GREENING FOOD PROCESSING INDUSTRIES IN VIETNAM: CONSTRAINTS AND OPPORTUNITIES

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ABSTRACT

The food processing industry is a large, rapidly growing sector in Vietnam and plays a vital role in its country's economic development. However, its development currently seems to go hand-in-hand with environmental deterioration. Up to now, most research and development activities, regulations and policy measures related to environmental management of (food processing) industry in Vietnam have mainly been focussing on what to do with wastes and emissions after they had been created. However, with several decades of experiences on environmental protection behind us, Vietnam recognizes that with the end-of-pipe approach, we have been treating environmental symptoms instead of the diseases. It is of course important to have technological (end-of-pipe) solutions to overcome existing pollution problems and to deal with accidental pollution events. But it is essential and more environmental friendly as well as economically to prevent wastes from being generated or to reuse their valuable materials. Working towards more sustainable development of (agro-) food processing industry in Vietnam, this paper provides a methodology to analyze and assess possibilities and approaches to move existing food processing industrial systems towards zero waste industrial ecosystems. Three case studies were carried out at household-scale, large-scale and group of different food processing enterprises in Vietnam. The case studies analyze how and to what extent the existing food processing industry in Vietnam could be transformed into more environmentally sound direction.

INTRODUCTION

The role of food processing industry in Vietnam's economic development is evident (Dieu, 2003). However, it is also obvious that production activities of this industrial sector contribute significantly to environmental deterioration. This will not only damage the environment, but also restrain the industrial development process in future. Though several pollution prevention approaches have been developed and practiced in developed and developing countries, each approach can only be applied successfully in some circumstances and is limited in others. Additionally, we can clearly envision that various strong points of these approaches are able to overcome each other's weaknesses. This arises the question how to make use of the strong points of the existing pollution prevention approaches for greening agro-industry, in this case especially for food processing industry in Vietnam. This potential is analyzed and assessed in this study to seek for possibilities and potency to move existing food processing industrial systems in Vietnam to a more sustainable (or a zero waste) industrial ecosystems. More specifically, this study seeks to answer the questions: How to apply and adapt the existing experiences of industrial ecosystem practices from highly industrialized Western countries in order to develop food processing industrial ecosystems with the existing institutions, technological and socio-economic conditions of Vietnam? Is it possible to apply the concept of ecosystems to large stand-alone firms as well as small (household) and medium sized companies? What would be core features of a zero waste industrial ecosystem model of food processing industry in Vietnam? Which actors, institutions and relations are crucial or potentially crucial to introduce the proposed model in practice? What are their specific roles and contribution? In order to answer these questions, we investigated the strong points of the existing pollution prevention approaches and integrated them in the development of a methodology for moving to a zero waste industrial ecosystem. Taking into account the diversity of the industrial system situations in Vietnam and its differences compared to highly industrialized countries, this methodology was tested by three different settings: (1) tapioca processing industry at household-scale in a village, (2) tapioca processing industry at a large-scale company and (3) different types of food processing companies, other than tapioca, in an industrial zone.

This paper first starts at the introduction of the methodology that was developed for greening food processing industries and three selected case studies. The second section will discuss similarities and differences between the three case studies. Constraints and opportunities in implementing a zero waste industrial ecosystem of food processing industry in Vietnam will be elaborated in the third section. The paper closes with general conclusions on applicability of the developed methodology and approaches for greening the food processing industrial sector and other industrial sectors.

POLLUTION PREVENTION METHODOLOGY

There are many different ways to get rid of wastes and achieve zero (or close to zero) waste industrial systems. Each approach has its strengths and weaknesses and its application often works under specific conditions and time-space constellations. Integration of different approaches can overcome the weaknesses and shortcomings of individual approaches. Lowe (1997) rightly states that the idea or concept of industrial ecosystem more or less takes together a large range of intra-plant innovations and approaches, and inter-plant collaboration in improving environmental and economic performance, both of individual companies and collective industrial systems. This section aims at developing a methodology how to come to an integrated model of pollution prevention for industrial systems, using the various theoretical ideas, especially focussing on cleaner production, waste exchange (reuse and recycling) and industrial ecology.

The starting point to develop such a methodology is formed by the material and energy flows in industrial systems. The material and energy flows that cannot be used in the industrial system cause emissions, waste and exhaustion of natural resources. Any methodology consequently starts with analyzing these flows, followed by analyzing the various possibilities to reduce the emissions, waste and natural resource use from these industrial systems. A systematic methodology to analyze various options to approach a physical-technological model of a zero waste industrial ecosystem by prevention of waste, minimization of waste, reuse and recycling within one company and within a wider network of companies and waste treatment option (or end-of-pipe solutions) can be specified into the following four basic steps:

- The first step is the analysis of the material and energy flows that run through the industrial systems and partly end up in waste. Without insight in the process flow data and the main points and causes of waste generation in the industrial processes no physical-technological model can be constructed.
- The second step focuses on the prevention of the waste generation: what is the maximum feasible prevention/reduction of all pollutants being generated at production sites. The identification and design of measures and options of prevention is often related to cleaner production studies.
- The third step concentrates on identifying, analyzing and designing potential internal and external recovery, recycling and re-use options. For wastes, which cannot be recovered internally (within the original production units), recycling and reuse in other plants or economic activities play a vital role in solving the industrial waste problems (Wei and Huang, 2001). This option ranks in the environmental management hierarchy often as the second most preferable method, following prevention of wastes. It is considered advantageous because, among others, natural resources are conserved, treatment and disposal is avoided, and the need for raw materials is reduced, thereby lowering costs (Chieu and Peters, 1994). Besides, many businesses benefit from the proximity or co-location of functions that are closely related to, or rely upon, the production process (ULI, 1988). The creation of a (waste) material flow network or waste exchange practices is part of this third step.
- Finally, the last step entails the identification of remaining wastes that need to be treated properly before discharging into the environment. End-of-pipe treatment technologies are usually helpful for a complete removal of remaining contaminants.

Together, these four steps form a systematic methodology that leads us towards a physical-technological model for (close to) zero waste industrial systems.

However, actual application of the physical-technological model might face severe difficulties and barriers since the industrial system as a whole and the various constituting subsystems might have conflicting interest, they are often confronted with a lack of coordination, meet financial problem and are not isolated entity but related to and embedded in complex social-economic conditions. No matter how innovative, original and closed the designed industrial system is in terms of its substance flows, this does not guarantee any success in terms of application and implementation of the whole model or even of few parts. To transform the developed physical-technological model for an industrial system from the design table to reality, it is essential that the complex social, economic and political relations and institutions between the industrial system and the actors outside are analyzed in depth. Only by understanding the existing relations of the industrial systems with, among others, government agencies, other economic entities and social actors, we are able to (i) identify the existing barriers that hamper the implementation and introduction of some or all of the alternatives of the physical-technological model, and (ii) to design the necessary transformations and changes in these social, political and economic relations and institutions in order to facilitate, support and enhance the possibilities of implementing some or all of the physical-technological options. In other words, we are in need of an analytical tool that provides us with the concepts to analyze existing interactions and relations between actors within and outside the industrial system, as well as the institutions that govern and structure these interactions and relations. Network analyses and models that relate industrial firms to the societal, economic, and policy environment are useful for this purpose, because, as van Koppen and Mol (2002: 142) state,

> *'Network models have the advantage of combining both the structural properties of institutions and the interactions between actors constructing a network. Networks can be characterized as social systems in which actors engage in more or less permanent, institutionalized interactions'.*

There is broad and well-established literature on network analysis, to which various disciplines have contributed. Most of the network studies in the field of the environment construct their concepts and analytical tools on an ad hoc basis, following directly from one or a limited number of empirical studies. Consequently, these network models and concepts often have a limited use in empirical studies. The triad-network model, as developed by Mol (1995), is a more theory-based conceptualization. It encompasses a policy, an economic and a societal network and is suitable for analyzing what role actors and institutions from different perspectives (political, economic, social) play in the construction and functioning of industrial systems, how these actors and institutions (can) influence the greening of industrial systems, how they trigger or hamper change and improvements in environmental management, etc. As such the triad-network model helps us in understanding and analyzing the relation between the developed physical-technological model on the one hand and the institutions and actors constituting the economic, social and policy environment on the other hand. Each of the three interdependent networks constitutes a combination of a specific analytical perspective, distinctive institutional arrangements and a restricted number of interacting (collective) actors, which are considered to be most important regarding that perspective. The three mentioned networks will be elaborated shortly and be applied to industrial systems.

Economic network. Economic networks basically focus on economic interactions via economic rules and resources between economic agents in and around industrial parks, industrial chains, or industrial sectors that form the object and unit of analysis (van Koppen and Mol, 2002). Economic network studies analyze: (i) the relationships between firms in a product chain by looking at the vertical interactions from input suppliers to producers and final consumers; (ii) the relationships between competing firms in the same (sub-) sector and interaction, among others via branch organization; (iii) the interactions between firms and other economic agents (such as bank, insurance companies, infrastructure companies) and research institutes and (iv) regional relations and interactions in restricted geographical areas.

