption in rice mill mainly used electricity in order to use in several unit operation. The three highest electricity consumed equipments are main axle motors to drive most of hinge unit consumed about 63%, husk vacuum pump in milling unit used about 13 % and Rubber hulling motor consumed about 11% and other minor units are approximately 13%.

- **Water consumption, wastewater generation and treatment**

The rice mill is characterized in the dry process industry, but exempt to the parboiled rice mill which used the water in soaking and steaming process. Water consumption of parboiled mill depends on several factors such as quantity of raw material (paddy), original moisture content in paddy, and method of paddy soaking. Over used of water is effected to the production cost and wastewater treatment cost.

Table 4.8 Wastewater characteristic of parboiled rice mill

Parameter	Value	Thai Industrial Effluent Standard
pH	6.7	5-9
Temperature (^oC)	38	40
DO (mg/L)	4	-
BOD_5 (mg/L)	9	≤ 20
Suspended Solid (mg/L)	239	≤ 50
Oil and grease (mg/L)	9.6	≤ 5
Water consumption (m^3/day) (Parboiled rice mill B)	420	-

Water consumption of parboiled rice mill B is 420 m^3/day, so the BOD loading from wastewater generation is 0.25 kg BOD/ton of paddy. Wastewater generation from rice mill could be from 3 sources; Wastewater from soaking and steaming process (parboiled mill), Wastewater from trapping of fly ash and remove ash from burner (mill using husk fuel), and Oil contaminated wastewater (mill using steam engine and boiler).

Comparing to the WHO (1993) Rapid Assessment of Pollution, the benchmark of parboiled milling is generated wastewater 1.5 m^3/day per ton product. The benchmark of BOD loading is 1.8 kg/ton and TSS is 0.07 kg/ton of product. It found that, this parboiled rice mill has generated waste water 0.7 m^3/day and BOD loading is 0.006 kg/ton. The values are lower than benchmark that could be acceptable. However, the wastewater has high value of TSS, which is 0.168 kg/ton. Thus, the pre-treatment of this fraction should be addressed in this rice mill.

In addition, the Table 4.8 shows the reference values of wastewater characteristic studied from rice mill effluent has oil and grease (lubricant and diesel oil are the major source of this parameter), and suspended solid values are higher than standard regulation. Most of wastewater is generated from the soaking and steaming process which is used high amount of water. The BOD loading in wastewater depends on the contaminated matters in paddy, because the deficient seed cleaning causes the higher contaminate dissolved in soaking-steaming water.

The parboiled rice mill is the major source of wastewater, due to high consumption of water in the process and less management of discharged wastewater. The pollution problems mostly from neglect of operation and maintenance, and inappropriate designed of treatment system. Furthermore, wastewater treatment system is only simple of pre-treatment such the rice mill discharged to the settling pond and storage in oxidation pond before discharge to the canal. Due to the less amount of parboiled rice mill established in

Province (7 parboiled mills), so this problem is not significant impact. However, the wastewater pollution can be caused the compliant and pollution to the local communities.

- **Air pollution and dust generated from boiler**

Emission of particulate represents to the efficiency of boiler and pollution control system of rice mill. The emission standard for rice mill boilers is regulated for particulate from the boiler stack and opacity measure. The rice mill emission was studied; the average particulate from boiler exhaust is 290 mg/m^3 from rice mill (Department of Industrial Works, 2006) but the average particulate from parboiled mill is about 1,200 mg/m^3 and exceed than Particulate standard (value for biomass source is not exceed than 320 mg/m^3).

The noise pollution from rice mill operation also causes significant problems to the health of worker. The local household can effected to the noise when rice mill operated and rice transportation. However, most of the rice mills situated far from the community more than 100-500 m., so it is rather impact to the health and nuisance to the local people in that area.

4.2.3 Rice-based industrial processing in the study area of Chachoengsao Province

This research mentioned in the rice based industry to identify and created the Eco-Industrial Network. The major sector of rice mill is the key point to study in the existing rice production technologies and its environmental implication, production process, material input, product, by-product and waste. Therefore, this part focused on the sample group of rice base industries along the value chain of product, by-product and waste to close the cycle loop of waste. The major types of rice value chain industries (product and non-product) are classified in the following Table 4.9.

Table 4.9 Rice mill and rice by-product industry in Chachoengsao Province

Type of industries	Number of Industrial establishments	
	Province	5 Districts
Total Rice Mill: Parboiled mill White Rice mill	**107** 7 100	**82** 7 75
Noodle/vermicelli	22	17
Seed Oil Extraction	3	1
Wood shaved	25	21
Organic fertilizer	7	5
Maize/soy bean powder	4	2
Animal feed mill	23	20
Small Power Producer	4	2
Total	**195**	**150**

The distribution of rice-base industrial established mostly in the study area of 5 districts, so the relationship of material flow in the area is properly and clearly to identified the existing

situation of material flow networking. The product, by-products from rice mill which identified previously in the Table 4.6 are used in selection the sample of existing rice based industries to create the network and complete the appropriate alternative options.

- **Rice noodle industry**

Fermented rice noodle industry is the one processing products from rice which is one mainly food stuff supplied to Thai people, so the industry is set up and distributed to every region. In Chachoengsao province, the rice noodle industry is well-known as largest source and supplied to Bangkok market and central region. The number of rice noodle industries established in province is 22 industries and 17 industries are set up in 5 districts.

The scale of rice noodle industry is divided into 1) household scale and small scale 2) medium scale and 3) large scale. Mostly of rice noodle industries in Chachoengsao Province are medium and large scale industries which are licensed to factory set up and Thai FDA. The production processes used the raw material such as broken rice, water, fuel, and electricity by inefficiency managed and pollutions is caused from the processes due to wastewater, and solid waste.

From the study of sample rice noodle industry, it situated in Muang district in the rice noodle estate. The business was established for 20 years, with supply noodle product to the local market, Bangkok and peri-urban markets. The rice noodle production capacity is 5 tons/day. Broken rice is used about 1:2 (raw material: product). The quality of broken rice, percentage of amylose in rice, and flour mixture loss during the processing are the variation of raw material used. Loss of noodle is mostly from cooling of vermicelli in extruding process and in process of forming a group of vermicelli, while the starch loss mostly in the extruding process.

Rice noodle production process

The major raw material is rice which chemical compound is in starch form. The starch composed with amylose and amylopectin in different proportion due to variety of rice. The main variety of rice such as Laueg pa tiw variety (non-glutinous rice) due to it has high content of amylase and its texture is suitable to produce rice noodle.

The compositions in rice noodle product are; moisture content 63.2-81.6%, Protein 3.6-7.3%, Fat 0.2-1.5%, Amylose 27.5-34%, Fiber 0.5-1.4% and ash content 0.2-0.9%. The reference of protein content in noodle should contain more than 5% and the noodle characteristic should be a little bit muddy texture (Kraidetch, 1992).

Starch production process is showed in the Figure 4.21; the broken rice is rinsed and clean with water about 2-3 times, and then the rice is fermented in the water storage tank about 3-5 days (make it soft). Rinse again before grinding in the mill and sifting. Then, keeping for one day before dewater by pressing in the cotton sack about 5-6 hours or using compress machine. The cake of flour is finished in this stage.

Flour steaming process; the cake is steamed in the cooking oven for gelatinization about 15-20 minutes. The steamed flour is knead with hot water in mixing machine (pasting) and passes through the filtering machine for uniform flour and separates the flour granules.

Extruding process: The mixed flour is extruded into the cooking with contained boil water. The boiled noodle become to the form of long string. The string is taking out and immediately put into water for cooling. Finally, the noodle string is set into a noodle group by manual and packing into baskets, and foam boxes for distribute and sale to the market.

Mass balance of rice noodle processing

From the production process in rice noodle industry, the mass balance of Figure 4.20 is showed the input, output and waste from rice noodle production process.

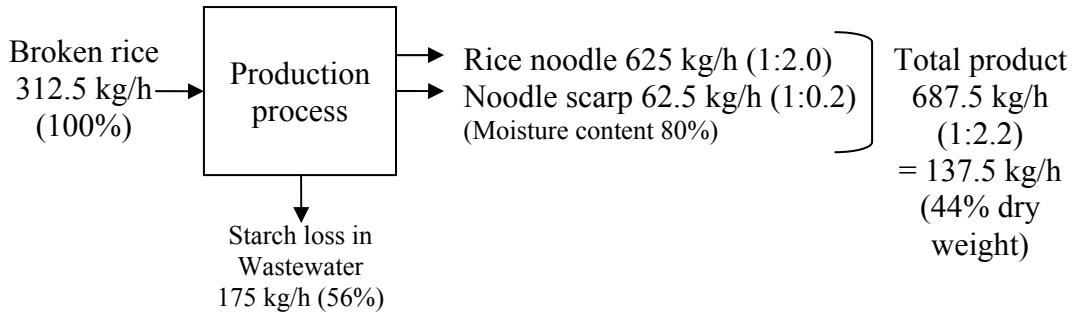


Figure 4.20 Mass balance of rice noodle processing

The data of typical industry are; broken white rice 2.5 tons/day which is imported from North region of Thailand and some of rice is brought inside the province. The working and operation times are 8 hrs/day and 25 days/month. Fermented rice noodle is produced from this industry about 5 tons/day with the sell price 10 Baht/kg. The noodle scrap is the left part with production process about 0.7 tons/day. This part can be sold in lower grade of noodle and sale in scale of basket (not per kg). Some of the scraps are used by the owner of industry in purpose of fish feeding at his pond. The Table 4.10 shows the input and output quantity, its purchasing price and sale price of product and by-product.

Table 4.10 Raw material consumed and product of Rice noodle Industry

Categories	Quantity	Price (Baht/ton)
Input: Broken rice (tons/day)	2.5	1,080
Electricity consumption (kWh/ton product)	83	250
Fuel wood (tons/day)	10	550
Water consumption (m^3/ton product)	20	15
Output: Noodle products (tons/day)	5	10,000
Scrap of noodle (tons/day)	0.7	2,000

The total production of this industry is 687.5 kg/h with moisture content in rice noodle approximately 80%. The total production of noodle in dry weight is 44% of raw material used. The starch loss is retained in wastewater stream is about 56% which is 175 kg/h of broken rice consumed.

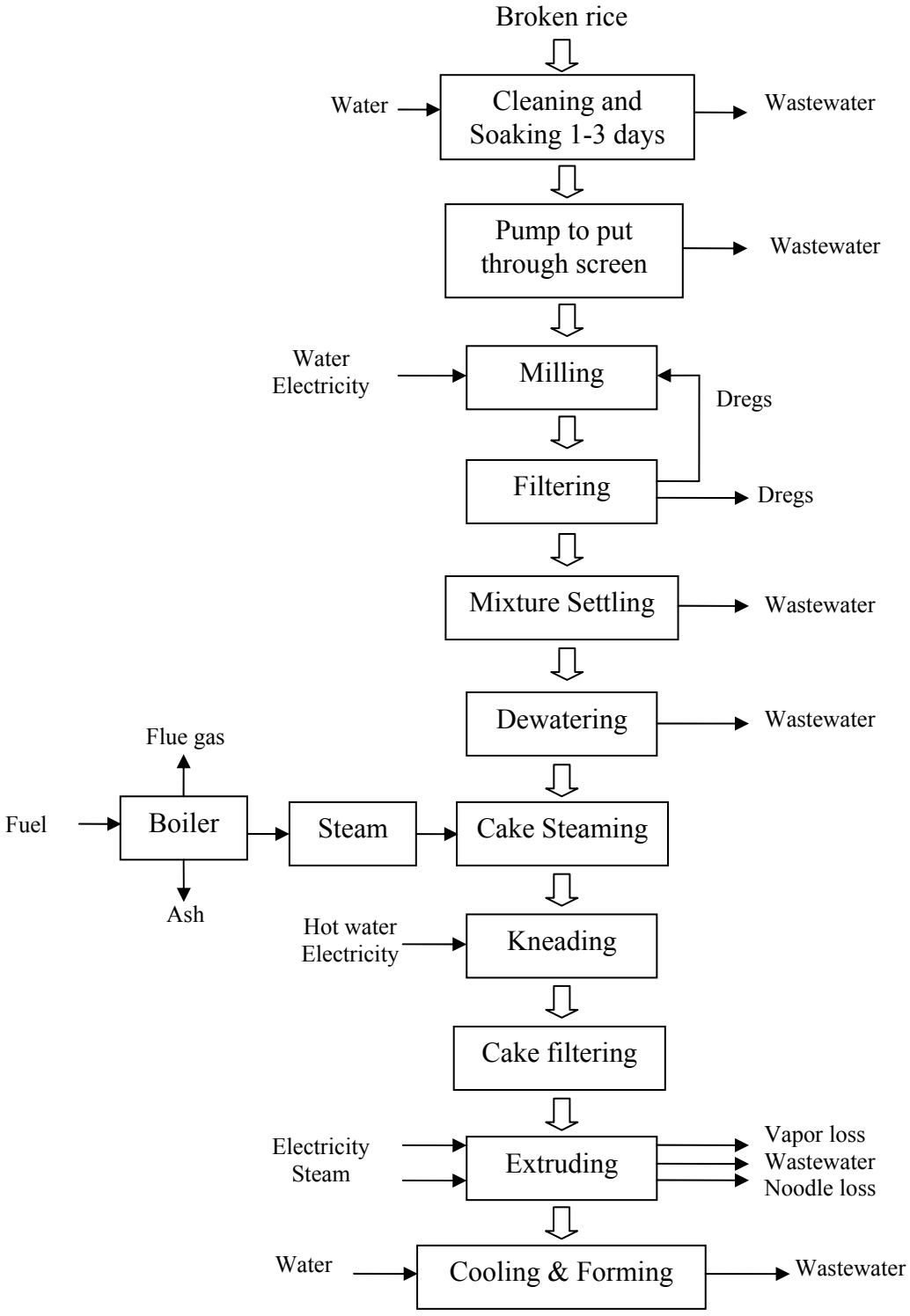


Figure 4.21 Rice noodle production process

Electricity consumption of rice noodle industry is 20,000 kWh/month. Energy consumed approximately about 83 kWh/ton of product. Fuel consumption in the industry also important sources of steam energy, biomass such as fuel wood, wood scrap from furniture manufacture, wood chips etc. are used about 10 tons/day, purchasing price is 55 Baht/ton.

Water consumption

Water sources of rice noodle process in the province are mostly from the river and canal. The industries are established depending on water source. There need improvement of water quality before using in the process. The process is simple, by using coagulant chemical such as alum. This water is used in cleaning and soaking process of rice. However, tap water also used in the rinsing and cooling noodle process due to high quality required in finishing process of noodle.

Water consumption in process is approximately 50 m^3/day (20 m^3/ton of product) and the highest process consumed water is in the process of cooling of noodle. Water using of each industry depends on water cost and water consumer behavior. The water used after processing is turn into wastewater and high value of BOD in the effluent due to the high organic contents.

Wastewater characteristics

The wastewater characteristic is presented from the study report by Shu Li, 1992 of selected rice noodle factory. The general information of factory is consumed of broken rice about 3 tons/day. The loss of rice matter to the wastewater streams are 80-170 kg/ton of broken rice (dry weight). The starch yield is 830-920 kg/ton of broken rice.

Table 4.11 Wastewater characteristic of specific rice noodle industries

Parameters	Water consumption (m^3/ton raw material)	pH	COD (mg/L)	SS (mg/L)
Total process	7-10	-	-	-
Washing process	1-2	8.2	2,620	10,650
Soaking process	1-2	5.4	930-2,760	900
Effluent pond 1	-	5.2	1,325	548
Fish pond	-	7.5	86	100

From the above information of Table 4.11, the rice noodle industry has significance of wastewater pollution. The water consumption and organic loading is mostly from soaking process. However, there is presented one of alternative solution such recycling the wastewater from process to feed the fish in the pond. This method favors to reduce the organic loading in the effluent, while increasing production of fish.

Figure 4.22 Wastewater and treatment pond

In addition, total amount of 17 of rice noodle industry in the study area being consumed the water about 600 m^3/day and all rice noodle industry are generated the BOD loading 253 kg/ton of noodle. However, the sample of rice noodle industry and other industry in noodle estate has discharged the wastewater to the common wastewater treatment system (Figure 4.22). The wastewater from sump of each industry is pumped to the oxidation pond and storage in the clarifier pond before release to the nearby field.

- **Rice bran crude oil industry**

The industry established in Bangpakong district and operated for 21 years ago. The industry installed the extraction unit operation from the investment and technology support of Japanese company (Joint venture). Thus, the extraction efficiency is about 80-90%. The plant can process rice bran 200 tons/day which the plant has two set of production lines (old unit and new unit).

The quality of raw material were preferred of Moisture content 12%, Oil content 18% (white rice bran) and 25% (parboiled rice bran), and Acid value not exceed 15. Due to high acid value presents an old of bran that make the high content of wax in crude oil product (low oil content).

Oil Extraction Process

The Figure 4.23 shows a flow diagram of the oil extraction process. The bran from about 40 rice mills in the study area go to the separator for separation of undesirable material such broken rice and stone from bran. The bran is sent to the heating unit, the two production lines of heating process are selected to operate. Considering of unit use is regulated by amount of rice bran; the new production process line is more suited to the high production capacity of rice bran 200 tons/day. Due to this unit use new technique of bulking pellet bran, it achieved higher oil fraction during extraction process. The conventional production process is able to produce only 70-80 tons/day.

The extraction plant received the heat bran; this plant has several units of extraction process which continuous flow of hexane in the close system and automatically controlling. Subsequently, defatted bran goes to the dryer to reduce moisture content less than 12.5% and miscella (it is mixture of hexane, oil and water) goes to evaporation unit of desolventizer.

The hexane evaporates at 70 °C and it is captured in condensing unit and sent to storage for reuse. The loss of hexane and water should be less than 0.2% in this process. The filtered crude oil is stored in the storage tank. In addition, the defatted rice bran and pellet are sent to separator and grinder unit. Finally, the defatted bran is sold to the retailer for animal feed production.

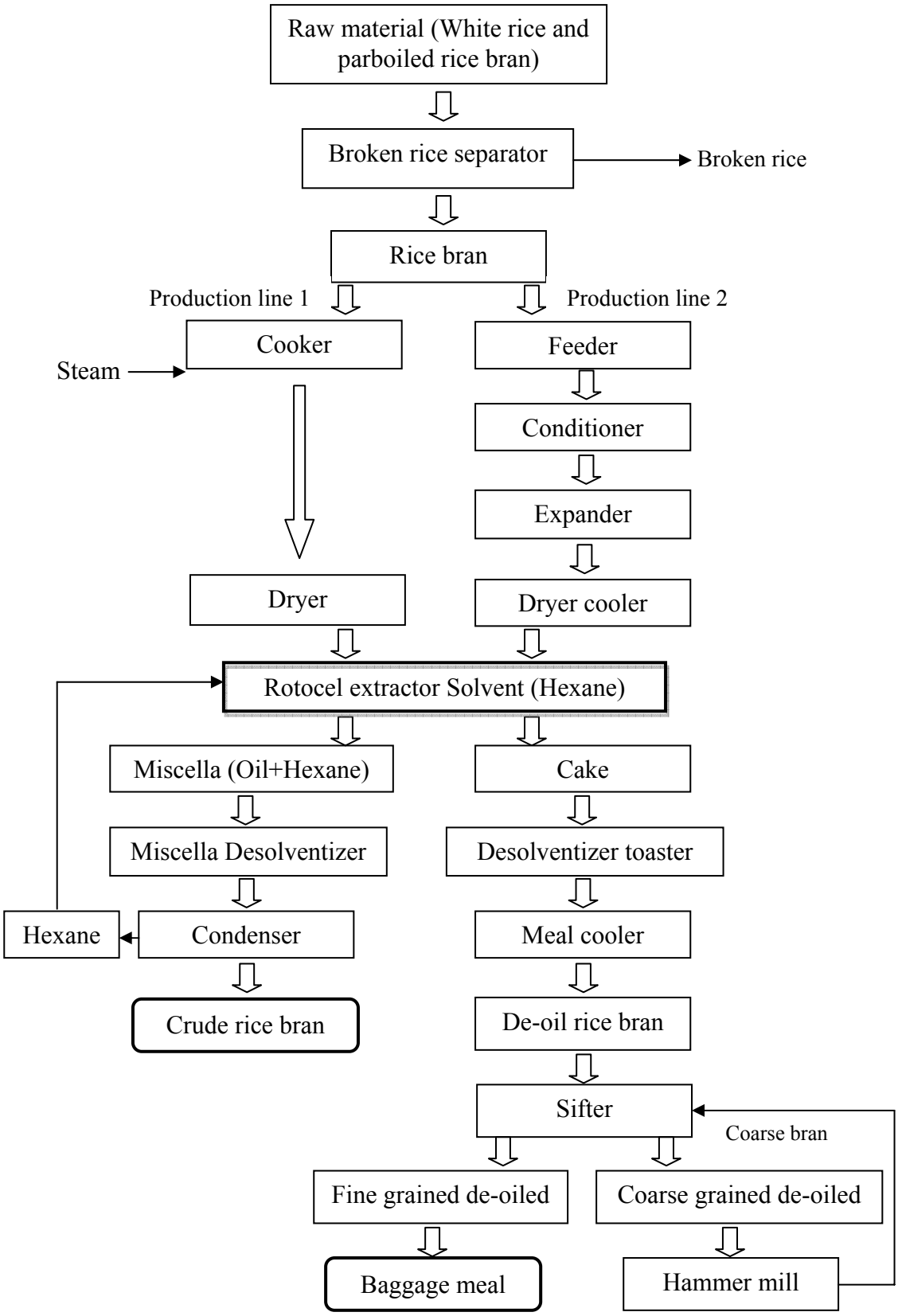


Figure 4.23 Rice bran oil extraction process

Mass balance

The input of the production process is rice bran which contains about 18% oil in raw rice and 25% oil in parboiled rice. The hexane is recycling in plant used that approximately no loss from process. The outputs are defatted bran and wastes and the product of crude rice bran oil to the market (distributor collected it to sale to the animal feed mill and farm for feeding in the region) with the price 18,400 Baht/ton. The mass balance of oil extraction process is shown in Figure 4.24.

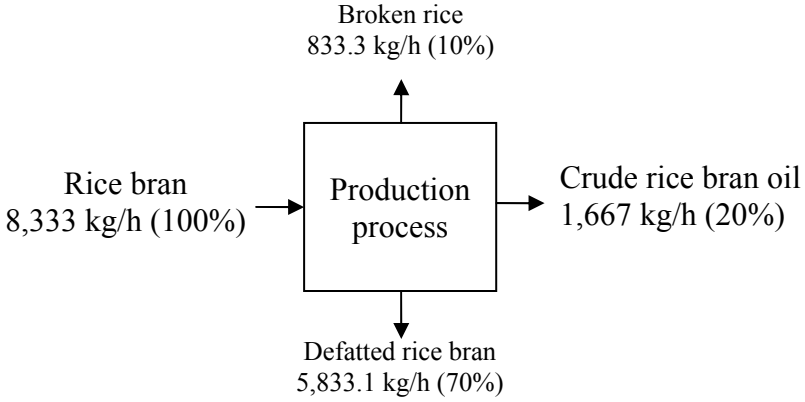


Figure 4.24 Mass balance of rice bran oil processing

The major point of this rice base industry is the link of by-product exchanged between rice bran oil industry and rice husk power plant. The steam is purchased to use in the extraction process from the power supply company (3 MW cogeneration power plant from biomass of rice-husk). The power plant is established by the same joint venture company as rice bran oil industry. Furthermore, the used water from condenser is produced in the process about 90 m^3/day with the sell price 80 Baht/m^3, and then sells to the power plant. The pollution prevention also implemented, the wastewater from the production process is high temperature about 100 °C are circulated in the drainage system around the industry, then storage to the pond in the industry area.

The rice bran oil industry has high technology of extraction and gets support from Japanese. Almost of processes are worked in automatically machine with require high performance of worker to control. The industry registered and operated under the Industry Office of Chachoengsao Province, DIW and Livestock office of Chachoengsao Province (Defatted rice bran production quality control are set every 3 months). National Food Institute relates about R&D of rice bran.

However, the company confronts to the problems of; rice bran is high competition with the other rice bran oil industries in country (about 15 industries and almost are situated in North-East region of Thailand). Rice bran price is increasing continuously due to supply chain since the farmer, rice mill, and wholesaler. The company needs the support from government and promotion about their product has high quality and healthy. Should set the formal team from institutional to research and analyze their products. Then, encourage Thai people to use high quality cooking oil as rice bran oil.

- **Biomass power plant**

The sample of rice husk power plant is situated in Bangpakong District for 16 years. Production capacity of electricity is 10.4 MW/day and with the electric current 3.3 kV. The plant uses rice husk and wood chips as the feed stock. The plant itself uses 1 MW and the excess electricity demand after production is sold to the customers.

The customers are divided into 2 groups: First, EGAT is main customer of purchasing electricity 8 MW/day. The power plant is the Firm-contractor under SPP scheme to sell the electricity to EGAT, with the contract time 25 year since 1999. Second, the group of customers around the power plant area about 1-2 MW/day (depend on the customer consumption need). Especially, the wood chip mill (The same share-holder company which located beside the power plant) is the major consumer of electricity for their operation processes such wood cutting and sizing into wood chips.

Group of customers around the power plant area (Bangpakong district):

- Wood chips mill
- Sag production industry (Sag weaving)
- Rice packaging plant
- Bangpakong warehousing
- Harbor (for ship transportation and logistic of goods)
- Machinery products company
- One company's office
- Staff housing (situated out of the power plant area)

Material and resources consumption

Material consumption of the plant includes raw material use as a fuel source 1.3 kg/kWh, it composed of rice husk and bark. Rice husk 240 tons/day is purchased from the rice mill within the province by the dealer company (contractor). The quality of husk should have moisture content in the range 13-15%. Bark 60 tons/day come from the co-located of wood chips mill. However, the raw material ratio is prioritized from the rice husk due to it has better quality. It controls the additional amount of bark used in the production process.

In the fluidized-bed combustion process, sand 3 tons/day is mixing with the fuel and burning in the 600 °C combustion chamber. De-mineral water about 20-23 m^3/day used in boiler. River water from Bangpakong River (Water pump capacity 3,800 m^3/hr but actually consumption about 70%) is used in cooling process. The stream passes through the screen for pre-treatment, then the water pass through the column for recirculation. Then the stream is returned to the river with the temperature increasing about 10 °C (Effluent temperature about 45 °C).

Production process

The fluidized bed combustion system, the boiler is used the heated de-mineral water to produce the steam. The combustion chamber temperature is about 800-900 °C, while burning of rice husk and wood chips as a fuel source. The steam is produce in the boiler unit to be higher exergy steam, and then run the steam turbine and generator for generating electricity. The flow diagram is showed in the appendix.

Waste generation and treatment

The source of wastewater is the blow down water 20 m^3/day. It is collected to store in the pond before recycle used. By spraying the recycling water, when dump and unload the ashes operation at the plant site. Ash was produced about 40 tons/day and it is collected by the dealer to planting and agricultural farming.

The quality of ash is low graded in purposing use of export for silica content. The power plant decided to produce electricity as the main product and ash is the by-product. The surplus amount of ash is sent to store at the power industry landfill. However, when the dealer needs to purchased the large amount of ash, the company can withdraw the old ash from the power plant's landfill.

Used engine oil about 20 L/month is sent to the boiler by mixing with fuel oil for combustion in the ratio of used engine oil: fuel oil = 1:1,000,000. The Electrostatic Precipitator (ESP) is invested to air pollution control and the consultant company regularly monitoring it. The sand after burning has to be changed every day. Used sand is disposed with the husk ash by dumping to their landfill.

The government support and regulation actors related to the power plant are EGAT, PEA, EPPO, PCD, DIW and Bangpakong municipality. The EPPO has selected the power plant to be the pilot project of biomass to energy, study of thermal conversion efficiency and analyzing the waste characteristic of ash, because it may possibly be hazardous waste. The power plant company is joined to the SPP association and set up the stake holder committees (three firms; industry, government, community) for regularly meeting.

The requirement of this business development has two major issues; Technical support such new technology to adopted and know how in new machinery and power production technologies to increasing production efficiency. Policy support, the power plant company concerns in sale price is too low in the market but high price of raw materials. Due to the competition increasing in joining to the SPP program from others company, then the rice husk price is increased.

4.2.4 Livestock sectors

- **Piggery farm**

The amount and distribution of pig in the study area of 5 districts is showed in the Table 4.12. There has two main types of pig farming; large scale commercial farming and smaller individual for supplementary occupation ones. The amounts of farms are varied due to its short term lead time for each batch of animals such as 4 months for pigs and depend on the market demand.

The farm size can be categorized into 4 groups by using the number of animals such following detail:

- Household size: it has less than 50 animals; the pig feeding is the supplementary occupation of family.
- Small size: it has 50-20 animals; mostly the farm feeding the hogs since it is piglet to increase the weight and sale to the market. Normally, the pig feed is the

premixed food, the prevention of disease system is not well, and the farms have not wastewater treatment system.

