CHAPETER 2 LITERATURE REVIEW

History of waste exchange can be traced back to 1970s. The **Organization for Economic Co-operation and Development (OECD) (1981)** began to study about waste management in 1981. Some results from this study indicated that lack of information for available wastes limit attempt to increase reuse or recycle wastes. Waste exchange was one solution of this problem. Waste exchanges in European countries operated by

- industrial societies for their members;
- Chambers of Commerce and similar organisations;
- industrial magazines;
- government; and
- independent laboratories sponsored by governments.

Successful of waste exchange in United Kingdom saved the money (opportunity cost) for new material value at six million pound from 125 exchanges. Recommendation from this study to promote markets for waste materials was developing future markets for secondary materials. This market could cope with risk from demand fluctuation of secondary materials, help dealers to have stable income, and better credit term. Important factor which had effect on successfulness of waste exchange is public participation.

Elizabeth W. Dorn and M. Timothy McAdams (1982) explained that changed policies and regulations of US. government make it more difficult to dispose wastes and encourage companies to investigate their waste management alternatives. Public opposition to dispose wastes in the environment and lack of suitable site for the disposal of all types of waste also cause that result. Waste exchange is an answer for wastes that cannot be reused or recycled or is difficult to reuse in-house.

Waste exchange will list wanted wastes and available wastes. Normally name of waste generators and waste users will not be published to prevent arousing public suspicion and benefit of their competitors that may gain from these information.

Waste exchange usually deal with the little known value products rather than by-products. Waste exchange can be divided into two types. Information exchanges or clearinghouses will provide listing of available wastes and needed wastes. Waste material exchanges will buy wastes and reprocess until meet the requirements of potential users and resell to them.

Recycling companies and resource reclamation will use service from waste exchange to test market and find new clients and new suppliers. They have concluded that exchange of wastes will happen in the following situations:

- from large companies that use continuous processes to small companies that use batch processes;
- from chemical manufactures to formulators; and
- from companies who require high purity of input materials such as pharmaceuticals or electronics companies to companies who can use low quality of input materials for example paints manufacturers.

The following are the lists of wastes that normally can be exchanged.

- acids and alkalis
- solvents
- catalysts
- residuals containing heavy metals
- oils
- combustibles
- plastics and rubber
- textiles

Factors that have an effect on the success of waste exchange are :

1. *Technical factor* Chemical and physical properties of wastes have to be compatible with the required specification of substitute input materials.
2. *Economic factor* Cost that occurred from exchanging wastes such as transportation costs must be balanced with disposal costs of that wastes or raw materials costs saved.
3. *Institutional factor* Waste generators and waste users should be willing to do the business with each other under the laws and regulations.

It is difficult to obtain information how success of waste exchange is. About 9 to 50 percent of the total number of lists are thought to be successful in exchange wastes at that time. From the study of Piedmont and Atlantic Coast Exchanges prevailed that primary reason for low use of their services is an unawareness of how their wastes can be used and the value of their wastes.

Jim Potter, ed. (1986) has summarised articles of recycling in California state. This literature describes hazardous wastes recycling. One article explained about off-site recycling, the similar concept as waste exchange, that wastes will be transported to recyclers or industries. Recyclers will purify wastes and sell them to generators or other users. Some examples of waste exchange in California are solvent leasing, battery recycling, drum recycling, and mercury recycling. Those examples are explained in the following.

- *Solvent leasing* Examples of industries that use this service are automotive repair and dry cleaning. Users will pay only fee for using solvent and they do not own it and return used solvent to solvent leasing companies without charging any cost. Leasing

companies will provide transportation of solvent to and from users' plant, and training for proper handling of the solvent. After they receive used solvent, they will purify it and lease to the same users or the others.

- *Battery recycling* Spent batteries can be recycled. Recyclers will crush batteries and smelt to recover lead.
- *Drum recycling* Used drums that contained hazardous materials can be reused by sending them to companies who offer cleaning or treatment services. They will use triple rinse method, thermal treatment by cutting the ends off the drums and heating them in special furnace, or other treatment. Those treatments have to be accepted by Department of Health Services, California state.
- *Mercury recycling* Products that contain mercury such as pressure or temperature measurements, fluorescent light bulbs can be recycled mercury. Recyclers will use distillation method to get mercury out of the products. Products will be heated in a sealed furnace under low pressure and mercury will be vaporised and condensed for reused.

Other examples of success in waste exchange is "off-spec" and slightly contaminated electroplating and etching solutions from the electronics industry are often reused by metal finishing industries who require low quality for their process solutions. Metal finishing wastes can be used to provide micronutrients such as zinc in agricultural fertilisers. Precious metals are recovered by some off-site recyclers, but the volume is small.

Industries who generate small quantity of wastes that would like to avoid the technical, economic, and managerial demands of on-site recycling can get benefit from using off-site recycling services. There are some disadvantages for off-site recycling industries in term of potentially high transportation and uncertain future liability costs and expenses associated with manifest record-keeping and hazardous waste generation fees.

Government policies and regulations have an effect on waste exchange. Some states including California try to ease regulations to promote waste recycle but still prevent public health and environment. Example of this is regulation reform of manifest requirements for hazardous wastes to promote solvent leasing. Leasers or haulers normally carry many drums of solvent for industries in each day. If they have to fill out completely full manifesting procedure, it will make difficulty of transportation. This will reduce interesting of companies who would like to operator this business. From this reason they allow to fill out only one manifest per truck per day.

National Environmental Board, Ministry of Science Technology and Energy of Thailand (1989) has summarised the possibilities of using wastes in Bangkok and vicinities area in some industries. The followings will

describe the examples of them that relevant to wastes from factories in Bangpoo Industrial Estate.

Battery manufacturer for car and motorcycle, scrap lead, old or expired battery, and dry lead sludge from wastewater treatment plant can recover lead for producing new battery or bullet, raw rubber scrap that not be contaminated with chemicals or other particle can be mixed with cloth to produce canvas, or mixed with asphalt to be road surface or burn in incinerator to produce steam for generating electricity, plastic scrap that not be contaminated with chemicals or other particle can be given to plastic manufacturing industry or used in pyrolysis process to generate steam, asbestos paper sent to asbestos manufacturer.

Chloromethanes, waste solution sent to distillation, chlorination with high temperature and pressure in nickel tube to get carbon tetrachloride.

Chloroalkali manufacture, alkali sludge from diaphragm cell process to dewatering process, coagulation and filtration then mixed sludge with lime, silica and coke after that melt at 1,000-1,040^0 C to get lead bar, Hg sludge from electrode contamination sent to dewatering and roasting to get Hg vapour and then condensation and demisting, brine impurities to react with H_2SO_4, NaOCl then filtrate liquid form react with $NaHSO_3$, H_2SO_4 and Sodium Hydrosulfide to get HgS for industries that related to Hg or mix with NaOCl to be brine solution for Chloroalkali industry.