Policy network. Policy networks concentrate on industry-government relations from a political-administrative perspective (Mol, 1995). All policy incentives and arrangements in supporting or regulating industrial sectors belong to the rules and resources, which are structured and negotiated within this network. It is therefore important to identify the relevant actors and institutions, which determine industrial and environmental policy, including their positions, strategies, resources and interactions (Vliet and Frijns, 1995). Applied to this research, policy network studies should clarify the relationships and interactions between the industrial enterprise(s), and local and central environmental management agencies and authorities. The legislation related to environment (including relevant laws, regulations, decrees, guidelines, standards, etc.), which can, should and sometimes have influenced environmental innovation in firms and industrial systems, is part of the formal policy network. And so are the resources available for local environmental authorities in terms of for instance monitoring equipment and manpower for control and enforcement. Analyzing the formal structure and relations between environmental authorities and industrial actors is often less telling than analyzing the actual practices, interdependencies, and institutional arrangements that are at work in greening (or the failures to green) industrial production locations and products.

Societal network. Societal network studies focus on the relationships between the industrial enterprise(s) on one hand, and local communities and local and national social organizations such as Youth Union, Women's Association, mass media and NGOs on the other. These social network studies try to analyze the nature of these relationships, the interdependencies between the actors, the resources being used in interaction patterns and the mechanisms at work. Focal point is if environmental consideration plays any role in these interaction patterns, how the existing relations can give environmental interest a better position 'on board' and how this can then influence, stimulate and support the adaptation of options from the physical-technological model. The studies of O'Rourke (1999), Woltjer (2001) and Phuong (2002) are good examples of Vietnamese social network studies on the greening of industry.

In selecting case studies to 'test' the developed methodology for designing zero waste industrial systems we have to balance between the diversity of industrial system situations that are found in industrializing Vietnam on one hand, and the practical limitations of labor-intensive research on each individual case study on the other. The latter does not allow for more than three extensive case studies. The former forces to take at least into account differences between:

- Small/household-scale enterprises and large-scale companies (partly related to domestic markets and international markets);
- One enterprise and a group of enterprises;
- A group of enterprises from one industrial sector and a group of enterprises from different industrial sectors (but still within the broad category of food processing industries);
- Enterprises located within and outside industrial zones, as industrial zones (or parks) have specific advantages in industrial ecology design.

These comparisons are important and necessary because, for instance, technological solutions for large-scale companies equipped with more advanced production process, might be not feasible for small-scale enterprises due to lack of investment, knowledge and skills, manpower, etc. A material flow network of a group of similar industrial enterprises will have different characteristics than a material flow network of a group of different industrial enterprises. In addition, differences in actors and institutional arrangements involved in environmental management of enterprises located inside and outside industrial zones will result in distinct facilitating networks for the two categories.

In order to fulfil the various criteria selected above, three case studies have been chosen. The first case study consists of a group of tapioca producing households in Tra Co Village, Dong Nai Province. These enterprises represent the characteristics of household (small) scale enterprise and are all in the same industrial sector. The second case study is within the same industrial sector: a large-scale tapioca producing plant called Tan Chau-Singapore Company in Tay Ninh Province . These case studies help us to understand the possibilities and difficulties in developing, applying and implementing the zero waste industrial ecosystem model in different scales of the same type of industry. The third case study focuses on a group of six different food processing enterprises located in Bien Hoa 1 industrial zone, Dong Nai Province. It is comparable to the case study on Tra Co Village in the sense that a group of companies are studied, but differs in terms of scale of the enterprises and industrial sectors. This case study also explores the potentials of industrial zones, compared to enterprises located outside industrial zones. The following description gives brief overviews on the studied sites.

Case Study at Tra Co Tapioca Processing Village

In Vietnam, tapioca producing units can be family (household) scale with only 3 employees, medium scale factory with about 15 employees, or large-scale factories with more than 30 employees. Household- and large-scale units are most prominent. That is the rationale behind the selection of case studies at Tra Co Village and Tan Chau-Singapore Company. In the South Key Economic Regions (SKERs) of Vietnam, Tra Co Village is a typical traditional tapioca production village. Environmental problems caused by tapioca production in this area are serious, but interestingly Tra Co Village is the only place where tapioca wastewater is partly and successfully reused in fish culture. At the period of conducting the case study, there were 65 tapioca production households in Tra Co Village.

The family (household)-scale tapioca producing units are concentrated in 13 districts in Vietnam (Table 1). However, in three provinces (Ho Chi Minh City, Dong Nai and Tay Ninh) a number of households are situated close together and form a village or a group of tapioca producing units. Tra Co Village (Dong Nai Province) was selected after reviewing three possible sites in the three provinces. In Tra Co Village, after observing the tapioca production process of different households, the household of Mr. Nguyen Van Thinh was selected for in depth study on material balances, for various reasons. First, the production capacity of this household is in the normal range of household units in Tra Co Village (about 7 tons cassava roots/household/day). Second, the production equipment, production area and number of workers represent the typical characteristics of a household-scale tapioca production unit in the village. Third, the householder and his workers were willing to help in mass measurements and sampling at each stage of the production process.

In each of the three selected villages, five tapioca production households were selected to observe the manufacturing technology and waste handling methods that have sensitive similarities and differences. These households' production processes differ in fresh roots' handling stage, roots' rinsing methods, starch extraction stage (different settling steps), final products (wet or dry starch) and used machines. In this way, it is possible to compare and analyze the reasons behind better or worse production efficiency and environmental performance and to generate options for prevention and minimization of wastes.

Table 1 Number of districts where family-scale tapioca producing units are located

City/Province	Number of district
Dong Nai Province	2
Ho Chi Minh City	1
Tay Ninh Province	2
Binh Dinh Province	2
Quang Ngai Province	1
Quang Nam – Da Nang Province	2
Ha Tay Province	2
Ha Bac Province	1
Total in Vietnam	13

Source: Khoa, 1998.

Case Study at Tan Chau-Singapore Company

Large-scale tapioca companies have been established in the South of Vietnam since 1990, they aim at satisfying the demand of raw material for monosodium glutamate, textile, paper industries, etc. These companies are Vietnam-Singapore Co., Ltd. and Tay Ninh Tapioca Company in Tay Ninh Province, Song Be-Singapore Tapioca Co. Ltd., VEDAN Tapioca Company in Binh Phuoc Province, VEDAN Tapioca Company in Dong Nai Province. Among these companies, Tan Chau-Singapore Company was selected for in dept case study, for various reasons. First, the current production technology of the company is similar to the other companies but the operational procedures were modified to reduce water consumption. Second, this is one of two existing large-scale tapioca companies that contribute considerably to industrial development in Tay Ninh Province. Third, Tan Chau-Singapore Company management board was willing to assist in all onsite measurements and interviews and showed willingness to increase the environmental performance of the company.

Case Study of Food Processing Companies in Bien Hoa 1 Industrial Zone

Among 68 industrial zones and export processing zones in Vietnam (Nhue, 2001), Bien Hoa 1 is the oldest industrial zone. It represents a "bad practice industrial zone" and contributes significantly to environmental deterioration, especially surface water of Dong Nai River and the air quality in Bien Hoa City, Dong Nai Province. It is located on an area of 551 ha about 6 km from the city centre of Bien Hoa City and 30 km from Ho Chi Minh City. Beside other industrial enterprises, the existing food processing companies in Bien Hoa 1 IZ are typical for Vietnam, producing cane refined sugar, milk products, coffee, soft-drink, cakes and candies and ice. The current situation of these companies illustrates the difficulties in applying advanced technologies to solve environmental problems of existing enterprises in Vietnam: less advanced technology, strong emphasis on end-of-pipe treatment, poor environmental awareness, no environmental management systems etc. A group of six food processing companies in Bien Hoa 1 IZ have been selected for conducting the case study. All data related to production processes and environmental implications of these enterprises were collected through site observations, direct interviews and inventory sheets (similar to enterprise manifest).

LEARNING FROM THE CASE STUDIES

Similarities from the Case Studies

In general, the scope of food processing industry extends from farms, where raw materials as crops (such as cassava, sugarcane, coffee, vegetables and fruits) and livestock (chickens, cattle, swine) are grown, to factories, where these raw materials are processed and then brought to the markets, where the final products are sold. At present, the food processing industry in Vietnam is a combination of industry and agriculture in such a way that the industry consumes agricultural products for its operation and the production of new products. More precisely, the industry extracts raw materials from farms, fresh water from natural resources and electrical and thermal energy for its operation, but it does little to compensate for the amounts of consumed energy, used fresh water and soil nutrients, which are utilized to grow agricultural products. In addition, its production activities contribute to the deterioration of the environment due to improper discharge, disposal and emission of the generated wastes. This study tries to overcome the un-sustainability of this system by developing a physical-technological model focussed on a zero waste industrial ecosystem.