- Medium size: it has 201-1,000 animals; this pig farm has developed in farm management and cultivation. The farm has feed the sows and sores to produce the piglet and hog feeding. The farms produce the feed and mixed the compositions used on-farm.
- Large size: it has more than 1,000 animals; this pig farm has completely system management and adopted the high technology in cultivation and diseases control system.

Table 4.12 Distribution and size of pig farm in the study area

District	Size of pig farm				Total farms	Number of 1,000 pigs
	Household	Small	Medium	Large		
Muang	11	32	33	23	99	74
Bangkhla	17	46	90	38	191	276
Bangnamprieo	0	2	1	1	4	3
Bangpakong	0	0	0	0	None	None
Banpho	0	4	13	8	25	26
Total	28	84	137	70	319	379

The pigsty building is made from permanent materials and mostly the hog and sow houses are built in 2 floors for easy cleaning. The slat is adopted to support the floor, for facilitated the cleaning process. Mostly, the farms have animal feed in automatic machine which can be supply the feed 24 hrs. River water (Bangpakong River and canals) is used for pig required about 50 L/day-pig and use in cleaning the pigsty building.

The wastewater characteristics from PCD studied on pig farms in the year 2005, as showed n Table 4.13 the value are differenced depend on each farm management. The major problems are odor and pest, the old type of farm has conventional treatment system such Open pond (Figure 4.25) but it has to use the large area and less maintenance.

Table 4.13 Wastewater generation and characteristic

Characteristic	Farm size	Minimum	Maximum	Average
Generation rate (L/pig/day)	Large	-	-	10
	Medium			15
	Small			20
BOD (mg/L)	Large	1,255	9,000	3,000
	Medium	460	7,650	2,500
	Small	239	19,280	1,500
COD (mg/L)	Large	2,152	18,388	7,000
	Medium	2,578	31,096	6,800
	Small	778	40,000	4,000
SS (mg/L)	Large	1,304	9,530	4,800
	Medium	149	14,500	3,000
	Small	82	1,887	2,000
TKN(mg/L)	Large	367	981	540
	Medium	235	3,371	500
	Small	261	24,480	400

Source: Pollution Control Department (2005)


Figure 4.25 Piggery farming and wastewater treatment

In 2000, the Department of Livestock set up the appropriately pig farming development project. To establish the pig waste treatment system of the pig farms in the region of Bangpakong River Basin and Thachin River Basin. Chachoengsao provincial livestock office was responded to develop the system to 106 pig farms in Chachoengsao Province. Anaerobic filter tank and Stabilization pond system are designed into 4 types and selected the appropriate to the size of farm.

The study area has one farm of pilot project developed under the National Energy Policy and Planning Office. The promotion of biogas production in animal farm project, phase II for small scale. The biogas system (fixed dome) is funded and implemented by Bureau of development and technology transfer, Ministry of Agriculture and Cooperative. The pilot farm is situated in Banpho district, which recently operate and produce biogas in household using.

Table 4.14 Biogas parameters of 1 pig (approximately weight 60 kg)

Description	Value	Unit
Wastewater generation	27	L/day
Biogas production	93	L/day
Organic fertilizer (liquid) or;	0.36	kg/day
Organic fertilizer (solid) moisture content 35%	0.12 (safety~0.10 kg/day)	kg/day

Source: Energy for Environmental Foundation (2007)

From the above information of Table 4.14, the estimation of total production of biogas from pig farm of the whole study area is calculated. The potential biogas production capacity is approximately 35,200 m^3/day due to it mentioned from the total of 379,000 pigs.

- **Poultry farm**

The amount and distribution of duck, broiler, and layer in the study area of 5 districts is showed in the Table 4.15. The most of poultry farming presented in Banpho district with the intensively of the layer to produced eggs.

The cultivation batch of chicken and duck are 45 and 55 days. The cage mostly constructed in single cage (1-2 chicken per one small cage) with row of bars and lifted the cage in the

second floor. Some chicken farm constructed over the fish pond, so the manure directly discharge to the fish pond as a fish feed. The building style mostly is gable proof and prepared 2,000 chicks/building. The cage cleaning operated everyday to collect the fresh solid and sale to the dealer to distribute for agriculture farmer and fertilizer plant in the province. The manure of chicken mostly solid part and one chicken produces manure about 7% of chicken weight.

Table 4.15 Distribution and size of poultry farm in the study area

District	Number of poultry farm			Total
	Duck	Broiler	Layer	
Muang Chachoengsao	1	4	30	35
Bangkhla	15	3	8	26
Bangnamprieo	0	1	39	40
Bangpakong	0	0	4	4
Banpho	42	20	35	97
Total farms	58	28	116	202
Total Number (1,000 birds)	149	659	5,164	5,971

In the year 2003, Chachoengsao province was badly affected areas during that initial outbreak of bird flu. So the farm have to moves to protect poultry through costly bio-security measures have finished off small-time breeding in this province, which has a mix of industrial estates, paddy fields and open, tree-filled areas that are substituted occupation to these poor farmers. Nearly 1,200 small poultry farms have been forced to shut down, because they failed to meet the new bio-security measures. To prevent the spreading of avian influenza in this area, Bureau of Livestock Standard and Certification, the monitoring program are being implemented regularly in this area.

Department of Livestock, responses to following the Ministerial Notification issues in Thailand Livestock Farming Standard 1999. This issue establishes for 3 standards of broiler, swine and milch cow, in order to quality improvement on animal products and farms to complied and meet the national standard and safety for the consumer. It is the voluntary program and cooperative from farmer, the certificated farm can obtained the special service in veterinary process. The scope of standard regulation of chicken farm is broadly about appropriate of solid and chicken waste management. The pig farm standard is regulated in appropriate waste treatment due to solid waste, carcass pig, pig manure and wastewater.

- **Fish cultivation**

Aquaculture in Chachoengsao Province also important in terms of it is the major source of protein feed in this central region. The Province has both fresh water and marine aquaculture. According to the appropriate of features of the land such as Bangpakong River is the major stream is suit to the fresh aquaculture in Bangnamprieo, Bangkhla, Muang, Banpho and empting into the upper gulf of Thailand (Bangpakong estuary). The types and number of aquaculture farms in the study area is showed in the Table 4.16.

The most aquaculture farming in the area is brackish shrimp (low salinity shrimp). The Black Tiger Shrimp is popular cultivated about 71% of total aquaculture area. The well-liked area of shrimp farms are situated in Bangpakong, Banpho and Muang. However,

there has some fish hatchery along the coast in Bangpakong and Muang District. The number of wholesaler and dealer of aquatic animal are 59 entrepreneurs. The wholesaler is playing a major role to distribute the fish and shrimp from farm to the market at Bangkok and peri-urban provinces.

Table 4.16 Types and number of aquaculture and registered farm

Aquaculture Types	Number of farm	Area (Hectare)
Brackish shrimp	13,189	15,565
Fresh fish	3,484	5,823
Brackish fish - Pond - Pen	 81 180	 281 7
Others (Frog, Crocodile)	150	81
Total	17,084	21,757

The shrimp farming is widely cultivated in the province, according to the spread of new technique of low saline tiger shrimp cultivation and high value of shrimp in the market. The rapid emergence of low salinity shrimp farming within inland freshwater areas has risen. The pollution from low salinity shrimp farm can be divided in 3 types; effluent during shrimp cultivation, effluent during harvesting, and sludge discharge.

Larger shrimp require substantial feed inputs and more frequent water exchanges to maintain a suitable growing environment. Uneaten food pellets, faeces, and eroded pond soil tend to accumulate at the center of the pond. The open system of shrimp pond generated the high pollution of untreated wastewater. Wastewater discharge from shrimp cultivation and harvesting two cycles in one year, the wastewater discharge is shown in the Table 4.17.

Table 4.17 Wastewater discharge from shrimp cultivation and harvesting

Parameter	One cycle	Whole Year (2 cycles)	Unit
Wastewater generation	288	576	m^3/ha
BOD loading	192	384	kg/ha
TKN loading	0.12	0.23	kg/ha
Salinity	3-10		ppt

Wastewater treatment is operated in some shrimp farm before discharge to the water bodies. Most of the wastewater was directly discharged from the open system pond, while the close system has not the effluent from farm. In addition, the fish farm wastewater is approximated values with shrimp farm but it has not salinity in wastewater.

The pollution from shrimp farming is the one source of degradation to the water quality of Bangpakong River and cumulative effect to this region. The Department of fisheries established the voluntary program of Thai quality shrimp in the schemes of Code of Conduct Standard (COC) and Good Aquaculture Practice Standard (GAP). However, these programs are in the earlier stage of developing and promoting.

4.3 Rice based Eco-Industrial network

Based on the earlier part, the rice-based eco-industrial network of the study area can be developed to close the loop of natural resource consumption and environmental impacts. The actual linkages between the studied of rice-based industries and other sector unit involved the complex flow of material inputs and outputs of by-products and waste is presented in the Figure 4.26.

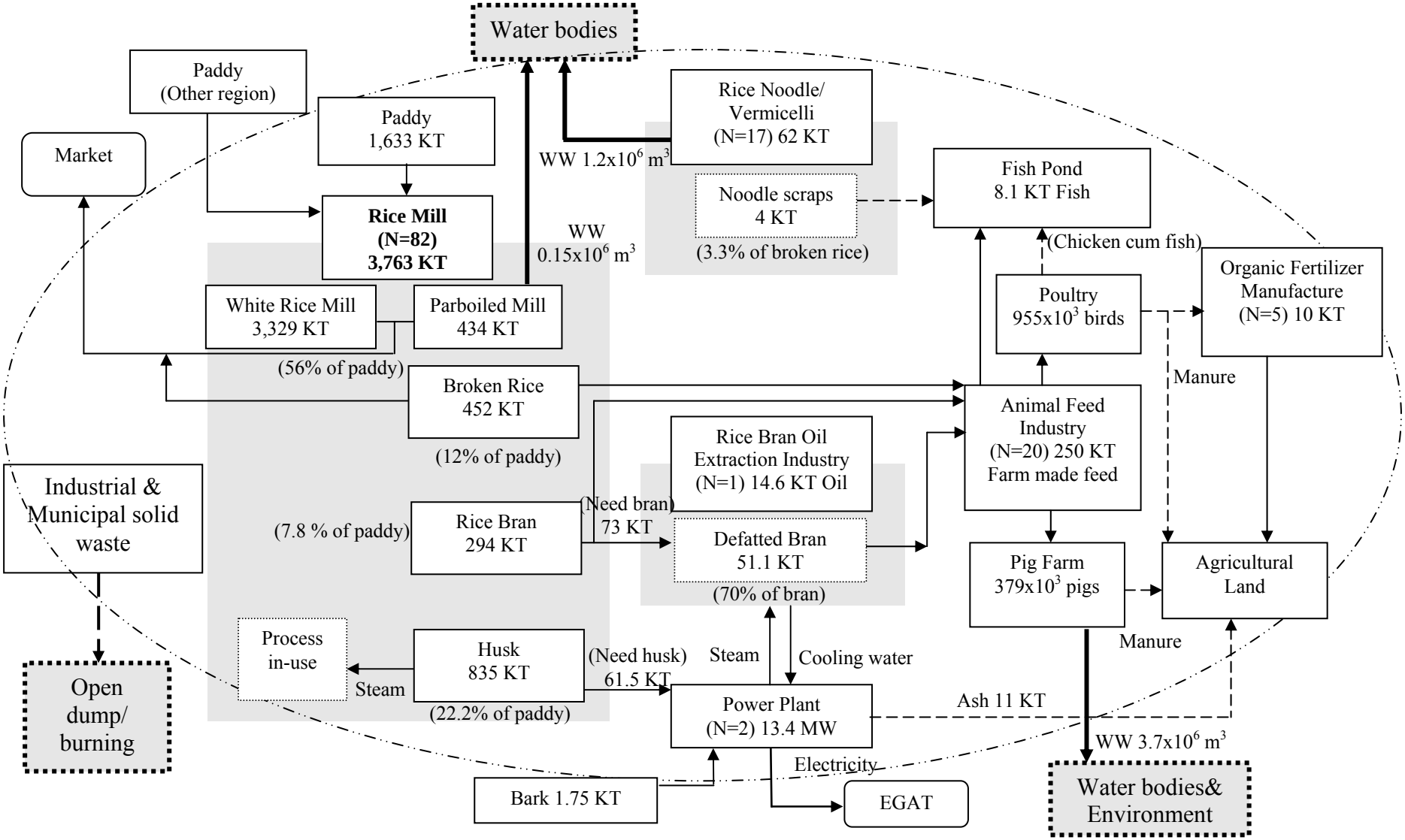


Figure 4.26 Actual Rice-based Material Flow Network in the study area

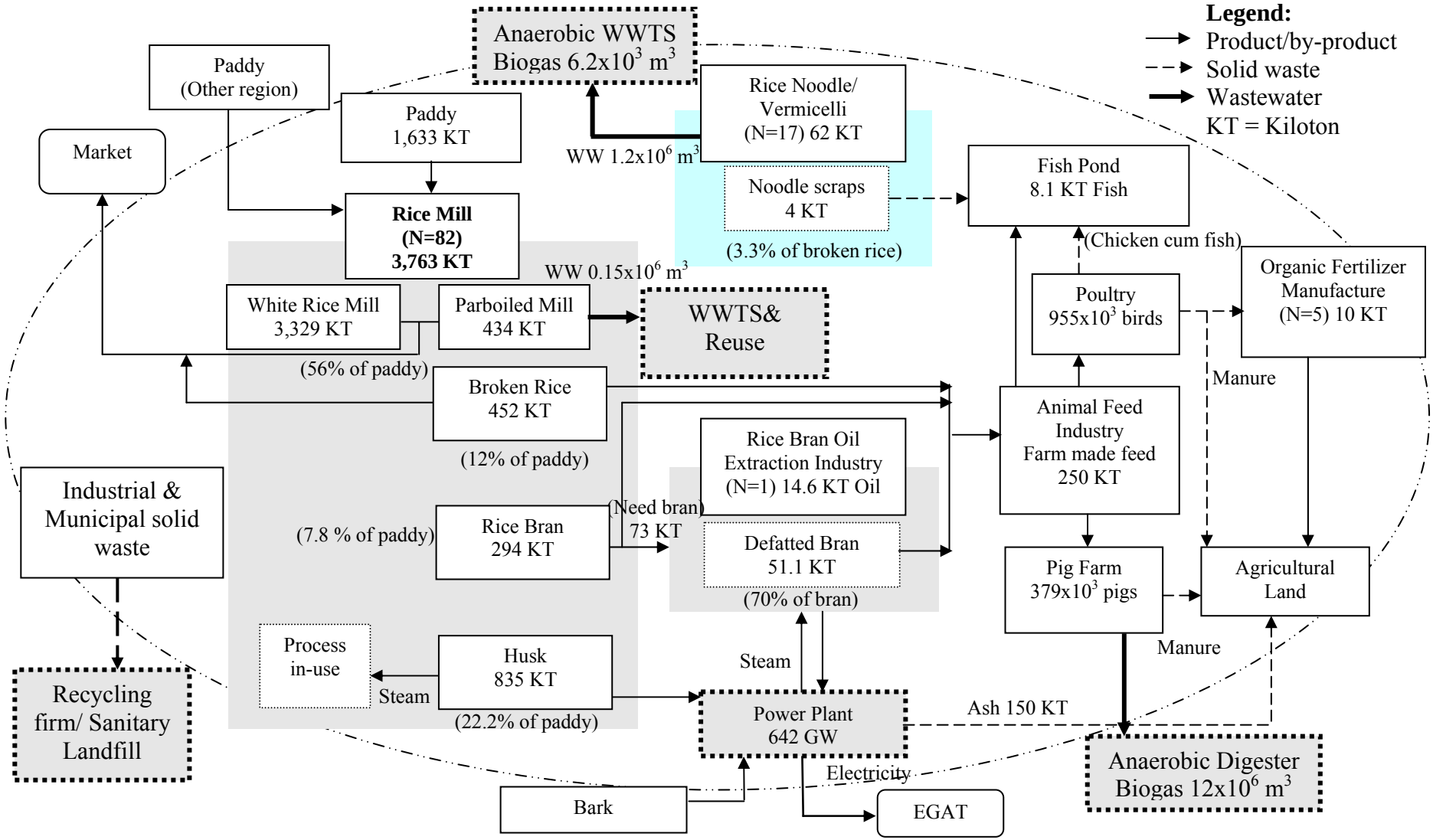


Figure 4.27 Rice-based Material Flow of Agro Eco-Industrial Network

4.4 The calculation explanation of material flow network

All the summarized data from previous part and the calculated information in this part facilitated to explain the formation of Agro Eco-Industrial Network of rice-based industry. The yearly production capacities of each type of industries that presented in the studied area are used in network to find out their presents production situation. The number and calculation value are presented in Table 4.18.

Table 4.18 Number of each types of factory in Network of the study area

Type of industries	Number of Industrial related to Rice-base EIN in 5 Districts	Production Capacity per one industry (Tons/year)	Whole industries (Tons/year of paddy)
Rice Mill:	**82**		**3,763,150**
Parboiled mill	7 (170 t/d of product)	62,050	434,350
White Rice mill	75 (120 t/d of product)	43,800	3,328,800
Noodle/vermicelli	17 (10 t/d of product)	3,650	62,050
Seed Oil Extraction	1 (42 t/d of product)	15,330	15,330
Wood shaved	21	-	-
Organic fertilizer	5	2,000	10,000
Maize/soy bean powder	2	30	60
Animal feed mill	20	50	1,000
Small Power Producer	2	10.4MW+3MW	-
Total	151		

Rice Production, are averaged from the information on the relation of power of machine production and Rice production of several industries in the 5 districts. The production capacity of rice mill is used the paddy consumed in production. The by-products composition of rice mill is calculated from the rice mill reference established.

The production capacity number of other industries in the network is used from the field survey. The production of industry also depended on the raw material (some sector demand is higher than supply), then the raw material has to imported from other regions such as paddy, husk. Agriculture and livestock is the role of organic waste recycling firm for the agro-industry, that they obtained the entire biodegradable residue in appropriate used from each type of industrial by-products and waste.

The purposed material network is showed in Figure 4.27. The proposal of new linkages to close the cycle of this AEIN are Biogas digester both rice noodle production and livestock especially piggery farm. The overview of technologies and environmental management is presented following this part.

4.5 Technology needs for EIN formation

Most of the small businesses in the region are driven by raw material availability and income generation than for increasing markets. Therefore the need to shift to advanced technologies has not yet been considered by the entrepreneurs. The following technologies are essential for the transformation to an eco-industrial cluster.

Paddy straw and Rice Husk

The transformation of the rice cluster as a part of an eco-industrial could be achieved by making the best possible use of the materials. These agricultural residues, paddy straw and rice husk could be used to generate electricity for in-house consumption or for exporting to the grid. For example, the 15 MJ/kg of energy potential of rice straw is used for thermal energy generation. This could be more efficiently used to generate electricity and save budgets on importing fossil fuels in addition to the environmental benefits.

Energy consumption in rice mills varies depending on whether the mill produces parboiled rice or white rice, while the parboiling consumes more energy. The energy required for the rice mill can be obtained from the utilization of the husks. In many mills, rice husk is burned under very low efficiency furnaces leaving black ash with high percentage of unburned carbon.

Assuming that all rice husks are utilized for power generation, and a specific consumption of 2 kg/kWh the theoretical power potential is considerable that it cannot be put to any simple use. Nevertheless, a consistent and stable supply of paddy for milling and rice straw is essential to establish and operate the electricity generation system. Therefore, the size of the individual mill and its supply chain are key factors in determining the feasibility of generating power.

An alternative use of Rice Husk Ash, with 85-90% silica content, rice husk ash can be used in the in the production of special cement and concrete mixes, high performance concrete, high strength, low permeability concrete for use in bridges, marine environments, power plants etc.

Rice Processing Units

The rice processing units in the region are typically small and medium enterprises with limited funds and relatively intermediate technology. Some industries have been using superior technologies, most of them are limited to improving productivity, reducing energy and raw material consumption, and increasing profits. Little industries have implemented waste recovery or wastewater treatment systems. Therefore, the principle of Cleaner Production and Technology should be applied to increasing production efficiency with environmental concern to each enterprise such as rice mill, rice noodle industry.

Essential technologies for rice processing industries include recovery of starch from wastewater and biogas wastewater treatment systems. Some research has been carried out in the production of ethanol from rice processing wastewater.

Piggery

The piggery sector in the study region has been following various innovative and modern industrial farms. However, all these have been formulated and implemented in improving productivity. Very little is focused on waste disposal issues and environmental concerns.

Integration of waste handling and treatment systems in the business is essential to favor growth and sustainability. Anaerobic digestion of piggery waste has been widely tried and tested in many countries across the world. The piggery sector needs to be familiarized with this technology as a means of reducing cost through parallel businesses of electricity generation from biogas generated in anaerobic digesters. The digestate and wastewater resulting from the digestion process can be used as organic fertilizer in agricultural fields.

Poultry

The open dumping of this poultry litter releases huge amounts of methane due to uncontrolled anaerobic digestion. Technology for high rate bio-methanation is essential in this region to recover resources.

4.6 Policies

This part deals with the existing industrial environmental policy framework that enterprises are set in. The actors and different of organizations play in the industrial development and environmental management are described. The policy network is involving of the rice-based processing in the province, also described by the roles of actors and policy situation at different level. That focusing how they can push towards a balanced concept of eco-industrial network.

4.6.1 Government administration system in Thailand

The Royal Thai Government's administration includes three levels: Central, Regional, and Local (Suwanmala, 2002) as shown in Appendix. The provinces ruled by provincial governors and districts by district chiefs. The organizations have the different respect to their operational frameworks. However, there have operated to comply with the NESDB plans and closely linking between organizations. The organizations can divided into many sections, nevertheless this research focused in the policies related to the industrial, environmental, economic and social that related to Agro Eco-Industrial Network (AEIN) as shown in Figure 4.28.

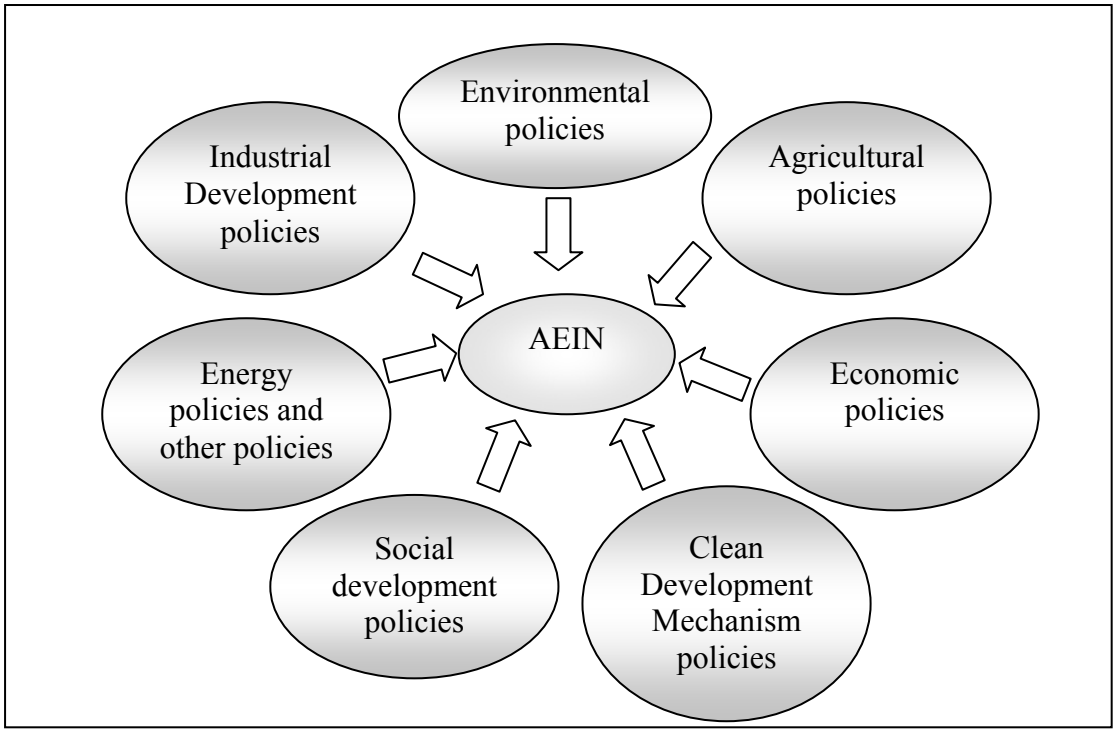


Figure 4.28 Policies affected to Agro Eco-Industrial Network

The environmental problems resulting from pressures are imposed by rapid industrialization and urbanization and also economic growth. Thus, the country has high potential to achieve sustainable development. The Thai Government has established a policy for industrial development and sustainable use of natural resources. The frameworks of industrial approach to environmental policy are established in the national economic and social development plans and other governmental agencies. This framework is now being translated into specific actions and projects at the local, national and international levels.

Institutions responsible for policies and strategies can be identified as major direct government agencies and indirect agencies that are in charge of various aspects as shown in the Figure 4.29. The institutional who affected to the other economic parts that linked in the AEIN also including explored.

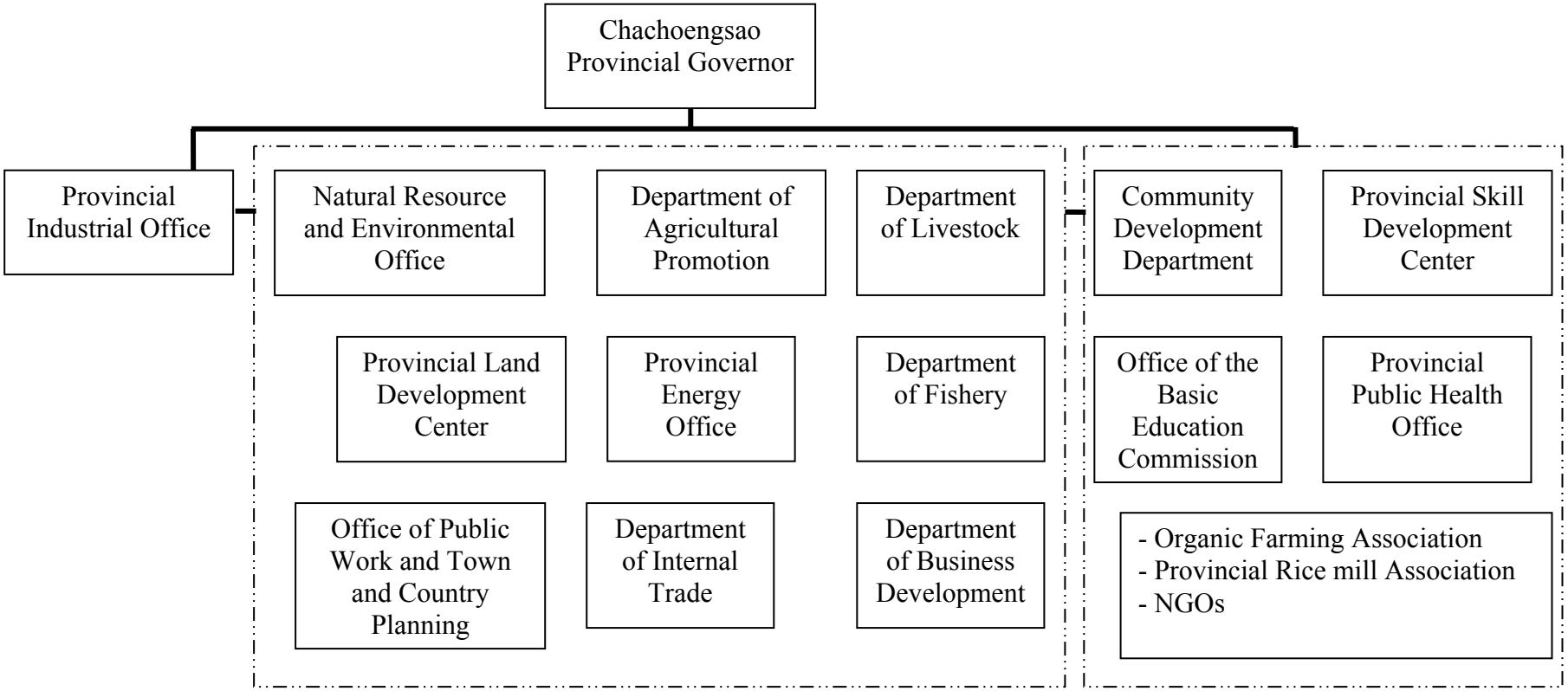


Figure 4.29 Local Administrative Organization affected to AEIN

4.6.2 National Level

The Thai government is composed of the Prime Minister's office and 19 ministry's offices and under this have departments which carry out the actual implementation of policies (Thai Government, 2007). These major agencies have formulated policies, strategies and plans such as following;

- The National Economic and Social Development Board (NESDB) is responsible for formulating overall development policies, strategies, plans, targets and guidelines for the industrial sector.
- The Ministry of Industry (MOI) is responsible for factory licenses, industrial regulations, and enforces laws giving industrial zones and estates. It also provides technical assistance, management training for the industrial sector.
- The Ministry of Finance (MOF) is responsible for taxes, duties and levies imposed on industries. It is also responsible for policies on tax concession to industrial development.
- The Board of Investment (BOI) is responsible to provide or facilitate industrial infrastructure for investors, it also offers incentives to investor such as one stop services.
- The Ministry of Commerce (MOC) has controlled prices and international trade.
- The Industrial Finance Corporation of Thailand (IFCT) offer credit medium and large scale firms through government and private sector channels.
- The Bank of Thailand (BOT) provides foreign exchange and rediscount facilities to selected industries and exporters.
- The Industrial Estates Authority of Thailand (IEAT) offers industrial estates and infrastructure for investors and also responsible for managing industrial estates.

