# CHAPTER 2 : LITERATURE REVIEW

## 2.0 Introduction to Extended Producer Responsibility (EPR)

The idea of a clean production system is to achieve the target of a closed loop flow of sustainable materials in our systems of food production and manufacturing. In a way, we could learn the dynamic flow of energy and constituents within our earth's self-sustaining ecosystem. Thus, Extended Producer Responsibility (EPR) is used as a tool in achieving goals of Cleaner Production. Among the aims to be achieved are (Manomaivibool *et al.*, 2007):

i) An overall waste prevention.

ii) Use of non-toxic constituents and processes.

iii) Development of more durable products.

iv) Development of closed materials cycles.

v) Development of more reusable and recyclable products.

vi) Rise in reuse, recycling, and composting.

vii) Regionalisation of production, consumption, and materials management.

## 2.1 Concept of EPR

EPR is a policy concept based on environment aiming at the end-of-life of a product's life cycle in reducing its burden towards the environment (Mazzanti, 2009). Moreover, EPR programs has an influence towards Design for Environment (DfE) practices such as re-use of products and packaging, dematerialisation and elimination of toxics in developing a sustainable management of materials (Manomaivibool, 2009).

The EPR movement also known as product stewardship or manufacturer take-back began in Europe (Khetriwal *et al.*, 2011). The program first began in 1991 with German Green Dot scheme that deals with waste packaging among a wide range of products and waste streams in packaging, end-of-life vehicles, electrical and electronics, batteries and accumulators, and used oil (OECD, 2005). The principle of EPR has two distinctive objectives which give importance towards the upstream and downstream improvement of products or product systems. This is important in ensuring an environmental sound management of the collection, treatment, and reuse or recycling of products (Manomaivibool *et al.,* 2009). Adding to that, the limited involvement of government in determining and achieving the performance indicator, products and minimal supervision has been an advantage to EPR (United Nations Environment Programme, 2007a). Therefore, EPR is considered to be a concept that shifts, as well as, balances the responsibility of the manufacturers or producers of an entire life cycle of a product (Nnorom and Osibanjo, 2008).

### 2.1.1 Types of Responsibility

According to Lifset and Lindhqvist (2008), the Extended Producer Responsibility is implemented through three main elements which are administrative, economic and informative. From this, the authority of a product is segregated into various types of responsibilities that include economic/financial, physical, liability and informative elements.

The producer's responsibilities are shown in Figure 2.1 which can be defined as below:

● Liability - responsibility of the producer towards the environmental damage caused by the product and the extend of this is determined by legislation.

●Financial responsibility -producer is responsible for the costs of the products, which include collection, reuse or recycling and final disposal of the products manufactured. These could be paid directly by the producer or by a fee.

● Physical responsibility - manufacturer has responsibility towards ownership of the products throughout its life cycle. This involves physical management and effects of the products that could cause environmental issues.

● Informative responsibility – extends the responsibility for the products by requiring producers to supply information on environmental properties of products being manufactured (Lindhqvist, 2000, Tojo, 2004).

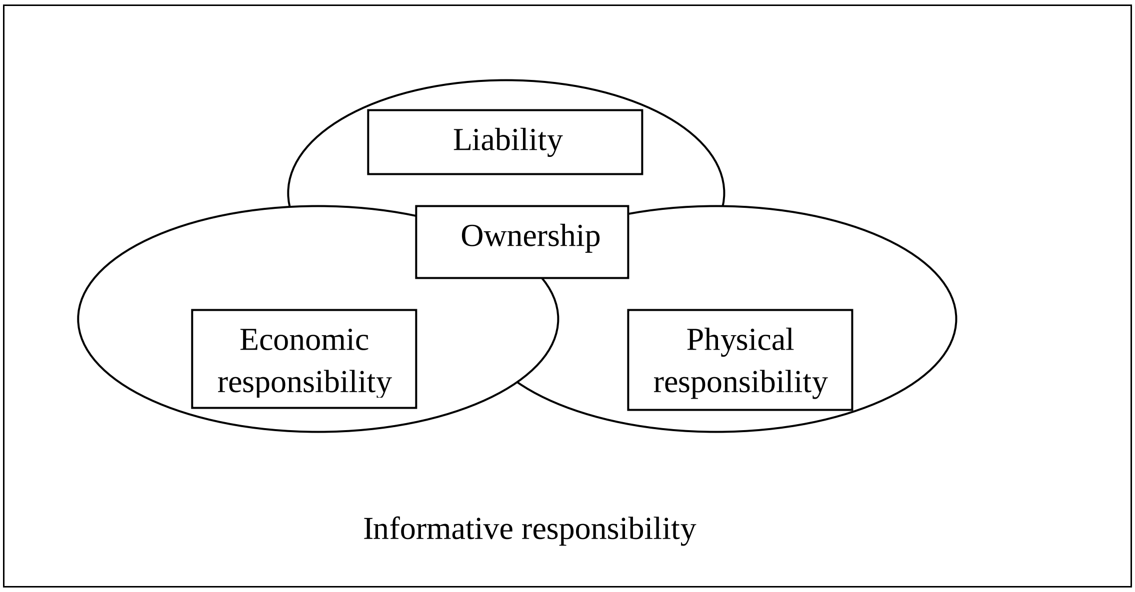



Figure 2.1 : Model for Types of Producer Responsibility

Source: Lindhqvist *(2000)* and Tojo *(2004)*

As a policy principle, EPR, gives producers and policy makers an opportunity in choosing the specific instruments adapted to the existing market and local conditions in performing their responsibilities (Carisma, 2009). EPR- based legislation is introduced in a divergent manner in each country, therefore, EPR based policies have been enforced distinctively among many countries (Huo *et al*., 2007).