Chrome plating scrap metal send to metal manufacturer or recycle. Chromic acid can be used in chemical process (chromium sulphate) to be used in sugar industries.

Clothing, cloth and string that not be contaminated and separated according to types and colour to produce rug, cushion, paper pulp, roofing material, and blanket, steel scrap, damaged steel and zipper scrap to produce steel bar and wire, damaged plastic button and plastic zipper sent to plastic manufacturer.

Electrical appliances, scrap metal produce steel wire and steel bar, scrap copper and aluminium produce electrical wire, scrap glass sent to glass manufacturer, scrap plastic sent to plastic manufacturer, scrap paper sent to paper manufacturer, spent lubricant mixed with some chemicals can be used as fuel in cement kiln.

Electrical wire aluminium or copper scrap melt to produce aluminium or copper bar, PVC send to plastic manufacturers.

Film can be sent to plastic manufacturing.

Food can industry, mung bean skin that not contaminated with toxic substances and other particles can be used for producing milk, fertiliser, and instant animal food, bone fur, and fresh can be used for producing gelatine and glue, fish entails can be used for animal feed, fertiliser, instant animal food, metal scrap can be used to produce steel bar and wire, can scrap can be used to produce new can.

Garment industries, NaOH from Mercerise send to dialysis process to extract crystalloid from colloid and reuse it in the process, oil & grease can be used as fuel, AZO pigment after going to sedimentation tank sludge from this process can be extracted AZO by using Alamine 36, Alcohol, Kerosene, Soda ash and NH_4OH.

Glass to contain film cleaning solution can be sent to glass manufacturing to make insulation material.

Machined steel, scrap steel with no contaminated to produce steel bar, wire and pipe, lubricant sent to redistillate or recover to be fuel.

Metal Cleaning Industry, spent solvent e.g. chlorinated solvent (1,1,1-Trichloroethylene, Trichloroethylene, Methylene Chloride, Perchloroethylene to redistillate, sludge from this process can be redistillated and use that solvent as fuel in incinerator or cement kiln (contain < 30% of solvent), but for 30-90% of solvent contained sludge using as fuel in cement kiln an furnaces.

Metal electroplating, acid solution sent to neutralisation, precipitation and leaching by H_2SO_4 then filtration to get $CaSO_4$ for indoor wall panel or tiles manufacture, then filtrate from this process is adjusted to pH 3 by alkali to get iron hydroxide form for using in laboratory, filtrate from secondary process sent to electrolysis to get Ni and Cu for electroplating, clear water sent to electrolysis and adjusted to pH 9 by lime to get Cd, Cr and Zn sludge for electroplating, cyanide in base solution is mixed with metallic iron to get Cu, Ni and Cyanide in clear water for electroplating, sent to evaporation process to get cyanide and sent to ion exchange to get metal chloride and sodium cyanide for electroplating.

Metal smelting industry, slag from furnace that not be contaminated can be used to produce cement road aggregate, steel scrap can be remelted to produce magnetic, steel bar and wire. Ash from coke process can be used for producing brick, ceramic grain for construction.

Packaging industry, damage PP sent to PP manufacturer, film paper used as fuel for heating, scrap PS sent to PS manufacturer, corrugated and box paper sent to kraft paper manufacturer, glass paper coated on plastic and damage aluminium foil recover plastic and aluminium.

Perchloroethylene waste solution sent to stripping and distillation to get hexachlorobutadiene.

Printing industry, unqualified printing document be used as cover book to protect from dirty and damage during storage and transportation, scrap paper sent to pulp and paper manufacturer, brass cup for containing ink sent to brass cup manufacturer, plate for printing book produced roof and zinc side wall, plastic contain film cleaning solution sent to plastic manufacturer.

PU foam manufacturer, scrap PU can be mixed with chemical to produce pressed (compressed) PU to produce cushion for bicycle.

Scrap PS is sent to PS manufacturer or burnt in pyrolysis system to produce gas and oil as a fuel for boiler.

Rubber or Latex foam, scrap is mixed with cloth to produce canvas or mixed with asphalt for road surface or burn in incinerator to produce steam for electricity producing.

Transformer manufacturer, scrap metal sent to produce steel wire and steel bar, scrap copper produce electrical wire, scrap rubber and insulator sent to pyrolytic reactor to get gas and liquid fibre, spent oil sent to redistillate to be fuel.

Vegetable oil manufacturer, coconut shell can be produced charcoal and activated carbon, coconut fibre produce bed; soybean shell produce animal food, seed with no contaminant that contain some vegetable oil to low grade vegetable oil by using e.g. benzene or hexane as solvent and wet seed from this process can be used for animal food or fertiliser.

Wood product, sterm produce fibre board, particle board and pulp, slab cut from log produce black board and accessories for door.

Shoe, plastic shoe sent to plastic manufacturer and pyrolytic reactor for gas and liquidfied fuel, paper box sent to paper manufacturer.

Tannery industries, tail, ear, fur, and others except skin can be used as animal food, connective tissue or fascia (no contaminant) can be used to produce gelatine or fertiliser. In vegetable tanning sugar from reaction of

skin + tanning → leather + sugar

Sugar can be sent to sugar refinery. Oil can be used as fuel. Organic sludge can be changed to fertiliser or biogas. Untanned skin can be used to produce glue.

In Textile industries, polymer scrap can be sent to plastic manufacturers. Over or under size textile can be sent to manufacturer to make pillow or bed.

Zinc plating scrap metal send to metal manufacturer, wastewater send to MeS process (solvent extraction) to get $FeCl_2$, $ZnSO_4$, 6 M HCl for laboratory using.

P. N. Cheremisinoff and L.M. Ferrnate (1989) describes the most common types of waste that transferred through waste exchange are solvents, acids, alkalis, metals, and metal sludges. They stated that only 10 percent of waste listed nationally are successful in exchange in USA. The factor that inhibit the success of waste exchange are :

- mix of contaminate in waste materials;
- insufficient volume of required wastes;
- high cost of transportation;
- inconstant of waste qualities;
- variation of regulations among each states;
- liability concern even wastes have already been transferred to users; and

- if waste generators have to store hazardous wastes more than 90 days due to low quantities of waste to meet the requirements, they will need a permit.

Acids, Alkalis, electronic equipment, laboratory chemical, adhesives, battery, leather, metal sludge, metal, oil, paints, paper, plastics, rubber, solvent, textile, wax, wood, packing materials, and compostable materials can be exchanged and normally published both waste wanted and waste available in waste exchange lists. (**Office of Waste Reduction Services in Michigan 1989**)

Example of waste that can be exchanged from **Alberta Waste Materials Exchange** are as follow :

- calcium sludge from water treatment plant;
- sulphuric acid, plastic, and lead from battery reclamation;
- silver and plastics from x-ray film recovery operations;
- perchloroethylene recovery from dry cleaning process;
- scrap steel from fabricators; and
- carbide tool inserts from machine shop operations.