These institutional have formed the National industrial Committee which duty and function to formulate and supervise the industrial sector. They are responsible for coordination and implementation process in policies, strategies, plans and works. The NSDB is the core agency that provides the studies and analysis to back up the planning of macro and sector plan. All the government agencies have to follow up this plan to achieve the development goal of nation.

Other indirect institutional also indicated to support the development policies, in order to formulate and implementation of policies, strategies and plans. The indirect agencies are describing the major department under ministries and its role and function in Appendix.

Recently, The Royal Thai Government and its 9th NESDB (2002-2006) emphasis six industrial policies as follows;

- Restructure the industrial sector and promote investment consistent with the national targets and development strategies, while taking into consideration the country's natural resources, traditional and proven Thai skills and local knowledge, potential in the area of production and marketing, and the need to strike a balance between utilization of domestic or imported raw materials.
- Promote the development of basic industries and linkages with related supporting industries.
- Development skilled personnel and labor in the industrial sector inline with future industrial development strategies. Support measures to increase value added in

industrial production. Promote and develop production processes that are of a high standard, pollution free or low environmental impact, while ensuring transparency and efficiency in management.

- Develop small and medium-size industries to play a significant role in the development of the country's industrial sector by supporting and promoting cooperation in research and development of technology and product among the public and/or private and educational institutions as well as the creation of an information network concerning production and marketing factors.
- Promote the role of financial institutions by supporting the establishment and operations of a venture capital fund as well as facilitated for guaranteeing credits for the development of small and medium-size industries.
- Support the growth of new entrepreneurs in small and medium-size industrial business in the new knowledge based economy.

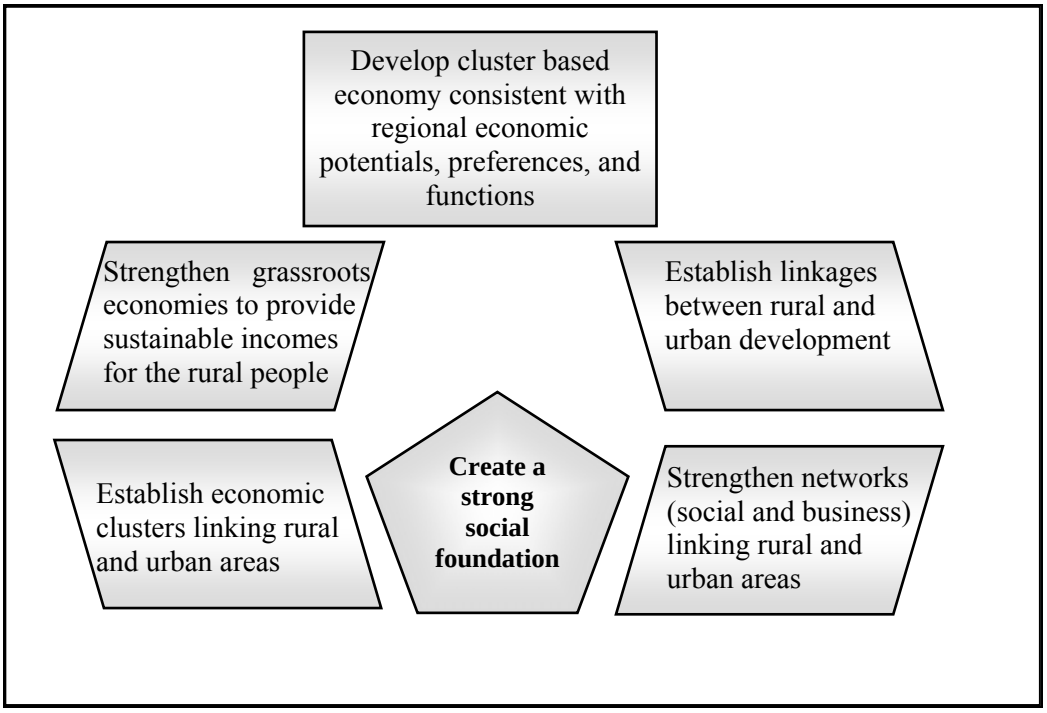


Figure 4.30 Action Plans for the 9th NESD Plan: Drive on Cluster development

- **Industrial Policy**

Therefore, the MOI formulated four policies to supporting these policies from NESDB for 2 national industrial policies;

- Provide assistance to reduce production costs in industrial plants through consulting services by improving production process and management, reduce energy cost, save energy and use alternative energy.
- Develop capacity of personnel both in the public and private sectors in the fields of modern production technology, environmental management, industrial safety and the adaptation of international standards i.e. ISO 9000, ISO 14000, ISO18000 and HACCP to be ready for the adaptation towards the new economy and supporting new economy and supporting new small and medium entrepreneurs towards the knowledge-based economy.

- Encourage measures to increase value-addition to industrial products and increase productivity in the industrial sector in the competition and sustainable development.
- Supervise factories with high risk and pollution, then encourage them to relocate in industrial estates, reduce industry's hazardous wastes by not less than 50% as well as promote the implementation of appropriate technology by focusing on quality of environment and safety in industrial plants such as improving standard on air pollution management, keeping air pollution control within standard, imposing strict measures for business which is the source of pollution and promoting clean production so that local authorities can jointly supervise factories through transparent and efficient management system.

Implementation of policy needs several of policy tools and instruments Organization such as Public enterprise, Public services, Taxation, Commercial, Financial, Procurement, Legal and regulatory, Political, Scientific and technical, Information, Education and Oversee agent. The respective government agencies are responded to introduce and set up these tools of policy to support the agro-industry, the organizations such as POM, NESDB, BOI, MOI, MOSTE, MOF, MOC, MOE, MOAC and MOL.

The regulatory measures always used by laws, acts, and regulations for supporting industrial policies which are linking to the network. The hierarchy of laws is as follows; 1) The Constitution; 2) Acts, passed by the Parliament and 3) Regulations and Notifications enacted by the respective Ministries. The main regulations putting integrated into the industrial sector are following this. Example of regulatory and law of rice mill is presented in Appendix as a case of incorporated law using in rice base industry.

- The Factory Act, B.E. 2535 (1992); MOI has created the ministerial rules that every factory under this act must comply and respect to the standards, location, methods, documentation, etc.
- Enhancement and Conservation of National Environmental Quality Act, B.E. 2535 (1992)
- The Hazardous Substances Act, B.E. 2535 (1992)
- The Public Health Act, B.E. 2535 (1992)
- Foreign Business Act, B.E. 2542 (1999)

Department of Industrial works

The department implementing the government service system capability development plan by providing the organization to the industrial business operators and the people. The agency responses to the service works such as; Machine registration, Industrial environment technology, Hazardous substances control, Factory control and inspection, Industrial registration, Safety technology, and Information center for industrial management and development. There has own policies to support the industrial sector in;

- Supervise and coordinate industrial business operation activities by following the guidelines of environmental preservation, safety, hygiene and energy economization
- Promote and support the capability and efficiency development of industrial business operation for sustained development

- Serve as the national information center for industrial works, machines, chemical substances, hazardous substances and volatile substances
- Look after the country's interests in international agreements regarding environment, safety and security

Department of Industrial Promotion

The department is the agency under Ministry of Industry, the leading of SMEs promotion and development, and responsibility to follow the guideline of MOI and Nation plan to involving their own policies to support the industrial sector. The policies are as followed;

- Encouraging investment in SMEs by; transferring knowledge to rural entrepreneurs, providing advice and incubator service, promoting use of consultancy fund for developing SMEs in rural area, carring the career training for cottage and handicraft to local, and providing investment loans for them.
- Encouraging the dispersal of urban industries to rural areas by; preparing the industrial feasibility studies, stimulating to investors, and providing information service for new entrepreneur.
- Establishing industrial networks by; promoting rural industries in form of community industries, promoting linkages between large and small industries, coordinating with government financial agency for loan.
- Promoting investors in highly potential industrial sectors and enhance the competitiveness of Thai industries by; Encouraging investment in and developing technological of SME supporting industries, and undertaking activities according to the master plan for the development of supporting industries.
- Enhancing the competitiveness of export-oriented industries.

The cluster development project was initiated following the SME promoting, the DIP's project aimed to developing mechanisms for sustainable cluster development. The piloted projects of three industries are selected, based on the concentration and distribution in area, impact to the economy, consistency with national policies and criteria. The one major project is of Food processing cluster in the Bangkok and peri-urban areas, the strategies of cluster development are exchanging their views, brainstorming, set up the common goal and vision, developing the business by increasing their capacity in terms of economic, innovation, production technology, and human resource.

Board of Investment Policy

Board of Investment suppose it appropriate to adjust Thai investment promotion policies and criteria for granting tax privileges in order to respond to the current and future economic and investment situation. The Board of Investment Announcement No. 1/2536 Re: Policies and Criteria for Investment Promotion and they prescribes the following policies and criteria for investment promotion;

- Every promoted project that has investment capital of 10 million baht and upwards (excluding land and working capital) must obtain ISO 9000 certification or similar international certification. This is to promote development of quality and production standards in Thai industries and, thereby, to enhance the competitiveness of Thai industry in the world market.

- Special promotion shall be given to regions or areas with low income and inadequate investment facilities. Maximum tax and duty privileges shall be given to these regions or areas.
- Importance is given to small and medium industries by applying a minimum level of investment capital of 1 million baht (excluding cost of land and working capital) for projects eligible for promotion.
- Priority is given to activities in agriculture and agricultural products, projects related to technological and human resource development, public utilities and infrastructure, environmental protection and conservation and targeted industries.

Criteria for Project Approval

In determining the suitability of a project for which investment promotion privileges are requested, the Board of Investment applies the criteria: the environmental criteria are also used for a project with investment capital (excluding cost of land and working capital) not exceeding 500 million baht, such; Adequate environmental protection systems are installed. For projects with a potential environmental threat, the Board shall prescribe special conditions on both the location of the project and the manner of pollution treatment.

Investment Zones and Criteria for Granting Tax and Duty Privileges

Zone 1; Approved projects located in Bangkok, Nakhon Pathom, Nonthaburi, Pathum Thani, Samut Prakan and Samut Sakhon shall be granted.
Zone 2; Approved projects located in Kanchanaburi, Chachoengsao, Chon Buri, Nakhon Nayok, Ayutthaya, Phuket, Rayong, Ratchaburi, Samut Songkhram, Saraburi, Suphanburi and Ang Thong shall be granted

Zone 3; Approved projects located in the remaining 58 provinces shall be granted.

All the zones are designed due to the consideration of supporting industrial investment promotion policies, to enhancement and promoting development to the regions and industrial setting up in the industrial estate zone.

Priority Activities

The Board places priority on promoting the following types of projects:

- Agriculture and agricultural products
- Direct involvement in technological and human resource development
- Public utilities and infrastructure
- Environmental protection and conservation
- Targeted industries

The projects will be entitled to the following privileges:

- Exemption of import duty on machinery regardless of location
- Corporate income tax exemption for eight years, regardless of location
- Other privileges entitled for each Zone

- **Environmental Policy**

The Ministry of Science, Technology and Environment (Recently, reforming to be Ministry of Natural Resource and Environment) is the body in charge of dealing with environmental issues in Thailand, through the environmental law “Enhancement and

Conservation of National Environmental Quality Act 1992". MOSTE, immediately after this law created 3 new departments in charge of environmental works; the Office of Environmental Policy and Planning (OEPP), The pollution Control Department (PCD) and the Department of Environmental Quality Promotion (DEQP).

National Environmental Board (NEB) presided by the Prime Minister, with the permanent secretary of MOSTE as the NEB's secretary. The policy and plans are then carried out by the OEPP, with part funding from the Environmental Fund. Pollution monitoring and control is performed by the PCD, which proposes the pollution discharge limits or pollution discharge standards, to the pollution Control Committee and the NEB. The approval limits are then announced by MOSTE.

The main policy for Enhancement and Conservation of National Environmental Quality for 1997-2016 consists of the following elements:

- Policy on Natural Resources
- Policy on Pollution
- Policy on Natural and Cultural Environments
- Policy on Community Environment
- Policy on Environment Education and Promotion
- Policy on Environmental Technology.

These issues of managing environmental quality are followed to the vision of; firstly, Natural resources are the base for SD, then utilization of these for economic development purposes is based on conservation and social justice. Secondly, administration and management of environmental quality are decentralized to be effective, with power being transferred from central offices to local institutions. Thus, all government agencies, the private sector, NGOs and local institutions can participate in formation of policy and planning and monitoring program. The last, people have awareness and are willing to work together to protect, and rehabilitate environmental quality.

- **Clean Development Mechanism Policy**

The status of CDM has beginning from Thailand in the international climate change scene. Thailand signed the Kyoto Protocol on 2 February 1999 and ratified it on 28 August 2002 (Jessie, 2007). The significance of the ratification for Thailand is that it could eventually claim the full benefits from CDM projects when the Kyoto Protocol enters into force. The government of Thailand issued a Cabinet Resolution on 1 July 2003 establishing the MONRE as the CDM designated national Authority (DNA). Also, included in this resolution are the establishment of the National Committee on Climate Change (NCCC) and the National CDM Advisory Board (NCAB).

The DNA unit will look at CDM projects with respect to satisfying sustainable development criteria, environmental impact assessment, and public participation. Also the unit will have an information center that caters to CDM investors and other stakeholders.

Major issues of GHG emissions of more than two-thirds of the total net emissions are CO_2 with methane accounting for 27%. CO_2 emissions come mainly from the energy sector and it has increasing trends from 1990 to 1998. These indicate that huge opportunities for GHG mitigation are found in the energy sector. In addition, Thailand's plans and programs in sustainable energy development are probably more advanced than other ASEAN countries,

particularly in the areas of energy efficiency and green independent power production or electricity production from new renewable energy sources.

The least-cost options in the energy sector that will contribute to further reductions in GHG emissions (ADB, 1998), the mitigation options were found to have net economic benefits and significant in Thailand as following this:

- Improving efficiency of existing facilities
- Adopting more energy efficient techniques in new capital stock
- Utilizing low emissions energy sources
- cogeneration in industrial sector
- increase in oil boiler efficiency in industrial sector
- application of efficient motors in industrial sector
- utilizing or switching to cleaner fuels

Through the CDM and international emission trading schemes, emission reductions generated from energy projects can be sold and carbon sales would provide additional cash inflows to the project to cover a portion of financing requirements. The strongest CDM candidates in Thailand are green IPP projects and power plant projects that are using renewable energy sources or wastes and designed to sell to the grid.

- **Power Generation Policy**

Electricity Generation Authority of Thailand (EGAT) is the sole body responsible for the generation, transmission and distribution and sale of electricity in Thailand. Realizing the threats to the national energy security, however, EGAT allows private promoters, technically referred to as Independent Power Producers, to establish and operate power generation projects and buys the electricity at nominal rates.

The power generation sector is usually categorized under the large scale business and is subject to significant investment and market risks. Nevertheless, the EGAT has also realized the power generation potential from biomass sources and allows generation at relatively smaller scales under special arrangements known as Small Power Producers (SPP) and Very Small Power Producers (VSPP). Table 4.19 presents an overview of the concessions for SPP and VSPP in Thailand.

Table 4.19 Small and Very Small Power Purchase Agreements in Thailand

Small Power Producers	Very Small Power Producers
▪ Co-generators or facilities using renewable energy fuels, ▪ Sell power to EGAT of not more than 90 MW for each project. ▪ Minimum purchase guarantee – not less than 80% ▪ Allows direct sale to industrial estates near the power plants	▪ Installed capacity of less than 1 MW ▪ Agricultural residues and wastes from agro industries (e.g. rice husk) ▪ Products converted from agricultural residues, and wastes from agricultural or industrial production processes. (e.g. tapioca wastewater) ▪ Municipal waste: RDF, Bio-methanation

Source: EPPO, 2007

The Renewable Portfolio Standard (RPS) is a flexible, market-driven policy that can ensure that the public benefits of wind, solar, biomass, and geothermal energy continue to be recognized as electricity markets become more competitive. The policy ensures that a minimum amount of renewable energy is included in the portfolio of electricity resources serving a state or country, and by increasing the required amount over time the RPS can put the electricity industry on a path toward increasing sustainability.

Thailand aims to increase renewable energy production of 0.5% in 2002 to 8% in 2011 by following RPS of 5%. Accordingly, new power plants need to generate 5% energy from renewable sources (solar, wind, biomass, solid waste and hydropower). Renewable Portfolio Standard, an innovative power purchase policy. Essentially, power generators under these special arrangements use biomass and biomass residues as fuels for power generation. In most cases, combined heat and power generators utilize the thermal energy and part of the generated electricity for in-plant purposes and sell the excess to EGAT.

- **Eco-industrial development policy**

The Industrial Estates Authority of Thailand has starting Eco-Industrial Estate that provided the vision for the development as “To apply the eco-industrial concept as the main strategy for future Thai industrial estate development” with the objective “to reduce the environmental impact and enhance business and social performance using the EIE principles, then expand to be come Eco-industrial Network and develop a stable and lasting industrial estate network for the nation”. The pilot projects are set in the plan and they are located in 5 industrial estates;

- Map Tap Phut Industrial Estate will serve as the key case for Eco-forum, Eco-plant, Eco-industrial estate and Eco-networking,
- Bang Poo Industrial Estate will serve as the center of implementing the "Clean & Clear" concept using environmental management measures, including Cleaner Technology, Green Productivity, EMS/ISO 14001 etc.
- Northern Region Industrial Estate (Lampoon) will serve as the center for waste management with emphasis on adding value and exchange of waste/by-products.
- Eastern Seaboard Industrial Estate will serve as center for water management
- Amata Nakorn Industrial Estate will serve as center for labor management

Eco-Industrial Estates refers to a group of production and service business operators seeking to raise standards of environmental quality, business performance and good relationship with neighboring communities through collaboration on natural resource and environmental management. Eco-development concerning industrial estates has focuses on the values and perceptions of the local population to improve the basic needs of the human welfare.

4.6.3 Policy Network

The policy network involving in the agro-based industry in Chachoengsao province, are also described in Figure 4.29. The relationship and linking between Central and Local Administration of the policies are in the vertical link. The Provincial Governor plays the important role as the center oversees the government organization. All the government office such provincial, districts, sub-districts and villages are locates in the province. The Provincial Governor has conveyed the Chachoengsao Provincial Development Strategies

from the Regional Development Strategies, set up by the group of 5 provinces in the eastern region are; Chachoengsao, Samutprakarn, Srakaew, Nakhonnayok, and Prachinburi. Their strategic master plan of the group is based on the 9 key issues of National Development Strategies.

The Provincial Development Strategies are adopted to be use for each province. All of the Provincial governments, both of local organization and provincial departments have to adopt to integrated and guided for their strategic plan. Chachoengsao Provincial Development Strategy (2005-2008) is composed with 4 issues;

- Urban planning and logistic system development to be served the urbanization of Bangkok metropolitan and Suvanabhumi airport with high capability.
- Promotion of tourism of Province, both natural and cultural place.
- Enhance the efficiency of natural resource conservation and environmental protection.
- Promote Agro industry production and Agriculture to the world market, with the food safety without toxic and industrial polluting.

In the case of AEIN, Chachoengsao Provincial Industrial Office is the major agency to oversee the industrial development. All of the industrial establishment and new industry in the province need the consideration and allowance according to the industrial and other laws regulate to each types of industry. The Provincial Industrial Office has mostly duty to following on their major responsibility such as; control and monitoring of industrial and hazardous waste, registering of industrial machinery, environmental health and safety in the industry, coordination and promotion the industrial and SMEs development, investment, and ISO initiative in industrial sector.

The Policy and Planing Section is planning the industrial development policies by consistent with the MOI and its department policies, also Provincial policy. Working with other organizations and supporting their implementation due to assigned responsibility. However, in reality these are most activities conducted by Department of Industrial Works. The number of officials in charge of provincial industry is limited about 20-25 for all 3 sections.

The Provincial Natural Resource and Environmental Office is the main actor in affected to the AEIN formation. To oversee the environmental and natural resource issues, one responded regional level organization located in the province. However, their function is under the Permanent Secretary of Ministry Office of MONRE. The Provincial Office works with linking to the Regional Environmental Office 13, with the responding in the regional agency to overcome the environmental management in eastern region. Therefore, the function and duty of both Regional and Provincial Environmental Offices are reasonably and similar but different scale of implementation. However, they are working with linking coordination.

The responsibility of Provincial Natural Resource and Environmental Office is described following this;

- Following the implementation plan under Regional Environmental Office 13 has developed.

- Obliged the Report of provincial environmental situation to the higher level such regional and MONRE.
- Working with coordination, monitoring, and evaluation on environmental plan and measures done in the province.
- Develop the environmental database and information system of the province.
- Consultation and education service of environmental management knowledge and measures.
- Environmental quality monitoring and control.
- Enhancement cooperation and environmental network, also promotion to public relations.
- Promotion the appropriate environmental technology and management to adapted with the local community.

The industrial environmental management policy in the local level, mostly are responded by the Provincial Industrial Office. However, the Provincial Environmental Office played as the supporting agency such as complaining case occurred, industrial project development concerning environmental issue. Recently, the position of the Office still presents as the undersized unit of the Provincial Forestry Office Building, due to the small number of Environmental official working.
In addition, there have linking government agencies to affected the AEIN development in the regional and local level. Those have related activities that unavoidably overlap and they situated and function under the province as the Provincial Department Offices. The major names and their related activities are listed below:

- Department of Agricultural Promotion, Ministry of Agriculture and Cooperative (MOAC) helps farmer groups to create income by food and non-food processing of agricultural produce.
- Department of Livestock, MOAC, assists farmers in to have higher production capacity by transfer the research and develop information, technology to the farmer. Implementing on animal health, breeding, environmental and animal sanitation. Mainly, regulator under livestock epidemic law, improving animal varieties, controlling animal feeding and nursing enterprises and controlling the rabies epidemic.
- Department of Fishery, MOAC, overlooks and promotes fishery businesses starting from harvesting to finish product manufacturing.
- Provincial Public Health Office, Ministry of Public Health, responses to development of holistic public health service, to promote health prevention and disease control, health care and recuperate for people. Enhance and promote the Public health networks towards sustainable development.
- Provincial Energy Office, Ministry of Energy, overlooks the environmental and safety of oil fuel and natural gas of private enterprises. Follow and function the energy policies from Regional Energy Center.
- Community Development Department, Ministry of Interior, it supports the Self-Sufficiency Theory to be adapted in local economy, develop the community leadership, local organization and empowerment. Develop the community management system and network that they can be self organized. And build the community information supported.

- Social Security Office, Ministry of Labor, and Provincial Skill Development Center. These organization help to protect the labor security and compensation, promotion and development labor and worker livelihood.
- Office of the Basic Education Commission, Ministry of Education, oversees the basic education system and school and development educational capacity and build the educational attitude to the student and teacher, also administrator level.
- Department of Internal Trade and Department of Business Development, Ministry of Commerce help the local entrepreneurs and local business in order to licensed, accounting and tax, promotion and development local community business. Accelerate the provincial business development and export, active provision of agricultural product for farmer. Enhance competitiveness of SMEs, and community business.
- Chachoengsao Land Development Center, Ministry of Agriculture and Cooperative (MOAC), and Office of Public Work and Town and Country Planning, Ministry of Interior, study and planning to the appropriate land and development to solve the land problems in local. Planning, guiding and following the regulations to manage the area zoning and land application.

These government organizations can be supporting and linking work, for minority responsible duty of each other. Purposing to support the provincial policies and planning. However, these institutional need to be linking actors to the local level administration in district, sub-district and villages. Chachoengsao has totally 22 municipalities, and 91 Sub-district Organization Administration and one of the Provincial Administration Office.

Generally, local government functions may be classified into 3 types: statutory, optional and those specified by other legislation. The laws that establish each particular form of local government specify functions. All forms of local government perform similar functions. However, urban local governments perform more complex services than rural local governments. The following specification of local government functions is based on those of urban local governments such as following this;

Statutory functions:
- Maintenance of law and order
- Provision of public transport
- Provision of sanitary services (water supply, waste disposal, sewage and drainage)
- Provision of fire engines
- Prevention and control of communicable diseases
- Provision of slaughterhouses
- Provision of public health services, welfare for mothers and children
- Provision and maintenance of public recreation space and facilities
- Provision of primary education.

Optional functions:
- Provision of market places, ports and ferry services, crematoriums, hospitals, public utilities, parks, zoos and recreation areas as well as sport facilities.
- Provision of vocational training and promotion of citizen's occupation
- Improvement of slum dwellings
- Maintaining government enterprises

Considering the above functions, the scope of local government function is very limited. Rural local government functions are further limited by the overlap of authority between that of local government and provincial administration. Many functions at the level of local government are performed by the central government, that departments extend their operations into the provinces.

For example; this includes the department of public works, the country and city-planning department, the department of public health and the revenue department. This leads to confusion and also obstructs the development and growth of local government.

4.6.4 Concluding Remark

From the above explored part of major institutional, actors, and policies. Those can be affected to the favor and hamper to the industrial development and Agro Eco-Industrial Network in the region. In addition, the entrepreneur's attitude and administrative officer also summarized to investigate the policies and implementation. The explore situation of the related policies and prospective planning can be concluded as following this;

- National level, the central government formulated the industrial policies as top-down administration to implementation. It specified only economic growth and some of social equity, but less incorporated to the environmental protection aspect. However, the overview of industrial development, environmental protection and other policies has initiative policies and strategies towards sustainable development, thus the government has opening to the long term perspectives.
- Ministry level, the main focusing of the national industrial policies has emphasized in economic growth. However, the implementation policies and strategies have less leaded to act in environmental protection. The implementation of regulation may not be strengthening in command and control of their duties.
- Local level, the information from the field study could help the existing situation of policies implication in the regional development. The perspective of entrepreneurs from several sectors could helped to investigated the final conclusion such as following this;
    - The environmental problems are the major issues in Provincial Strategic Planning, due to several deterioration of natural resource and environmental problems facing. Because the weakness of command and control regulation implementation from the local actor and organizations in the province. In addition, the speedily developments with not strengthen planning of mega project, structure, industrial and services, and agriculture are forced to the natural revival capacity.
    - The labor has to be increasing the skill and supporting educational to provide for industrial growth. However, the indigenous knowledge and local development projects should be support in technical and policies from the local administration such as Organic farming that still constraint to the other policies (such import of inorganic fertilizer and complete system company).
    - The incomplete of access to market such information, incomplete of statistical data from small and medium industries and farmers comparing to the large industries and contracted farms. So, these enterprise are obstructed in supporting and development both technology and finance supporting.

- The absence of regional initiative to encourage the industrial development and the need of joint public and private development master plan for the regional scale.
- The unstable condition and market price of agricultural and agro-processing products due agricultural environment and cultivation system. The standardization of products has to be improved and certified for competition and export.

Recently, the Strategic Planning of Provincial has developing to solve these situations from the joint and cooperation by whole administration levels and local people to cope and develop their Province.

- The industries and entrepreneurs studied in the region, by their nature and scale of operation, they fall into the Small and Medium Enterprises category. The need and potential of its SMEs and has made strong policies in accelerating their growth, and improving national economy after economic crisis. Various institutions have been formed to foster the growth of SMEs. The Province is classified under Investment Zone 2 of the Thai Investment Promotion Zones. New industrial activities in these regions qualify for the following fiscal discounts:
  - 100% waiver of import duty on machinery for industries in estates.
  - 50% waiver for industries outside the estate.
  - Corporate income tax exemption for 7 years for industries within industrial estate and 3 years outside the estate.
  - Exemption on import duty for raw material for 1 year in both cases.

Chapter 5

Conclusions and Recommendations

Chachoengsao Province is one of the less urbanized and industrialized regions of the country evidenced by the presence of traditional agro industries. The eastern districts of the Province also are the fringe areas of the Bangkok urban. There has the natural condition favored for economy development and availability of labor promotes agriculture as a majority occupation. This research aimed to exploring the possibility formation of Agro Eco-Industrial Network on rice-based industry. The conclusions are presented following this;

5.1 Conclusions

1. In this case study, the focus is on the networking of two major different sectors of rice-based industry and agricultural farming to yield better environmental and economic results. The study analyzed the potentials of creating a network of agro industrial sectors in solving environmental problems.

The uncontrolled discharge of waste and wastewater from rearing and processing operations into the waterways are the major issue. Consequently, that high organic matter is generated in the study area could be treated and utilized by Small-scale biogas generation systems and Biogas as fuel for cooking or industrial heat and power generation. Both of rice industry and piggery farming could be obtained biogas 12 million m^3/year, while reducing BOD loading 8,200 tons/year to the water bodies and environment.