Table 2.1: Policy instruments for the EPR based policy

| | |
|---|---|
| Administrative instruments | Collection of discarded products, substance and landfill restrictions, re-use and recycling targets, fulfillment of environmentally sound treatment standards, fulfillment of recycled material content standards, product standards. |
| Economic instruments | Product taxes, advance disposal fee systems, deposit-refund systems, upstream combined tax/subsidies, tradeable recycling credits. |
| Informative instruments | Report to authorities, labeling of products, consultation with local governments about collection network, information provision to consumers about producer responsibility/source separation, information provision to recyclers about structure and substances used in products. |

Source: Tojo (2004).

Under the real concept of EPR, the different types of responsibilities determine the strength of EPR mechanism based on the involvement of the producer or manufacturer in every aspect (Manomaivibool, 2009). Such arrangement would provide an effective incentive to the producers in minimizing the costs of their products that will enhance the process of recycling or treatment. The concept of EPR is also used as a tool in curbing issues related to generation of waste and pollution as well as promoting cleaner production (Lifset and Lindhqvist, 2008).

Generally, EPR shifts the costs of waste management from local authorities to producers, thus internalizes the environmental costs into product prices. As a policy principle, EPR extends the producer's responsibility on the product to the post consumer stage which turns out to be flexible for both producers and policy makers in fulfilling their responsibilities (Carisma, 2009).

### 2.1.2 EPR as a policy approach

Under the general concept of EPR, the policy tool can be divided into various categories. These usually work together to establish a framework of EPR aiming at a specific group of products. These are some elementary policy tools used in practice as described below (Scott and Thompson, 2007).

1. Product Take-Back mandate – Under this, the manufacturers/producers have the responsibility of taking back their products at the post-consumer stage (Khetriwal *et al.,* 2011).
2. Voluntary product take-back with recycling rate targets - It is a voluntary approach with industries agreeing to take-back their products with targeted recycling rate. This does not require any intervention from the government or law regulations as well as penalties for not achieving their target (Khetriwal, *et al.*, 2011).
2. Advance Disposal/Recovery fees – An ARF, also known as Advance recovery fee is a fee or tax charged upon the sales of a product. The fee may be visible to the

consumers upon purchasing their products. The retailer or producer collects the fee and may have no other responsibilities beyond the products's end-of-life management (Kojima *et al.,* 2009).

3. End-of-life Waste Management Fees – At the level of disposal or recycling, the consumers are charged a fee which covers cost of managing the product they are disposing away (Kojima *et al.,* 2009).

4. Deposit/Refund – Producers may be assigned to collect the deposit for refund and end-of-life collection. A consumer pays the deposit when the product is purchased. Depending on the material targeted, it is then refunded based on the packaging or when the product is returned partially or fully by consumer for reuse, recycling or disposal (Kojima *et al.,* 2009).

5. Tax on Virgin Materials/Tax Credit for use of Recycled material – Based on certain raw material utilized in manufacturing of products, a manufacturer will be required to pay a tax on their products. They could also claim a tax credit for the use of certain materials which are recycled in the manufacture of their product. The main aim of such an instrument is to reduce the use of virgin materials at source (Kojima *et al.*, 2009).

6. Rates of Reuse, Recycling, and Reduction Target– Laws are established that mandate goals or target rates for collection of products or materials that help establish collection infrastructure. Recycling and reuse goals and rates help drive technology and design changes (Walls, 2006).

7. Landfill/Disposal Ban – Certain product or product component is prohibited to be disposed of. Many other countries ban disposal of particular items in landfills (or incinerators) such as refrigerators, dishwashers, computer monitors; tyres; various

kinds of household hazardous wastes such as paints, fluorescent light bulbs, batteries; and other items (Walls, 2006).

### 2.1.3 Different Appproaches Towards EPR

The implementation of different instruments under EPR approach ranged from fully voluntary to mandatory options (OECD, 2001). According to Rachna (2008), the choice of approach is particularly influenced by two vital factors such as environmental impacts and value of e-waste. In this, the producer's involvement can differ with shared control and operations, between the two different approaches. Thus, the products with a high residual value would be much lower compared to market value that will generate recycling program which covers costs of collecting, sorting and reprocessing of material. This pushes for need of government intervention and regulations focusing on group of products with high environmental impact and low residual value. The two different approaches are discussed as below (OECD, 2008).

**i) Mandatory Approach**

Mandatory approach is supported by government regulation and is in a continuous debate in the field of natural resource management under the EPR approach. This approach require setting up legal mechanisms such as regulations/ordinances and the establishment of an appropriate authority, in terms of ensuring a compliance (Herold, 2007). For example, a high volume product with low residual value would require the government's involvement. Moreover, the costs of implementing a mandatory programme should be evaluated and it could be significant as well (Hotta *at al.*, 2008)

### ii) Voluntary Approach

Many industries prefer the voluntary approach towards EPR. The representatives from industry are convinced that voluntary initiatives provide flexibility to the producers in developing innovative concept towards sustainability. Moreover, ecological advantages could be gained through regulated events at any costs (Khetriwal *et al.,* 2009).

However, critics have pointed out that many voluntary initiatives have ineffective objectives, lack of non-existent public reporting practices, lack of authority in enforcing goals, public reporting practices as well as attracting ‘free riders’ (Walls, 2006). According to EPR researchers, Tojo (2004) and Lindhqvist(2000), voluntary EPR programs are not as essential as other obligatory programs in encouraging changes worth to be enforced by the regulation of government. EPR programs driven by the legislation are not truly voluntary (Robinson, 2009).