The three case studies show that excessive generation of non-products (including reusable/valuable materials, wastes and air pollutant emission) arises due to:

- Inefficient technology, as in the case of household tapioca processing units at Tra Co Village.
- Inadequate processing, resulting from a poor knowledge of the process by operators, like during the cassava root rinsing stage at tapioca producing households in Tra Co Village or the current application of water and processing wastewater circulation in Tan Chau-Singapore Company.
- Inadequate consideration on onsite reuse and recycling, such as selling spent coffee grounds to farmers to reuse as soil conditioner instead of onsite reuse as fuel to provide thermal energy (Bien Hoa Coffee Factory), releasing hot gases to the atmosphere instead of recovering its excess heat for drying fibrous residues (Tan Chau-Singapore Company).
- Inadequate offsite reuse and recycling, which could be done by food processing companies in Bien Hoa 1 IZ and Tan Chau-Singapore Company.
- Cheapness of natural resources (such as the free of charge availability of ground water, cheap water supply).
- Lack of knowledge about waste(water) treatment and recovery of valuable materials from non-products.
- Financial limitation for environmental investment.
- No strict enforcement on pollution prevention and environmental protection, lack of incentives to encourage the implementation of waste reuse and recycling.
- No active civil society on environmental issues.

Seeking possibilities to overcome the mentioned causes of excessive generation of non-products, these case studies have revealed that cleaner production, waste exchanges and ideas of industrial ecology are valuable in greening food processing industry, though the feasible technical options and organizational schemes are different in the three cases as we will see in the next section.

Characteristics of food processing industry lead to the generation of three types of non-products, which are mainly organic in nature. First, liquid non-products that normally consist of three types of wastewater: (1) process wastewater (rinsing wastewater and settling wastewater from household-scale tapioca processing units, wastewater from the starch extracting stage of large-scale tapioca processing company, wastewater from machine cleaning of other processes, etc.); (2) cooling and heating wastewater; and (3) domestic wastewater. Second, solid non-products, which are unqualified raw materials (such as cassava hard roots and wood shells, unqualified vegetable and fruits, etc.); generated residues from the processes (cassava fibrous residues and pulp, spent coffee grounds, molasses, etc.) and unqualified packaging materials (broken cardboard boxes, plastic bags, tin cans, etc.). Finally, air pollutants and surplus heat are generated from boilers and heaters, which use diesel oil and fossil oil as fuel. Except for air pollutants, surplus heat and unqualified packaging materials, the other major non-products are organic in nature and it is difficult to avoid their generation completely due to the importance of maintaining food hygiene and product quality. However, the case studies have revealed that for putrescible and biodegradable non-products, the logical solutions with respect to environmental, economic and technological feasibility, include:

- Prevention and minimization at source as much as possible;
- Wherever possible, the continuing use as raw materials for livestock feed production (for instance fish feed from tapioca wastewater, swine feed from cassava fibrous residues and pulp);
- Where appropriate, the application of composting to convert organic waste materials (such as cassava hard roots and wood shell, residues from fruits and vegetable, spent coffee grounds, etc.) to soil

conditioners and fertilizers; or production/ recovery of biogas for self-generation of energy by application of anaerobic digestion of organic non-products or recovering methane gas from anaerobic wastewater treatment process;

- Treatment of the remaining un-reusable non-products for further reuse, like use of treated wastewater for irrigation and watering;
- Proper treatment of wastes (including wastewater, air pollutants and solid wastes) before discharging to avoid adverse impacts on the natural environment.

It proved in all three case studies that these are possibilities to transform the current food processing industrial system (closer) to a zero waste industrial ecosystem, in which the food processing industry (and other related industries, which use its products and byproducts as raw materials) and agriculture are integrated.

Analysis of current actors and institutions aims at understanding the existing relations of the industrial systems with, among others, governmental agencies, other economic entities and social actors, which might hamper the implementation and introduction of some or all of alternatives of the proposed industrial ecosystem model. Several similar points have arisen from the three case studies. First, state environmental management authorities, especially the provincial DOSTEs, face difficulties of high workload, lack of expertise and scarce resources for monitoring and enforcement. To some extent, provincial DOSTEs have forced producers to implement environmental protection activities, for instance the installation of wastewater treatment systems or chimneys. However, the current environmental monitoring and enforcement programs of the DOSTEs have not been competent enough to force producers to keep on operating the systems properly in order not to deteriorate the environment with their effluents. This explains why tapioca producing households in Tra Co Village not even take notice of environmental pollution caused by wastewater from their production processes. Second, specific regulations and incentives for producers to make their production processes more ecologically sound as well as reuse and recycle wastes are completely lacking at the moment. Therefore, it should not surprise us that all studied companies have not carried out auditing programs, which is the first important step to implement a cleaner production program. The current activities of waste reuse and recycling are conducted not with the purpose to protect the environment, but mainly because of economic saving of producers. Fish culture farmers in Tra Co Village use tapioca wastewater from tapioca producing households, but in fact they have no idea about environmental protection or waste exchange, reuse and recycling. Their reason to do so is just because they can reduce the cost of buying fish feed. Though eggshells from BIBICA Company are an excellent calcium source for livestock feed production, they are disposed together with the domestic solid waste because the profit increase from this source is insignificant for such a large-scale company. Third, influence from economic agents does not seem to encourage producers to improve their production efficiencies and environmental performances. Except for some demonstration projects on the implementation of cleaner production in Ha Noi and Ho Chi Minh City, banks in general provide credit with short payback periods and without preferential interest rates for environmental investment. Therefore producers, who have financial limitations, face difficulties in getting a loan from a bank for environmental investments. Fourth, there is hardly any enduring relation between research institutes and the producers in neither production nor environmental protection. Finally, the civil society is not actively involved in environmental issues. This is especially where the local community is equal to the producers and profiteers of environmental problems as the case of Tra Co Village. In addition, this is the case, where social organizations are not interested in environmental issues and non-governmental organizations that could focus on environmental issues are non-existent.

Dissimilarities in the Case Studies

Beside similarities found in the case studies, several dissimilarities can also be indicated. The diversity of industrial systems in Vietnam in terms of scale (household, large), size (one enterprise and group of enterprises), industrial sector (one food processing industrial sector and different food processing industrial sector) and location (within and outside IZ) are causing the dissimilarities. Therefore, it is made clear in these case studies that any general or national approach to green food processing industry is doomed to fail in practice if in its operationalisation these differences are not taken into account.

Dissimilarities between household- and large scale company. To compare household-scale and large-scale companies, the case studies on tapioca processing industry were conducted at Tra Co Village and

Tan Chau-Singapore Company. Though these case studies were conducted for one industrial sector, the proposed options and implementations to approaching a zero waste industrial ecosystem are not the same. First, the proposed technological options for household-scale units differ from that of a large-scale company. The traditional tapioca production technology at households in Tra Co Village is not suitable for the proposed cleaner production measures like a more modern tapioca production technology as applied in Tan Chau-Singapore Company. For instance, though using the same countercurrent principle to reduce the amount of used fresh water and generated wastewater, the existing tapioca production technology of the households in Tra Co Village does not suit the proposed water circulation option of Tan Chau-Singapore Company. Whereas it is a possibility for Tan Chau-Singapore Company to reuse heat from high temperature emission to dry their fibrous residues, this is impossible for the households. In addition, because of the continuous operation during ten months a year, it is easier to convince large-scale tapioca processing company to implement cleaner production measures to minimize the generation of wastes. But it is difficult to do so in the case of households, which usually put their tapioca production processes in operation for three months every year. With respect to reuse and recycling options, it is feasible to install as well as facilitate a livestock feed production enterprise, composting plant, biogas plant and fishponds within the boundaries of Tan Chau-Singapore Company reducing transportation costs, it is impossible to do so for each individual tapioca producing household. Installation of a wastewater treatment system to treat tapioca wastewater for irrigation and to recover biogas for self-sufficiency in energy seems an attractive option for Tan Chau-Singapore Company, but is also impossible to apply for the households. However, this does not mean that it is completely impossible to improve the environmental situation of these tapioca producing households. The case study at Tra Co Village has revealed that the limitations of individual households in implementing waste exchange options can be overcome by co-operating among the production households. Installation of a central composting plant, a central biogas production plant and a central wastewater treatment plant to reuse and treat non-products from all tapioca producing households of the village would help to solve the existing environmental problems in this case in an economically and environmental friendly way. By doing so, the group of tapioca producing households can benefit from the collective offsite reuse and recycling and environmental services (waste collection and treatment system).

Second, difference in size (in terms of employees and production capacity) of producers leads to differences in organization of the cleaner production program. For a large-scale firm like Tan Chau-Singapore Company, it is possible to organize a study team itself to conduct a cleaner production program, but it is not feasible for each household in Tra Co Village, which have 3-5 workers. Again, one cleaner production study team could be organized for all tapioca producing households in the whole village. But, without economic incentives, it is not easy to get all 65 households in Tra Co Village to participate voluntary in the cleaner production program. In addition, the company has better skilled staff for specific tasks, for instance production technology, machine reparation, administration, etc., so it is easier to train workers to become adapted to new technologies or installations.