Factors that hinder waste exchange concept from study of **Seymour I. Schwartz and Wendy B. Pratt. (1990)** are:

- Waste generators are unwilling to change waste management mechanism from disposal to waste exchange.
- There is low incentive on waste exchange. Even though there are new land disposal bans, regulations in term of transportation, manifesting, and storing wastes for waste exchange are the same as that of land disposal or treatment.
- Operations of waste exchange have not enough fund to run the system.
- There is uncertainty of liability on waste exchange. Some waste generators are not sure about liability on waste exchange who will be liable when misuse of wastes happened. From this reason, they prefer to choose the method that known liability such as disposal.
- Low quality of waste materials, high cost of exchanging wastes, and insufficient amount of waste available are also barrier on waste exchange.

There are some recommendation from this study as follows :

- Reduce liability on waste exchange by defining term of agreement in contract, and examine waste management practice and environmental records of waste users. But this method also reduce interesting on exchange waste by potential users.
- Government promote waste exchange concept by creating guidelines for this concept.

- Tax incentive for waste exchange should be established.
- It should have RCRA TSDF permit for waste exchange.
- Some changes in regulation should be happened to promote waste exchange such as storage time of waste for waste exchange concept should be longer than now to allow negotiation on exchange.
- Potential users should be educated to know how to use wastes in their process.

P. N. Cheremisinoff and John A. King (1991) reported that if laws and regulation regarding environmental prevention emphasis on treatment and disposal, waste minimisation will not be realised. They found that in practice regulators and regulated community have mostly focused on treatment and disposal or end-of-pipe technique. Now they prefer to use waste minimisation techniques than end-of-pipe techniques since they are not enough to protect their environment. They also reported barriers of waste minimisation as follows:

- lack of information and guidance concerning waste minimisation;
- lack of in-house expertise to examine characteristic of waste and waste minimisation technique; and
- lack of awareness on waste minimisation of companies.

From EPA report to congress (**cited in P. N. Cheremisinoff and John A. King, 1991**) it concluded that mandatory standards of waste minimisation are not feasible nor desirable. The solution for this problem is to develop waste minimisation program providing assistance to waste generators in term of technical and information. First step of waste minimisation is to identify characteristics of waste streams.

CALMAX (**Kathryn Barwick, 1992**) is a free service information network for waste exchange located in California state. It will inform people who can exchange their wastes with potential users and people who can use others' wastes as raw materials. Concept of waste exchange is finding use of waste materials without any change in their character for instance using styrofoam peanuts for packing material. But this concept also give benefits for recycle wastes. The benefits of CALMAX are :

- encourage and facilitate new market for waste materials;
- reduce disposal costs;
- promote economic development by helping start-up business find free or inexpensive raw materials;
- improve wealth of community by using wastes as raw materials;
- conserve landfill space; and
- increase resource diversion.

Louis Theodure and Young O. McGuinn (1992) has concluded that factors that inhibit pollution prevention is lack of information about supply and demand of waste. Recently there are many waste exchange centre established in USA but they are not widely accept from industries due to liability concern. Transportation cost and special handling cost of waste transfer also hinder waste exchange concept. Suitable industries for waste exchange should be located near each other.

Pollution Control Department, Ministry of Science Technology and Environment of Thailand (1992) has studied how industries in Bangkok and surrounding provinces utilise their wastes. The conclusion from this study is some industries reuse, sell or donate their waste to the users. The users can use those wastes to be benefit to them by using as raw materials or reprocessing them and resell. Since this is an informal process, there are some obstacle to fully utilise those wastes. This effect also give more work to ones who responsible for those unutilise wastes and increase costs of treatment. The suggestion from this study to acquire maximise utilisation of wastes are as follows:

1. Industries that have the same types of operation should set up institute for their own in order to easily get help in form of training or supporting from government. They should exchange their knowledge and technologies of how to manage their wastes. If possible, their waste management system should be the same system to get high efficiency in waste management.
2. Industries located in the same area such as industrial estate should find the way to reduce their wastes before sending them to central treatment plants. This method will reduce load of central treatment plant and industries may be get benefit from reuse their wastes.
3. Industries should co-ordinate with government agencies or other organisations that have knowledge or technologies of how to reduce and reuse wastes. They should set up seminar or training course about how to manage their wastes. This method will help industries more understanding of waste management, good attitude of how wastes can be reused, and can use this knowledge to improve efficiency of waste management in their industries.
4. Clean technologies should be used or production processes should be modified to maximise using raw materials and generate less or none wastes.
5. Industries should support universities or research and development organisations to find the suitable technologies for reuse and reduction wastes. These technologies should be developed to use in practical business operations.
6. Industries should co-operate with government agencies in detail study of waste generation by giving information such as how they manage their

wastes or types and quantities of generated wastes for waste management planning in the future.

7. Government should have incentive for industries who try to improve their waste management such as reduce import tax for equipment or instruments that used for reduce or recycle wastes, or establish waste exchange centre to give information for exchange available wastes and wanted wastes.
8. Waste collection system should be improved. If every types of wastes are mixed, it will be difficult to separate valuable wastes from the rest and it costs a lot of money to separate valuable waste. This effect will hinder the reuse or recycle concept. Consequently, different types of wastes should be separated at source of generations in order to use easily and suitable method to recover valuable wastes.
9. Company policies related to waste management should be emphasised on reuse and recycling wastes. The benefits from this are reducing production costs, waste treatment costs, and waste disposal costs.
10. Public relation and advertising should transfer information to people about how they can benefit from their wastes.
11. Laws and regulations regarding reuse and recycle wastes should be established or reformed to reduce any obstacles of this concepts and prevent environment and health of people.

G. Favila (1994) described the established the new Industrial Waste Exchange Program (IWEP) in Philippines.

IWEP was operated in 1988 by a government agency, the Environmental Management Bureau (EMB), who received grant from the International Development and Research centre (IDRC) of Canada. Due to restrictions on fund management, EMB could not charge fee from anyone who receive services. This effect make this programme unsustainable and it stop after completed grant period. During its life, it was successful in exchange waste from waste generators and waste users.

Since this program has been successful, The Philippine Business for the Environment (PBE) was persuaded to revive this programme. During this time it receive grant from private companies for example San Miguel Corporation and the PHINMA Group and international donor agencies such as USAID, IDRC, and the World Bank under its Metropolitan Environmental Improvement Project.