In 2001, The Organization for Economic Cooperation & Development (OECD) mentioned issues on free riders, reuse and recycling rates, as well as, higher collection rates reached through programs under the government’s regulation. EPR would be mandated only if efforts are approached voluntarily and it fails to achieve the goals. This is quite prominent in most of the other countries such as France and Germany where there was dissatisfaction with the voluntary EPR applied in packaging (OECD, 2008). Such event usually result in reduced operational costs, resource and energy as well as increased credibility with the public and shareholders. At present, the voluntary based EPR programs, been said to have emerged in situations under these following criterias:

1) high risk of associated liabilities with improper disposal;

2) high value associated with discarded product;

3) low-frequency, high-value transactions between the manufacturer and a consumer;

4) relatively close/ ongoing relationship between the consumer and manufacturer; or

5) high-end products for both environmental/social targets that may increase loyalty of customers (Steiner, 2007)

When it comes to decision-making process of EPR programme, analysis was done based on the development of certain product category. This include the factors that influenced the programme which could provide an insight in considering the elements or approach of EPR (Herat, 2008a).

## 2.2 Benefits of EPR

The concept of EPR which has been introduced based on the role of producers and a number of aspects differ in terms of economic, social and cultural context among individual countries. The implementation of such programme covers both the products, as well as, the industries (OECD, 2005). Therefore, the environmental benefits of EPR would usually depend on specific components of the programme (OECD, 2005). The stages involved in a product's lifecycle usually depends on The Polluter-Pays principle which aims to point out and assign responsibilities to groups involved especially the producers. They are capable of making changes to the design of their product at initial stage (OECD, 2008).

According to Basiye (2008), the product chain management is able to enhance the effective use of natural resources by increasing the possibility of closing of the material loops. This would eventually improve the management of materials as they are less needed in the reuse and recycling process (Herold, 2007). Apart from that, EPR also sets its priority towards the end-of-life management of a product's life cycle in reducing the costs associated throughout the production. It is designed to be environmentally friendly (Greenpeace, 2005). This would be beneficial in promoting a competitive manufacturing among the manufacturers or producers.

In this context, various systems such as Advanced Recycling Fee (ARF) system, recycling fee and deposit-refund system is used to assign the social and environmental cost when a product is discarded (OECD, 2005). Therefore, the consumer would be regarded as polluters as they are solely responsible for the cost of waste management which is often included into the price of product. Adding to that, incentives would be given to consumers to produce less waste and high awareness level will increase their knowledge to reconsider disposing of functional but disused products (OECD, 2005). As far as the municipality is concerned, there would be less burden on waste management as the responsibility of financial and physical burden would be taken over by producers. The theory of EPR is implemented as a measure to reduce the impact on environment associated with products final disposal (Akenji *et al.* 2011). Lifespan of a product will be extended upon the reuse and refurbishment of products as the cleaner production process takes place in collecting and discarding them in the most environmental friendly way. This in turn, improves the design of a specific product for dismantling and improves the demand to develop the technology of collection or recycling (Jain, 2009).

As a whole, EPR policy does not only reduce the costs of waste management but enhanced the efficient practices of waste management which eventually improves the relationship between the producer and consumer as a community (Akenji *et al.*, 2011).

## 2.3 Challenges of EPR

One of the biggest challenges of EPR in this current developing economy is the problem of identifying the producer or manufacturer. According to Manomaivibool *et al.*, (2007), the problem has been emerging among the countries which are developing where the 'free riders' tend to gain the benefits of activity without paying for it or carrying out any physical or financial responsibility. Therefore, Khetriwal *et al.*, (2009), have stated several reasons in identifying the producer.

**i) Competition with the informal waste management sector**

The informal waste management sector has been operating on low costs compared to formal recycling which operates on a higher cost. The informal sector will have an easy access towards the end-of-life products as they do not invest into labour protection and control over pollution as well as avoid paying taxes (Liu *et al.,* 2006; Khetriwal *et al.,* 2009). In comparison to the formal sector with limited exposure towards the end-of-life products, a more strategic scheme is required to make the system more convenient and standardized (Hotta *et al.*, 2008).

### ii) Poor framework for waste collection and treatment

Introduction of EPR based systems, has become a financial shift from the government to the producers (Akenji *et al.*, 2011). OECD countries have already established EPR legislation with a waste collection system in place. This is however different in developing Asian countries as they have no established waste collection system (Zhang, 2011). In terms of recycling, the level of knowledge and awareness is still low among the staffs who are trained in learning the appropriate recycling process (Widmer *et al.*, 2005). In order to introduce a more universal EPR system, a more reliable approach is needed under different phases to construct changes in the system as well as the infrastructure (Hotta *et al.*, 2008).

### iii) Perceptions of e-waste

As far as e-waste management is concerned, in developing countries, awareness on this issue have been lacking among the public. The cause of this could be due to poverty and low hiring rate of employees that leads them to neglect issues on management of electronics (Robinson, 2009). However, in industrialized countries, environmental issues related to electronics have been a concern among the nation thus, high awareness level on the event contributes to systematic disposal of the electronic components. The electronics that have been utilized by the consumer is a resource that is beneficial and has to be properly recovered and discarded using fundamental technologies (Van Rossem *et al.*, 2006).