Moreover, increasing the resource efficiency of the entire system also is advantaged from creating network by waste and by-product exchange. Agricultural and agro industrial residues are high calorific value with high potential to produce electricity 642 GW/year from rice husk biomass. Small-scale biomass power and decentralized power generation systems are important technology advancements.

2. The material flow in the rice and livestock clusters of Chachoengsao indicates the potential for its transformation to an eco-industrial network. Introduction of technologies are essential for a successful transformation. Appropriate policy development considering all related issues of the eco-industrial cluster and rightly integrated with national and local development priorities is essential.

3. The main strength points of eco-industrial network are the creation of new business that utilize disposed resources as raw materials-rice husk/biomass power generation; piggery waste biogas. As well as increase competitiveness of business by reducing production costs; cost reduction in waste disposal and income generation through resource recovery from waste.

4. Current national policies are encouraging – Environmental, Agricultural, Investment promotion, Power Generation. There has special emphasis on rural-urban linkages in the NESDB plan. Also, Agro industries in the regional have gained prominence in the NESDB plan with an importance on EIN.

5. Barriers to Eco-Industrial Cluster are concluded below;

- Lack of appropriate technologies prevents full resource recovery and complete reuse between the existing network.
- The industrial sectors studied are unique in their kind and do have certain characteristic. However, the age of technology in use and Cleaner Technology in the sector is assumed to be a major barrier in its transformation.
- The disjointed linkages between and within business units reduce the opportunities for cooperation and have collective benefits.
- Though all individual policies are attractive, no separate policy adequately addressing all issues in a holistic way exists. The overlapping and inappropriate implementation and monitoring levels of the government organization to development policies, this affected to environmental management responsibility.
- The concept of Industrial Ecology is still unfamiliar to the actors, institutional and policy makers. The opening phase of concept used in the country, it is only in the investigation process and limited pilot project.

6. The industrial profile of the Province clearly indicates the role of agriculture and livestock in regional development. Both agriculture and livestock are resource dependent. The agriculture sector is a major resource consumer, while the livestock is a major source of pollution. This feature needs the function of organization and specific planning to integrating and well coordinating from several actors for better sustainable development.

7. Inter-firm and intra-firm linkages play an important role in the transformation to an eco-industrial network. It is through these linkages that the various benefits of sharing resources and their associated environmental and social gains realized. Local community networking and business association should be supported and promoted to participation. This is build a joint public/private committee and meeting in regional development.

5.2 Recommendations for further study

1. To study cost-benefit of waste recycling/recovery techniques. Also evaluation in terms of the benefit gains of each proposal environmental friendly industries, to link with the social suitable.

2. The network linkage between the industries need to be examined and investigated in order to the strengthen connection. Due to this research is marked force, there need well planning for future development. The selected case study of industry may be mentioned to the different case such scale, individual/group of enterprise.

3. The proximity and re-locating industries were not concerned when formed the network, for future study it is need to be mentioned.

4. The application of Geographic Information System from Natural Resources and Environmental data based would be adopted for the future study, due to its implications of data linkages in spatial scale.

References

Asian Development Bank (ADB). (1998). *Asia Least-cost Greenhouse Gas Abatement Strategy*: Summary Report. ADB Manila. ISBN No. 971-561-186-9.

Allenby, Braden R. and Richards, Deanna J. (1994). *The Greening of Industrial Ecosystems*. National Academy of Engineering. National Academy Press. Washington, DC. ISBN-10: 0-309-04937-7.

Ayres, R. U. and Simonis, U. E. (1994). *Industrial metabolism: Restructuring for Sustainable Development*, United Nations, University Press. ISBN 92-808-0984-9.

Board of Investment (BOI). (2006). *Industrial Investment Promotion Policy*. Retrieved 18 September, 2006 from http://www.boi.go.gh

Chachoengsao Province. (2006). *Provincial Strategic Planning*. Retrieved 20 September, 2006. from http://www.chachoengsao.go.th

Chachoengsao Provincial. (1996). *Chachoengsao: City of Prospects*. Bangkok. TCG Printing.

Chiu, S. Y. and Peters, B. (1994). *Industrial Pollution Prevention*, Asian Development Bank Report.

Cohen-Rosenthal, E. and McGalliard, T.N. (2003), *Eco-Industrial Development: the Case of the United States*. Retrieved March, 2006. from http:// www.jrc.es/iptsreport/vol27/english/COH1E276.htm

Department of Industrial Production (DIP). (2006). Industrial development policy and statistical information. Retrieved 19 January, 2007 http://www.smethai.net/en/

Deog-Seong O., Kyung-Bae K. and Sook-Young J. (2005). Eco-Industrial Park Design: a Daedeok Technovalley case study. *Habitat International, 29*, 269–284.

Douglass, M. (1995). Global Interdependence and Urbanization: Planning for the Bangkok Mega-Urban Region. In McGee, T. G. and Robinson, I. W., *The Mega-Urban Regions of Southeast Asia*, pp. 45-76. Canada: UBC Press

Food And Agriculture Organization Of The United Nations (FAO). (1998). *FAO Regional Wood Energy Development Programme in Asia*, Field Document No.52. Retrieved 4 September, 2006. from http://www.rwedp.org

Frosch, R. A. and Gallopoulos, N.E. (1989). Strategies for manufacturing. *Managing Planet Earth*, pp. 97-108.

Gertler, N. and Ehrenfeld, J.R. (1996). A Down-to-Earth Approach to Clean Production. *Technology Review*, February-March, pp. 48-54

Graedel, T. E. and Allenby, B. R. (1995). *Industrial Ecology*. New Jersey : Prentice Hall. ISBN 013-046713-8.

Inyang, H. I., Terezinha Ca´ssia de Brito Galvão and Helene Hilger. (2003). Waste recycling within the context of industrial ecology. *Resources, Conservation and Recycling 39*, 1-2

Khan, F. I., Natrajan, B. R., Revathi, P. (2001). GreenPro: a New Methodology for Cleaner and Greener Process Design. *Journal of Loss Prevention in the Process Industries, 14*, 307-328.

Kirchner, E. (1995). Eco-Industrial Park Find Growing Acceptance. *Chemical and Engineering News, 20*, 15

Lowe, Ernest A., Moran, Stephen R., and Warren, John. (1997). *Discovering Industrial Ecology: an executive briefing and sourcebook.* Battelle Press Cleveland, OH.

Lowe, E.A. (1997). Creating By-products Resource Exchanges: Strategies for Eco-Industrial Parks, *J. Cleaner Production*, 5(1-2): 57-65

Lowe, Ernest (2001). *Eco-Industrial Park Handbook for Asian Developing Nations: A Report to Asian Development Bank*. Environment Department, Indigo Development, Oakland, CA. Retrieved 23 August, 2006. from http://www.indigodev.com/Handbook.html

Manahan, S. E. (1999). *Industrial Ecology: Environmental Chemistry and Hazardous Waste*. Lewis Publishers.

Nagle, G. and Guinness, P. (2004). *The nature of the rural-urban fringe*. Retrieved 6 August, 2006. from http://www.geocases.co.uk/default.htm

Oldenburg K. U. and Geiser K. (1997). Pollution prevention and…or industrial ecology. *Journal of Cleaner Production, 5*, 103-108.

Panyarachun, Anand. (1996). H. M. *The King and the Environment*. Retrieved 10 August, 2006. from http://www.anandp.in.th/en_speech/e010202.pdf.

Public Relations Department (PRD). (2006). *Information of the country*. Retrieved 25 September, 2006. from http://thailand.prd.go.th/the_inside_view.php?id=1373

Roberts, B. H. (2004). The application of industrial ecology principles and planning guidelines for the development of eco-industrial parks: an Australian case study. *Journal of Cleaner Production 12*, 997–1010.

Sriroth, Klanarong. (2005). *Outlook of Biomass Utilization as Biofuel in Thailand. Biomass-Asia Workshop.* Tokyo, Japan. 19-21 January 2005. Retrieved 11 August, 2006. from http://www.cassava.org/Pub/2005.htm

Sundhagul, Malee and Atthasampunna, Poonsook. (1983). *Bioconversion of carbohydrate residues in Thailand.* Bangkok Microbiological Resources Centre (MIRCEN). Retrieved 8 August, 2006, from http://www.unu.edu/unupress/unupbooks/80362e/80362E0a.htm

Suwanmala, C., 2002. *Fiscal Decentralization in Thailand*. International Workshop on Intergovernmental Fiscal Relations in East Asia. January, 2002. Bali, Indonesia.

Tanticharoen, Morakot. (2000). Thailand: Biotechnology for Farm Products and Agro-Industries. In G. J. Persley and M. M. Lantin (eds), *Agricultural Biotechnology and the Poor: Proceedings of an International Conference*, Washington, DC.

Thai Government. (2007). *Thailand: Ministries and responsibility service*. Retrieved 5 February, 2007, from

http://www.thaigov.go.th/th/service/Ministry.aspx?M_CODE=76&M_NAME=หน่วยงานภาครัฐ&menu=3

Thailand Health Profile. (2000). *Thailand Health Profile 1999-2000*. Ministry of Public Health. Retrieved 7 September, 2006. from http://www.moph.go.th/ops/thealth_44/

Thailand Investor Service Center (TISC). (2006). *Industrial development policy*. Retrieve 2 November, 2006 from http://www.thailandoutlook.com/thailandoutlook1/govrnment+policy/Government+policy+Update/SMEs+Policy.htm

Thailand Investor Service Center (TISC). (2007). *Thai Government Policy: SME policy*. Retrieved 16 March, 2007. from http://www.thailandoutlook.com/thailandoutlook1/government+policy/Government+Policy+Update/SMEs+Policy.htm

Tibbs, C.B. Hardin. (1992). Industrial Ecology: An Environmental Agenda for Industry, *Pollution Review*. Spring, pp. 804-806.

Todoc, L. Jessie. (2007). CDM in Thailand: Status and Policy Issues. Retrieved 5 May, 2007. from http://cdmasean.pelangi.or.id/countrypapers/cp-thailand.pdf

Tran Thi my Dieu. (2003). *Greening Food Processing Industry in Vietnam: Putting Industrial Ecology to work.* Wagningen. Wagningen University. ISBN 90-5808-825-1

Wikipedia. (2006). Map and Profile of Chachoengsao Province. Retrieved 30 August, 2006 from http://en.wikipedia.org/w/index.php?title=Chachoengsao_Province&oldid=50779432

United Analyst and Engineering Consultant Co., Ltd. (2000). *Final Report: Survey and study for an establishment of nuisance standard for Offensive Odor, Dust and Noise from Rice Mill Factories*. Bangkok.

World Bank (1986). *Environmental Guidelines; Environment Department.* Retrieved August 5, 2006, from http://ces.iisc.ernet.in/energy/HC270799/HDL/ENV/enven/vol235.htm

World Health Organization. (2004). *World Health Report 2004*. Retrieved 5 August, 2006, from http://www.who.int/whr/en

World Health Report. (2004). *World health statistic and profile*. Retrieved 4 October, 2006. from http://www.who.int/whr/en/

Appendix A

Questionnaire

Questionnaire Survey on Agro Industries in Chachoengsao Province

Interviewer: Ms. Niranchana Authayanraksa
Graduate Student, Environmental Engineering and Management

1. Name and address of the industry?
2. What is your main product?
3. How much do you produce? (Choose any one)
    a. Per Year :
    b. Per Month :
    c. Per Week :
    d. Per Day :
4. What are the raw materials?
    a. _____Quantity_____Price_____
    b. _____Quantity_____Price_____
    c. _____Quantity_____ Price_____
    d. _____Quantity_____Price_____
    e. Water consumption: _____ Price_____
    f. Electricity Consumption:_____ Price_____
5. What are your by-products?
    a. _____Quantity_____Price_____
    b. _____Quantity_____Price_____
    c. _____Quantity_____Price_____
    d. _____Quantity_____ Price_____
6. What are the waste streams?
    a. Solid:_____ Quantity_____
    b. Solid:_____ Quantity_____
    c. Solid:_____ Quantity_____
    d. Liquid /Effluent:_____ Quantity_____
    e. Liquid /Effluent:_____ Quantity_____
    f. Liquid /Effluent:_____ Quantity_____
7. How do you dispose the waste? Sell / open dumping /Exchange

8. Is there a possibility of recycling/reusing the waste?
    a. If not, why?
    b. If so, is it done?
        i. At what price do you sell the waste?
        ii. Who buys your waste?
        iii. How is it used?
9. How many people work in your industry?
10. Does the number of people working depend on season or work requirement?
    a. If it depends on other factors. Please explain why and how
11. What is the ownership of you industry?

    Individual / Family Owned / Registered Small Scale
12. Were any permissions / license required to start this business?
    a. If so from which departments?
        i. _____
        ii. _____
        iii. _____
        iv. _____
13. Did those departments support you in any way? (For example, by giving any financial support, market support, tax benefits, etc)
14. Do you have any association of industries like yours?
    a. If so what are the main activities of the association?
    b. Are they helping to solve any problems faced by the industries?
15. Does your industry involve in any social upliftment activity?
    a. If so, What are they?
    b. If not, don't you think, industries consume public goods and hence have a social responsibility? What is your opinion?
16. What do you think has the Government done to improve industries like your's? Do you have any specific suggestion to be made to the Government?

แบบสอบถามข้อมูลด้านการจัดการของโรงงานอุตสาหกรรมเกษตร

ผู้สัมภาษณ์: น.ส.นิรัญชนา อุทยานรักษา

นักศึกษาปริญญาโท สาขาวิชาวิศวกรรมและการจัดการสิ่งแวดล้อม

คำชี้แจง: 1. แบบสอบถามแบ่งออกเป็น 4 ส่วน ดังนี้

ส่วนที่ 1) ข้อมูลทั่วไปของสถานประกอบการ

ส่วนที่ 2) ข้อมูลกระบวนการผลิต

ส่วนที่ 3) ข้อมูลวัสดุเหลือใช้ ของเสียจากการผลิตและการจัดการ

ส่วนที่ 4) ความคิดเห็นของสถานประกอบการ

2. กรุณาตอบทุกคำถาม และคำตอบของท่าน ผู้ดำเนินการศึกษาถือเป็นความลับ โดยจะไม่มีการเปิดเผยไม่ว่ากรณีใด โดยจะนำข้อมูลไปใช้เฉพาะในการศึกษาเท่านั้น

ส่วนที่ 1) ข้อมูลทั่วไปของสถานประกอบการ

1. ชื่อสถานประกอบการ

.....

2. ที่อยู่โรงงานเลขที่.....หมู่.....ซอย.....ถนน.....

ตำบล.....อำเภอ.....จังหวัด.....รหัสไปรษณีย.....

โทรศัพท์.....โทรสาร.....E-mail.....

บุคคลติดต่อชื่อ.....โทรศัพท์.....

ตำแหน่ง.....

3. ประเภทอุตสาหกรรม.....

ดำเนินกิจการมา.....ปี

ลักษณะความเป็นเจ้าของ ❒ธุรกิจส่วนตัว ❒ธุรกิจครอบครัว (ประมาณ 30 ปี) ❒บริษัทร่วมทุน

4. สัดส่วนการขายสินค้า: ตลาดภายในประเทศ.....**.....%**, ตลาดต่างประเทศ.....**%**

5. จำนวนพนักงานทั้งหมด.....คน: ชาย.....คน, หญิง.....คน

6. ช่วงเวลาการทำงาน.....วัน/สัปดาห์ วันละ.....กะ กะละ.....ชั่วโมง

7. สถานที่ตั้งของสถานประกอบการ

❒มีชุมชนตั้งอยู่ในรัศมี 50 เมตร ❒มีชุมชนตั้งอยู่ในรัศมี 50-100 เมตร

❒มีชุมชนตั้งอยู่ในรัศมี 100-500 เมตร ❒มีชุมชนตั้งอยู่ในรัศมีมากกว่า 500 เมตร

ส่วนที่ 2) ข้อมูลกระบวนการผลิต

8. ชนิดของวัตถุดิบที่ใช้ในการผลิต

8.1 วัตถุดิบหลัก 1).....ปริมาณ.....ตัน/วัน, ราคา.....บาท/ตัน

2).....ปริมาณ.....ตัน/วัน, ราคา.....บาท/ตัน

3).....ปริมาณ.....ตัน/วัน, ราคา.....บาท/ตัน

8.2 วัตถุดิบรอง 1).....ปริมาณ.....ตัน/วัน, ราคา.....บาท/ตัน

2).....ปริมาณ.....ตัน/วัน, ราคา.....บาท/ตัน

3).....ปริมาณ.....ตัน/วัน, ราคา.....บาท/ตัน

8.3 อื่นๆ .....ปริมาณ.....ตัน/วัน, ราคา.....บาท/ตัน

9. ชนิดของผลิตภัณฑ์

9.1 ผลิตภัณฑ์หลัก 1).....ปริมาณ.....ตัน/วัน, ราคา.....บาท/ตัน

2).....ปริมาณ.....ตัน/วัน, ราคา.....บาท/ตัน

3).....ปริมาณ.....ตัน/วัน, ราคา.....บาท/ตัน

9.2 ผลิตภัณฑ์รอง 1).....ปริมาณ.....ตัน/วัน, ราคา.....บาท/ตัน

(By-products) 2).....ปริมาณ.....ตัน/วัน, ราคา.....บาท/ตัน

3).....ปริมาณ.....ตัน/วัน, ราคา.....บาท/ตัน

ขายต่อให้กับสถานประกอบการประเภท.....

.....

10. ระยะเวลาการทำงาน.....ชั่วโมง/วัน, ...วัน/เดือน

11. การใช้พลังงานและเชื้อเพลิงในโรงงาน

❒ พลังงานไฟฟ้า ปริมาณ..... กิโลวัตต์/เดือน หรือ .....บาท/เดือน

❒ น้ำมันเชื้อเพลิง ปริมาณ..... ลิตร/เดือน หรือ .....บาท/เดือน

❒ ลิกไนต์ ปริมาณ..... ตัน/เดือน หรือ .....บาท/เดือน

❒ ก๊าซธรรมชาติ ปริมาณ..... ลบ.ฟุต/เดือน หรือ .....บาท/เดือน

❒ พลังงานชีวภาพ (เช่น แกลบ, ฟืน, เศษไม้, ไบโอก๊าซ ฯลฯ) ระบุ.....

ปริมาณ..... ลบ.ฟุต/เดือน หรือ .....บาท/เดือน

❒ อื่นๆ ปริมาณ..... ./เดือน หรือ .....บาท/เดือน

12. แหล่งน้ำที่ใช้ในโรงงาน

1).....ปริมาณน้ำที่ใช้.....ลบ.เมตร/เดือน หรือ.....บาท/เดือน

ใช้ในการ.....

2).....ปริมาณน้ำที่ใช้.....ลบ.เมตร/เดือน หรือ.....บาท/เดือน

ใช้ในการ.....

3).....ปริมาณน้ำที่ใช้.....ลบ.เมตร/เดือน หรือ.....บาท/เดือน

ใช้ในการ.....

4) อื่นๆ.....

13. โปรดอธิบายกระบวนการผลิต หรือ แนบแผนผังประกอบ

ส่วนที่ 3) ข้อมูลวัสดุเหลือใช้ ของเสียจากการผลิตและการจัดการ

14. ประเภทของเสียที่เกิดจากกระบวนการผลิต

ประเภท	ปริมาณ (ตัน/เดือน)	วิธีการจัดการ/กำจัด
<u>ของเสียและขยะ</u> 1.		
2.		
3.		
4.		
5.		
<u>ของเหลวหรือน้ำเสีย</u> 1.		
2.		
3.		

15. สาเหตุที่ไม่มีการกำจัด (เลือกได้มากกว่า 1 ข้อ)

○ไม่มีความจำเป็น ○ปริมาณของเสียมีน้อย ○กำลังศึกษาและออกแบบ

○ไม่มีเงินลงทุน ○เสียค่าใช้จ่ายในการกำจัดสูง(.....บาท/เดือน)

○ขาดเทคโนโลยีที่เหมาะสม ○ขาดแคลนเจ้าหน้าที่ ○อื่นๆ.....

16. ของเสียของบริษัทท่านสามารถนำไปรีไซเคิลหรือใช้ประโยชน์ใหม่หรือส่งไปให้สถานประกอบการอื่นได้หรือไม่

❒ ได้ โดยขายต่อให้กับ.....

นำไปใช้เพื่อ.....ราคา.....

❒ ไม่ได้ เนื่องจากสาเหตุ

○ของเสียมีปริมาณน้อย ○ไม่มีแหล่งรองรับ ○ไม่ทราบว่าโรงงานใดต้องการ ○ไม่มีหน่วยงานประสานงานเพื่ออำนวยความสะดวก ○เสียค่าใช้จ่ายสูง

○สามารถใช้ประโยชน์ภายในโรงงานได้

❒ อื่นๆ.....

ส่วนที่ 4) ความคิดเห็นของสถานประกอบการ

17. การเข้ามาทำงานของพนักงานขึ้นอยู่กับฤดูกาลหรือตามที่โรงงานต้องการแรงงานเป็นช่วงๆหรือไม่

❒ไม่ (พนักงานทำงานตลอดทั้งปี)

❒ใช่ เนื่องจาก.....

18. บริษัทของท่านต้องมีการจดทะเบียนหรือได้รับอนุญาตในการจัดตั้งหรือดำเนินกิจการหรือไม่

❒ไม่ต้องจดทะเบียนหรือขออนุญาต

❒ใช่ โดยได้รับอนุญาตจากหน่วยงานราชการใดบ้าง (โปรดระบุทั้งระดับจังหวัดและท้องถิ่น)

1).....

2).....

3).....

19. หน่วยงานราชการได้มีการช่วยเหลือและสนับสนุนธุรกิจของท่านหรือไม่ อย่างไรบ้าง โปรดระบุ (ตัวอย่างเช่น เงินทุนสนับสนุน, ด้านภาษี, การตลาด, เทคโนโลยี ฯลฯ)

.....

.....

.....

20. บริษัทของท่านได้มีเข้าร่วมสมาคม การรวมกลุ่มหรือเป็นสมาชิกในกลุ่มผู้ประกอบการประเภทเดียวกัน หรือไม่

20.1 ชื่อกลุ่มหรือสมาคมที่เข้าร่วมและจุดประสงค์/กิจกรรมหลักที่ดำเนินการของกลุ่มสมาชิก

1)ชื่อ.....กิจกรรมหลัก.....

.....

2)ชื่อ.....กิจกรรมหลัก.....

.....

3).....

20.2 ทางสมาคมมีส่วนร่วมในการสนับสนุนและแก้ปัญหาของกลุ่มผู้ประกอบการได้อย่างไรบ้าง

.....

.....

.....

21. บริษัทของท่านมีส่วนช่วยเหลือและสนับสนุนในด้านของชุมชนและสังคมหรือไม่

❒ ไม่มีส่วนร่วม เพราะ

.....

❒ มีส่วนร่วม อย่างไรบ้าง

.....

.....

22. ท่านต้องการให้รัฐบาลปรับปรุง ช่วยเหลือ และสนับสนุนสถานประกอบการของท่านในด้านใด อย่างไรบ้าง

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Appendix B

Production process

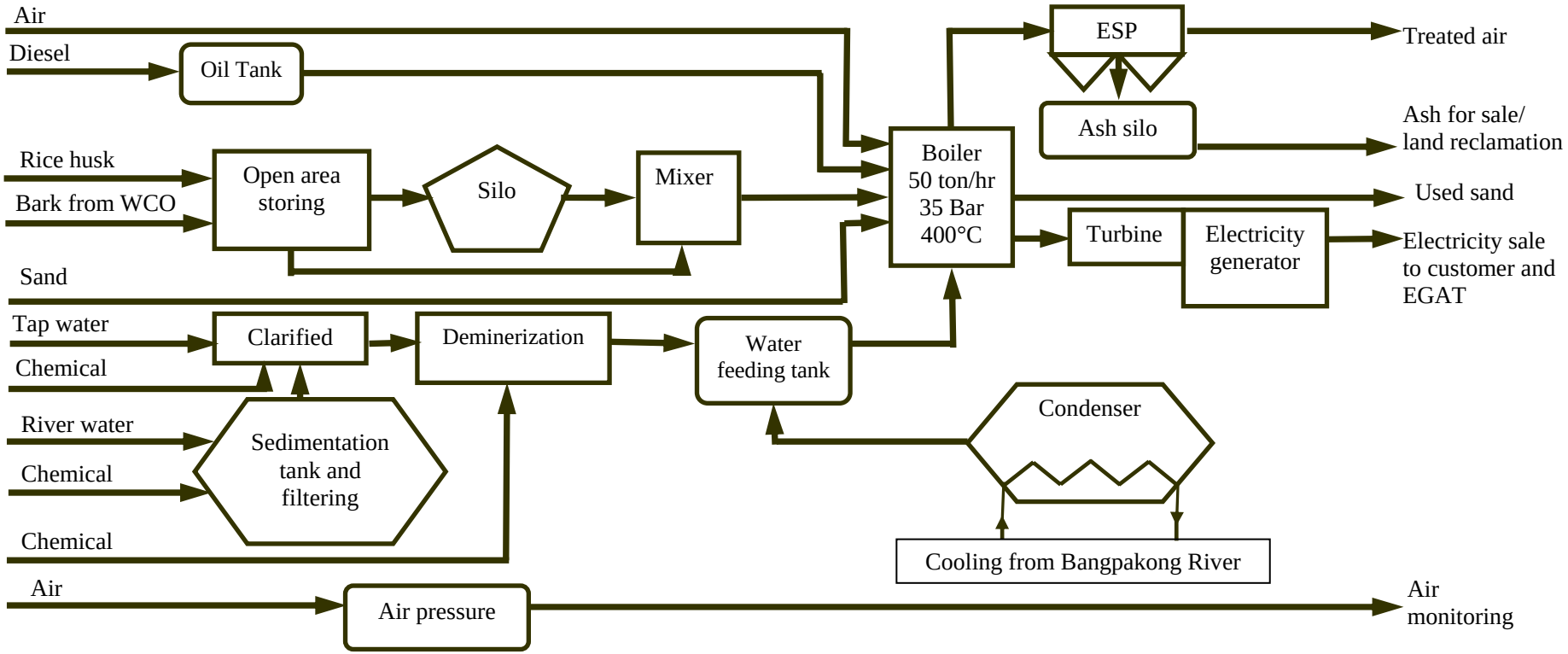


Figure B1. Biomass Power Plant Production Process Diagram

Appendix C

Thai Standards

Table C1. Thai Classification and Objectives of Surface water quality

Classification	Objectives/Condition and Beneficial Usage
Class 1	Extra clean fresh surface water resources used for : (1) conservation not necessary pass through water treatment process require only ordinary process for pathogenic destruction (2) ecosystem conservation where basic organisms can breed naturally
Class 2	Very clean fresh surface water resources used for : (1) consumption which requires ordinary water treatment process before use (2) aquatic organism of conservation (3) fisheries (4) recreation
Class 3	Medium clean fresh surface water resources used for : (1) consumption, but passing through an ordinary treatment process before using (2) agriculture
Class 4	Fairly clean fresh surface water resources used for : (1) consumption, but requires special water treatment process before using (2) industry
Class 5	The sources which are not classification in class 1-4 and used for navigation.

Table C2. Surface Water Quality Standards (major parameters)

Parameter	Units	Statistics	Standard Value for Class					Methods for Examination
			Class1	Class2	Class3	Class4	Class5	
Temperature	C°	-	n	n’	n’	n’	-	Thermometer
pH	-	-	n	5-9	5-9	5-9	-	Electrometric pH Meter
Dissolved Oxygen (DO)[2/]	mg/l	P20	n	6.0	4.0	2.0	-	Azide Modification
BOD (5 days, 20°C)	mg/l	P80	n	1.5	2.0	4.0	-	Azide Modification at 20°C , 5 days
Total Coliform Bacteria	MPN/100 ml	P80	n	5,000	20,000	-	-	Multiple Tube Fermentation Technique
Fecal Coliform Bateria	MPN/100 ml	P80	n	1,000	4,000	-	-	Multiple Tube Fermentation Technique
NO_3 -N	mg/l	-	n	5.0			-	Cadmium Reduction
NH_3 -N	mg/l	-	n	0.5			-	Distillation Nesslerization

Remark:

P Percentile value

n naturally

n' naturally but changing not more than 3°C

* when water hardness not more than 100 mg/l as $CaCO_3$

** when water hardness more than 100 mg/l as $CaCO_3$

Source: Notification of the National Environmental Board, No. 8, B.E. 2537 (1994), issued under the Enhancement and Conservation of National Environmental Quality Act B.E.2535 (1992) , published in the Royal Government Gazette, Vol. 111, Part 16, dated February 24, B.E.2537 (1994).