Third, differences in the existing organizational structure of the industrial systems also lead to differences in the organizational structure of the proposed industrial ecosystem. While Tan Chau-Singapore Company is responsible for the installation and operation of the wastewater treatment system, the households can only pay the (public or private) owner of a central wastewater treatment system to treat tapioca wastewater generated from their production process after it has been installed and put into operation. In other words, in the case of household-scale producers, it is necessary to have a third actor, who is responsible for treatment of un-reusable non-products. Tan Chau-Singapore Company is able to manage the proposed industrial ecosystem, but it is obviously impossible for each tapioca producing household to do so.

Finally, relations between these industrial systems and the current actors and institutions are partly different. For a large-scale company like Tan Chau-Singapore Company, Ministry of Science, Technology and Environment (MOSTE) played its role in the initial stage of the company by appraising the environmental impact assessment report. So far, MOSTE has not directly influenced the environmental improvement at Tra Co Village. While Tay Ninh DOSTE has monitored the environmental situation of Tan Chau-Singapore Company from its initial stage (1996), environmental problems at Tra Co Village have just started to receive attention by Dong Nai DOSTE in 2001. By applying regulations in compliance with environmental discharge standards, Tay Ninh DOSTE has at least succeeded in forcing Tan Chau-Company to store tapioca wastewater in ponds without discharging it into Tha La River.

However, it is very difficult for Dong Nai DOSTE to use strong enforcement instruments such as fine, administrative punishments or closure to all 65 tapioca producing households that violate environmental regulations, because this will create significant social problems. The role of customers in pushing producers to take into account both product qualities and environmental qualities only seem to be relevant in the case of large-scale companies that participate in international markets.

Dissimilarities between one large scale enterprise and a group of enterprises. Compared to a group of enterprises (for instance 65 tapioca producing households in Tra Co Village), the designing and implementation of a proposed zero waste industrial ecosystem for one company (for instance Tan Chau-Singapore Company) is much easier, for several reasons. First, collection of non-products from a group of enterprises is certainly more difficult than that of one company. For instance, in order to collect tapioca wastewater of Tan Chau-Singapore Company for further handling, we only have to design a sewer network within the company, but in case of Tra Co Village, it has to be done for the whole village. Second, convincing one company to participate as an anchor in the model is easier than to get agreement from all 65 tapioca producing households in Tra Co Village. Third, the implementation of a cleaner production program (to conduct the proposed cleaner production measures) for one company is much easier than in case of a number of tapioca production households. Cleaner production training in one company is surely less difficult compared to training a whole village.

Dissimilarities between a group of enterprises from one food processing industrial sub-sector and a group of enterprises from different food processing sub-sectors. The case studies at Tra Co Village and Bien Hoa 1 IZ have revealed that the operationalization (or application) of the developed methodology for a group of enterprises from one food processing industrial sub-sector also differs from that of a group of enterprises from different food processing industrial sub-sectors. A group of enterprises from one food processing industrial sub-sector will generate almost the same non-products. This leads to two main advantages:

- Benchmarking can be done by these enterprises themselves. It is possible to compare the production efficiency (for instance unit of product per unit of input or unit of non-products per unit of input) and environmental performance (for instance unit of waste per unit of product or input) among these enterprises. This is not only helpful in selecting feasible solutions to reduce the generation of non-products but also in convincing producers to learn experiences from each other.
- By a group of enterprise, the same kinds of non-products are generated in larger amounts making it worthwhile to reuse, recycle or treat them. It is possible to gather the non-products from the different enterprises and handle it by the same method. Additionally, it is easier and more economic to handle large amounts of one non-product by one method than to handle small amounts of different non-products using different methods.

The disadvantage of having a group of enterprises from only one food processing industrial sub-sector is that these enterprises can not use each other's products and reuse byproducts (or non-products). In other words, the material flow network, which is often essential to reach a zero waste industrial ecosystem, can only be created by adding new enterprises that use and produce different inputs and outputs. However, because food processing industry manufactures food for human beings, it is usually only possible to use each other products as raw materials (for instance sugar and tapioca starch for confectionery company, milk for instant coffee mix production, etc.) and impossible to reuse non-products from each other. Except for some non-products, like wrapping materials, which have to be re-manufactured in other processes (such as paper or plastic processing), most organic non-products from food processing industry are suitable for producing one of the following non-food products: livestock feed, fish feed, industrial grade alcohol, biogas, compost and irrigation water. Organic non-products (usually the largest part of all non-products in the food processing industry) generated from different food processing enterprises, are of course not uniform though they are all organic in nature. For instance, molasses of Bien Hoa Sugar Company contain different organic compounds and contents compared to waste fruits from DONA NEWTOWER J. V. Company or spent coffee grounds of Bien Hoa Coffee Factory. Wastewater from all food processing companies in Bien Hoa 1 IZ certainly contain biodegradable organic contaminants. However, the concentrations of organic contaminants in terms of COD or BOD_5 of wastewater from these companies are totally different. This makes reuse and recycling processes more complicated than in the case of uniform non-products from one food processing industrial sub-sector.

Dissimilarities between industrial system located inside and outside industrial zone. Beside several dissimilarities discussed above, the developed industrial ecosystem model for enterprises located within an industrial zone also differs from that of enterprises located outside the industrial zone in several points. First, enterprises located within an industrial zone can benefit from collective environmental services (such as a common wastewater treatment system, composting, collection and handling other wastes) of the Industrial Zone Infrastructure Development Company. Second, these enterprises can reduce transportation costs for non-products to recyclers, which are also located within the industrial zone. However, if the industrial zone is located far away from available agricultural fields, food processing enterprises located in the industrial zone face a large disadvantage. Because agriculture provides raw materials for these enterprises and also serves as an environmental friendly receiving body for wasted materials, close physical distance between the enterprises and agricultural lands can be an important condition for successful implementation of the developed industrial ecosystem model. This brings several potential economic and environmental advantages:

- Reduction in costs and time to transport raw materials from the fields to the enterprises;
- Minimizing loss of quantities and qualities of raw materials due to long distance transport from the agricultural fields to industrial processing enterprises;
- Reduction in costs of wastewater treatment, because only pretreatment is necessary to use wastewater for irrigation, instead of complete treatment;
- Water resource conservation thanks to the possibility of reusing wastewater for irrigation, instead of using (surface or ground) water;
- Providing a clear life-cycle benefit by returning composted organic solid wastes into soil (of crop fields) as conditioners;

Finally, actors and institutions involved in the policy network of enterprises located within an industrial zone are different with those located outside. Enterprises located within an industrial zone are normally under an administrative management of the Industrial Zone Infrastructure Development Company or Industrial Zone Management Board and District Industrial Zone Authority. These institutional and policy actors can play a significant role in creating the conditions that support the development of the proposed model, educating and advising (potential) participants on the opportunities to improve their production efficiency and environmental performance as well as monitoring the last. These actors can also cooperate intensively with environmental authorities on various levels.

CONSTRAINTS AND OPPORTUNITIES TO APPROACH A ZERO WASTE INDUSTRIAL ECOSYSTEM OF FOOD PROCESSING INDUSTRY IN VIETNAM

The case studies have revealed several constraints hampering the implementation of cleaner production, waste exchange and even end-of-pipe treatment approaches, which play important roles in moving the current food processing industrial system in Vietnam to a more sustainable industrial ecosystem. However, besides these constraints, there are also opportunities to approach a more sustainable development of food processing industry in Vietnam. Discussions on these constraints and opportunities will focus on the following main aspects: (1) technical dimensions, (2) environmental policy, (3) economic aspects and (4) public participation. Of course, not all constraints and opportunities are of equal relevance for all situations.

Technical Constraints and Opportunities

Constraints. Technical constraints refer to the lack of five needed facilities: (1) know-how, (2) willingness to change the current techniques, (3) information dissemination, (4) advanced equipment, and (5) monitoring facilities. First, the case studies have revealed that producers often do not know how to implement cleaner production measures, to conduct reuse and recycling and to treat waste properly. So far, it is hard to find any plan or even ideas to implement cleaner production programs in the studied companies. Implementation of cleaner production does not seem to have any urgency in their development strategy. Several economic and technological feasible possibilities for onsite and offsite reuse and recycling of non-products have not been practiced in the studied areas. For instance, Bien Hoa Coffee Factory has not considered onsite reuse of spent coffee grounds to approach self-sufficiency in thermal energy. BIBICA Company does not know that it is wasting an excellent calcium source for livestock feed production. DONA NEWTOWER J. V. Company does not seem to realize that waste fruits are raw materials to produce bio-fuel. Recovery of biogas from anaerobic treatment of tapioca wastewater to generate energy is a new idea for Tan Chau-Singapore Company. Concentration levels of substances in the effluent from the existing wastewater treatment system of the studied companies, which are often higher than allowed following Vietnamese discharge standards, give evidence that these companies do not pay attention nor know how to treat it properly.

Second, technical constraints also refer to lack of willingness of producers to change the current techniques. They all do believe in the current production efficiency and do not want to modify their operational habit. They have the prejudice that any change in the processes takes too long to be implemented and may affect the product quality, especially in case of food, this may be a strong barrier. Additionally, extra investment adds to their unwillingness to any change.