**iv) Poor transboundary movement of e-waste**

The import and export of e-waste has been unpredictable over the years and the exact figure has yet to be determined. It is generally exported to the Asian region in which Korea and Japan lead as the e-waste producers in Asia (Akenji *et al.*, 2011). The transboundary movement of e-waste includes secondhand electronics and other valuable mixed metal which is difficult to be differentiated that creates a drawback while exporting to other countries. Hence, there is an urge to establish an efficient monitoring system to treat these electronic components accordingly and import to other countries( Kojima, 2005).

Overall, although the EPR system has given a positive outlook, the challenges have highlighted that there are certain components which needs to be restudied to adapt with all levels. This requires enforcement of regulations, social and physical infrastructure, and ability to evaluate the resource needs to comply with the objectives of EPR system. From this, different issues related to EPR based system could be addressed in an appropriate manner (Kojima *et al.*, 2009).

## 2.4 EPR and e-waste

The emergence of this EPR concept has made a shift from the end-of-pipe approaches to life cycle approach (Morf *et al.*, 2007). Walls (2006) claimed that EPR policies are preferred over non-EPR policies when there is a problem of illegal disposal of the waste stream. In the case of e-waste management, government in Europe, has favoured EPR-based waste management systems over traditional ones. From this, financial burden on local governments has been reduced and is in line with the 'Polluter-Pays' principle (Khetriwal *et al*., 2009).

An important step towards a sustainable waste and resource management in Europe is solution towards e-waste issue. This has given a successful output (Terazono, 2008). Moreover, this great initiative is adapted and encouraged in other developing countries (Khetriwal *et al.,* 2009). From the implementation of WEEE Directive, awareness on issues surrounding manufacture, product extension of e-waste together with other practices in addressing the common waste has encouraged recycling towards reaching attainable target of sustainability (McKerlie *et al.,* 2006).

Therefore, EPR is a useful beneficial policy tool towards achieving sustainable development as it creates economic, environmental and social benefits (Atasu *et al.,* 2011). In order to achieve global challenges of sustainability, countries like Japan and Western Europe, have come to terms that a collaborated effort is needed to address the issue (Akenji *et* al., 2011). Thus, more focus has been given towards the progression of manufacturing process of less impact, end-of-use stage of activity, energy/constituent and efficient goods/technologies (Kojima, 2005).

However, while there is an expanding volume of work on EPR as a policy measure, its application towards managing e-waste still remains incomplete. The thesis of Tojo (2004) has analysed on legislation and policies through a comparative study of selected EPR programs for electrical and electronic equipment (EEE). It focuses more on framework and study of EPR regulation practiced in Japan. Moreover, Kautto (2009) has also pointed out on EPR based law for Japan that looks at the home recycling equipments and tools that discusses on its state of application and challenges. The practice has successfully been applied throughout Europe in management of waste packaging as well (Basel Action Network, 2010).

Generally, it is a principle that seeks to enhance environmental performance of both products and their selective systems (Basel Action Network, 2010). The introduction and evolution of EPR potrays several patterns in environmental policy making. This applies in many incidents when there is an issue over illegal disposal of the waste stream particularly e-waste as a poor remedy towards the functional recycling markets (Abbas, 2011). The incorporation of EPR into legislation, differs with the initial implementation solutions (Abbas, 2011). From this, the majority of governments have decided to initiate the responsibility among the manufacturers or producers for the disposal and final taking back of their instruments (Agamuthu and Victor, 2011).

## 2.5 EPR in Asia

Principle of EPR first emerged in European legislation and was limited to the export of waste and secondary materials to Asian countries due to limited recycling capabilities in Europe (Kibert, 2004). Apart from this, very limited research has been conducted as concerns the development of EPR in Asia, particularly in economies (Tojo, 2004).

In the later years, some work has been done on emerging Korean and Taiwanese regulations on take-back and deposit-refund systems (Bohr, 2007). This has been pursued as regards to the existence and development of Japanese EPR regulations, and even some work comparing European legislation with Japanese legislation in this field (Babu, 2007).

### 2.5.1 Japan

Japan is the world's second largest economy with a population more then 100 million, and has long been at the forefront of industrial, technological and economic development amongst Asian countries (Goodman, 2008). The country has long been considered a regional leader in terms of environmental policy and management development (OECD, 2001). This has been supported with evidence of types of regulations which have been passed by the Japanese government in the last decade, specifically to control the waste stream (OECD, 2008).

Extended Producer Responsibility (EPR) is an environmental policy principle which has had particular success in the country, due to waste management concerns as regards to landfill capacity (OECD, 2008). Economically the costs for wastes dumping were also on the rise and the lack of space were the main drivers for introducing EPR in Japan (OECD, 2008). This has led to the government seeking alternative ways of affecting the waste stream. The change in waste management strategy has been a major factor attributing towards the success of an EPR programme, particularly in terms of waste separation to promote recycling, re-use and also as regards the reduction of waste generated (Manomaivibool, 2008).

The development of EPR programmes in Japan, with particular reference to complex products such as electrical and electronic equipment were the main driver for regulatory developments (Akenji *et al.*, 2011). The increasing waste volume of equipments, has led to the development of collection and recovery targets being set in order to prevent and minimize waste generation. Japan has adopted an in-depth whole life cycle approach through the basic law which takes into account material use, design, manufacturing, as well as after use aspects such as how to collect waste and how to treat or recycle (Liu *et al.*, 2006) .

In addition, the Japanese indicate that EPR policy should start with regulation, to create an appropriate environment and then turn to voluntary approaches. There has been a tendency towards moving back to voluntary regulations in Japan as many of (landfill and waste management problems have been addressed and corporate behaviour has changed dramatically as a result of EPR law) (Chung and Murakami, 2008). Main reason for this change has been that regulations have led to a decrease in product innovation, and voluntary measures are seen as a solution to this (OECD, 2001). Voluntary approaches arise from mutual understanding. Producers should be responsible for any environmental impacts from their products (Cobbing, 2008).