Based on Standard Methods for the Examination of Water and Wastewater recommended by APHA: American Public Health Association, AWWA: American Water Works Association and WPCF : Water Pollution Control Federation**.**

Table C3. Thai Industrial Effluent Standards

Parameters	Standard Values	Method for Examination
1. pH value	5.5-9.0	pH Meter
2. Total Dissolved Solids (TDS)	not more than 3,000 mg/l depending on receiving water or type of industry under consideration of PCC but not exceed 5,000 mg/l not more than 5,000 mg/l exceed TDS of receiving water having salinity of more than 2,000 mg/l or TDS of sea if discharge to sea	Dry Evaporation 103-105 °C, 1 hour
3. Suspended solids (SS)	not more than 50 mg/l depending on receiving water or type of industry or wastewater treatment system under consideration of PCC but not exceed 150 mg/l	Glass Fiber Filter Disc
4. Temperature	not more than 40°C	Termometer during the sampling
5. Color and Odor	not objectionable	Not specified
6. Sulphide as H_2S	not more than 1.0 mg/l	Titrate
7. Cyanide as HCN	not more than 0.2 mg/l	Distillation and Pyridine Barbituric Acid Method
8. Fat, Oil & Grease (FOG)	not more than 5.0 mg/l depending of receiving water or type of industry under consideration of PCC but not exceed 15.0 mg/l	Sovent Extraction by Weight
9. Formaldehyde	not more than 1.0 mg/l	Spectrophotometry
10.Phenols	not more than 1.0 mg/l	Distillation and 4-Aminoantipyrine Method

Parameters	Standard Values	Method for Examination
11.Free Chlorine	not more than 1.0 mg/l	lodometric Method
12.Pesticides	not detectable	Gas-Chromatography
13.Biochemical Oxygen Demand (BOD)	not more than 20 mg/l depending on receiving water or type of industry under consideration of PCC but not exceed 60 mg/l	-Azide Modification at 20 °C , 5 days
14.Total Kjedahl Nitrogen (TKN)	not more than 100 mg/l depending on receiving water or type of industry under consideration of PCC but not exceed 200 mg/l	Kjeldahl
15.Chemical Oxygen Demand (COD)	not more than 120 mg/l depending on receiving water of type of industry under consideration of PCC but not exceed 400 mg/l	Potassium Dichromate Digestion
16.Heavy metals		
1. Zinc (Zn)	not more than 5.0 mg/l	Atomic Absorption Spectro Photometry; Direct Aspiration or Plasma Emission Spectroscopy ; Inductively Coupled Plama : ICP
2. Chromium (Hexavalent)	not more than 0.25 mg/l	
3. Chromium (Trivalent)	not more than 0.75 mg/l	
4. Copper (Cu)	not more than 2.0 mg/l	
5. Cadmium (Cd)	not more than 0.03 mg/l	
6. Barium (Ba)	not more than 1.0 mg/l	
7. Lead (Pb)	not more than 0.2 mg/l	
8. Nickel (Ni)	not more than 1.0 mg/l	
9. Manganese (Mn)	not more than 5.0 mg/l	
10. Arsenic (As)	not more than 0.25 mg/l	Atomic Absorption Spectrophotometry; Hydride Generation, or Plasma Emission Spectroscopy; Inductively Coupled Plasma : ICP
11. Selenium (Se)	not more than 0.02 mg/l	
12. Mercury (Hg)	not more than 0.005 mg/l	Atomic Absorption Cold Vapour Techique

Source: Notification the Ministry of Science, Technology and Environment, No. 3, B.E.2539 (1996) issued under the Enhancement and Conservation of the National Environmental Quality Act B.E.2535 (1992), published in the Royal Government Gazette, Vol. 113 Part 13 D, dated February 13, B.E.2539 (1996)

Appendix D

Government Institutional and Regulations

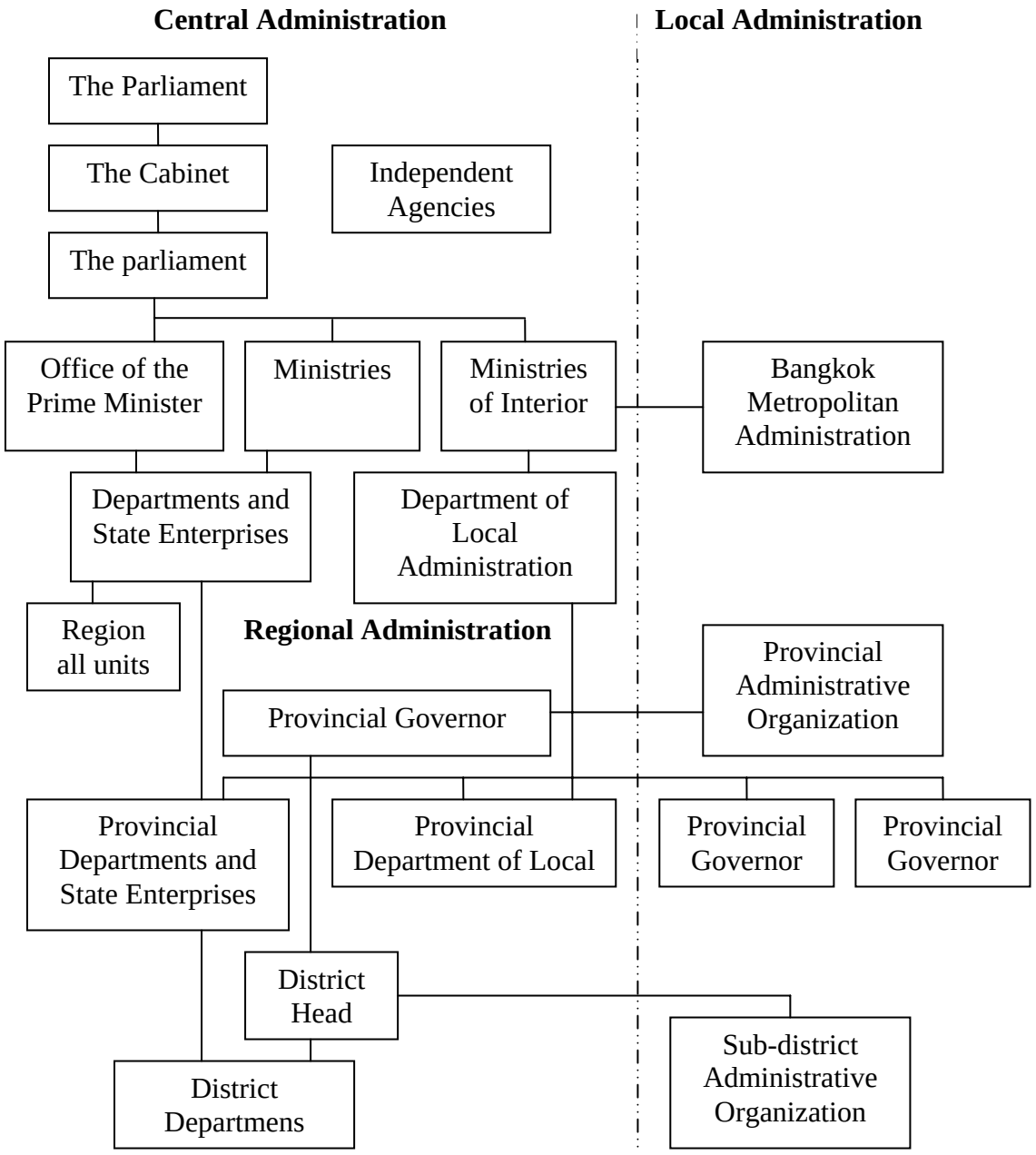


Figure D1.Administrative structure of the Royal Thai Government

D2. The Ministry of Industry's Policy Guidelines

The Ministry of Industry is an agency responsible for the promotion and development of industry, mineral resources and energy. The Minister has set up policy guidelines covering the period between 2001-2006 in compliance with the 9th National Economic and Social Development Plan, the policy of the present administration and the Ministry's role and mission as follows:

- **Short-term emergency measures**

1. Coordinate with relevant agencies to set up the action plan for " one tambon, one product " projects so that each community can use its local knowledge and potential to develop its products with support from the Ministry of Industry in terms of technology, production technique, management and marketing in view of linking the community's products to both domestic and foreign markets through the chain-store system.

2. Jointly set up the SME Bank to solve liquidity problems in the industrial sector by restructuring the management of the Small Industry Finance Corporation (ISFC) with emphasis on the increase of cash flow and reduction of interest rates and ownership registration of machinery to be used as asset to increase capital, thus providing assistance to existing entrepreneurs as well as opportunity and choice of financial sources to new entrepreneurs so as to create and maintain production base, employment, income creation and export.

3. Provide assistance to reduce production costs in industrial plans through consulting services so as to improve production process and management, reduce energy cost, save energy and use alternative energy.

4. Support measures to solve liquidity problems of the industrial sector by promoting the ownership registration of machinery to be used as asset for loans, cooperating with commercial banks to provide credit to SMEs, accelerating management restructuring, increasing branches and increasing capability to analyze credit as well as reducing interest rates of the Small Industry Finance Corporation (SIFC).

5. Expedite tax restructuring program to reduce production costs and disadvantages of Thai industry's competitiveness.

6. Modernize laws on factories and industrial standards to facilitate industrial entrepreneurship.
7. Expedite the implementation of the Industrial Restructuring Plan in terms of production, management and marketing so as to yield real and continuous results.

8. Develop capability of personnel both in the public and private sectors on the fields of modern production technology, environmental management, industrial safety and adoption of international standards such as ISO 9000, ISO 14000, ISO 18000 and HACCP to be ready for the adaptation towards the new economy and supporting new small and medium entrepreneurs towards the knowledge-based economy.

9. Set up measures to alleviate the impact of and get ready for free trade under the agreements of WTO, AFTA and other economic groupings as well as encourage the private sector to share information on trade, investment and analysis on the impact of agreements in the framework of international cooperation agreements.

- **Long-term measures**

1. Restructure production in the industrial sector and promote investment in compliance with the objective and strategy of the country's development, taking into account natural resources, skill, local knowledge, potential in production and marketing as well as the balanced use between local raw materials and dependence of import.

2. Promote the development of basic industry and linkage of continuous industry having continuous results on the production restructuring of the industrial sector as well as promote, support and develop mineral-based economy and basic industry to strengthen industry's linkage system.

3. Strengthen the industry with potential to develop and with high knowledge-and-skilled base, by promoting Thailand as the world's source of quality food production and processed agro-industrial products.

4. Develop SMEs as an important factor in the country's industrial development by supporting and promoting cooperation in R&D of products and technology among the government, the public sector and the academic institutions and creating IT network on production factor and marketing as well encouraging SMEs to do business in e-commerce.

5. Promote the role of financial institutions and the setting up and implementation of venture capital funds as well as credit guarantee in order to develop SMEs by setting up SME Business Plan to have access to credit sources and increase credit for individual SMEs as deemed necessary.

6. Encourage measures to increase value-added to industrial products and increase productivity in the industrial sector in view of competition and sustainable development by which the total factor productivity growth of the industrial sector is not less than 2.5% per annum as well as increase network and process to develop main factors which are conditions of success in productivity such as HRD and increased competitiveness in science and technology.

7. Promote industrial development in local, communal and regional areas to create business with strong management system leading to development of sustainable quality management by developing local job groups, promoting production of Thai products, creating brand name for local products as well as encouraging system to manage industrial land in the form of industrial estates in the areas having potential to be developed as the country's economic area, by encouraging the private sector to take part in establishing industrial estates and encouraging entrepreneurs to locate their factories in industrial estates.

8. Promote sub-contract and production linkage among industrial groups for mutual support and technology exchange and linkage between strong community business and industry business as well as setting up industrial groups capable of exchanging natural resources and being partners (industrial clusters).

9. Supervise industrial factories with high risk and pollution and encourage them to relocate to industrial estates, reduce industry's hazardous wastes by not less than 50% as well as promote the implementation of appropriate technology by focusing in quality of environment and safety in industrial plants such as improving standard on air pollution management, keeping air pollution control within standard, imposing strict measures for business which is the source of pollution and promoting clean production so that local authorities can jointly supervise industrial factories through transparent and efficient management system.

10. Link the Industrial IT system and rules and regulations on trade and export between the capital and the regional areas including local authorities to create early warning system and serve as information for adaptation in the fast-changing situations.

11. Accelerate the establishment of independent institutes to support industrial development in various sectors such as wooden product and furniture institute, pharmaceutical and chemical institute, ceramic institute and plastic institute.

12. Promote and expand cooperation in the fields of industry and investment with foreign countries including neighboring countries to form partnership in trade, economic and social

development and to draw up development plan for the whole country with process to continuously assess the development.

D3. Table of Structure and Linkages of Government agencies both direct and indirect in formulation and implementation of policies, strategies and plans: Related to Industrial Development

The supervision of seven major direct governmental agencies			
Level	**Organization/ Ministry**	**Department/Division/Agencies**	**Roles and Function**
Nation	Prime Minister's Office; Governmental Policy	National Economic and Social Development Board (NESDB)	Policies, Strategies and Plans; Plans of 1st to 10th
		The Board of Investment (BOI)	Plans, Policies, Service, Consultant, Promote
Ministry	The Ministry of Industry (MOI)	Department of Industrial Promotion	Development, Services, Training, Consultant Management Promotion, Design production
		Office of Industrial Economics	Policies and Plans, Service Information Technology
		Office of the Permanent Secretary	Service, Support Region and local investor, Cooperation Public/Private Participation
		Department of Industrial Works	Permission, Factory licenses, Fees, Support Technology, The Factory Act, B.E. 2535
		Thai Industrial Standards Institute	Standard Production, Permission
	A State Enterprise Agency under Ministry and carrying out the government's industrial development policy	Office of Small & Medium Enterprises Promotion	SMEs National Database
		Thailand Productivity Institute	Suggestion, Process Improvement, Quality Control ISO 9000, QS 9000, ISO 14000, ISO/TS 16949, Thailand Quality, Award..
		Industrial Estate Authority of Thailand (IEAT)	Land, Infrastructure, Zoning, Management, Operation, One Stop Service, e- Business, Permit, Licensing, Privilege
	Ministry of Science and Technology	Office of the permanent Secretary	Office of Technology Transfer & Promotion
		Thailand Institute of Scientific and Technological Research	Industrial and Technical, Industrial Metrology, Testing & Packaging Center

		National Science and Technology Development Agency	R& D Improvement of production, Training, Testing and measuring services Technology Transfer Group
	The Ministry of Commerce (MOC)	Department of Export Promotion	Export Promotion Policy
		Department of Foreign Trade	Foreign Business Act.
		Department of Internal Trade	Support
Ministry	The Ministry of Finance (MOF)	Fiscal Policy Office	The fiscal Policy
		Government Saving Bank	Fund Load
		The Custom Department	Tax, Tariff
		Export-Import of Bank Thai	Tax Refunds on exports
		Small Industrial Finance Cooperation	Fund load
		Small Industrial Credit Guarantee	Participation, Public foreign to support
		The Industrial Finance Corporation of Thailand (IFCT)	Load long-term funds to medium- and large-scale firms from credit
		The Bank of Thailand (BOT)	Foreign Exchange, Loans in low interest
Indirect government agencies related to support and performance			
Ministry	Ministry of Natural Resource & Environment	Pollution Control Department	Air Quality and Noise Standards Enhancement and Conservation of National Environmental Quality Act.
		Department of Environmental Quality Promotion	Environmental protection
	Ministry of Education	Office of the Higher Education	Knowledge
		Office of the Vocational Education Commission	Knowledge
	The Ministry of Transport and Communications	Many Department / division to work infrastructure	Oversees and construction infrastructure
	The Ministry of Public Health		The Public Health Act, B.E. 2535

Sources: Thai Government (2007)

D4. Table of Industrial Policies related to the Rice mill

Hierarchy of laws	Subject	Year of announcement	Organization
Act of Legislation	The Factory Act	B.E.2535 (1992)	Department of Industrial Works, MOI
Act of Legislation	Enhancement and Conservation of National Environmental Quality Act	B.E.2535	MOSTE (A parted to MOST and MONRE)
Ministerial Regulation	Issued Pursuant to the Factory Act B.E. 2535; Types in the list annex of factory	B.E.2535 (1992)	Department of Industrial Works, MOI
Ministerial Notification	No.1060 Industrial Product Standard Act: Rice roller manufacturer	B.E.2532 (1989)	Thai Industrial Standard Institute, MOI
Ministerial Notification	No.1060 Industrial Product Standard Act: Small Manufacturer of rice milled machine	B.E.2532 (1989)	Thai Industrial Standard Institute, MOI
Ministerial Regulation	No.2 Issued Pursuant to the Factory Act B.E. 2535**;** 1)Location, Environment, Appearance of the Building and Interior of the Factory 2)Machinery, Equipment or Things Used in the Factory 3)Workers in the Factory 4)Control of the Release of Waste, Pollution or Anything Affecting Environment 5)Safety of Factory Operation	B.E.2535 (1992)	Department of Industrial Works, MOI
Ministerial Regulation	No.3 Issued Pursuant to the Factory Act B.E. 2535**;** Reporting/information of the factory operation	B.E.2535 (1992)	Department of Industrial Works, MOI
Ministerial Notification	No.4 Occupational and safety registered assigns in the industry	B.E.2514 (1971)	Department of Industrial Works, MOI
Ministerial Notification	No.7 The industry setting up the products types and quality	B.E.2516 (1973)	Department of Industrial Works, MOI
Ministerial Notification	No.13 Performing and responsibility of the permitted factory	B.E.2525 (1982)	Department of Industrial Works, MOI
Ministerial Notification	No.18 Performing and responsibility of the permitted factory	B.E.2528 (1985)	Department of Industrial Works, MOI

Ministerial Notification	No.22 Performing and responsibility of the permitted factory	B.E.2528 (1985)	Department of Industrial Works, MOI
Ministerial Notification	No.24 Performing and responsibility of the permitted factory; Hazardous substance management	B.E.2530 (1987)	Department of Industrial Works, MOI
Department Notification	No.1 Control for industrial waste keeping, disposal, transportation and management of the factory	B.E.2531 (1988)	Department of Industrial Works, MOI
Ministerial Notification	The support measure for the industry that certified the Product Certification and Industrial Standard	B.E.2542 (1999)	Department of Industrial Works, MOI
Ministerial Notification	Regulation to the scale and type of factory, pollution control and management of the industry, pollution treatment administrator	B.E.2545 (2002)	Department of Industrial Works, MOI

D5. Table of Air pollution control and air quality standard

Hierarchy of laws	Subject	Year of announcement	Organization
Ministerial Notification	Prescribing the air pollutants measure and standard of the emission from industry	B.E.2548 (2005)	Department of Industrial Works, MOI
Ministerial Notification	No.2 Prescribing the air pollutants measure and standard of the emission from industry	B.E.2543 (2000)	Department of Industrial Works, MOI
Ministerial Notification	National Environment Board; No.10 Prescribing the Ambient Air Quality Standard	B.E.2538 (1995)	MOSTE
Ministerial Notification	National Environment Board; No.12 Prescribing the Standard of SO_2 (1 hr) in the Ambient Air Quality	B.E.2538 (1995)	MOSTE
Ministerial Notification	National Environment Board; No.21 Prescribing the Standard of SO_2 (1 hr) in the Ambient Air Quality	B.E.2544 (2001)	MOSTE
Ministerial Notification	National Environment Board; No.10 Prescribing the Ambient Air Quality Standard	B.E.2547 (2004)	MONRE
Ministerial Notification	Regulation of air pollution control and emission standard for Rice mills boilers	B.E.2548 (2005)	MONRE
Ministerial Notification	National Environment Board; No.15 Prescribing the Standard Noise Quality in the Ambient	B.E.2540 (1997)	MOSTE

D6. Table of Water quality standard and Wastewater discharge

Hierarchy of laws	Subject	Year of announcement	Organization
Ministerial Notification	No.2 Prescribing the Industrial Effluent Standard	B.E.2539 (1996)	Department of Industrial Works, MOI
Department Notification	Issue pursuant to Ministerial Notification No.2; Prescribing the effluent quality necessity different from the limited standard	B.E.2540 (1997)	Department of Industrial Works, MOI
Ministerial Notification	No.3 Regulation and standard for industrial control facilities	B.E.2539 (1996)	Pollution Control Department, MOSTE
Ministerial Notification	No.4 Prescribing the types of industry and industrial estate to be regulated as the source of water pollution and need effluent treatment and control	B.E.2539 (1996)	Pollution Control Department, MOSTE
Ministerial Notification	Stipulate the types of industry and industrial estate to be regulated as the source of water pollution and need effluent treatment and control	B.E.2536 (1993)	Pollution Control Department, MOSTE
Department Notification	Sampling method of effluent from industry and industrial estate; sampling method, frequency, time and period of sampling	B.E.2539 (1996)	Pollution Control Department, MOSTE
Department Notification	No.67/2534 Require the permission and approved for all sources of wastewater discharge to the water courses	B.E.2534 (1991)	Marine Department, MOT
Department Notification	No.419/2540 Prescribing the effluent control and standard from the industry and industrial estate source	B.E.2540 (1997)	Marine Department, MOT
Department Notification	No.435/2540 Prescribing the types of industry and its effluent is required to meet the standard	B.E.2540 (1997)	Marine Department, MOT

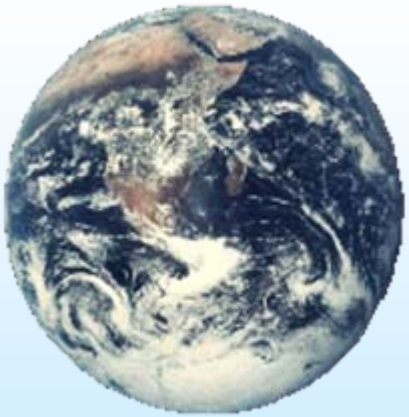
D7. Table of Policies and law related to the energy and boilers

Hierarchy of laws	Subject	Year of announcement	Organization
Ministerial Notification	No.18 Duties of permit industry in boiler operation (about boiler)	B.E.2528 (1985)	Department of Industrial Works, MOI
Ministerial Notification	No.26 Duties of permit industry in boiler operation (boiler management)	B.E.2534 (1991)	Department of Industrial Works, MOI
Department law	Regarding to registration of engineer to boiler facilities and control	B.E.2528 (1985)	Department of Industrial Works, MOI
Act of legislation	Energy Development and Promotion	B.E.2535 (1992)	Department of Energy Development and Promotion, MOST (2002, Changed to Department of Alternative Energy Development and Efficiency, MOE)
Act of legislation	Enhancement of Energy Conservation	B.E.2535 (1992)	Department of Energy Development and Promotion, MOST
Act of legislation	Prescribing the controlled industries	B.E.2540 (1997)	Department of Energy Development and Promotion, MOST
Ministerial Regulation	No.5 Reporting form of the required information of industry; process, energy consumption and conservation, industrial energy plan. To control and monitoring the industry follow their plan	B.E.2540 (1997)	Department of Energy Development and Promotion, MOST
Ministerial Regulation	No.6 Regular the reporting method and time of submission from the industry. Regularly control to following the industrial conservation plan.	B.E.2540 (1997)	Department of Energy Development and Promotion, MOST
Ministerial Notification	Procedure of inspection reporting and energy analysis in the industry	B.E.2540 (1997)	Department of Energy Development and Promotion, MOST

D8. Table of Laws related to the economy

Hierarchy of laws	Subject	Year of announcement	Organization
Ministerial Notification	Rice product standard	B.E.2540 (1997)	Department of Foreign Trade, MOC
Ministerial Notification	Prescribing Thai Hom Mali Rice as a Standardized Commodity and Standards for Thai Hom Mali Rice	B.E.2544 (2001)	Department of Foreign Trade, MOC
Ministerial Notification	Prescribing Thai Hom Mali Rice as a Standardized Commodity and Standards for Thai Hom Mali Rice (No.2)	B.E.2545 (2002)	Department of Foreign Trade, MOC
Ministerial Notification	Prescribing Thai Hom Mali Rice as a Standardized Commodity and Standards for Thai Hom Mali Rice (No.3)	B.E.2546 (2003)	Department of Foreign Trade, MOC
Ministerial Notification	Rules and Methodologies of Commodities and Thai Hom Mali Rice Standards Inspection B.E.2545 (2002)	B.E.2545 (2002)	Department of Foreign Trade, MOC
Ministerial Notification	Establishing Customs Checkpoints Where Exporters or Senders of Standardized Thai Hom Mali Rice Shall Present the Certificates of Commodity Standard	B.E.2545 (2002)	Department of Foreign Trade, MOC
Ministerial Notification	Establishing Fees for Commodity Standard Inspection And Issuance of Thai Hom Mali Rice Certificates (No.2) B.E.2545 (2002)	B.E.2545 (2002)	Department of Foreign Trade, MOC
Department Notification	CSI (Bureau of Commodity Standard Inspection) Establishment of Locales of Areas for the Purpose of Inspecting Thai Hom Mali Rice Destined for Export	B.E.2545 (2002)	Department of Foreign Trade, MOC
Department Notification	Procedure and Methodology of Thai Hommali Rice Sampling to genetic prove	B.E.2547 (2004)	Department of Foreign Trade, MOC

Environmental and Techno-Policy Analysis of an Agro Eco-Industrial Network in Chachoengsao Province



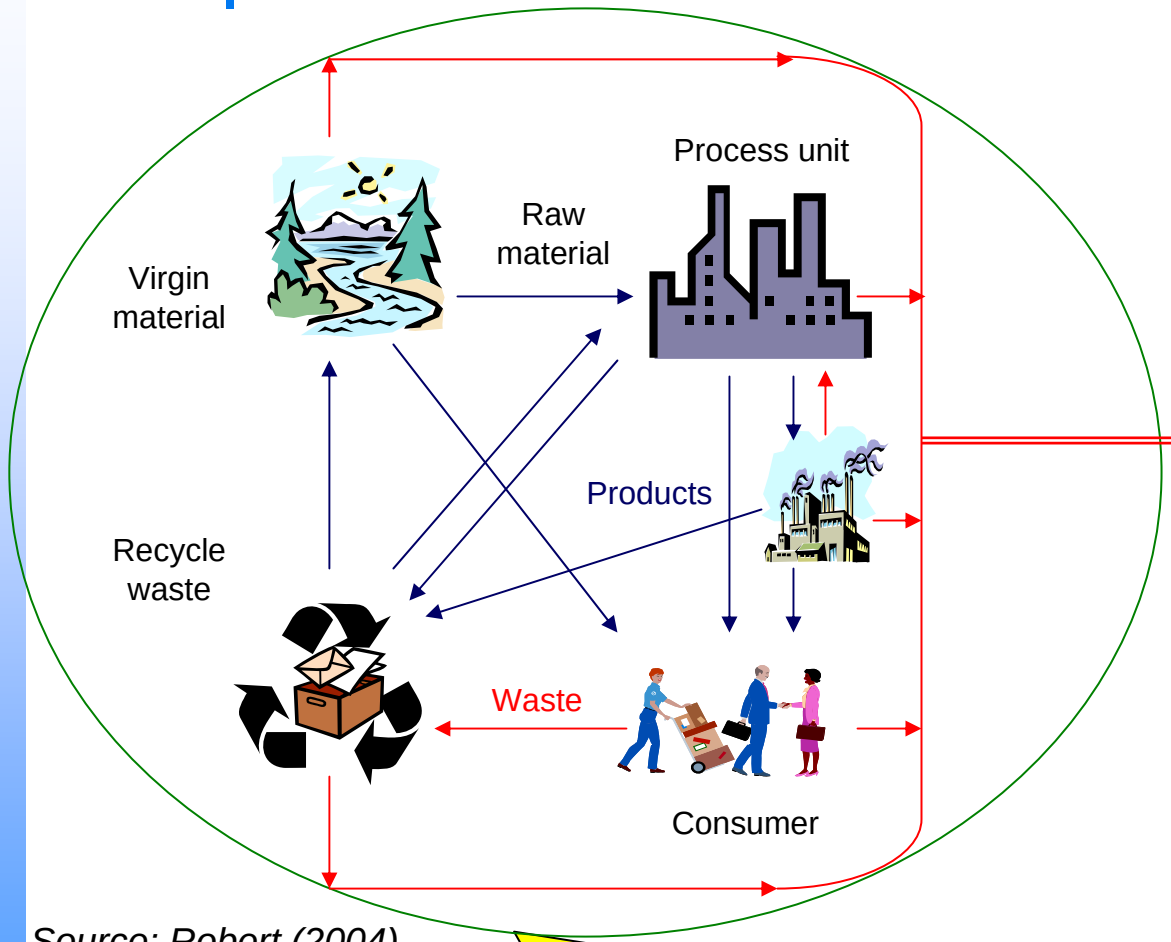
Examination Committee:

Prof. C. Visvanathan (Chairperson)
Dr. Nowarat Coowanitwong
Dr. Thammarat Koottatep
Dr. Shabbir H. Gheewala