Third, lack of information dissemination also contributes to the technical constraint. This explains why not all producers know about the existing technical solutions to improve production efficiency and environmental performance fitting to their cases. Reuse of tapioca wastewater, as fish feed is one of the evidences for that. Though this technique is applied successfully in Tra Co Village, it is unknown in Tay Ninh Province. All case studies show that it is hard to find enduring or even incidental cooperation between research institutes and producers. This limits opportunities of producers in accessing new techniques to improve their production efficiency and environmental performance. In addition, due to little demonstration and full-scale application of the laboratory studies, it is also difficult to convince producers to carry out waste reduction and minimization.

Fourth, lack of advanced equipment for the production process, such as in the case of tapioca processing households in Tra Co Village is one thing causing high amounts of generated non-products and wastes. Finally, lack of monitoring facilities and continuous measurement and assessment of environmental performance of producers is another constraint, which is attributed to improper implementation of environmental protection activities of several producers for a long time. All three case studies show that none of the producers have data on material flows of their production processes, though these data are very important for them to know whether their processes are operated efficiently.

Opportunities. There are several opportunities to overcome these constraints and to further implement a zero waste industrial ecosystem for greening food processing industry in Vietnam. First, cleaner production and waste exchange are actually not completely unknown in Vietnam. Successful demonstration projects on cleaner production in Ha Noi and Ho Chi Minh City do not only illustrate the potentials and possibilities to implement cleaner production in Vietnam, but also provide at least the know-how on cleaner production. The experiences of these projects can serve as the foundation for further multiplying to other enterprises. The case studies also show that waste exchange is not completely lacking in Vietnam. This is illustrated by several existing activities such as selling non-products to other producers instead of throwing it away (tapioca producers sell fibrous residues, other food processing companies sell broken cardboard boxes, plastic bags, etc.), or reusing non-products in agriculture (Tra Co Villagers reuse tapioca wastewater as fish feed). In other words, future implementation of waste exchange or reuse and recycling in Vietnam is possible, provided that precaution is taken into account in order to avoid secondary pollution from reuse and recycling processes.

Second, successful cleaner production demonstration projects convince producers that it is not difficult to improve their production efficiency in terms of technical modification and costs. Third, the establishment and achievements of the Vietnam Cleaner Production Center (VCPC) in recent years (from 1998 to now) can play a role in overcoming the lack of technical information dissemination and lack of awareness on the importance of cleaner production. Several activities carried out by VCPC such as organizing training and awareness-raising seminars; editing guidance manuals on cleaner assessment; preparing reports, video tapes, brochures and leaflets; conducting cleaner production assessment at companies; etc., (VCPC, 2003) have been efficient ways to expand and disseminate cleaner production technologies to producers. It is necessary to have intermediary organizations as a bridge to transfer information from VCPC to companies. These intermediary organizations might be branches of the VCPC in each key economic region of Vietnam, Division of Science and Technology of provincial DOSTEs, environmental centers, general cooperation, branch association, etc. In the same way, provincial DOSTE in collaboration with environmental centers or research institutes can conduct and disseminate cleaner production measures for household production units, which are currently not among the targets of VCPC. Similarly, the limitation on technical information related to waste exchange could be overcome by either integrating this program in the activities of VCPC and its branches[1] or establish waste information exchange centers as sub-sections of the Division of Science, Technology and Information belonging to provincial DOSTEs and Industrial Zone Infrastructure Development Companies.

Fourth, Vietnam can learn experiences on production technologies, cleaner production, waste reuse and recycling from other countries and adapt them for use in the technological conditions of the country. Openness to trade and investment alongside with industrialization might offer opportunities for enterprises to take advantage of newer and cleaner technologies imported from other industrialized countries (Rock, 2000, 2001). Growing of foreign investments in industrial development might help Vietnam modernizing the industrial system and achieving more sustainable development.

Finally, in order to force producers to conduct auditing programs, provincial DOSTEs or industrial zone authorities need to give a clear and specific content of environmental reports and material manifests so that producers have to carry out measurements and give more detailed data on their production processes and waste generation. By doing so, environmental management authorities can compare and recognize whether production processes of those producers are operated efficiently and environmental friendly to advise them in conducting a cleaner production program.

Environmental Policy Constraints and Opportunities

Constraints. Environmental policy constraints refer to four main points: (1) strong emphasis on end-of-pipe treatment; (2) lack of incentives to encourage investment and implementation of cleaner production and waste exchange, (3) low or no price for using natural resources and absence of waste treatment fees, and (4) lack of environmental management (division) of the company.

First, the existing environmental legislation strongly emphasizes end-of-pipe solutions, while cleaner production and waste reuse and recycling is mentioned briefly without concrete and practical incentives and guidelines for implementation. This is shown through all three case studies. For instance, to overcome environmental pollution due to tapioca processing in Tra Co Village, Dong Nai DOSTE and the People Committee planned to install a new sewer system[2], in stead of seeking solutions to reduce the generation of wastes. In case of Tan Chau-Singapore Company, the pressure put on the company at the initial stage was on treatment of wastes rather than orienting them to optimize their material flow within the production process and paying attention to onsite and offsite reuse and recycling of non-products. This is also the case of food processing companies in Bien Hoa 1 IZ. These companies installed wastewater treatment plants just to fulfil the requirements from environmental authorities without proper care on treatment efficiencies. That is the reason why concentrations in these effluents from these plants are usually above the Vietnamese standards and contribute to the deterioration of surface water.

Second, there is no incentive to encourage investment and implementation of cleaner production and waste exchange. Disposal of wastes (such as waste fruits from DONA NEWTOWER J. V. Company, eggshells from BIBICA Company, etc.) together with domestic solid waste is an evidence of this constraint. Third, low resource pricing and non-existing pollution treatment fees are among the major regulatory constraints in encouraging the implementation of cleaner production and waste exchange. This is illustrated by the case of tapioca producing households in Tra Co Village, where the producers can use ground water free of charge for their production activities. They do not care about minimizing water losses, because it costs almost nothing. In addition, they do not have to pay for discharging their wastewater and generated wastewater finally does not end up in their own yards.

Finally, most producers do not have a separate environmental management division. Therefore, so far, except for the operation of wastewater treatment systems and selling non-products for recycling, hardly any other activity focussing on improvement of environmental performance are carried out by producers themselves.

Opportunities. In order to promote the implementation of cleaner production and pollution prevention as well as further approaching to a zero waste industrial ecosystem for food processing industry in Vietnam,

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[1] Burnside Cleaner Production Center plays an important role in providing information on waste reduction and prevention, and cleaner production to existing industrial estates (Smolenaars, 1996).

[2] Including a sewer network and wastewater treatment plant.

the following key measures should be taken into account. First, it is important to establish financial incentives to encourage the implementation of cleaner production and waste exchange in the environmental regulation system. By setting a waste treatment and disposal fee based on unit of generated waste (amount of waste per unit product), for instance the higher the unit generated waste, the higher the fee, will encourage producers to minimize the generation of wastes from their production processes.

Second, appropriate pricing of natural resources and materials and removal of subsidies for water and electricity supply as well as for the waste collection and disposal service is essential. It is of course of great importance to determine suitable charging rates. Too high charging rate will affect the economic performance and competitiveness of business, while a too low rate will discourage producers to pay attention to environmental protection. For electricity and water supply, the Government Pricing Committee in collaboration with Electricity of Vietnam and Water Supply Companies have to carry out studies to estimate appropriate prices of electricity and water supply for industrial producers and submit them to the Government to make a decision about. Similarly, in the case of treatment and disposal fee of wastes, it is the task of MOSTE and DOSTEs in collaboration with environmental centers and waste treatment companies to estimate proper prices. The implementation of such a pricing system can only be done after promulgation by the Government.

Finally, without continuous maintaining environmental protection activities of participated companies, all attempts to approach more sustainable development are meaningless. In addition, because “cleaner” is a comparative expression and “cleaner” today may not be “cleaner” tomorrow (Sakurai, 1995: 2) and industrial development is a dynamic process, establishment of a permanent system or institutions to facilitate and implement proper environmental pollution prevention activities is necessary. This can be done in different ways at different levels. For companies above a certain size (such as medium- and large-scale companies), it is suggested to establish a separate environmental management section, which is able to conduct environmental monitoring, auditing, designing cleaner production measures as well as properly operate the waste treatment systems. For small-scale or household-scale production units, where it is difficult and impossible to establish separate environmental management sections for each unit, Environmental Management Sections of District Urban Management Divisions will play important roles.

Economic Constraints and Opportunities

Constraints. Economic constraints refer to three main points: (1) lack of incentives from economic agents; (2) poor influence from customers and consumers, and (3) financial limitation. First, all three case studies show that so far, economic agencies such as banks, tax agencies and insurance companies have not provided companies any incentives to apply cleaner production and pollution prevention measures. No tax exemption or tax reduction is applied for environmental investment of companies. Insurance companies have only emerged recently in Vietnam and are mainly related to health insurance rather than risk insurance for industries.