PBE will distribute bi-montly magazine, Business and Environment, that contain available wastes and needed wastes, possible uses of industrial wastes, cases of successful waste exchanges, information on clean technologies, and management practices. All those information can be accessed through Philippine Sustainable Development Network (PSDN) electronic bulletin board. PBE will not charge fee to companies who would like to list his information about their waste on IWEP bulletin.

Beneficiaries from waste exchange are waste generators, waste users, and general public. Waste generators will save waste treatment or disposal costs and can get income from selling their wastes. Waste users will save their raw materials costs and can get stable source of raw materials. General public will have better environment owing to reduced amount of generated wastes. It also can translate benefit to goodwill of companies. From this reason PBE consider that Industrial Waste Exchange is win-win-win situation.

Greenpeace (1994) have summarised effect of reuse hazardous wastes to hygiene. This effect might reduce interest in using waste exchange concept. The effects are :

- It may have some heavy metals in sludge form distillation process of chlorinated solvent, paints, or lacquers. If waste users do not handle this sludge correctly, it will be harmful to environment and human. And during distillation process, operators may have illness from exhaust vapour of chlorinated solvent, paints, or lacquers.
- Some portions of scrap polyethylene for reuse come form hazardous waste containers. When they are washed, hazardous waste will leak to the environment if there is not proper management. When scrap polyethylene is melt, it may be create carcinogen chemical such as benzene and xylene.
- PVC may use cadmium and lead as plasticizer, those materials are carcinogen. When scrap PVC is recycled, those hazardous materials may leak to the environment. If scrap PVC is melt with scrap PET, char and vapour of hydrochloric acid and phthalic anhydride or formaldehyde that poison to human will be leave out.
- Lead and tar will be used to cover cable especially the old one. When cable scrap is melt to remove metal, lead will be vaporised. For new cable that made from copper coated with PE or PVC is burnt to remove copper, dioxin will be generated since copper is the catalyst for dioxin formation. This material are carcinogen.
- Retread of scrap tyres may generate chlorinated hydrocarbon that cause cancer in human. Zinc, additive in tyres making process, will cause air pollution problem, when scrap tyres are burnt. And burning scrap tyres may generated dioxin vapour.
- Scrap steel that use in steel factory may come from hazardous chemical container or car. When scrap steel is melt in furnace, hazardous vapour will be occurred.
- Sewage sludge that use as fertilisers may be not suitable when consider in term of public health since it may have germ, or virus that can transfer to vegetable or rice. Industrial sludge also that have heavy metal for instance mercury, cadmium, or arsenic is not suitable to use as fertiliser.

- When copper scrap from electronic industry is melt to recover copper, hazardous vapour will be occurred.
- Melting process of scrap aluminium normally use flux from compound chemical of potassium chloride, sodium chloride, and calcium fluoride to remove unwanted materials. Sludge from this process usually is hazardous substance. If it is not handled properly, it will cause many problems to environment and human health.
- When scrap battery are melt to recover lead, hazardous vapour is created. This substance may cause harmful to metaboric and neuro-psychological. Children who expose this substance will have brain symptom. Furthermore, lead will destroy peripheral neurotoxicity, decrease the efficiency of removal uric acid in kidney, and inhabit haemoglobin production in blood.

Rangsan Pinthong (1994) has summarised factors that limit waste exchange concept as follows:

1. *Education level of waste generators and potential waste users* It has an effect on reuse waste. Some people think that it is not economical to reuse waste though they do not investigate in more details. Some people do not know how to reuse waste or where they can transfer waste to users.
2. *Waste dumping method* People always mix any wastes before they dump them. This effect make reuse or recycle waste more difficult than separate waste when it is discharged. Since other unwanted materials contaminate valuable waste, when it is reused or recycled it have to purified and this make cost of reuse or recycle high.
3. *Incoming status of people* If people have no financial problems, they will not think about recycle or reuse waste.
4. *Attitude and tradition of people* The thinking of people about waste has an effect in either increasing or reducing amount of reused or recycled waste.
5. *Quantities and qualities of waste* If quantities or quantities of wastes is not constant and unbalance, it is difficult to trade them.
6. *Information about real waste management cost* Most people in developing countries always think that cost of open dumps waste is the lowest cost Because they do not know exactly what is the real cost of disposal method. From this reason they ignore concept of reuse or recycle waste.
7. *Costs of reuse and recycle waste* Some cost of reuse and recycle waste especially transportation cost may hinder reuse or recycle waste.

He has also investigated operation of waste exchange in Thailand. He found that waste material exchange has established in form of informal process. Operation groups that use this system can be divided into five different types

1. *Small scale recycle shops* Most shops are located near disposal solid waste site to buy valuable wastes that segregated by scavengers. They will resell those wastes to industries.
2. *Three wheelers* This group of people will buy valuable wastes that segregated by household and resell to junk shops.
3. *Junk shops* This group will buy valuable wastes from three wheelers or scavengers that segregate waste from garbage bin in roadside. From investigation of Environmental Resources Limited in 1987 and Tams-Pirnie International in 1988 (cited in Rangsan Pinthong, 1994), there are approximately 950-1,000 junk shops in Bangkok to buy bottles, plastic, metal, and paper from three wheelers or scavengers. They may be process them for instance cleaning or separate into different types before sell to industries.
4. *Wholesaler* This group of people will have a contract with waste users such as paper industries, plastic industries to sell required wastes to them in specified types, quality and quantities. Wholesalers will buy required wastes from the above explained groups of people and improve quality to meet the requirement before sell them to industries.
5. *Industries* There are industries that buy off-spec products, unwanted materials or by-products to reuse or resell to potential waste users.

From his investigation, all of the above operations are informal system and are waste material exchange system. If government do not support or develop in term of finance, technologies, and management to be formal system, it will be difficult to monitor in order to increase efficiency of reuse or recycle wastes.

In **Reuseable News of USEPA (Spring 1994)** has published the successful story of New York's Materials for the Arts and EPA Region 2 for changing scrap fabric to valuable products. This waste from textile factory can be used for painting by artists.