By Ms.Niranchana Authayanraksa

Contents

Industrial Ecology

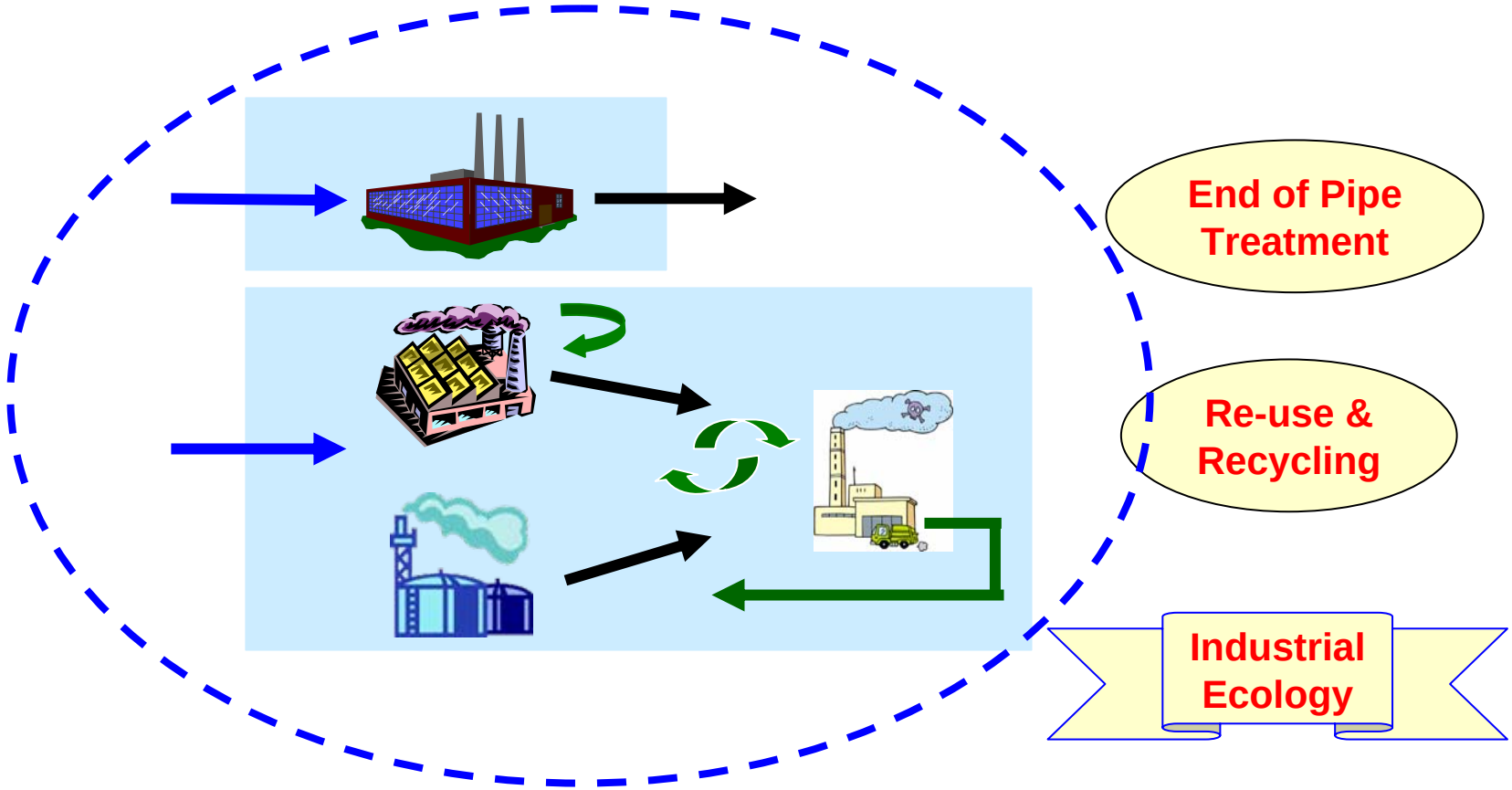


Source: Robert (2004)

- Novel approach to achieve Sustainable Industry
- New concept to environmental management and innovative business strategy
- Tool for formulating policy, regulations and incentives

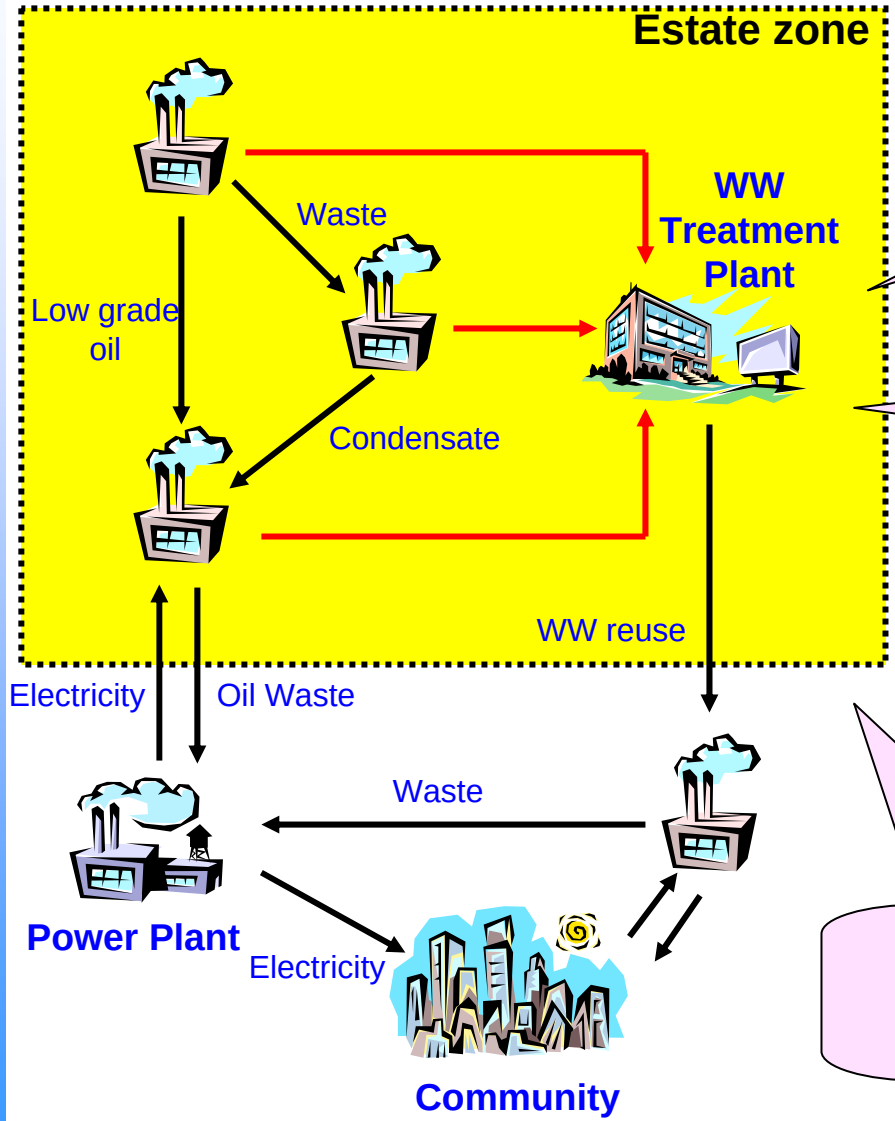
➢ Industries as "**Eco-systems**"
➢ Energy flows and material exchanges between industries and natural ecosystems

Environmental Management



- IE implies other PP approaches, including CP & End-of-pipe Treatment
- Try to Closed the Loop with complete material recovery (Recently, unachievable with existing technology)

Eco-Industrial Network



- A set of companies ting → Improve ronmental, social, and economic performance in a region

Industrial Estate

Eco-Industrial Park

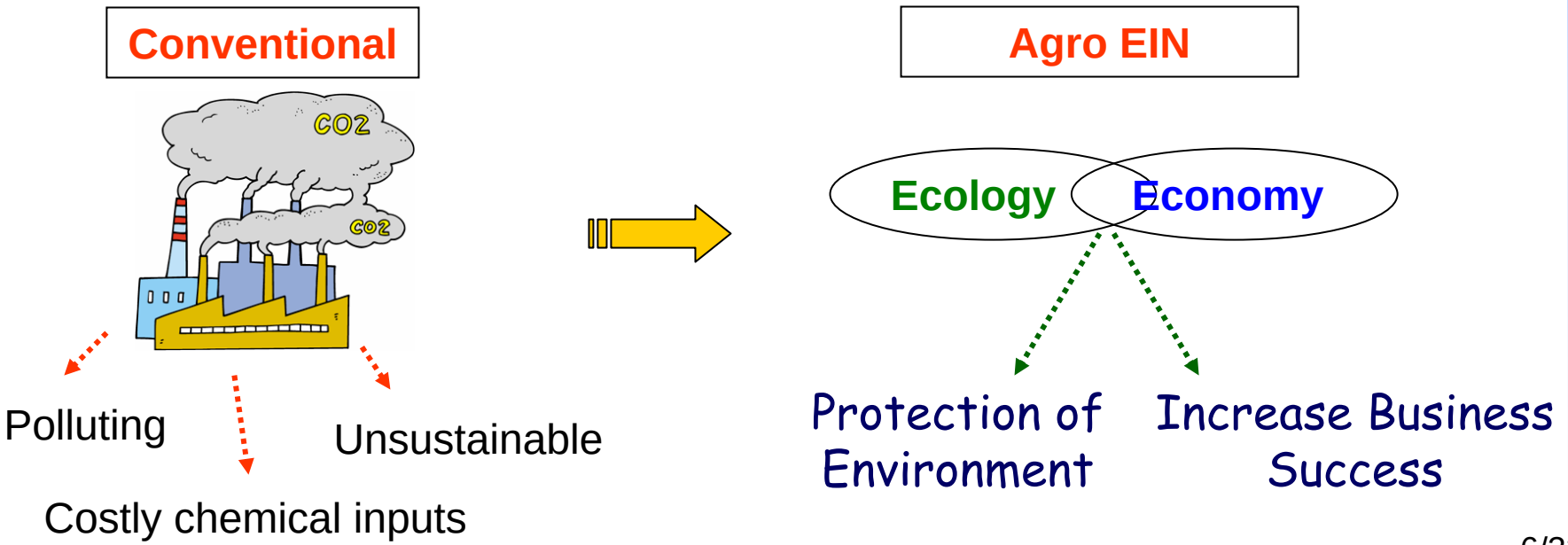
is to exchange by-product materials, energy, or water among companies

- Regional Scale; unlike an EIP (Co-location)

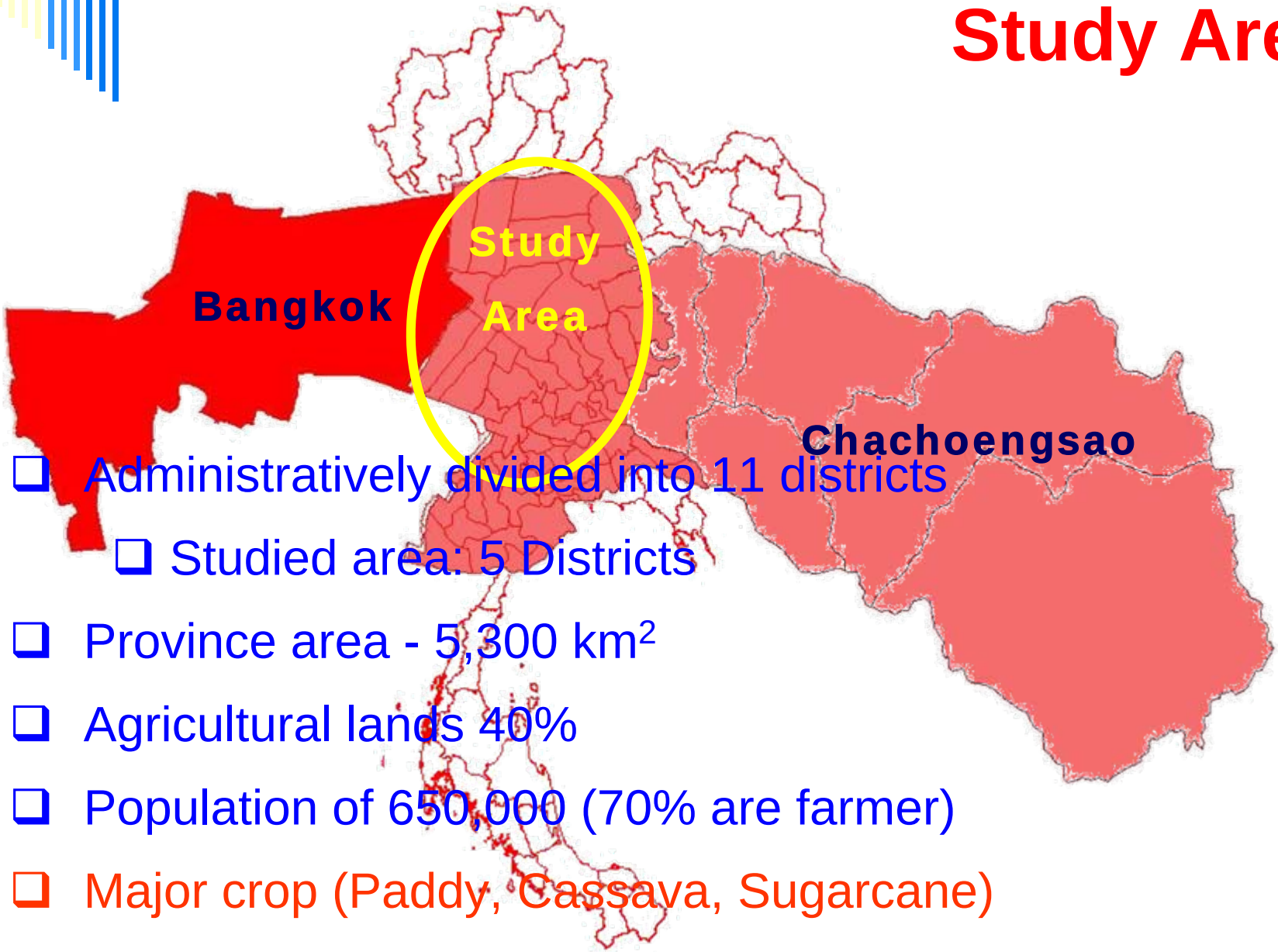
Eco-Industrial Network

Agro-based Industry

- Based on **agricultural and forestry** production
- Purpose:
  - To preserve and refine raw products
  - To extract and concentrate the valuable constituents
- Agro Eco-Industrial Network: using basic strategies of EIN
- High opportunity for profitable by-product flow between tenants
  - e.g. biomass, energy, and water intensive companies in food processing
- Support sustainable agriculture and livelihood of rural communities



Study Area

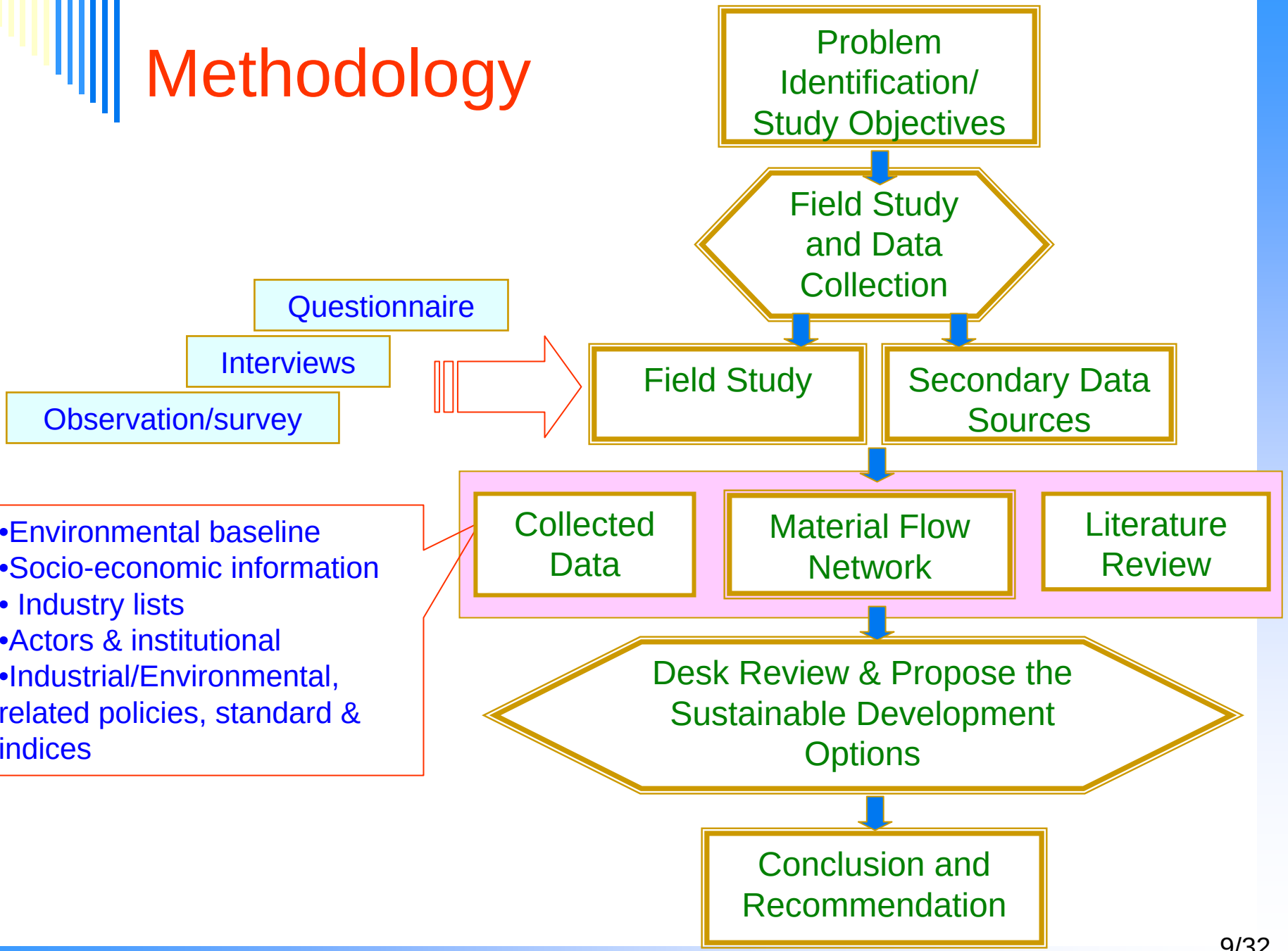


- Administratively divided into 11 districts
  - Studied area: 5 Districts
- Province area - 5,300 km^2
- Agricultural lands 40%
- Population of 650,000 (70% are farmer)
- Major crop (Paddy, Cassava, Sugarcane)
- Mix of rural and urban areas

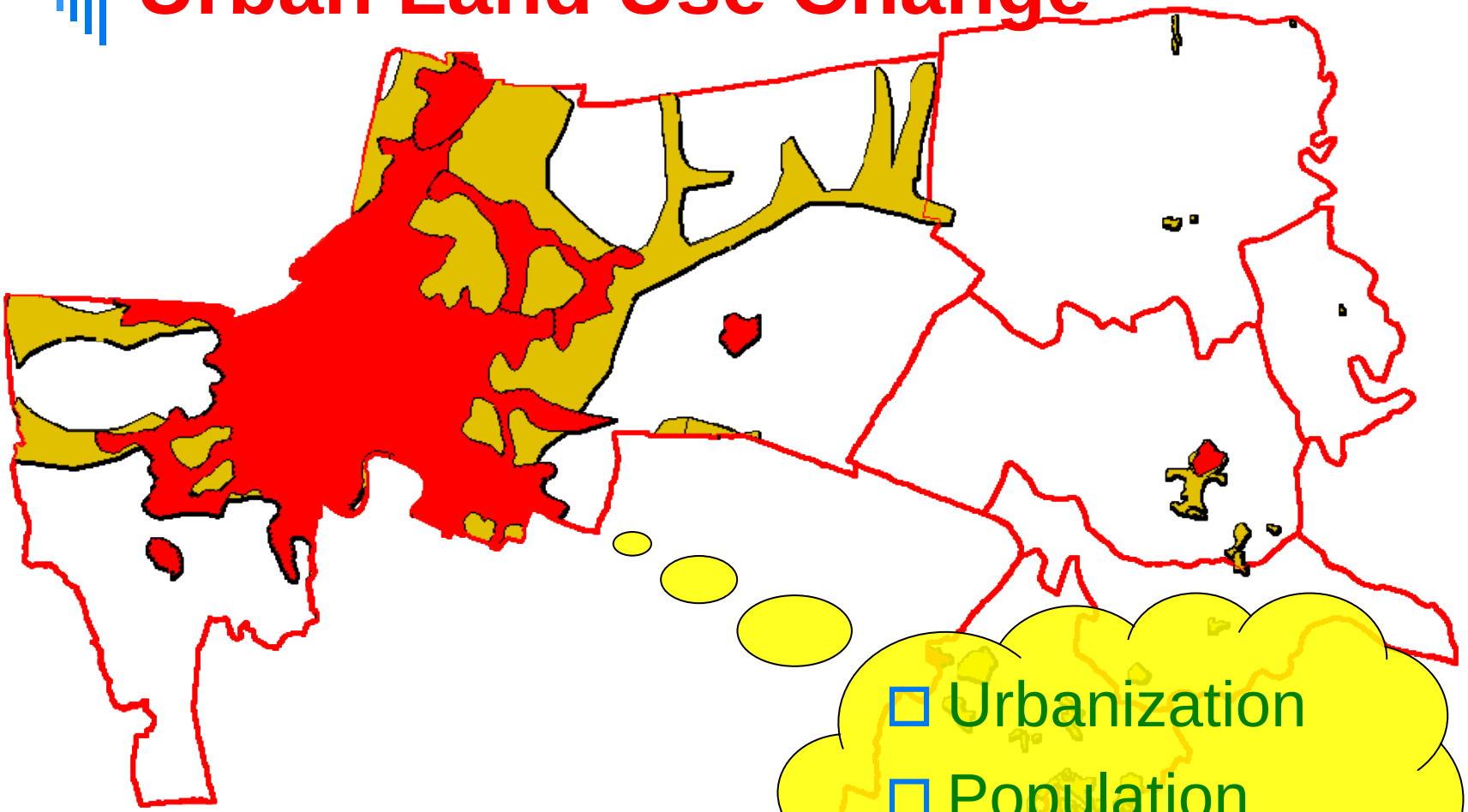
Objectives of study

- To investigate the existing environmental, economic and technological situation of agro-based industries in the fringe areas of Chachoengsao Province
- To study the existing role and level of integration of policies related to the development of industrial clusters and local communities
- To develop the material flow network so as identify the alternative use of waste and by-product and optimize resource use

Methodology



Urban Land Use Change



- Urbanization
- Population Growth

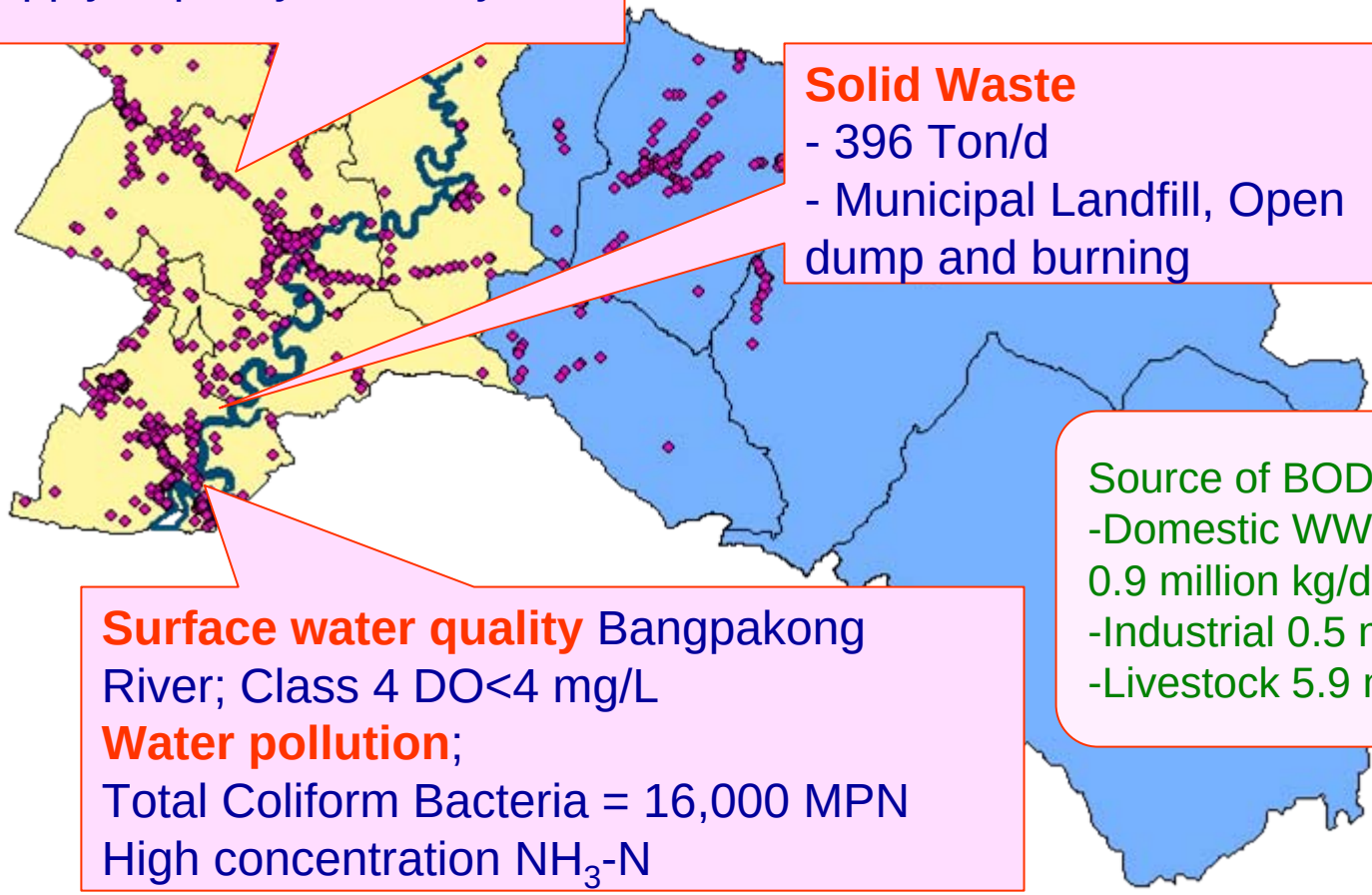
Bangkok & 5 Study Districts - 1990

Bangkok & 5 Study Districts - 2003

Bangkok & 5 Study Districts – 1990 - 2003

Environmental Problems

Deficient Water Consumption;
-Water consumption 1,000 m^3/yr
-Water supply capacity 850 m^3/yr



Solid Waste
- 396 Ton/d
- Municipal Landfill, Open dump and burning

Source of BOD loading
-Domestic WW
0.9 million kg/d
-Industrial 0.5 million kg/yr
-Livestock 5.9 million kg/yr

Surface water quality Bangpakong River; Class 4 DO<4 mg/L
Water pollution;
Total Coliform Bacteria = 16,000 MPN
High concentration NH_3-N