Second, the case studies also show that national customers and consumers play no role yet in pushing food processing companies in Vietnam to both qualities of product and environment take into account nor have a role in triggering companies to get interested in ISO certifications. No product among the studied companies having eco-labels or are in a stage of working towards a labeling system. Unfamiliarity with eco-labeling of Vietnamese customers and consumers give further evidence of this constraint. The industrial grade alcohol producing from reusable materials (such as high quality molasses of sugar companies) has not been specified, in terms of environmental protection, compared to that from original raw materials (such as wood). It is attributed to the common situation in Vietnam because environmental performance is not taken into account by customers and consumers in selecting their products or suppliers.

Last but not least, lack of capital for environmental investment is always a challenge for the implementation of cleaner production measures as well as end-of-pipe treatment, especially in the case of household-scale units. So far, there is a limited financial assistance for implementing cleaner production measures (only for some demonstration projects).

Opportunities. There are several opportunities to overcome these economic constraints. First, cleaner production demonstration projects, that have recently been established in Ho Chi Minh City and Ha Noi, show that environmental funds with a preferential interest rate could help to facilitate the implementation of cleaner production (Nhan, 2001). This shows that companies are willing to borrow money from credit institutions for environmental investments. Vietnam can also learn from experiences of other Asian countries in applying soft loans and special schemes giving benefit on taxes (Chandak et al., 1995; Roestamsjah and Cahyaningsih, 1995; Rock, 1996) to make cleaner production and environmental pollution prevention more attractive.

Second, except for household-scale production units (as in the case of Tra Co Village), large-scale companies increasingly export part of their products to several foreign countries in the world (as the cases of food processing companies in Bien Hoa 1 IZ and Tan Chau-Singapore Company). Starting at Eastern European and USA markets might be instrumental in an ISO 14000 accreditation process for companies, which were granted the Certificate of Quality Management System ISO 9000 (such as Bien Hoa Sugar Company, Bien Hoa Coffee Factory, DIELAC Powder Milk Factory). In other words, customers and consumers will be able to push these companies to pay more attention to their environmental performance. Moreover, achievement of ISO 9000 of some companies (such as BIBICA Company, DIELAC Powder Milk Factory) directly triggered by their operation in European and USA markets, is a good start for these companies to move further into the implementation of proper environmental management system (EMS). Because from this position, the steps towards an EMS according to ISO 14000 might be smooth as these companies already have experience with the necessary internal organization and reporting and with accreditation procedures (Magno, 2001).

Finally, besides establishment of financial incentives, those companies, which face financial limitations, should start with cost-effective low and no-cost cleaner production measures that are easy to implement. The savings from these low- or no-cost solutions could then be used to fund the applications of other more costly options.

Constraints and Opportunities on Public Participation

Constraints. A key catalyst for adoption of environmental-friendly production practices is a strong public preference for them. In several cases in Vietnam, environmental reforms are triggered by local community complaints (O’Rourke, 1999; Woltjer, 2001; Phuong, 2002). However, the case studies indicate existence of several constraints that hamper community action with respect to the studied companies. First, the overall level of environmental awareness of residents remains low. The local community hardly knows anything on long term impacts caused by (industrial) wastes nor do they pay attention to that. This is especially the case where the community is equal to the producers and profiteers of the environmental problems. For instance in Tra Co Village, villagers can earn income from tapioca wastewater as fish feed or from recovery of fibrous residues and pulp, so they do not complain about the dischargement of tapioca wastewater into the environment. Farmers living in the surrounding of Tan Chau-Singapore Company can sell cassava roots to the company and buy with preferential prices both wet fibrous residues and hard roots and wood shells. In addition, some households have family members that are employees of the company. So there is no reason for them to complain about environmental problems caused by these production activities.

Second, limited access to environmental agencies also contributes to restrain the role of the community. In several cases, the community members do not know DOSTE or its functions. Therefore, they usually need help from other social organizations such as the Retired Civil Servants’ group, the Veterans’ Association, the Women’s Association, or the media to transfer their complaints to higher authorities. This is illustrated through the case study at Bien Hoa 1 IZ. Thus, the lack of interest in environmental issues of these social organizations (as indicated in the case studies at Tra Co Village and Tan Chau-Singapore Company) is another constraint for public participation.

Finally, lack of local and national independent NGOs working on pollution issues is also among the most significant constraints. In other (developed and developing) countries, domestic environmental NGOs link to international environmental NGOs, and in that way succeed to mobilize concerned citizens to participate in policy-making and support social movements to push state organizations and industrial polluters towards radical environmental reform (Phuong, 2002). In the absence of such NGOs, citizens in Vietnam lack a powerful source of support.

Opportunities. In order to enhance the role of communities in detecting environmental pollution and changing behavior of the polluters, it is important that the communities become more aware and get more knowledge about the environment and environmental quality in their livelihood. The Government can help to increase environmental awareness among citizens by including environmental issues in curriculum of primary schools and widening opportunities for the establishment and functioning of domestic, national environmental NGOs as well as international NGOs. Supporting of the Government in establishment of special programs on science and education focussing on environment of television, radio and newspaper is another effective way to disseminate environmental information to citizens. Finally, in order to facilitate community action, the state environmental authorities have to provide specific guidelines, so that citizens know on how, where and to whom their complaints can be sent.

APPLICABILITY OF THE POLLUTION PREVENTION METHODOLOGY IN APPROACHING A ZERO WASTE INDUSTRIAL ECOSYSTEM

This section evaluates the applicability of the developed pollution prevention methodology in approaching a current industrial system towards more sustainable system after testing through three case studies and follows by discussion on proposed physical-technological models to approach zero waste industrial ecosystems of food processing industrial sector and other industrial sectors.

Applicability of the Developed Pollution Prevention Methodology

Though several similarities and dissimilarities arose from three case studies, it is possible to draw some general conclusions on the proposed methodology for developing a zero waste industrial ecosystem. First, the methodology to design a physical-technological model of a zero waste industrial ecosystem following four basic steps proved feasible and applicable in any industrial system. No matter how large or small the industrial system, where it is located, what kind of production processes are used, how homogenous or heterogeneous, none influences the logic of investigating the process flow data, waste generations and solutions to prevent, minimize, and treat wastes. By following the four basic steps of the developed methodology (analysis of the existing material flows, selection of appropriate possibilities for prevention and minimization of waste generation, material flow network creation, and waste treatment), one can screen and select suitable technical solutions to move an existing industrial system to a more sustainable system.

Second, the case studies show that without an analysis of actors and institutions, any physical-technological model remains a theoretical possibility at best. Without understanding the existing relations of the industrial systems with governmental organizations, other economic entities and social actors, we can not identify the existing barriers that hamper the implementation and introduction of (options of) the developed physical-technological model. Further more, we have no basis to give adequate solutions to change these existing relations in order to facilitate, support and enhance the possibilities of implementing some or all proposed options of the model. An analysis of actors and institutions following a triad-network model proved useful in all case studied industrial systems.

A Zero Waste Industrial Ecosystem Model of Food Processing Industry

The possibilities and approaches for greening food processing industry in Vietnam are drawn from three case studies and generalized in a general physical-technological model as presented in Fig. 1. Though operationalization of this model will vary due to the diversity of (food processing) industrial systems, this generalized model is the foundation for governmental authorities, planners, policy makers and environmentalists in reforming existing industrial systems and establishing new industrial systems as well.

In this model, the agricultural sector supplies raw material for both the food processing industrial sector and livestock sector, for instance sugarcane for sugar processing, green coffee beans for instant coffee production or cassava for tapioca starch processing and for pig breeding. The industrial sector receives major input from agricultural fields, supplies products to the market and other enterprises, and returns biomass back to the agricultural lands after a composting process as well as to the aquacultural sector (such as tapioca wastewater as fish feed). The livestock sector also supplies manure to the composting plant or biogas production plant. Other related industrial sectors (for instance enterprise B, a livestock feed production enterprise or enterprise C, which use product of enterprise A as raw material) exist to process products or byproducts from the food processing enterprise (for instance enterprise A in the model), which requires virgin materials from agricultural fields for processing (see Fig. 1). Thus, onsite transfers of energy and materials exist among agricultural fields, industrial enterprises, livestock and fish breeding. Besides, each sector also has to connect to the outside for delivering products to the market and importing other inputs to the industrial ecosystem. By doing so, food processing industry and agriculture can cooperate for environmentally sound development of both.