Attractive of waste exchange is reduced when distance between waste generator and potential waste user is increased. Generally waste users will provide transportation or pay for some costs and waste generators will provide samples and available test data for waste evaluation by waste user. Contaminated and obsolete polyol resins from foamed polyurethane moulder can be used in carpet backing manufacture. **(Environmental Services Division, State of Michigan, 1994)**

Ryan Anderson, Andy Bankert, Ryan Cush, and Matt Perrone (1994) stated that industrial ecology was the system which included the environment in the consideration. It would optimise the total material cycle from the origin to the disposal. He addressed that the meaning of industrial ecology can be the material recycling through companies network or less

using resources and energy to produce products. He explained the success of three projects which adopted industrial ecology. First one is Dow chemical began in 1981. This company encouraged its employee to propose the plan for reducing energy uses and wastes in form of contest. Since the contest began, there were 575 projects implemented. These could continually save over 110 million US$ per year. The second project was in AT&T. This company used the concept of design for environment (DFE) which applied for product or process design activity. It could minimise the environmental effects of manufacture, use, and disposal of products. The last project was happen in auto industry. This company tried to reuse fluff which comprised of plastic 30%, glass 20%, rubber 15%, and dirt 25% generated from non-metallic car parts. All these material were shredded and currently sent to landfill. Vehicle Recycling Partnership (VRP) found the way to reuse it. There are two possible methods. First, it can be incinerated to produce energy. Second, it can be used as ingredient for the production of cement for making sidewalk. From these evidences, he concluded that industrial ecology was feasible for industries to use. Other benefits beyond saving the money are improving companies reputation in environmentally concern, in turn the companies would receive more public support as well as more credit from the banks and insurance companies. Furthermore, this activity would help companies comply with laws and regulations, attract to good employees who would like to work with environmentally responsible companies, and provide new economic instruments e.g. tradable permits, taxes, or charge to the companies.

U.S. Environmental Protection Agency (1994) have reviewed operation of waste exchange in North America. Findings from this study are resented as follows:

1. Non-Federal Exchanges have both passive exchange centre and active exchange centre. Reuse and recycle hazardous wastes were limited by liability concerns and Resource Conservation and Recovery Act (RCRA) via waste exchange centres. Non-hazardous wastes are more transfer than hazardous wastes through waste exchange centres. Lists of wastes available tend to be wastes that difficult to exchange or have a lower value than wastes that exchanged by specialised brokers who deal with narrow list of waste that make profit for them when they resell or directly sold by waste generators who have their own network for continuously or large volume generated wastes. Size of waste exchanges are small. Some waste exchanges use only a fraction of one person's time while the others use six full-time people. Budget for operation waste exchanges ranges from 10,000 US$ to 200,000 US$. Some waste exchange serve regional but some waste exchange serve only one state. Due to establishment of the National Materials Exchange Network (NMEN), a computerised listing service funded by EPA, the number of waste exchanges centres is rapidly increasing. The other reason that might be effect this result is participating

in NMEN might reduce administrative costs for some local exchanges. As a result of low value or difficulty in exchange of wastes listed, self financial support charge from who receive services appear to be unrealistic goal. Measurement of how success of waste exchange is very difficult due to limitation of measures such as number of transactions or volume of waste transferred and difficulty to access the value of educational, technical, and promotional assistance services. But when compare some measures for example cost per ton transferred, waste exchange seem to compare well to other forms of publicly-funded reuse and recycle concept.

2. Federal Exchanges, for example Department of Defense (DoD)'s Defense Reutilization Marketing Organization (DRMO) has established system to exchange wastes both hazardous and non-hazardous wastes within DoD facilities first before offering them to external users. Other federal exchange, General Services Administration (GSA) is less extensive in exchange hazardous wastes and not as well differentiated as the DoD system.

Recommendation from this study are summarised as follows:

- Integration of non-federal and federal waste exchange information systems, sharing lists an promotion of exchanges should be promoted in both direction. This effect may increase the interest of private sector to participate in exchange wastes by creation of a larger market for reuse waste.
- Since established national information framework help to focus on more proactive services and support the operation of new and developing waste exchange centres, national information network should be continuously supported.
- Alternatives such as grant should be considered to support the development and continuation of waste exchanges that fulfil the range of appropriate objectives and roles such as active approach or some provision of market testing of exchange services should be included. Because of limitation of grant, interested waste exchange should be encourage to propose their own market testing their services.
- Promote the visibility of waste exchanges in the business community and among trade groups in additional ways.
- Analysis in more detail which types of hazardous wastes are transferred by whom despite of regulatory barriers. If appropriate this information should let other people know about the success to promote exchange waste.
- Develop tools to help waste exchanges monitor transactions and other activities.

Woolf (1994) summarised reports on international trade in lead battery acid battery scrap. This scrap material would be transferred from heavily industrialised countries such as USA, UK to developing countries in Asia and Latin America. The reason was costs of handling this waste in Asia or Latin America is lower than costs in industrialised countries plus transportation costs due to not compliance with environmental and occupational health laws in Asia or Latin America. There were many evidences show that people and animal nearby battery recycling facility suffer from lead poisoning such as blackened teeth, high lead in blood, nausea, and death. Other toxic contaminants discharged from battery recycling facilities are mercury, antinomy, arsenic, PVC, and sulphuric acid.

Gertler (1995) did the thesis regarding industrial ecology, the alternative model for the organisation and management of the technological structure. He stated that traditional approaches for environmental management consider only individual processes and industrial units which is different from industrial ecology. It was a systematic way considering interaction between industries and environment to form closed-loop materials and energy flow. There were two different approach in industrial ecology. First one was the consideration of impact of products and services such as life-cycle assessment and design for environment. This approach focused on products. Another is industrial symbiosis which try to use waste materials and energy from one enterprise as input for another. This approach focused on the production processes.

He noted that industrial ecosystems was the results from the repeated implementation of industrial symbiosis. Participating enterprises were required to more co-operate than traditional approach. And they had to trust each other.

He examined the successful of industrial symbiosis in Denmark and found that the environmental regulation which based on performance standard, not technology standard, was one factor to make this system happened.

He mentioned that zero emissions, idea of Gunter Pauli, which was used in Japan was the concept of multi-industry cluster of factories using waste from one plant as the feed stock by others.

The effect of Resource Conservation and Recovery Act (RCRA) was reviewed in his thesis. Results from his finding are RCRA hinder the reuse of by-product as in industrial symbiosis since it was very complicate and expensive to comply with this Act. For instance, General Motor sometimes was not willing to ship regulated waste to broker, waste exchange, or potential users due to liability under RCRA. He summarised aspects which made industrial symbiosis was more difficult to use in the following.

- *Permitting requirements for storage wastes before recycling* Storage facility prior to recycling was required to have RCRA permit.

Getting this permit was very high time-consuming, cost a lot of money, and required many resources.

- *Mixture and derived from rule* This rule made the reuse of residues from pollution control technologies of listed wastes as inputs more difficult. For example, sludge from wastewater treatment plant may be classified as a listed waste which required complex methods to handle it under RCRA.
- *90 days rule* According to RCRA, anyone who stored hazardous waste on-site longer than 90 days required to have Treatment, Storage, and Disposal Facility (TSD) permit. This process might not be viable for small generator who would like to store waste to certain amounts in order to reduce costs of transportation.
- *Liability* Generators still had liability even though they send their waste to reuse by others.
- *Restriction on sending waste off-site* When waste was hazardous under RCRA, generator had to obtain EPA identification number and comply with manifesting system if waste was sent to off-site. These processes were not appropriate for using waste as feed stock.
- *Uncertainty and lack of regulatory flexibility* This aspects lead to difficulty in recycling, reuse, or recovery wastes.