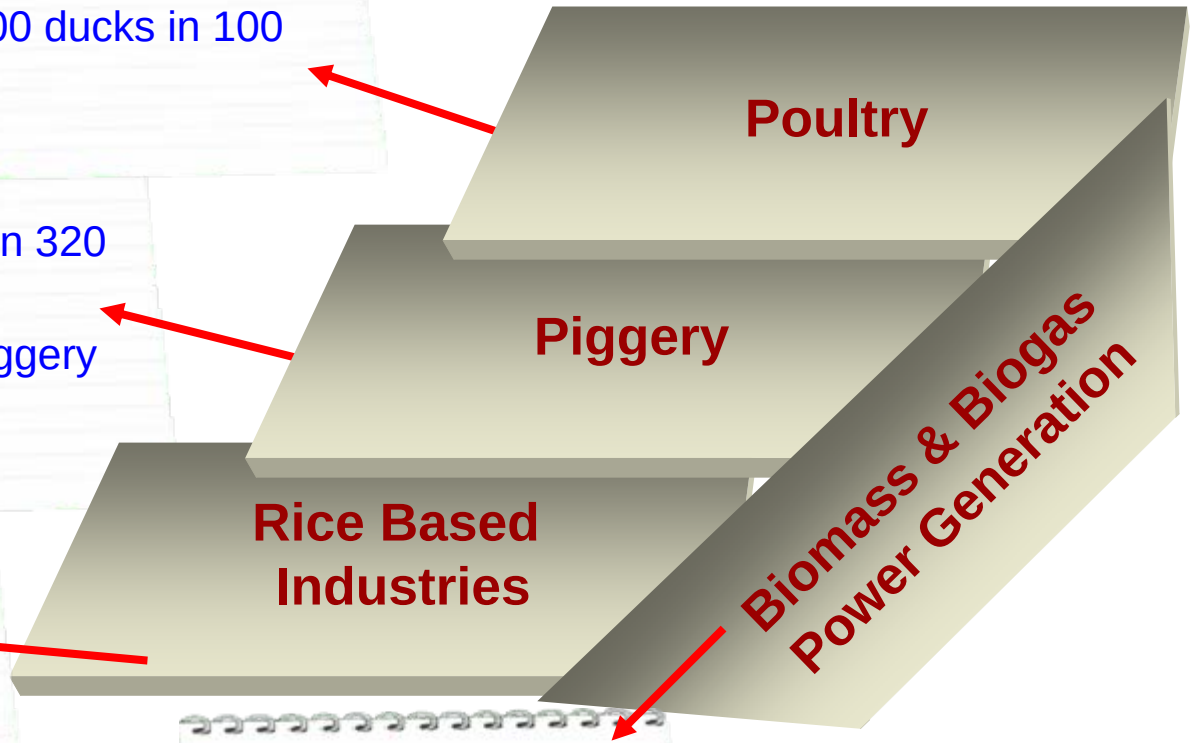
Results and Discussions

- ✓ 5 million chicken in 330 farms
- ✓ 700,000 ducks in 100 farms

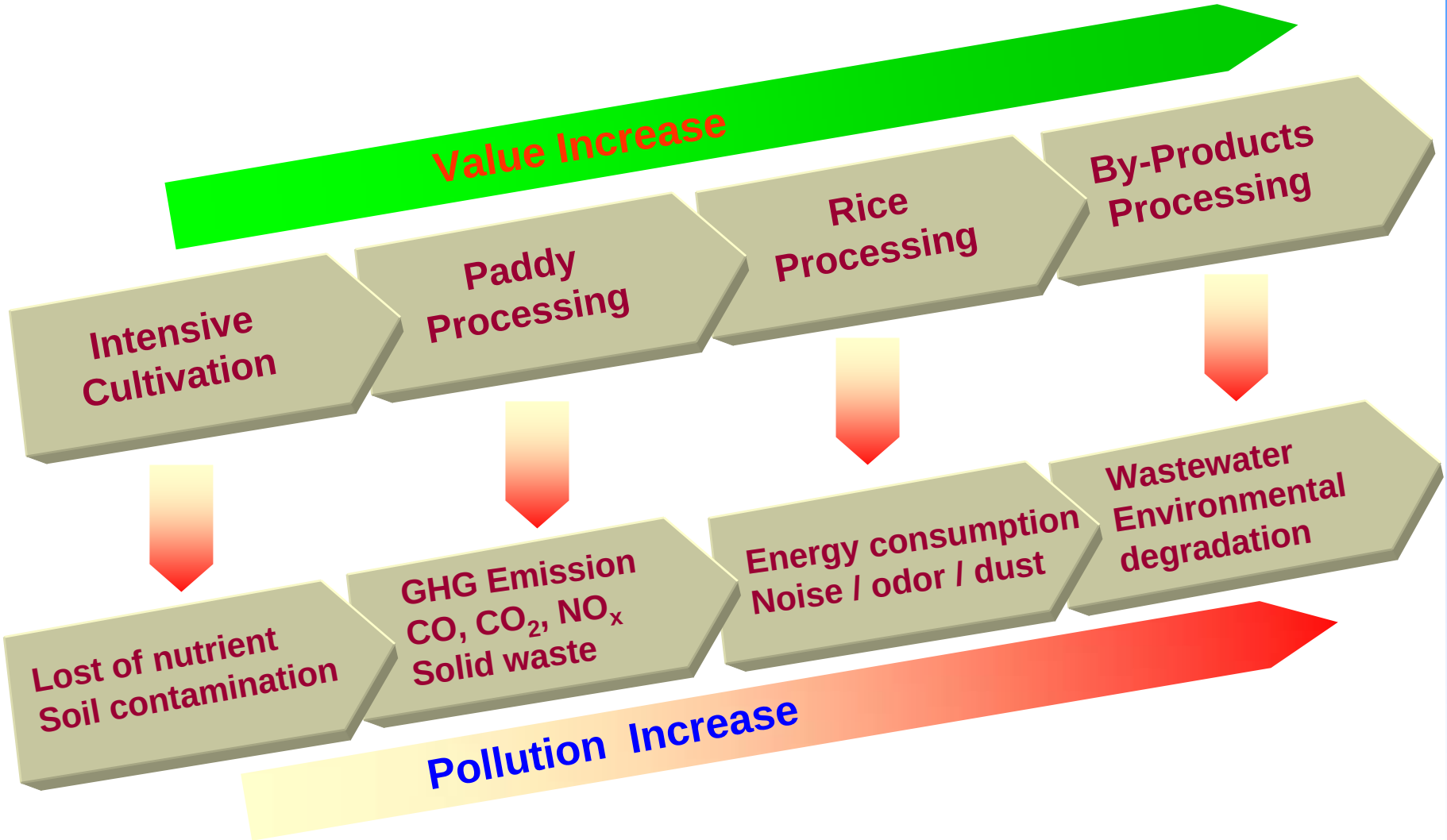
- ✓ 379,000 pigs in 320 pig farms
- ✓ 300 tons of piggery waste

- ✓ 82 Rice Mills
- ✓ 17 Rice Noodle industries
- ✓ 1 Rice Bran Oil Extraction Industry

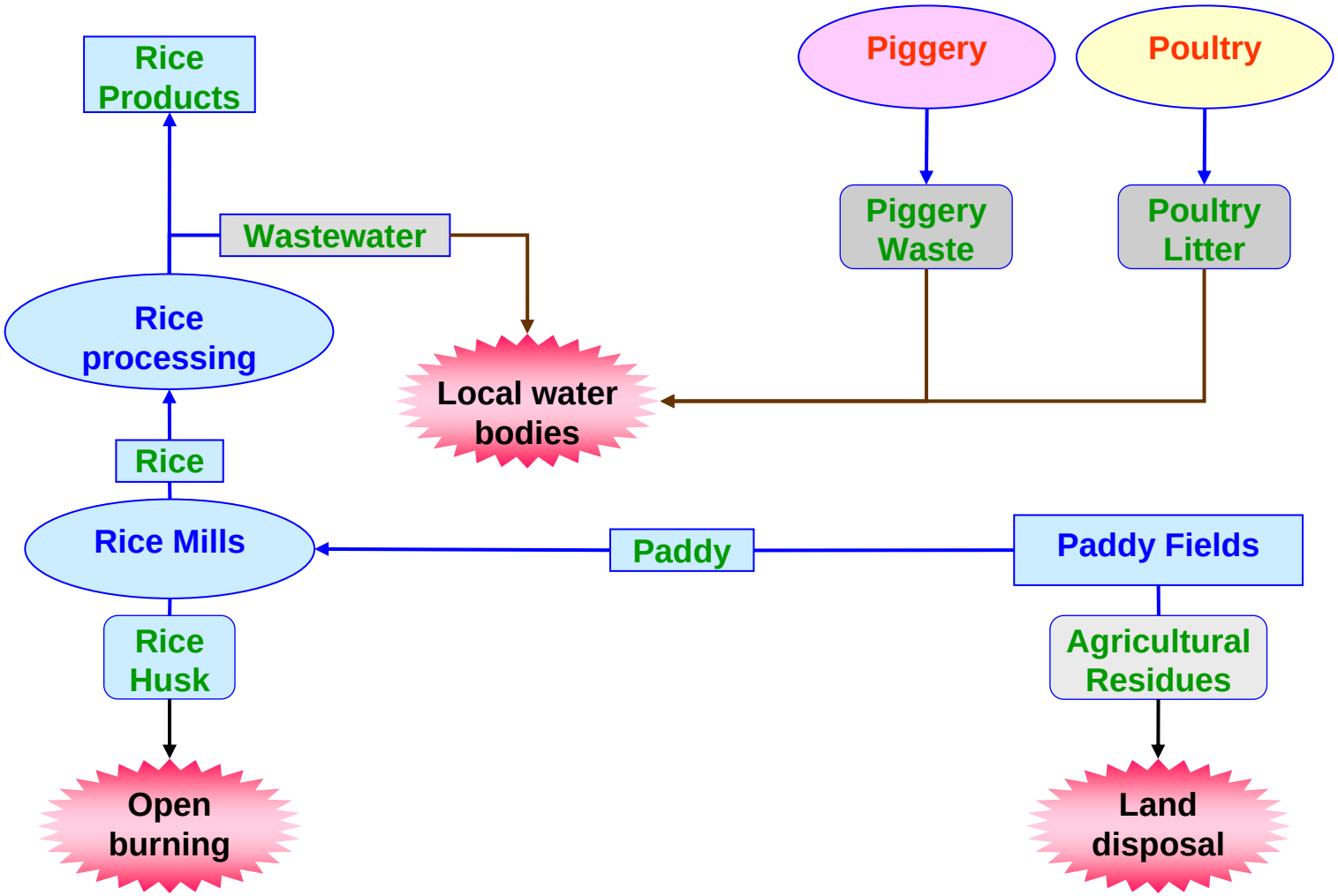
- ✓ 10.4 MW Rice husk Biomass Power Plant



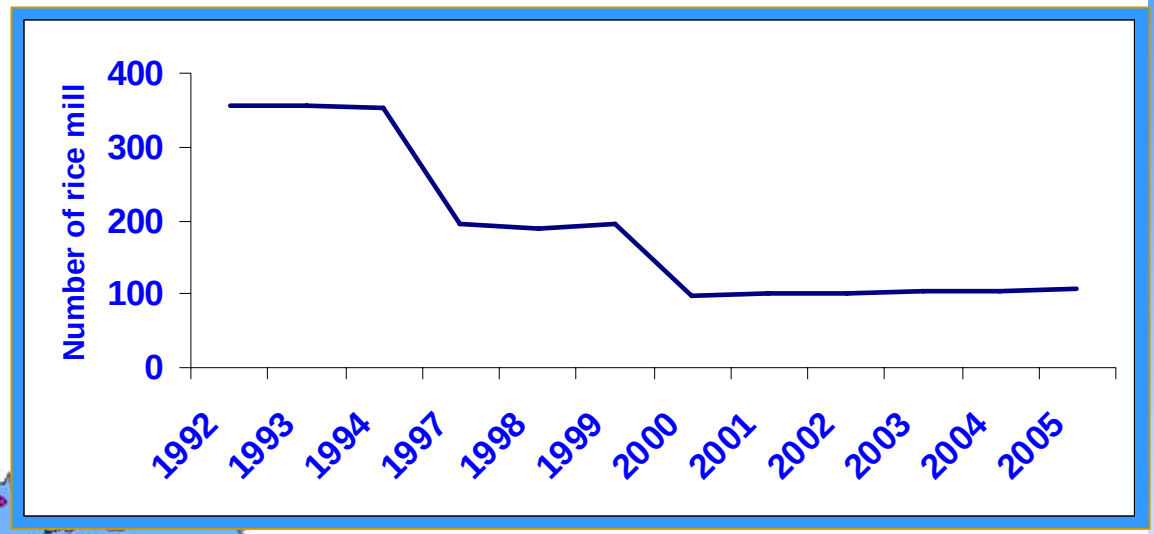
Rice-based Value Chain

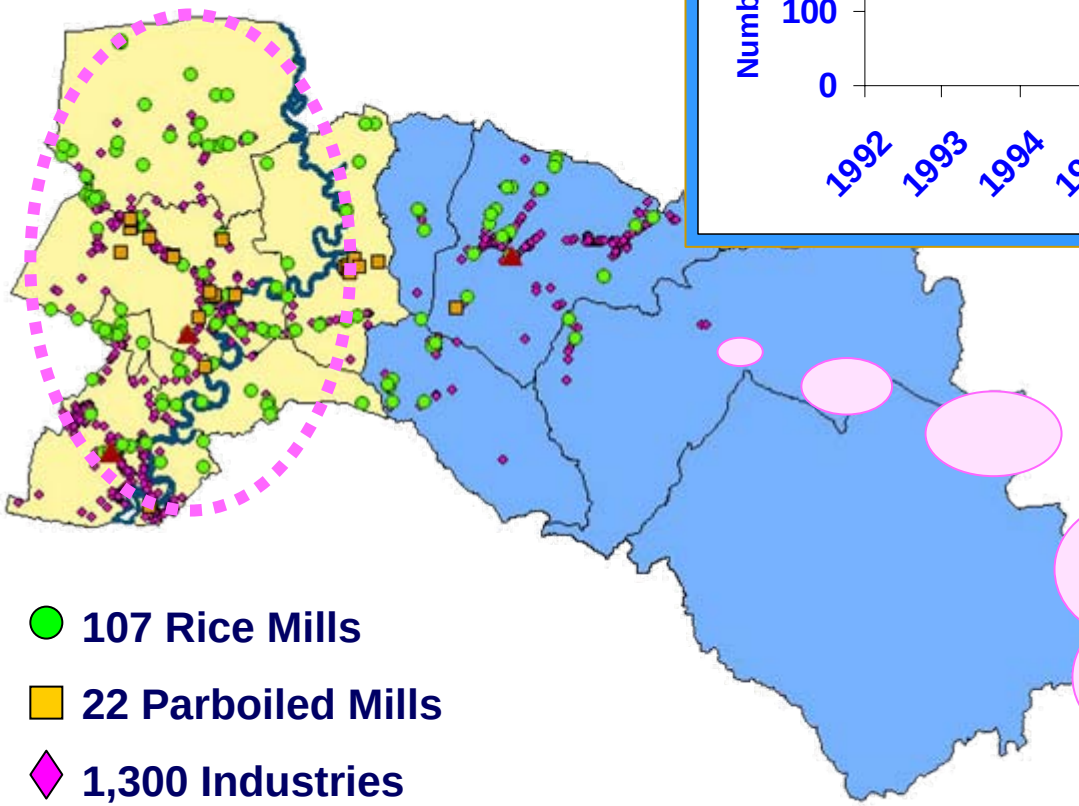


Existing Material Flow



Rice Mill Statistic





- 107 Rice Mills
- 22 Parboiled Mills
- 1,300 Industries

Rice mill established:

44 Small

15 Medium

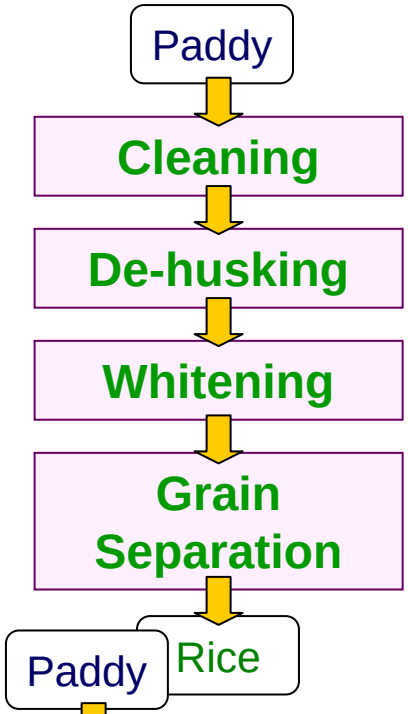
48 Large

Paddy Processing

White Rice Mill →Dry process

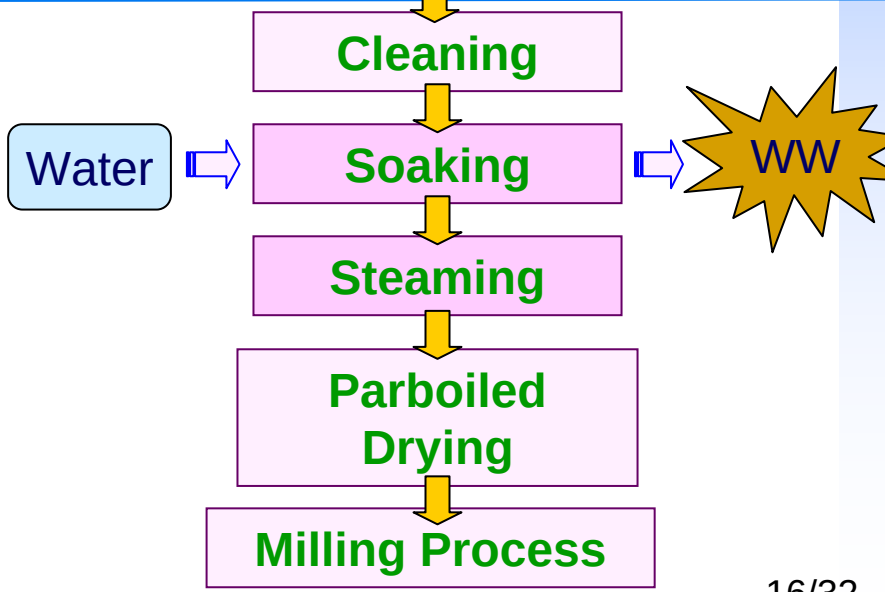
- Production capacity = 150 ton/d (paddy)
- 24 hours, 250 days/yr working



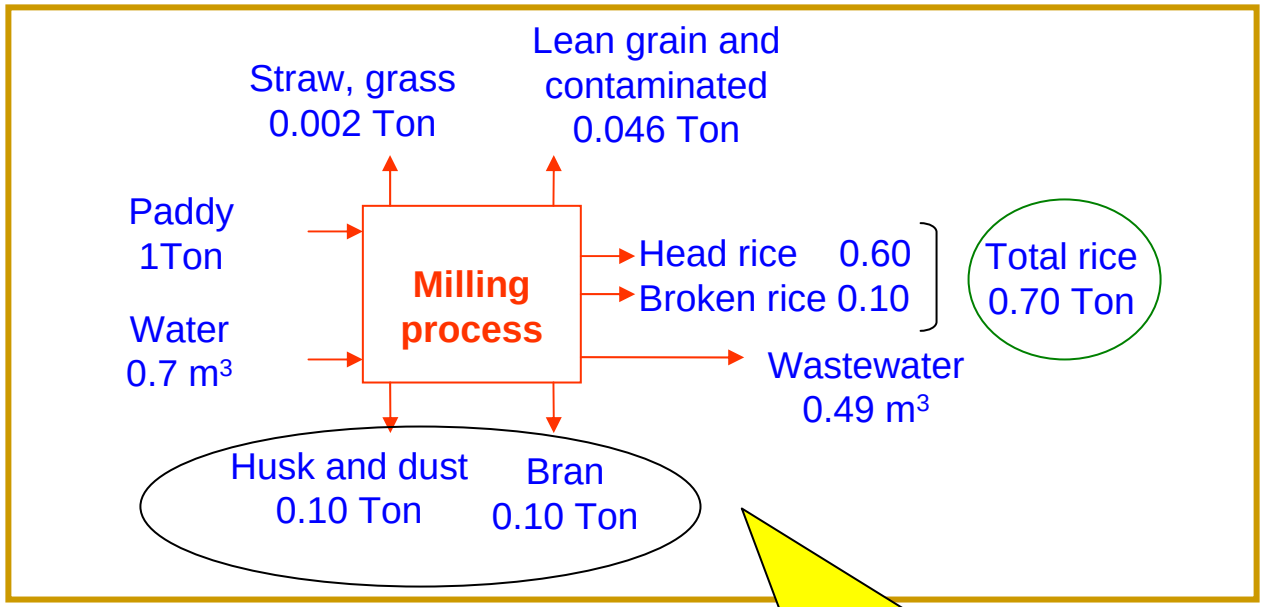


Parboiled Mill

- Production capacity = 600 ton/d (paddy)
- 24 hours, 250 days/yr working

Parboiled Rice Mill: Mass Balance



- Energy consume;
  - Electricity 44.4 kWh/ Ton
  - Husk Fuel 0.04 Ton
- Water consumption = 25 m^3/d
- Dust and particulate matter
  - Boiler = 290 mg/m^3
  - Standard= 320 mg/m^3

By-product and Waste Value

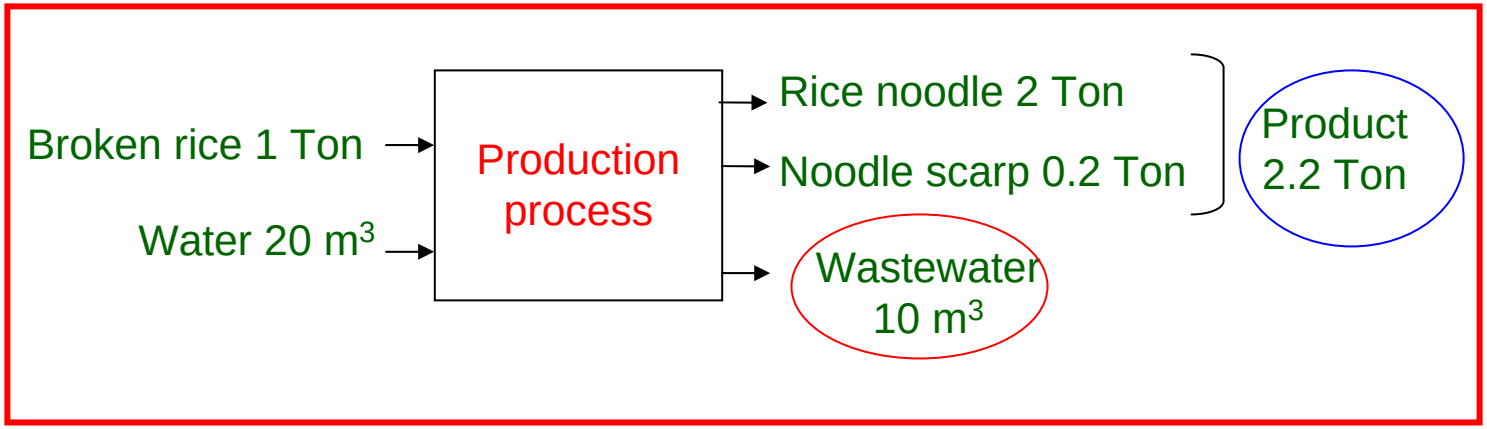
- Bran 8,000 ฿/T →Oil extraction industry
- Husk 800 ฿/T →Power plant
- Straw 1,200 ฿/T →Farm
- Ash 500 ฿/T →Farm

Parboiled Mill WW Treatment

Parameters	Effluent	Thai effluent standard
pH	6.7	5-9
Temperature (^oC)	38	$\leq$ 40
DO (mg/L)	4	-
BOD_5 (mg/L)	9	$\leq$ 20
Suspended solid (mg/L)	239	$\leq$ 150
Oil and grease (mg/L)	9.6	$\leq$ 5
Water consumption of selected Parboiled Mill (m^3/ton product)	0.7	-

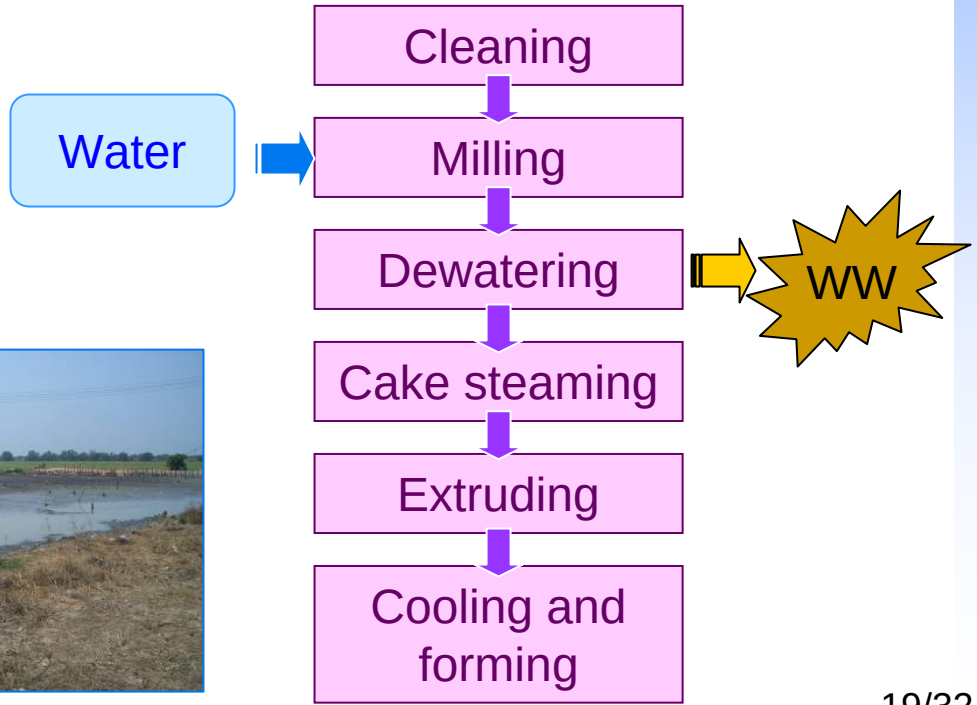
Major source:
- **Rice soaking & cooking process**
- **Lubricant & oil spill**

Rice Processing: Rice Noodle Industry



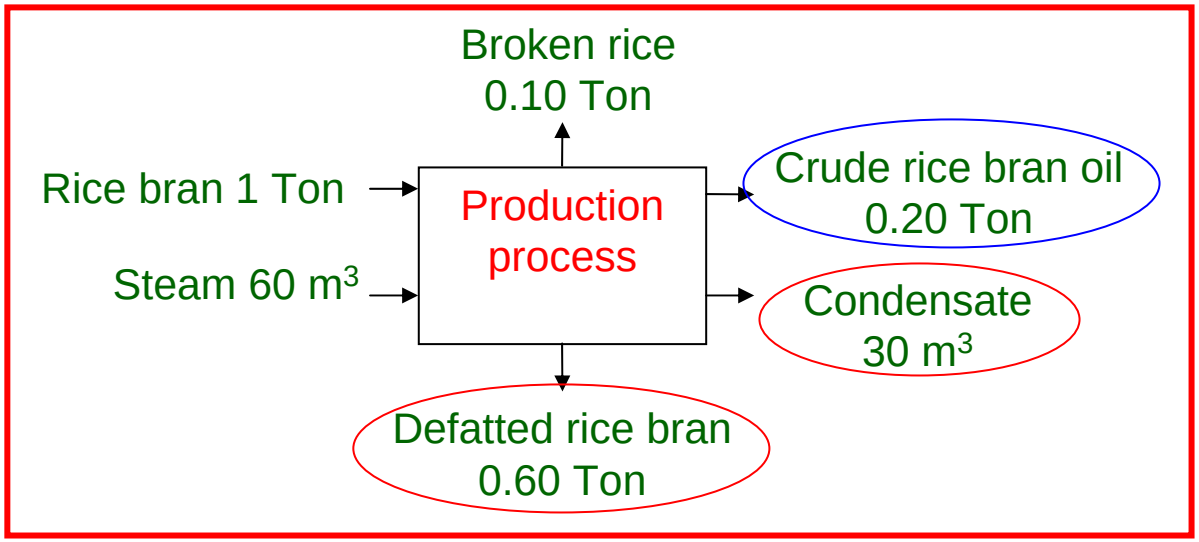
Energy consumption:

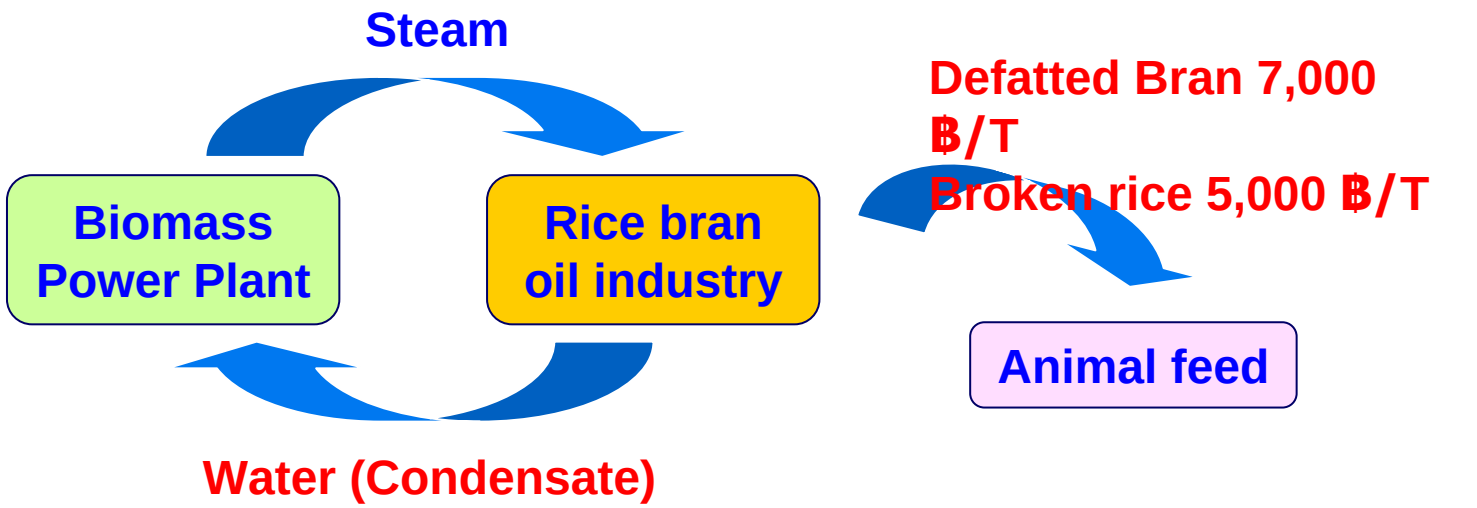
- **Electricity 83 kWh/Ton product**
- **Fuel wood 10 Tons/d**