Overall, in Japan the main driving force for EPR policy change can be attributed to strong, mandated government leadership, both local and central. There has been much discussion concerning the issue of the Japanese consumer and their relationship to environmentally friendly products or participation in EPR programmes such as take-back schemes (OECD, 2001; OECD, 2008; Tojo, 2004). The general public also had a major role to play in the decisions taken by the Japanese government when introducing EPR. The higher income amongst Japanese population is also seen as a major driver for corporate involvement in EPR, since the increase in income meant they could afford environmental products (Environmental Protection Department, 2011). As a result, companies begin to develop socially value added products. This was also done to achieve better competitive advantage as Japanese companies cannot compete with other Asian companies in terms of cost or price (Kibert, 2004).

In Japan it is not so unusual for the consumer to have responsibility for the environment or society. An advanced waste management system for separation, collection and treatment has been a key factor for the success of local EPR initiatives, and in addition the importance of the local recycling industry (Akenji *et al.,* 2011; ENHESA, 2005)

### 2.5.2 Taiwan

Taiwan, an island off the coast of mainland China with a population of 22 million, saw a major systematic change take place through the introduction of EPR programmes in 2002. In Taiwan, regulations are placed on products as well as industrial operations, similar to European countries and Japan (Kibert, 2004; ENHESA, 2005). The Taiwanese regulations are based on the polluter pays principle (other European countries and Japan), which require manufacturers to take an active part in the disposal of their product (Yu *et al.*, 2010).

In Taiwan, EPR regulations and programmes were driven because of a waste management crisis resulting from rapid industrialization. One of the key factors in Taiwan's success with EPR has been in response to waste crisis which came in the form of major cities such as Taipei starting to have recycling programmes, kerbside collection and separation of domestic garbage (Tojo, 2004). The introduction of this form of "efficient waste separation, collection and treatment systems'' has been crucial in the implementation of a Taiwanese EPR programme (Osibanjo and Nnorom, 2008). The creation of such waste management infrastructure required that special attention also be paid to the local recycling industry. Taiwanese recycling industry now operates "on a type of subsidy system whereby the government collect money, collect charges from the producers and then uses the money to subsidise the collectors and the recyclers (Tojo, 2004). This is has been considered a very effective means of supporting end-of-life industries (Kibert, 2004).

According to Taiwanese EPR law, everyone, including producers and the consumers are responsible for consumption and production (Shaw, 2004). However, in practice, only the producers take the bulk of the burden, do the recycling and the recycle. This is because they are more easily controlled and we can force burden on the consumer through legislating the producer (Watson and Crowhurst, 2007).

Deposit-refund systems serve as better consumer related EPR schemes in Taiwan (Shaw, 2004). This deposit refund system will be very useful, since it provides incentive for the consumer to return the product. It has been proved to be a very effective measure and something Taiwan is further exploring, along with other regional economies such as Korea (UNEP-UNCTAD, 2007). Taiwan with EPR, experience very easy and convenient, with minimal time consumption on the part of the consumer, to be successfully implemented (Shaw, 2004).

The Taiwanese government and industries are considering green design as the next measure for their EPR programme (Empa, 2005). Although the government is perceived to have been the most influential through its legislative power with industry, the mass media is also seen to have played a crucial role in helping the government to implement the schemes through informing the public (Goodman, 2008).

### 2.5.3 China

China has a population of 1.3 billion, coupled with a rapidly expanding economy, predicted growth of 9% in gross domestic product (Zhang *et al.,* 2010). The country has been expanding as a result of the wide-spread manufacturing, resulting in growing problems of pollution and waste generation (Zhang *et al.*, 2010). China is considered as a country in the region with the potential for the fastest EPR programme development (ENHESA, 2005).

The structure and role of the central government is of course a key factor which sets China apart from the other countries (Yu *et al.,* 2010). Strong mandated EPR programmes are still the best solution for China, as considering the fact that respondents perceive China's corporate EPR policies or schemes as very rare, since the importance of corporate environmental management has not been realized in the local market (Widmer *et al.,* 2005). Currently in China, the take-back use an integrated, mixed approach, rather than just a voluntary approach. Voluntary on its own is very difficult because of the economic development at this stage (OECD, 2008).

The government's officials are regarded as one of the biggest barriers for China in developing the suitable policy and legislative environment required for EPR programmes to be effective (OECD, 2005). China was highly involved with both regional and international in the last decade, the country has now imposed restrictions on used materials (OECD, 2008). This has drastically improved the quality of materials coming into the country (Zhang *et al.,* 2010). The need for strong government leadership and action, legislative measures targeting the waste stream, both on a producer and consumer level, the creation of a waste infrastructure and the need for education are all strong factors (OECD, 2005; Tojo, 2004).

## 2.6 EPR in Developing countries

Since 1990's, countries like South Korea, Japan, and Taiwan have already practiced the application of EPR to e-waste, automobile , packaging and container waste (Zhao *et al.*, 2008). In such, China started its new recycling system based on EPR just recently in January 2011 (Townsend, 2011). Other developing countries in Asia include countries such as Malaysia, Thailand, Vietnam and Indonesia in which they are preparing to create an efficient EPR recycling system as well (Manomaivibool *et al*, 2009). From this, the overview looks into background of such movements and types of regulation to producers on the EPR recycling systems particularly in Asian countries (Manomaivibool *et al.,* 2009). The application of EPR in developing countries as well as challenges and opportunities in practicing them are also discussed further (Luo *et al.,* 2011 and Liu *et al.,* 2006).