Factors which have effect on the successful of waste exchange are reported by **Nemerow (1995)** as follows:

- the possibility of sharing information to the persons outside a particular industrial plant and transportation costs;
- a small amount of waste available of many small factories are infrequently and unpredictable;
- different minor contaminants of similar wastes may cause incompatible;
- permit required under RCRA for small waste generators who have to store waste onsite for more than 90 days to reduce transportation costs and have considerable amount of wastes.

He has proposed the industrial complexes for pulp & papermill, tannery, sugarcane, textile, fertiliser-cement, fossil fuel power plant, steel mill-fertiliser-cement, plastic manufacturing industrial, cement-lime-power plant, wood (lumber) mill, power plant-agricultural, power plant-cement-concrete block, cannery-agricultural, nuclear power-glass block, and animal feedlot-plant food.

He has described that waste users should accept that they may have to slightly change product specifications or manufacturing techniques, and sometimes modify wastes for further uses. Since factories have to depend on each other in the complex. Any changes such as plant shut down, or labour strike in one factory will have an effect to the others. From this reason, stand-

by systems i.e. availability of virgin raw materials should be provided to reduce this effect.

Ed Cohen-Rosenthal, Tad McGalliard, and Michelle Bell (1996) mentioned that industrial ecology or industrial symbiosis or eco-industrial park, similar concept as waste exchange, was the community of business that co-operate to get benefit greater than the sum of each company's benefit in managing their wastes for example they exchange their wastes or energies. This concept had already proven for a long time. For example Nestles plant in New York State could use toxic chocolate oil as an input for cosmetic manufacture. The famous eco-industrial park and the origin of the concept was in Kalundborg, Denmark operated since 1970s. Some places in United State were demonstration sites of eco-industrial park concept such as Baltimore, Maryland; Cape Charles, Virginia; Brownsville Texas; Chattanvoga, Tennessee. Design driven for eco-industrial park in USA were industrial ecology concept, brownfield or abandoned site redevelopment, business development and networked manufacturing, and new environmental management technologies.

E-LYNX (1996) reported example of hazardous waste exchange as follow:

- Steel dust from grinding process can be used as a raw material to make solid steel;
- Aluminium dust from grinding process can be used as a component in graphite manufacture; and
- Kerosene contaminated with 10% of oil from cleaning process in metal part manufacture can be used as lubricant in trepanning process of small companies.

There are some conclusion of law and regulation in USA regarding hazardous waste and surplus material as follow :

- Hazardous wastes will be not classified as hazardous waste under RCRA when they are reused as safe, effective substitute for products and do not require treatment prior to reuse. But there are some exceptions to the this exclusion.
- CFR Section 66201.10 defined term of Surplus material as material that is not used and transferred to another company for common use. Company neither require special authorisation to receive surplus material nor manage it as hazardous waste.

RTI (1996) had done two studies about industrial ecology. First study was involving the study and analysis of economic, environmental, technical, and regulatory issue for eco-industrial park development in Brownsville, TX. Another was fieldbook for the development of eco-industrial parks which

used for planning, developing and managing eco-industrial parks. It was noted that the successful of eco-industrial park might depend on participating industries, location of it, local political and regulatory environment, attitude of participating industries to work together, availability of resources, and the openness of local developer to a new development strategy. There were some risks in operation of eco-industrial park which might be greater than traditional co-operation. These risks were created from uncertainty of technologies and regulatory when enterprises were depend on each other. It noted that regulatory often created disincentive for eco-industrial park development. It should be changed to be more flexible in order to support the activities in eco-industrial park. Industries who produced by-products which have low ratio of value to weight usually had high opportunities to convert by-products to valued materials. This reason was low transportation costs when recover value from by-products in eco-industrial park.

Fieldbook also identified risks and strategies to minimise them as follows:

- *Loss of a critical supply or market* Since waste materials from one industry will be used by another industry, this risk would be happened if generator changes his processes, product mix, or close down the operation. Supply contract and maintaining standby capability with alternative suppliers could be used to minimise this risk.
- *Low quality of by-products could damage the equipment or lead to low quality products produced from them* Contract for buying waste, and quality control standards and processes should be applied.
- *Misuse of secrecy information by competitors* Contract to prevent this and trust among participating enterprises should be established.
- *Decreased flexibility for waste reduction and substitution of toxic materials* Pollution prevention should have first priority before eco-industrial concept would be adopted.

Since waste from one industry did not always perfectly match for the input of another industry, researches and studies should be conducted to promoter exchange of waste.

The Clean Washington Centre (August 1996) has issued fact sheet of Beneficial Reuse of Spent Foundry Sand. Sands that reused many times in the moulding process until they become too fine particles (particle of 100 sieve size or less), black colour, and combine with heat degradation will be discarded as spent foundry sands. These are typically non-hazardous and commonly comprise of olivine and silica sands. Applications of these sands are summarised as follows:

1. It can be used for substitution for conventional asphalt concrete fine aggregate up to 15% for asphalt concrete.
2. It can be used for producing topsoil or topsoil additive of building agent for composted yarn waste.
3. It can substitute regular sand at low percentages in structure grade concrete.
4. It can be used for brick and pave that made from fly ash of coal-burning electrical power plants (C-grade fly ash).
5. It can be used up to 13% in production of portland cement. This content will has slightly higher compressive strengths than conventional one but still retain key characteristics for example set time.
6. It can be used as potential silica source of mineral woo; products.
7. It can substitute regular sand in flowable fill that normally used as backfill for trenches (sewer, conduit, utility).

Washington State found that there were some obstacles for reuse spent foundry sands such as costs, availability and quality of supply, regulation requirements and concern, knowledge of potential waste users.

US EPA (1996) state that the benefits from using waste exchange services are:

- waste disposal costs can be reduced;
- material and supply costs can be reduced;
- more efficient work practices can help to save money; and
- revenues can be got from marketing reusable materials.

Waste exchange is one of the simplest, least expensive waste prevention strategies. First step to implement waste exchange in company is to survey potentially reusable products and supplies. Opinions from employees can help to define which materials can be reused.

W. Reid Lea, Marty Tittlebaum, and Margaret Reams (March 1996) have studied the factors that hinder the recycling of hazardous wastes in Louisiana. They found that those factors generally related to lack of knowledge about recycling and conflicts in regulations. The conclusions from this study are shown below.

1. Since people are more accept word "industrial recyclable materials" than word "hazardous wastes", any projects that involve recycle hazardous waste should use word industrial recyclable materials in order to reduce public concern about recycling operations.
2. There is a misunderstanding of the derived form and mixture rule of EPA. Some people think that end products from mixture of any materials with hazardous wastes are hazardous wastes. From this reason, they prefer to send these wastes to disposal facilities even they can recycle. In fact, some

end products will be defined as hazardous wastes when they display hazardous characteristic. Derived form and mixture rule should be defined more clearly and this will promote recycle wastes.