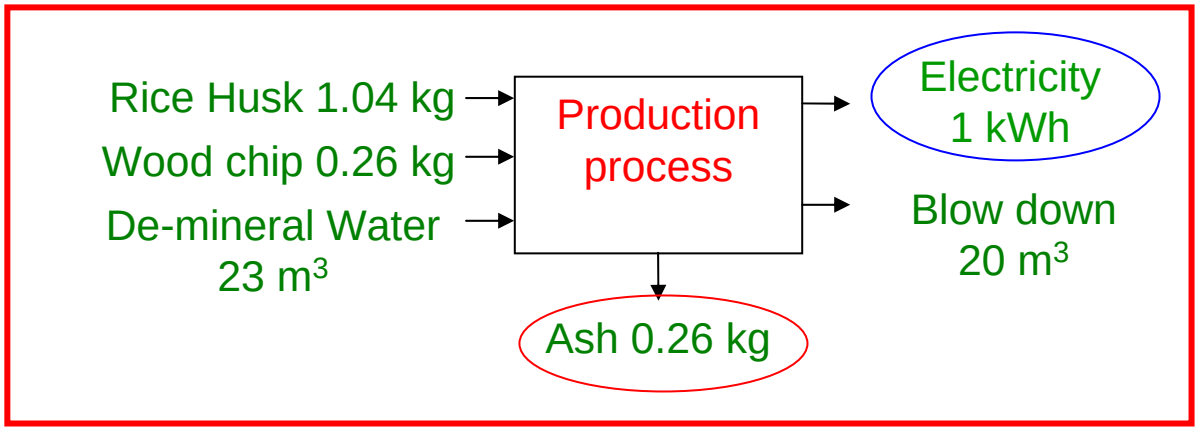
- **Wastewater 10 m³/Ton**
- **BOD 0.22 kg/Ton product**

Rice Crude Bran Oil Industry

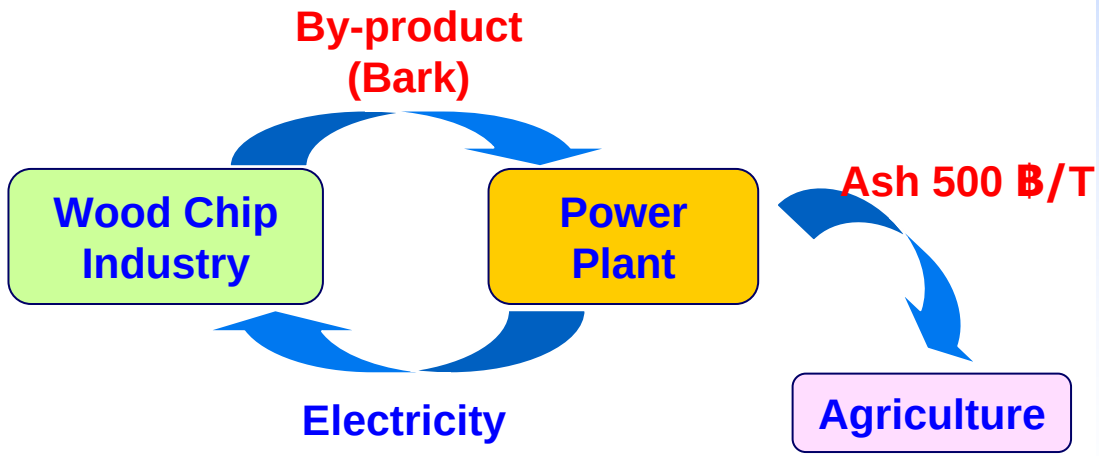




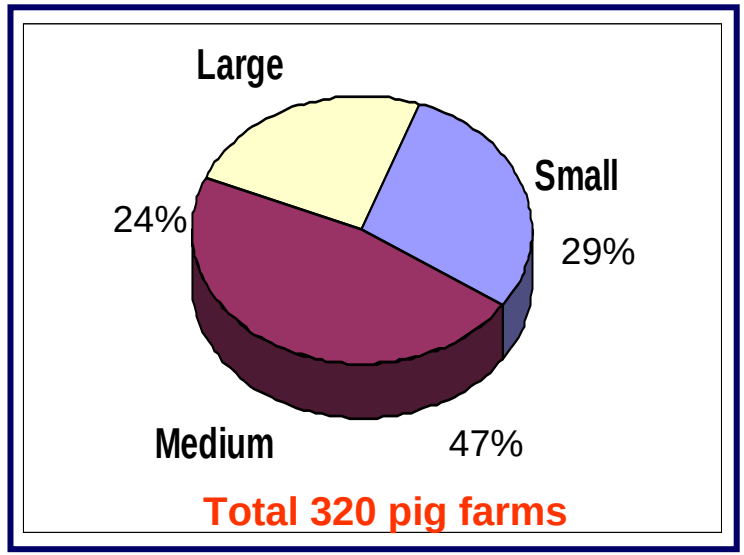
Biomass Power Plant



- Fluidized Bed Combustion
- Electricity 10.4 MW/d ;
  - Sale to local customers = 1 MW/d
  - EGAT= 8 MW/d
  - In-plant use= 1 MW/d



Piggery Farm



- **Existing waste management**
  - Pig Manure;
    - Solid→ Sale to the farmer & composting
    - Wastewater→ Directly discharged/ Pond/ Treatment system
  - Existing Wastewater treatment system
    - Anaerobic filter tank
    - Stabilization pond

Parameter	Value
Generation rate (L/pig/d)	27
BOD (mg/L)	2,500
COD (mg/L)	6,800
Biogas Production (L/pig/d)	93
Organic fertilizer (kg/d)	0.36

Poultry Farm

Description	Chicken
Total farms	202
Total Number (x1,000)	5,971
Average body weight (kg)	2
Wet waste (%TLW/d)	6.6
Total Solid (%TWW)	25.3
Biogas Production (m^3/kg waste)	0.1

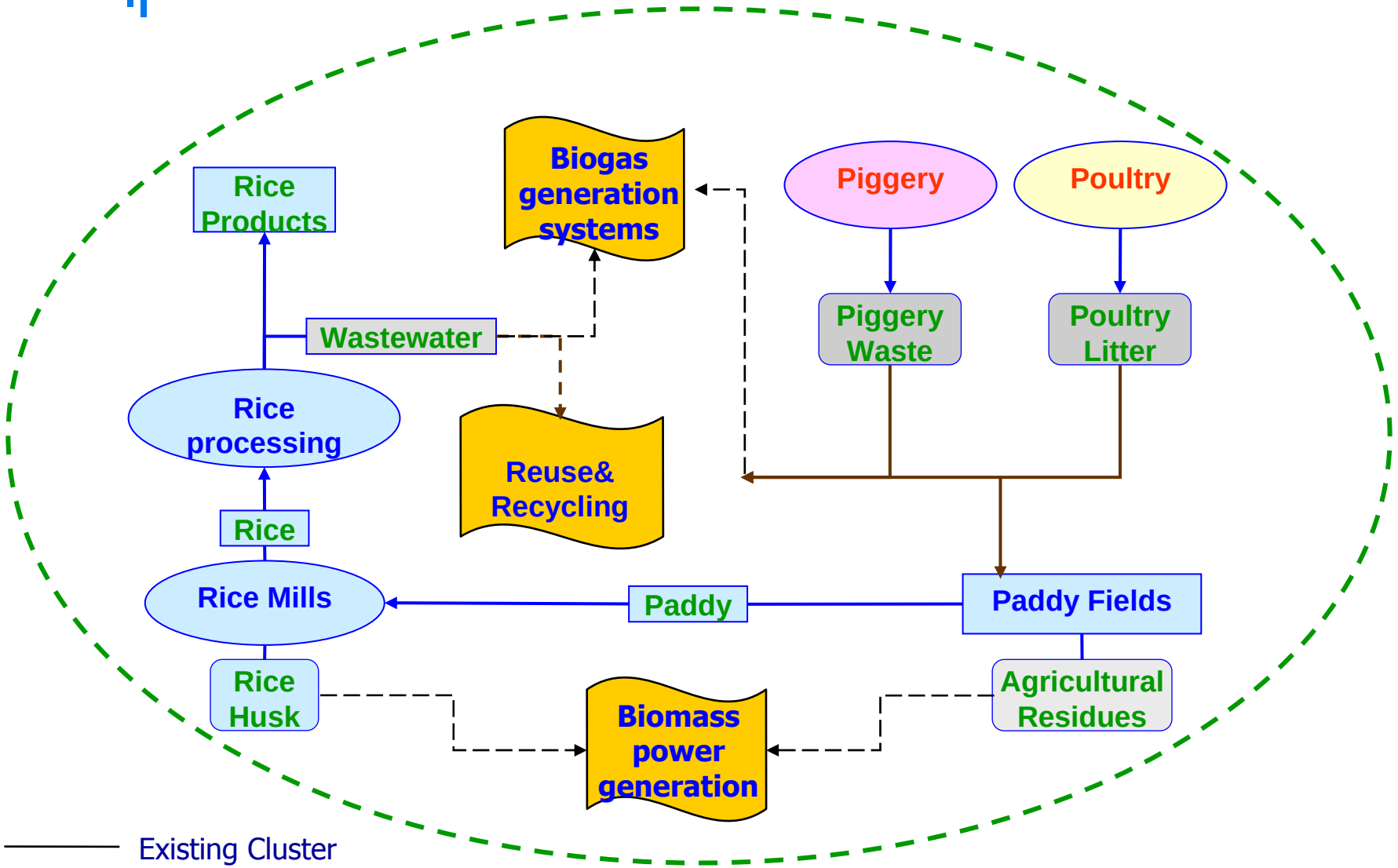
Note: TLW = Total life weight, TWW = Total wet weight

Litter

→Sale for organic fertilizer 1,000 ฿/Ton

→Chicken cum Fish farm/ sale for fish feed

Proposal Agro Eco-Industrial Network



Major changes and Improvement

Existing Network	Proposed Technology	Agro EIN
 Parboiled rice mill WW	WWTS	Recycle Water 150,000 m^3/yr
 Rice Husk & Residues 835 kT/yr	Biomass Power Generation	Electricity Sale to EGAT and Local businesses 642 GW/yr
 Piggery WW 3.7 Million m^3/yr  Rice noodle WW 1.2 Million m^3/yr	Biogas generation system	Biogas production; ✓ Rice noodle industry = 6,205 m^3/yr ✓Piggery = 12 Million m^3/yr

Gaps of the proposed Technologies

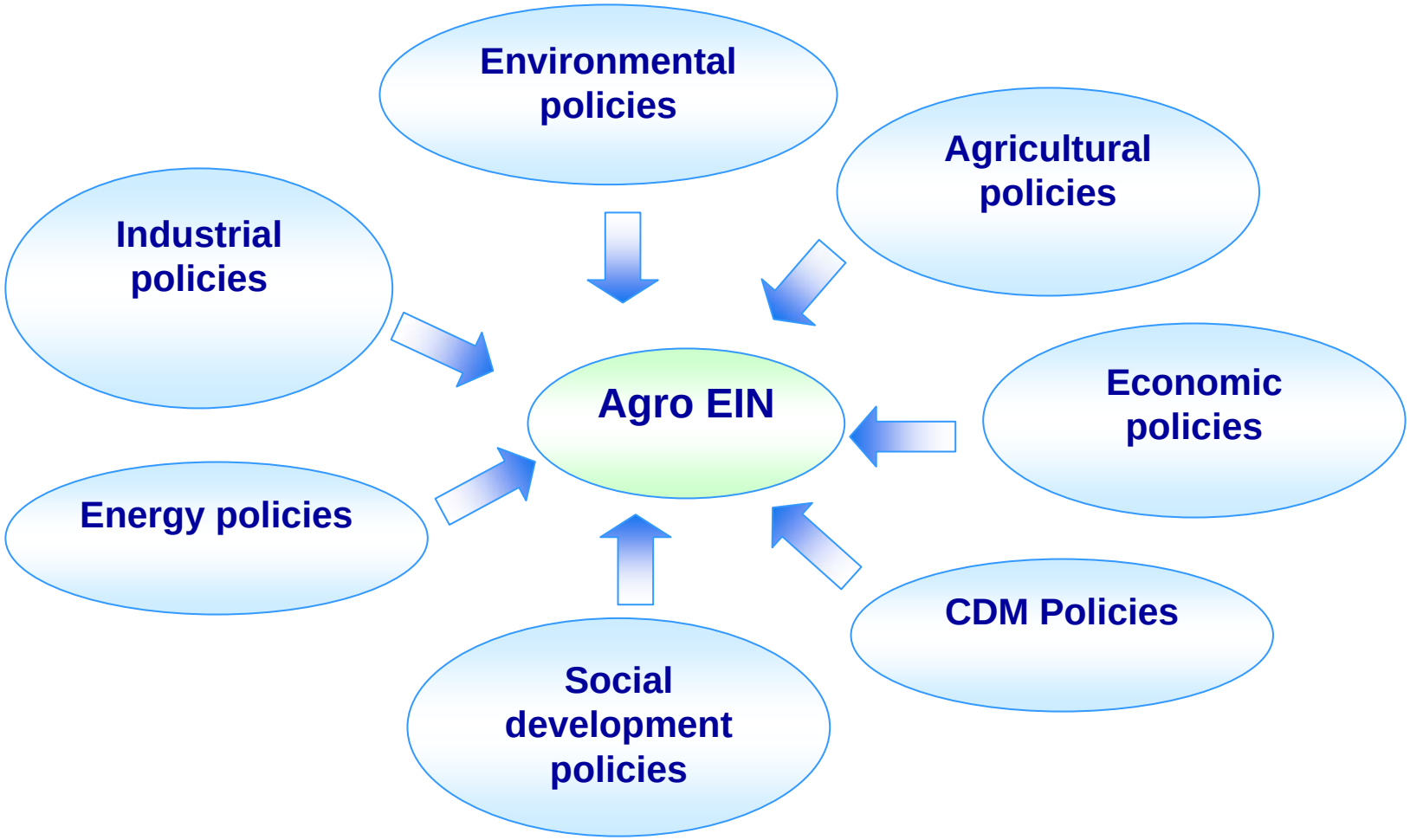
Prevents environmental degradation

- Biogas generation systems
  - High capital investment
  - Lack of labor skill, expert and technical support
  - Lack of monitoring and control from organization

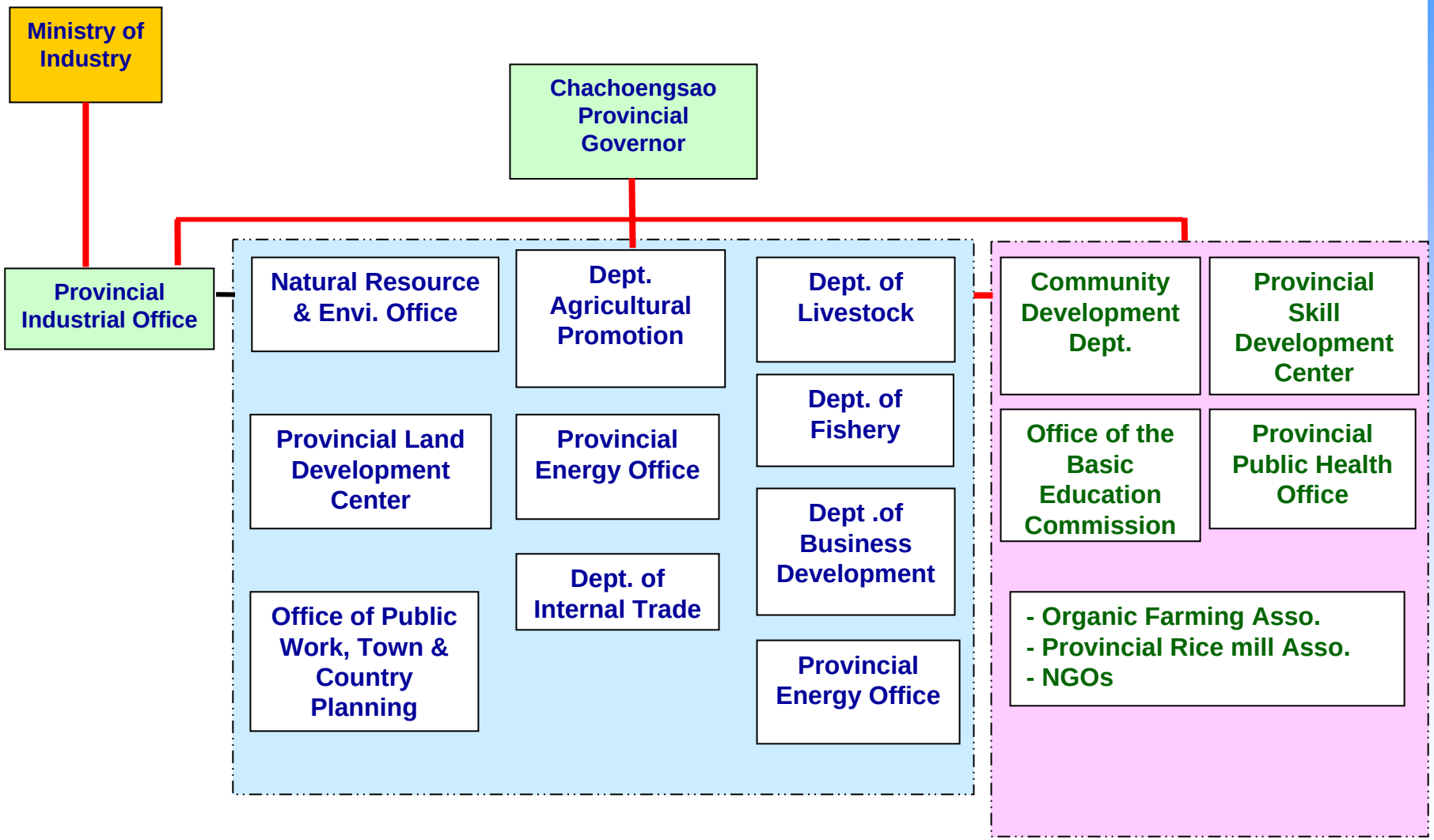
- Biomass power generation
  - Rice husk purchase price increasing
  - Deficiency of technical support

Efficient use of resources

Policies Related to AEIN



Local Administration



Major Policies Fostering AEIN

- National Economic and Social Development Plan
- Factory control; DIW
- SMEs and Cluster development policy; DIP
- Investment Promotion; BOI

Agro-Industrial Development Policies

Environmental Protection Policies

- Policies on;
- Natural resource
- Pollution
- Natural and cultural environments
- Community environment, education & promotion
- Technology

- CDM projects and policy
- Renewable Portfolio Standard
- SPP and VSPP schemes
- Rural and regional development strategies and policies

Supporting Proposed EIN Policies

Conclusions

- The material flow of rice and livestock clusters of Chachoengsao indicates the potential for its transformation to an eco-industrial network
- Introduction of technologies are essential for a successful transformation; the proposed technological used in this research are Biogas generation systems and Biomass power generation
- Appropriate policy considering all related issues of the eco-industrial cluster and rightly integrated with national and local development priorities is essential

Recommendations for further study

- The network and linkages between and within business units need to examine the Market-based and economy
- Cost-effective technologies for Small & Medium -scale, decentralized biomass power and biogas generation is required
- Evaluation in terms of the benefit gains of each proposal environmental friendly industries, to link with the social suitable

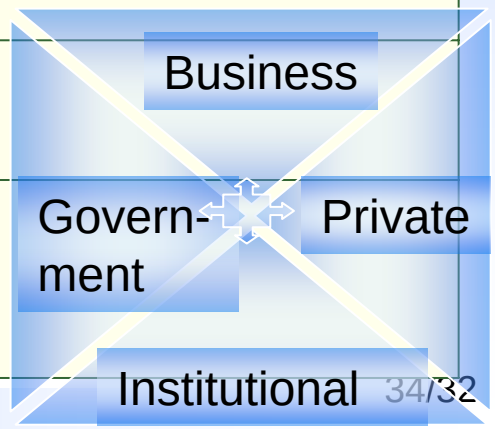
Thank you

EIN Benefits

Community	Local Businesses	Environment
Dynamic, diverse, stable economic base	Increased profitability and competitiveness	Improved environment and habitat
Increased local business opportunities	Enhanced market image	Continuous environmental improvement
Improved tax base	Cost savings through shared services	Reduced exposure to pollutants
Increased community pride	Cost reductions due to Improved efficiency of materials and energy use	Reduced greenhouse gas emissions
Tax savings since tax breaks aren't required to attract new business	Access to public funding programs and private financing	Innovative environmental solutions

EIN Benefits

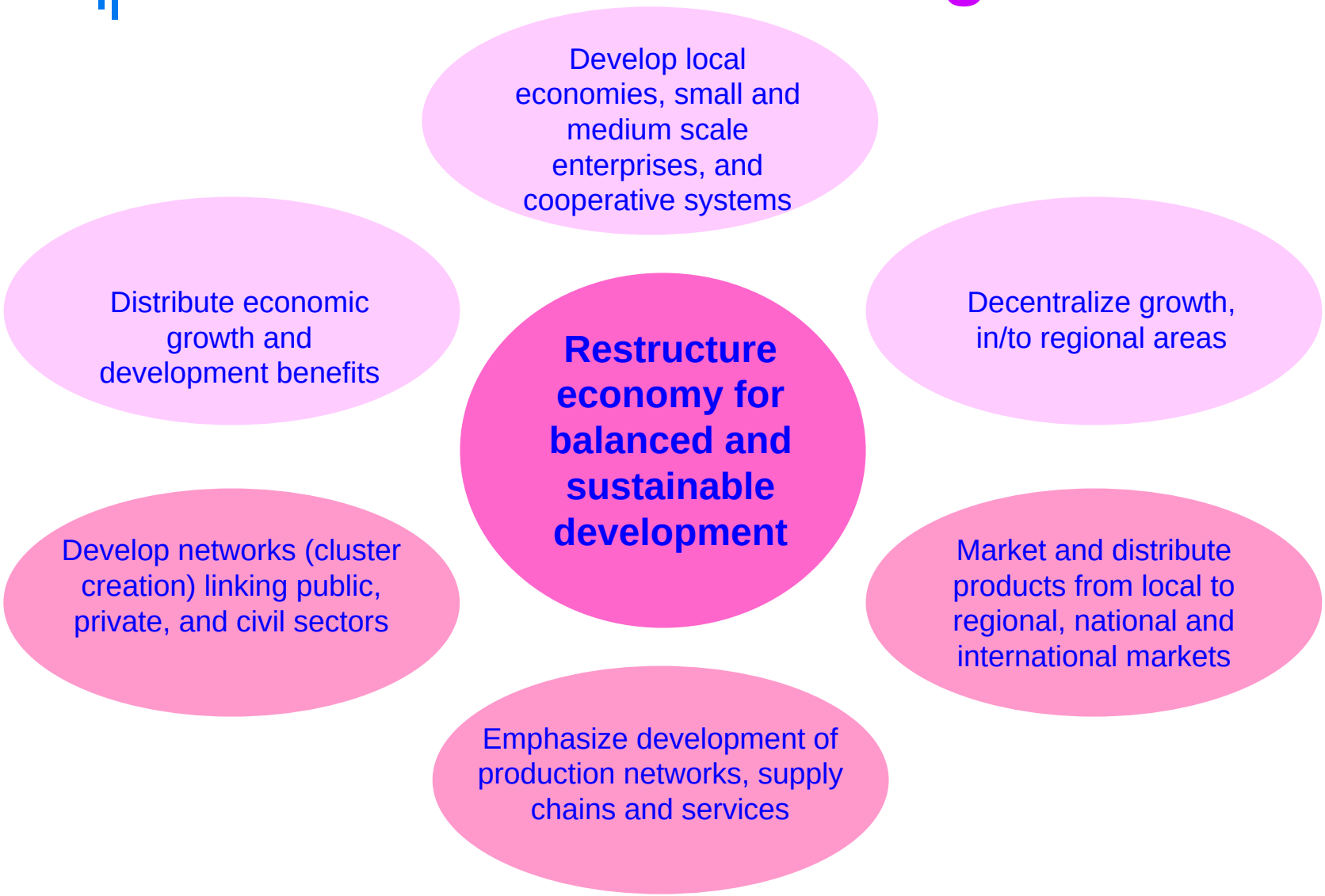
Community	Local Businesses	Environment
Recruitment of higher quality, greener companies	Higher value for developers	Preservation of environmentally significant areas
Increased and sustained property values	Reduction of disposal costs	Increased protection of natural ecosystems
Partnership with business	Income from sale of by-products	More efficient use of natural resources
Reduced impact on infrastructure, including waste disposal	Reduction of environmental liability	Improved environmental management systems
Improved aesthetics	Improved public image	
Stable, diverse job-base	Increased employee productivity	



Problems and Constraints to the Development of Agro-industrial Sector

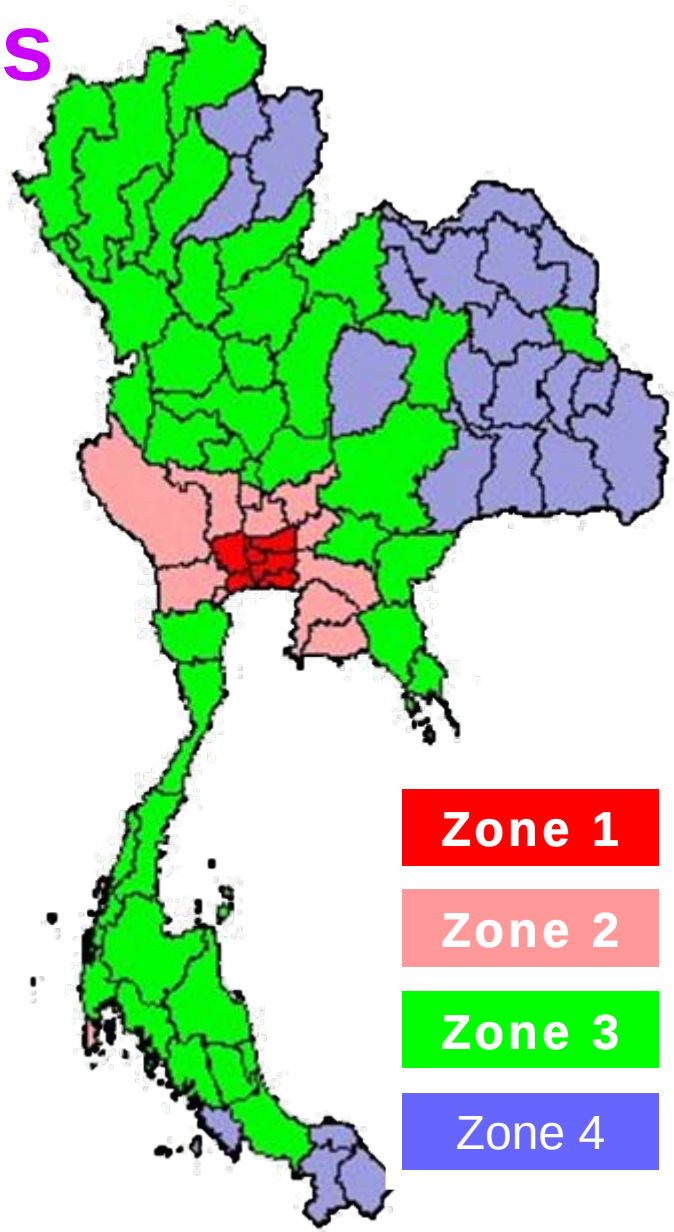
- Inconsistent and insufficient supply of raw material, seasonality of crops
- Poor quality of raw material supply, high losses during transport
- Inappropriate/obsolete processing and equipment
- Poor and inconsistent quality of processed products
- Sub-optimal use of processing facilities and equipment
- Poorly trained personnel and a lack of food technologists
- A lack of proper hygiene practices and Inappropriate packaging materials/high packaging cost
- Weak or non-existent market development
- A lack of technical support
- Absence of good management of the processing facility once commercialized

9th NESDB Plan Strategies



Investment Benefits

- Chachoengsao is classified under Investment Zone 2
  - 100% waiver of import duty on machinery for industries in estates
  - 50% waiver for industries outside the estate
  - Corporate income tax exemption – 7 years within industrial estate and 3 years outside
  - Exemption on import duty for raw material for 1 year in both cases
- Relocating industries from Zone 1 to Zone 2



Incentives for Rural Industries

- **Board of Investment, Thailand identified and classified 30 agro industries for special incentives**
  - **Livestock, Slaughtering, meat and food processing, animal feed, agriculture products and waste re-processing – identified as priority activities**
  - **Machinery import duty exemption**
  - **Corporate income tax exemption for a period of 8 years regardless of zone with no limits**




Power Purchase Policy

- **Small Power Producers**
  - Co-generators or facilities using renewable energy fuels
  - Sell power to EGAT of not more than 90 MW for each project
  - Minimum purchase guarantee (> 80%)
  - Allows direct sale to industrial estates near the power plants
- **Very Small Power Producers**
  - Installed capacity of less than 1 MW
  - Agricultural residues & wastes from agro industries (e.g. rice husk)
  - Products converted from agricultural residues & wastes from agricultural or industrial production processes. (e.g. tapioca wastewater)
  - Municipal waste: RDF, Biomethanation