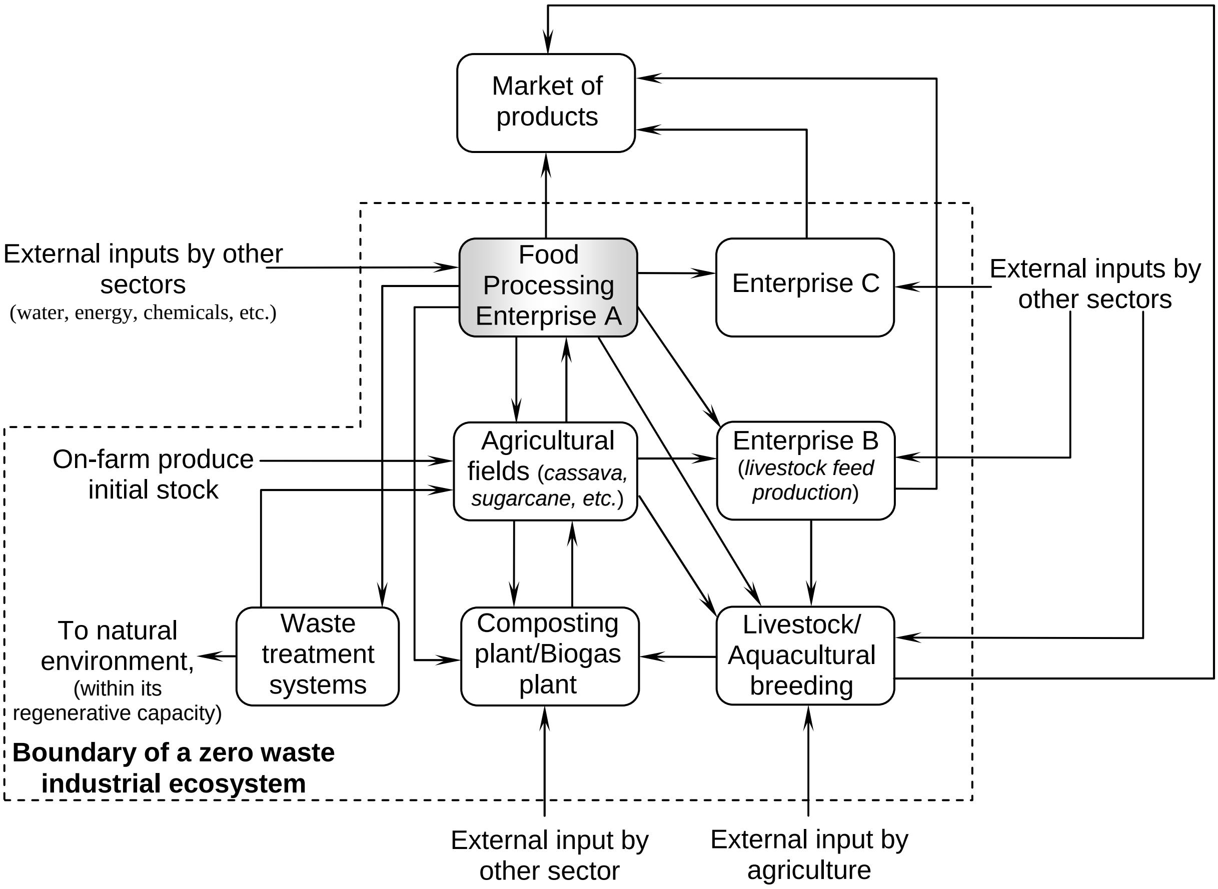

Fig. 1 General recommended physical model of a zero waste industrial ecosystem for food processing industry.

Non-products of the food processing industry are mainly organic materials, which can be reused as raw materials for livestock feed production, composting, biogas production, fish feed, and few specific products such as industrial grade alcohol. The companies (livestock feed company, composting plant, biogas production plant, fish culture households, alcohol company) do not face high risks of losing supply or market if the food processing company closes down or changes its product for any reason. First, each of these companies usually uses non-products from the food processing company to substitute a proportion of one of its, often virgin, raw materials. By doing so, they reduce their spending and simultaneously help to reduce requirements on treatment of non-products and avoid damage to the natural environment due to improper treatment and disposal. In case the food processing company closes down, reduces capacity or changes its product, these companies can fall back to the originally used raw material. Second, the biodegradable characteristics of non-products from the food processing industry always makes them suitable raw materials for composting or biogas production. Third, even in case the food processing company changes its production process to produce different food products, it is still possible to reuse its organic non-products for composting, biogas production and irrigation (after pre-treatment). Finally, variation in the quality of the organic non-products does not cause significant effects on the quality of products (for instance compost, biogas, water for irrigation, etc.), because it is always possible to adjust mixtures of these non-products with other available materials (such as rice straw, sawdust, livestock faeces, etc.) before entering the recycling processes. Thus, in the case of food processing industry, offsite reuse and recycling could help to complete the prevention of organic non-products from becoming wastes.

From the case studies we conclude that this physical-technological model can be applied for different existing food processing industrial systems: one company, small/household-scale or medium- and large-scale companies, a group of enterprises from one food processing industrial sub-sector or from different food processing industrial sub-sectors, enterprises located within or outside industrial zones. Of course, this model is designed and applied for food processing industrial sub-sectors that use agricultural products as raw materials. In some cases food processing companies do not use agricultural products as raw materials (such as seafood processing companies, confectionery companies, Coca-cola company), so they do not have to be located close to agricultural fields. In those cases, some of the proposed elements in the developed physical model might not play the role of recylers of non-products from the food processing company. However, this does not mean that these elements do not have to be involved in the system. For instance, if enterprise A in the proposed model is a seafood processing enterprise, two main non-products from its production process will be organic solid non-products (including residues of fish, shrimp, cuttle-fish, etc.) and wastewater. Certainly, these organic solid non-products can be reused as raw materials for livestock feed production, while wastewater has to be treated properly before discharging or reusing for watering or irrigation (if possible). In this case, agricultural fields and the composting plant/biogas production plant will not recycle non-products from seafood processing enterprise, but these elements can be important in recycling non-products from the livestock breeding sector as well as supplying raw materials to the livestock feed production enterprise. In other words, though relations among the proposed elements of the model of a zero waste industrial ecosystem of food processing industry might differ in different food processing industrial systems, the main proposed elements creating cooperation between industry and agriculture remain similar. The relationships between food processing industrial sub-sectors, which do not use agricultural products as raw materials, and other elements in a proposed physical-technological model of a zero waste industrial ecosystem is described in Fig. 2.

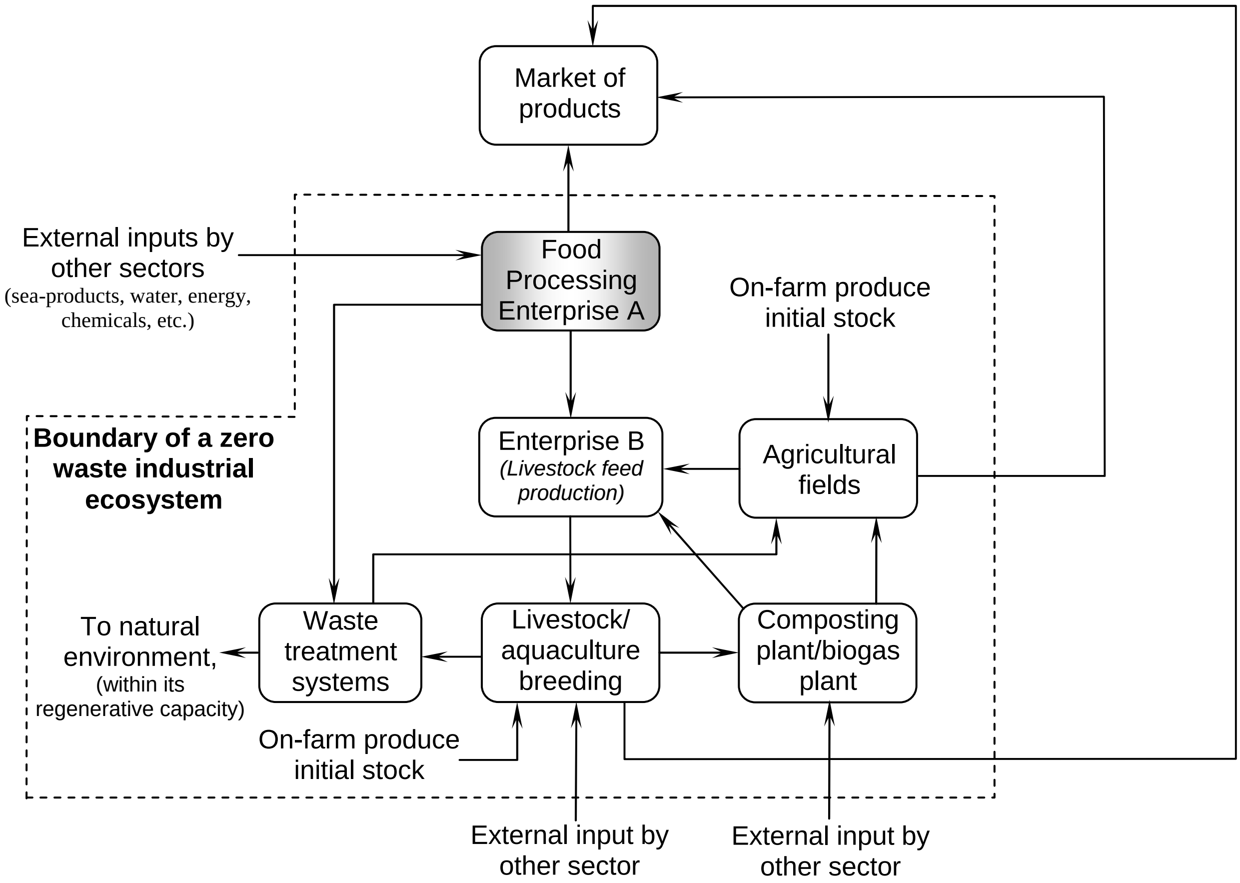

Fig. 2 A Proposed physical model of a zero waste industrial ecosystem of food processing industrial sub-sectors, which do not use agricultural products as raw materials.