3. Small companies have insufficient resources to deal with recycling, waste minimisation, and regulatory barriers. Consequently, they prefer to dispose wastes than recycle them. Recycling ombudsman should be established to assist small companies deal with ant problems about recycling.
4. Information about successful or failure of recycling effort is difficult to gather. This is key factor of recycling programme.
5. Ones who would like to recycle hazardous wastes are required to get the treatment, storage, and disposal (TSD) permit. They have to pay a lot of money to get this permit so that it may be uneconomical to recycle some type of wastes especially by product and sludge wastes. Conflicts of regulations between the state also hinder recycle operations. For example, Texas regulation do not define catalyst as a waste so that it is not hazardous waste. But in Louisiana is different, regulation define catalyst as hazardous waste even it is the same characteristics in both states. As a result of this, any people who would like to recycle catalyst required to have TSD permit even the catalyst is came from Texas State. Time and expense to get TSD permit make recycle catalyst uneconomical. Now EPA and Department of Environmental Quality (DEQ) in Louisiana offer limited scope of TSD permits for recycling purposes. It can reduce costs of acquired TSD permit and can promote recycling operations.

David T. Allen and Kirsten Sinclair Rosselot (1997) mentioned that successful of waste exchange depend not only mass of resources but also the concentration. Material at low concentration was recovered when its value is high. There were two important required information to assess the possibility on recovery material from waste. First is the waste flow rate and composition. Second is the technologies and practice on waste management such as segregation method or recovery technologies.

Tad McGalliard, Bruce Clemens, Michael Gresalfi, Bruce Fabens, and Ed Cohen-Rosenthal (1997) stated that concept of eco-industrial development based on industrial ecology, flexible manufacturing, and business clustering to attract business opportunities and growth in accordance with higher levels of environmental performance for anticipating enterprises. This concept was the sustainable development concept and a results-oriented strategy. Business networking was the key factor for successful of industrial ecology. Items which should be investigated for eco-industrial development are:

- material flows e.g. types of industry, materials, waste materials, by-products, and infrastructure;

- market alignment such as market relationships and opportunities;
- ecological resources for example environmental constraints, government environmental assistance program; and
- community resources for instance business networks, training and education.

They also examined the implementation of industrial ecology at Kalunborg in Denmark. It was the famous eco-industrial park in the world. There were five partners in this park i.e. four industrial enterprises and one municipality. Four industrial enterprises are Statoil Refinery, Asnaes Power Plant, GYPROC who produce plasterboard, and Novo Nordisk who produce pharmaceutical and bio-technical products. Not only wastes were exchanged in this group but also energy. Model of how they exchanged wastes and energy is shown below. Amount of savings from using industrial ecology is described in Table 2-1.

Table 2-1 Amount of savings per year in Kalundborg when applied industrial ecology concept

Reduced Resources Consumption	Reduced Emissions	Reuse of Waste Products
Oil 19,000 tons	CO_2 130,000 tons	Fly ash 135 tons
Coal 30,000 tons	SO_2 3,700 tons	Sulfur 2,800 tons
Water 600,000 m3	-	Gypsum 80,000 tons
-	-	Nitrogen in sludge 800,000 tons

Source : Tad McGalliard, Bruce Clemens, Michael Gresalfi, Bruce Fabens, and Ed Cohen-Rosenthal.(1997)

Factors which promoted successful of industrial symbiosis in Kalundborg are:

- The enterprises function together. Waste products from one enterprise can be used for the others.
- Distances among enterprises are closed. From this reason, costs of waste transportation is low.
- Enterprises trust each other and openness.
- Pressure from cultural and regulatory promote environmental awareness.

Benefits from industrial symbiosis are reuse of waste materials, reduce consumption of resources, reduce environmental impact, and efficiently utilise energy resources.

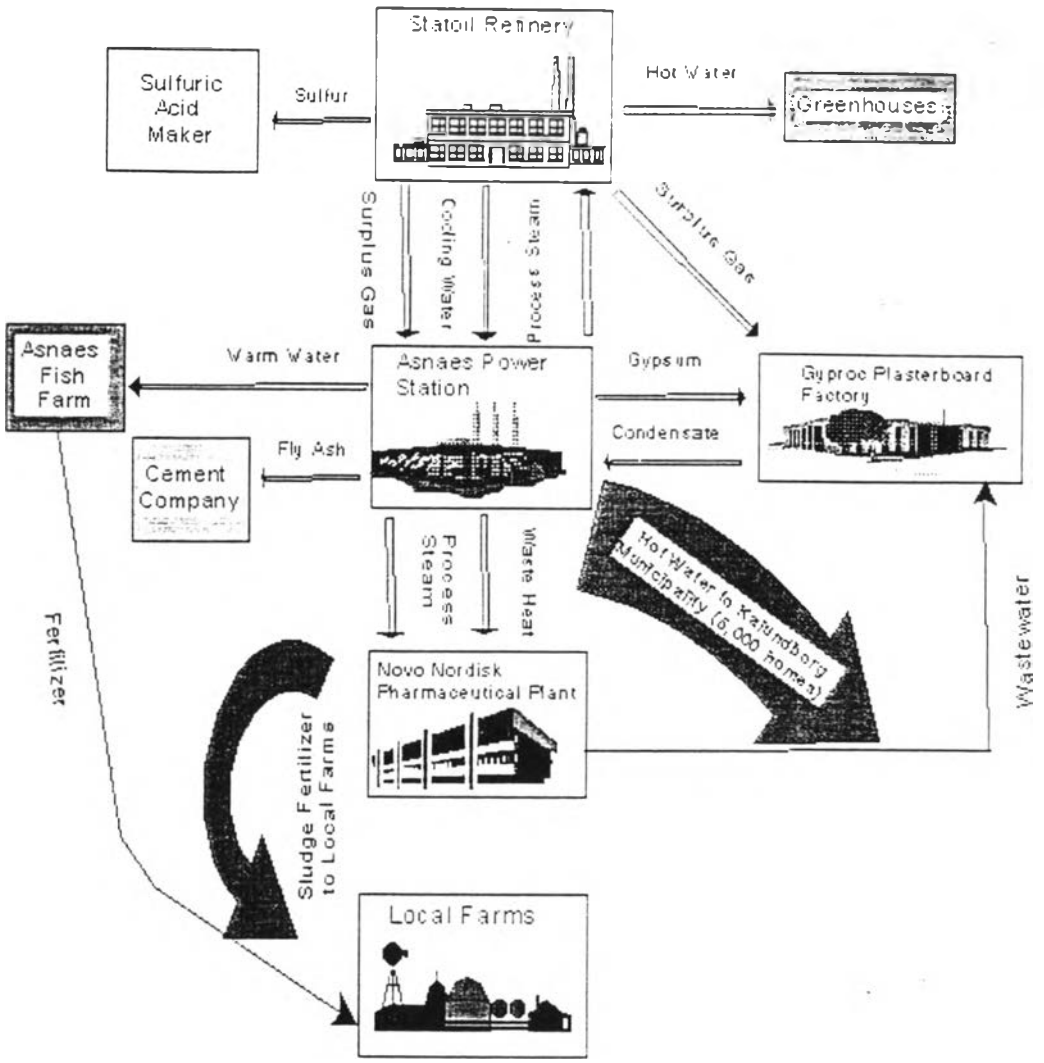

Figure 2-1 Kalunborg Industrial Symbiosis

Source : Tad McGalliard, Bruce Clemens, Michael Gresalfi, Bruce Fabens, and Ed Cohen-Rosenthal. (1997)