The government plays an important role in developing a recycling system of EPR while stating the objectives clearly after evaluating the issues concerned in current recycling system (OECD, 2008). A new recycling system can always create opportunities to decrease costs of environmental disposal of items and recycling of target products, to increase job opportunities, and to secure the resources (OECD, 2005). It is fundamental that manufacturers or producers are against the new system implemented by government. It is the government's responsibility in explaining the importance of establishing EPR, which is entirely based on knowledge of issues on recycling system as well as benefits from new recycling system (Kojima *et al.*, 2009). Government should tackle this in cooperation with other producers or stakeholders (Kojima, 2005).

In developing Asia, many challenges are in store as the legislation related to EPR are easily gaining popularity and recognition for development and management of electronic waste (e-waste) (Agamuthu and Victor, 2011). Therefore, several well-developed countries have created an EPR model for the developing region and it is the latter's responsibility in practicing them (Akenji *et al.,* 2011). Moving into the challenges of EPR application in developing countries are (1) large market non-branded share for a particular product, (2) relationship with informal collectors, (3) a few certified recyclers on specific wastes, (4) competition with informal recyclers and (5) poor producers' association that does not cover small and medium industries (Bohr, 2007).

In the phase-in approach, the EPR application is balanced to the national economic development level, which is capable for enforcement of environmental policy, market product for recyclables and items, awareness of consumer, and relationships among main stakeholders (Hotta *et al.*, 2008). Thus, in establishing EPR by each country, it should start extensively at both preliminary and implementation stages, with focus on waste management (Herold, 2007). This is to examine specific situation of respective individual countries in suggesting a suitable policy tool, advising stakeholders, assess and inspect implementation and progress towards target of performance (Manomaivibool, 2009).

From this, a regional collaboration is required for continuous development and also to address trans-boundary flows of e-waste to be more precise (Osibanjo and Nnorom, 2008). Akenji *et al.,* (2011) has also stated that this pathway would be able to apply more effective measures on the export of e-waste from industrialised to nonindustrialied countries, thereby helping to assure that harmful recycling and treatment is avoided.

## 2.7 Introduction on e-waste

Electronic waste, also known as e-waste has been referred to as obsolete component or electrical and electronic equipment (EEE) that has reached its end-of-life. It is also a short term in describing different types of electric and electronic equipment that is of no value to the person owning it (Junaidah, 2010). The volume of e-waste produced and the hazardous content containing priceless materials have been on the rise, and e-waste seems to be bulking up the waste stream in the form of discarded electronic and electric component (Herat and Agamuthu, 2012). Despite being a major issue, this has also created an opportunity in business for some parties (Agamuthu and Victor, 2011). There are several definitions in which e-waste is used synonymously (Widmer *et al.,* 2005). Keller (2011) has defined e-wastes as being of no purpose to the owner and is often misinterpreted consisting of IT related tool and computers only. There is certain amount of toxic materials found in e-wastes. For example, heavy metals such as mercury and cadmium approximately at about 70%, comes from the electronics which have been disposed in the landfills (Herat and Agamuthu, 2012). Other than that, the monitor display of television has an average 4-8 kg of lead with the glass alone weighing with 20% lead (Herat and Agamuthu, 2012). Generally, e-waste could be divided into two categories which are ‘white’ goods and ‘brown’ goods. The white goods consist of washing machine, refrigerators and microwaves. The computers, televisions, and radios fall under the brown category. Hazardous heavy metals and other substances found in electronic products contaminates groundwater and results into other environmental threats (Ongondo *et al.,* 2011).

Since the speed of innovation of product manufacturing has resulted in a shorter life span, electronic product obsolescence is becoming more rapid (Schwarzer *et al.,* 2005). The estimated lifespan and weight of electrical and electronic equipment (EEE) is displayed in Table 2.2. European Union (2010), conducted a study which has stated that e-waste is exceeding three times faster than any other single waste streams in the waste management. This is due to the exponential rise at about 15% of e-waste per year caused by the short product life which doubles the volume of e-wastes (Herat and Agamuthu, 2012).

At present, with the developing new technology and design in the electronic industry, many electronic products have been affected with early obsolescence caused by the fast paced information technology around the world (European Union, 2010). As the quantity of e-waste have been increasing over the years, the issue has caught the attention of the policy makers (Agamuthu and Victor, 2011). In addressing the issue of e-waste, one of the most prominent option of policy in extending the producers responsibility from their products to the consumers is the Extended Producer Responsibility (EPR) (Department of Environment Malaysia, 2012).

The concept of EPR and its applicability in the area of end-of-life management of EEE is very much efficient (Herat, 2008b). It then examines the decade-long experience of using EPR to manage e-waste, focused on the experience of dealing and overcoming specific issues, provided lessons for policy makers (Gaidajis *et al.*, 2010). In addition to that,

five issues discussed among the policy makers were:

i) Challenges in the EPR based system ,

(ii) Finance security in ensuring a smooth and self-sustaining functioning system,

(iii) A logistics network for the take- back and collection of the e-waste,

(iv) To ensure compliance of the various parties involved, and

(v) Reducing the threat of monopolistic practices (Herat, 2008a).