Approaching a Zero Waste Industrial Ecosystem: a Physical Model of General Industries

In this section, we will in general terms discuss what a physical-technological model of a zero waste industrial ecosystem look like (compared to that of food processing industry) when it is developed for other agro-industrial sectors and other industrial sectors, which do not use agricultural products as input. As discussed in above sections, operationalization of a developed physical-technological model will be different due to the variation in the complex social, economic and political networks between the industrial system and other actors. Therefore it is impossible to generalize these relations for any industrial system. The discussions in this section focus on the physical-technological model, which can be used as a guidance for moving the industrial system into a sustainable direction. In addition, the proposed material network flow is developed with the hypothesis that all industrial enterprises participating in the model carry out cleaner production measures to prevent and minimize the generation of non-products from their production processes.

Agro-Industries. In order to be able to come to a general physical model of a zero waste industrial ecosystem for agro-industries, it is logical to indicate typical characteristics of these industrial sectors, inputs needed for their production processes and potential generated non-products. Moreover, these are the foundation to evaluate differences between the physical model of food processing industry and other agro-industries.

In general, agro-industries are industries, which use agricultural products as raw material input. More precisely, agro-industries comprise four main industrial sectors: (1) food processing industry, (2) crop processing industry, (3) livestock feed processing industry, and (4) slaughter industry[3]. Because these industrial sectors require agricultural products for their production processes, again integration between agricultural cultivation, livestock breeding and agro-industrial manufacturing seems to be the most likely strategy. The crop processing industry receive products of agricultural fields (such as paddy, corn, cassava, etc.) to produce foods for human consumption or raw materials for other production processes (such as rice, maize powder, cassava chips or powder etc.). Several products and byproducts of crop processing industry are raw materials for livestock feed production, for instance bran, maize powder, cassava powder, etc. Products of the livestock feed industry supply of course to the livestock breeding sector. Products of livestock breeding include (1) milk for the dairy industrial sector, (2) eggs for confectionery industrial sector, or (3) meat from slaughterhouses. Non-products from these industrial sectors mainly consist of organic solid and liquid (wastewater) materials, which are recyclable back to agricultural fields, and air emissions, which have to be treated. Thus, a general approach towards a zero waste industrial ecosystem of agro-industries can be specified in Fig. 3. This model is similar to the proposed model for a food processing industrial ecosystem (as presented in Fig. 1 and 2), but it is an integration of all agro-industrial sectors and also implies the model of a zero waste industrial ecosystem of food processing industry.

Non-Agro-Industries. Several industries do not use agricultural products as raw materials in their production processes, for instance for the production chemicals, construction materials, electric and electronic equipment, petroleum, energy, etc. Because their required inputs are not from agricultural products, it is less crucial to locate these industrial enterprises close to agricultural fields. Because non-products from these industrial sectors often contain potential toxic compounds (for instance heavy metals, chemicals, acid and base contaminants, etc.), reuse of waste streams for agricultural purpose is often impossible. However, these industrial sectors can have symbiotic relationship, in which wastes from one company are utilized by another, as it is illustrated by several experimental industrial ecosystems in the world. In other words, the kind of the industrial sector does not restrain the development of a zero waste industrial ecosystem and the developed methodology can be a good starting point to analyze and assess possibilities and approaches. The discussion in applicability of the pollution prevention methodology in approaching a zero waste industrial ecosystem has revealed that this methodology is feasible and applicable in any industrial system. Therefore, application of this methodology to analyze and asses possibilities and approaches to achieve a zero waste industrial ecosystem of other industrial sectors is strongly suggested because: (1) there is an advantage of availability of the methodology, which has been proved its applicability through case studies in food processing industries; (2) application of this methodology in other industrial sectors will help to prove again that it is possible to apply the same methodology for different industrial sectors; and (3) by doing so, there is a possibility to improve this methodology, so that it can be applied for any existing industrial system. It is worth to emphasize that in the case of non-agro-industries, the basic symbiotic relationship of the system is not based on industry and agriculture as the case in food processing or agro-industrial sectors, but it is rather based on industry-

[3] This classification is based on the definition of agricultural products in Vietnam. Therefore, industrial sectors such as wood processing, pulp and paper, etc. which use forestry products as raw materials for processing, are not categorized among agro-industries.

industry coexistence. This means that if for instance producers from only one kind of industrial sector (which produce the same product) are located in an area (for instance an industrial zone), there is no opportunity to create a material flow network or symbiotic relationships among producers by making use of products or non-products from each other. This also means that concentration of any kind of industrial sector in an area is not a preferable configuration from the industrial ecology point of view. Only coexistence between certain industrial sectors that helps to increase both economic and environmental benefits and leads to approaching a zero waste industrial ecosystem is expected to develop.

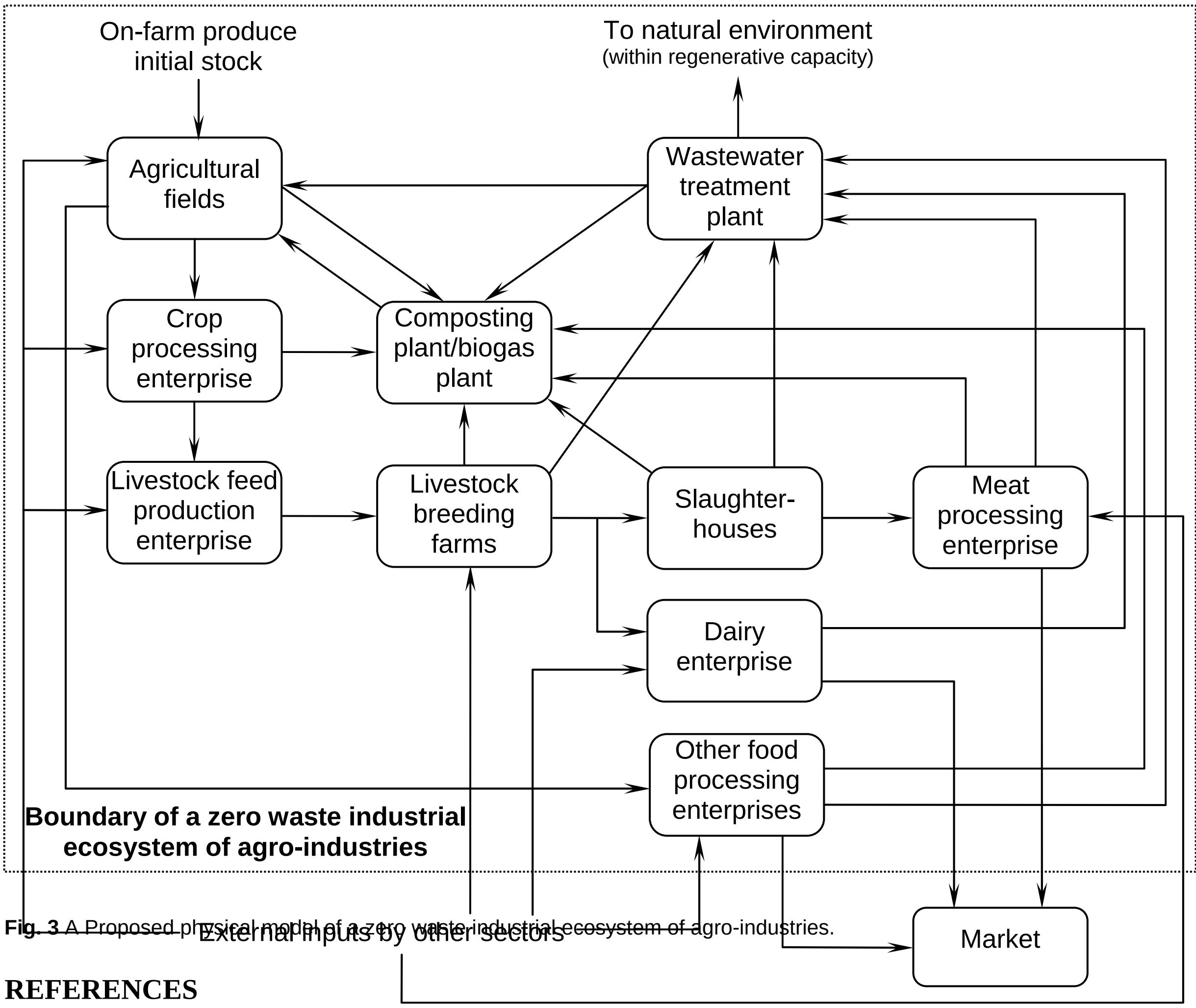

Fig. 3 A Proposed physical model of a zero waste industrial ecosystem of agro-industries.

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