The Renew Catalogue (1997) reported example of successful waste exchange in USA for used sulphuric acid that used in circuit board manufacture. Metal finishing manufacturer can get benefit from using this waste in pickling process.

Suren Erkman (1997) summarised the historical of industrial ecology. He noted that there are some differences in the meanings of industrial metabolism and industrial ecology. Industrial Metabolism meant the study

for the linkage between flow of materials and energy through process and the environment. Industrial ecology meant to understand industrial working system and its interaction with environment and identified how they could be adjust to be similar to the natural ecosystem function. He also mentioned that many authors agreed that the definitions of industrial metabolism/ecology should have three keys elements i.e.

- it is integrated, systematic, and comprehensive view of all units in industrial economy and their relation with environment;
- it considers the complex patterns of material and energy flow inside and outside the industrial system which is different from traditional approach; and
- it emphasises the sustainable industrial ecosystem.

He mentioned that industrial ecosystem considered waste as a product which is contrast with cleaner technology and pollution prevention perspective. He recommended before industrial ecosystem is established, a detailed study of the material flows and assessment of economic and policy aspects had to be done.

David T. Brown (1998) is the person who was in charge of pilot project for CIET Materials Exchange at Burapa University. According to conversation with him, he informed that no waste have been exchanged by CIET Materials Exchange. The factors which obstacles it are :

- poor environmental regulatory and enforcement regarding waste generation so that industries are not penalised for producing large amount of waste or improperly disposing of them ;
- inexpensive landfill waste disposal fee;
- low awareness of the benefits of waste minimisation in industries;
- poor communications amongst industries who produce wastes; and
- unwilling to let other companies know about his waste materials.

He has introduced CIET Materials Exchange at Novotel Rimpae Resort, Rayong to the industries located in Eastern Seaboard. In his paper, he mentioned about sustainable integrated waste management which help people to use materials and energy efficiently. But there are factors that hinder sustainable integrated waste management. These factors are short term financial pressures, lack of training and expertise, fiscal expediency, poor infrastructure, irrational or inconsistent government or corporate policies, and poor regulatory climate. These situation can be avoided by focusing on reducing, reusing, and recycling to reduce the wastes. First wise step to do this is to conduct waste audit.

Waste audit help waste generators to know where their wastes generated, how they are generated and how much they are. From this information, industries can identify the opportunities to reduce, reuse, and

recycle their wastes, making materials and energy use more efficient and less damaging to the environment.

He, his staff and Burapa University have set up CIET Material Exchange. This is the first on-line marketplace in Thailand for trading waste funded by Canadian government. Waste generators and waste users can publish their information on the web without charge after they have applied for a CIET Material Exchange account. They can access CIET Material Exchange via internet at http://ciet.buu.ac.th or http://203.154.83.21. This system can either be accessed by using word wide web which supports text and graphics or Lynx which supports only English text.

Kneese (1998) suggested that in order to promote industrial ecology widespread, market should be restructed to reflect the full social costs and incentives for example effluent and emission fees should be developed by policy makers. He also mentioned that laws, regulations and market supported conventional economic conception of production and consumption processes so that recovery and recycling waste could not be incorporate in day to day operation. When first law of thermodynamics was applied, wastes or energy generated from the production process should go somewhere either to environmental or to be used in other industries. He proposed model to analyse the flows of materials through the economy which was the combination the economy and the environment and used the first law of thermodynamics in this model. He addressed two economic instruments which should be adjusted to not distorted the price system were subsidies and fees. Subsidies which promote inefficiently and ineffectively using of natural resources should be revised. Fees should such as effluent and emission fees should be used to encourage the conservation of environment.

Pollution Control Department, Ministry of Science Technology and Environment of Thailand (1998) has studied current recycle in Thailand. Waste exchange is one topic of this study. The results from this study revealed that informal sector e.g. three wheelers have an important role in recycle. To be successful in implementing waste exchange, benefits of existing system have to be compromised.

In Thailand network of recycle waste is clear and give high return of investment. Demand for any kind of raw materials is unlimited. Effective network of waste exchange centre in the future will not create any problems for existing systems. On the other hand it will enhance waste recycling.

Market of waste product is one important factor. We have to study structure of production process by using pure raw material compared with waste material, potential market of new raw material and waste, factors that effect waste exchange market, attitude of waste users, public involvement, and competitive of other materials for same purpose. The result from the study can be used to plan and promote waste exchange market. Technologies

of using wastes also have an effect on waste exchange market. The last one is legislation and organisation to enforce or enhance any one or organisation that engage waste exchange. Factors that have effect on demand of waste product are price of product that depend on demand of products, price of substitution raw materials, transportation costs, income of users.

Result from this study mentioned that normally waste product was approximately 3% of production rate. There were 157 factories of melting plastic registered with DIW but some plastic waste before sending to these factories will sent to crushing and cleaning plastic factories. Foam waste can be sent to meting factories to produce foam pallet (GPPS) be used in solving collapse at neck bridge, mixing with soil for agricultural, and surface of lightweight concrete.

Junk shops and Wholesaler can design not to buy waste materials if its cost is low. Since cost of steel can is low, there is no separation for this item. Glass bottle has a transportation problem and distance to buyer is very far so that there is also no separation types of glass bottle. Due to light weight of foam, costs of transportation is high.

Number of recycle Factories in Samutprakarn are 12, 7, 22, 44, 8, 2, 9, 1 for paper, glass, plastic, steel, aluminium, copper, brass, foam respectively (from DIW, 1996)

PET waste can be used as raw material for producing carpet, cloth and doll. Normally pulp can be reused for four times before quality of product produced from this pulp is poor. Products produced from waste pulp are newspaper, paper box which has white colour at the back.

Portion raw material cost of product has a significant effect for recycling or reuse that waste material. Higher portion raw material cost, higher potential for recycling or reuse.