Table 2.2**:** Estimated lifespan and weight of electrical and electronic equipment (EEE)

| Equipment | Life span (years) | Mean weight (kg) |
|---|---|---|
| Personal computer & monitor | 5-8 | 25 |
| Laptop | 5-8 | 5 |
| Printer | 5 | 8 |
| Mobile phone | 4 | 0.1 |
| Television | 8 | 30 |
| Refrigerator | 10 | 45 |

Source : UNEP and UNU (2009)

### 2.7.1 Categories of e-waste

Generally, a large amount of e-wastes consist of obsolete electronic appliances such as main frames, computers, servers, monitors, television and display devices, telecommunication devices such as cellular phones and pagers, calculators, audio and video devices, printers, scanners, copiers and fax machines. Besides that, e-waste also covers recording devices such as DVDs, CDs, floppies, tapes, printing cartridges, and electronic components such as chips, processors, mother boards, printed circuit boards, and etc. (Hawari and Hassan, 2008).

Townsend (2011) has once quoted in the European Union on the definition of e-wastes as below:

*"it is an equipment which is dependent on electric currents or electromagnetic fields to work properly and equipment for the generation, transfer, and measurement of such*

*current and fields designed for use with a voltage rating not exceeding 1000 Volts for alternating current and 1500 Volts for direct current.”*

The proper definition and identification of categories of e-waste are critical for the sound management of e-waste. As defined above, most of the electrical appliances utilized at home consist of components such as televisions, mobile phones, iPods, printers, fluorescent lamps, power tools, toys and etc. These are the e-waste under the current development in this modern society.

### 2.7.2 Global generation of e-waste

Quantity of WEEE which have been used by consumers are based on the reliability of data generated in different parts of the world. Therefore, the amount of used electronic products reaching their end-of-life cannot be measured precisely as it is based on estimation made upon the sales data and estimated life span of WEEE (Herat and Agamuthu, 2012).

In comparison with other used e-waste products, the prediction on the amount becomes a crucial task since the consumers prefer to stock in used WEEE in household and offices. Inventories on e-wastes have already been carried out constructively in several regions of the world in determining the composition and amount of e-waste (Chung and Zhang, 2011).

According to the summary of Ongondo *et al.*, (2011), the prediction of e-waste data available from many different sources have been identified and listed in Table 2.4. An estimation of global generation of e-waste by Li *et al.,* (2011) gives an annual production of 20-25 million tonnes.

Table 2.3: The main categories of e-waste as defined by the European Union's Revised WEEE Directive.

| E-waste category | Examples of products |
|---|---|
| Equipmentof temperature exchange | Air conditioning equipment, refrigerators, freezers, dehumidifying equipment, heat pumps, radiators containing oil and other temperature exchange equipment. |
| Screens monitors, and equipment containing screens with surface greater than 100cm². | Televisions, screens, monitors, LCD photo frames, laptops, notebooks. |
| Lamps | Lamps, straight fluorescent lamps, compact fluorescent lamps, fluorescent, high density discharge lamps, low pressure sodium lamps, LED. |
| Large equipment (any external dimension greater than 50cm) | Washing machines, cloth dryers, dish washing machines, cookers, electric stoves, electric hot plates, musical equipment, large printing machines, copying equipment, large medical devices etc. |
| Small equipment (external dimension not more than 50cm) | Vaccum cleaners, carpet sweepers, microwaves, irons, toasters, electric knives, electric kettles, electric shavers, scales, calculators, radio sets, video cameras, video recorders, Hi-fi equipment, toys, smoke detectors etc. |
| Small IT and telecommunication equipment (no external dimension more than 50 cm) | Personal computers, GPS, mobile phones, pocket calculators, routers, printers, telephones. |

Source: Herat and Agamuthu (2012)

Table 2.4 Generation of e-wastes

| Country | E-waste generation (tonnes/year) | Per kapita generation (kg/person) |
|---|---|---|
| Germany | 1,100,000 (2005) | 13.3 |
| United Kingdom | 940,000 (2003) | 15.8 |
| Switzerland | 66,042 (2003) | 9.0 |
| China | 2,212,000 (2007) | 1.7 |
| India | 439,000 (2007) | 0.4 |
| Japan | 860,000 (2005) | 6.7 |
| Nigeria | 12,500 | 0.9 |
| Canada | 86,000 (2002) | 2.7 |
| South Africa | 59,650 (2007) | 1.2 |
| Argentina | 100,000 | 2.5 |
| Brazil | 679,000 | 3.5 |
| United States | 2,250,000 (2007) | 7.5 |
| Kenya | 7350 (2007) | 0.2 |

Source : Herat and Agamuthu (2012)

## 2.8 E-waste management

E-waste disposal methods were, in large part, the same as other municipal waste disposal methods. These methods include storage, landfill, incineration, reuse, recycle, and recovery (Chi *et al.*, 2011).

### 2.8.1 Storage

For most consumers of electrical and electronic equipment, the first step in e-waste disposal chain is both large and small storage (Herat, 2008b). An electronic device is often replaced with a new model. This is because the newer one has more advanced functions, design and/or aesthetics not because the old one stopped functioning (Herat, 2008c). In the United States, the cost associated with safe and legal recycling may outweigh the revenue received from recycled commodities. Recyclers typically charge households and business for this service (Herat and Agamuthu, 2012). Many times, consumers choose to store the waste temporarily as the cost to get rid of such waste is high (Hayashi *et al.*, 2009).

### 2.8.2 Landfill

The cheapest method of waste disposal is the dumping of waste in the landfill or ground (Hayashi *et al.*, 2009). Toxic chemicals from electronics products can leach into the land and are released into the atmosphere, impacting nearby environment and the residents (Herat, 2008a). In many European countries, regulations have been introduced to prevent electronic waste being dumped in landfills due to its toxic component. However, the practice still continues in many countries. For example, in Hong Kong, it is estimated that 10-20 percent of discarded computers go to a landfill (European Union, 2010).

Landfill is very common, where there is no separate collection and recycling system for e-waste (European Recycling Platform, 2012). Though widely used for waste disposal, landfills are prone to leaking (US EPA, 2010). E -waste disposed in landfills can leach heavy metals and other toxins into the soil, and contaminate the water table (UNEP, 2007). Besides that, vaporization is also of concern in landfills. Disposal of computers in landfills poses environmental hazards when lead and cadmium, leach into soil and groundwater. However, the disposal of certain types of e-waste in landfills, such as CRTs, is banned in many places (UNEP and UNU, 2009).

### 2.8.3 Incineration

Process of burning hazardous materials in electronic waste to destroy harmful chemicals is known as incineration. Incineration minimizes the amount of material that must be disposed of in a landfill (US Environmental Protection Agency, 2010). An incinerator is a type of furnace that burns material at a controlled temperature, which is high enough to destroy harmful chemicals (Chung *et al.,* 2011). A properly designed incinerator can minimize, through flame combustion, toxic organic components in hazardous waste and the volume of the waste fed to them (Cobbing, 2008). Although, it destroys a range of chemicals, such as PCBs, solvents and pesticides, incineration does not destroy metals (Chung *et al.,* 2011). Incineration is not an effective method for treating metalbearing hazardous wastes, such as electronic wastes since metals will not combust (Chi *et al.,* 2011). Prior to incineration, if the waste is not segregated, the output from the combustion process is often toxic stack emissions and residual ash containing heavy-metals, which require a secondary form of disposal (Electronics Take Back Coalition, 2010).

Most basic form of incineration is to just burn waste, reducing the volume and producing an inert ash which could be sent to landfill (Electronics TakeBack Coalition, 2010). Incineration is also used for metal recovery operations, especially copper from wires. The copper recovery process in developing countries starts when cables and wires are manually stripped and separated into insulation (PVC) and conductors (copper) (Barba-Gutierrez *et al.,* 2008). The cables are then burned in an open fire, where not only copper is extracted, but highly toxic dioxins and furans are also released into the air and soil (Barba-Gutierrez *et al.,* 2008).

Finally, the resulting copper is smelted in small furnaces without any environmental safety measures (Barba-Gutierrez *et al.,* 2008). A number of substances produced by the incineration process have a direct effect on human health, such as brominated and chlorinated dioxin which is carcinogenic (Robinson, 2009). Others have an effect to the local and global environment, such as hydrocarbon ashes, sulfur, and nitrogen, causing acid rain (Robinson, 2009).

### 2.8.4 Donation and Reuse

Donations and reuse extend the life of an appliance, rather than final disposal. Donations are made to charitable institutions or to economically weaker sections of society (Townsend, 2011). There are some charitable institutions that collect discarded equipment, especially TVs, PCs and cell phones for donations to developing, low-income countries in Asia an Africa (Tang *et al.*, 2010a). This practice is hotly debated as 'dumping' of e-waste from rich to poor countries, saddling them with the burden of safe disposal (Nquyen *et al.*, 2009). This is due to certain amount of electrical and electronic equipment (EEE) that is discarded by its original owners. Reuse of EEE is a common intermediate step that extends its usable life. Often, intermediaries provide channels for reuse, such as second-hand equipment sellers, or online auction sites (Nguyen *et al.*, 2009).

### 2.8.5 Recycling and Resource Recovery

E-waste recycling can include several activities, such as dismantling, sorting and segregation, remanufacturing and recovery operations (StEP, 2005). These processes can be done mechanically as well as manually (Khetriwal *et al.*, 2011). Recycling of e-waste is gaining importance considering the precious metals it contains. This created an e-waste processing industry in Europe. Recycling of computers and their components, represents the safest and most cost-effective strategy (Ladou and

Lovegrove, 2008 ).The process of recycling by removing and treating hazardous components conserves natural resources, reduces environmental and public health hazards, protects workers safety, and reduces the high cost of permanently storing and disposing of hazardous waste in permitted hazardous waste facilities (Kojima, 2005). Moreover, precious metals and other materials contained in these discarded electronics after being cleaned and sorted have high values in the recycling market (Kojima, 2005). Although electronic products contain valuable metals and precious materials, it is not profitable to recycle these products in the developed countries (Herat, 2008b). The problem with recycling is the lack of collection incentives and the newly emerging recycling infrastructure, as well as the high costs of material collection, handling, and processing (Osibanjo and Nnorom, 2008). In the absence of suitable techniques and protective measures, recycling of e-waste can result in toxic emissions to the air, water and soil that pose a serious health and environmental threat (Goodman, 2008). Incorrect recycling processes such as open-air incineration and acid leaching are commonly used to recover precious metals (Huo *et al.*, 2007). This is due to halogenated substances found in plastics, both dioxins and furans which are generated as a consequence of recycling from e-waste (Gaidajis *et al.,* 2010).

## 2.9 E-waste Collection system

As discussed by US EPA (2010), the main categories of e-waste collection system include manufacturer or producer take-back schemes, municipal collection schemes and recycler/dismantlers collection schemes. The organized waste management schemes consist of reuse and recycling that ensures the toxic constituents in e-waste are not damaged and do not pose as a threat to the environment and human health.

The effectiveness of the collection schemes are measured using the following factors as below (US EPA, 2010):

▪ Convenience and adaptability of the collection facilities

▪ Reduced product movement

▪ Reduced manual handling

▪ Removal of toxic constituents

▪ Segregation of recyclable equipments

▪ Sufficient and consistent informative details to the user

## 2.10 Effective e-waste management system

In creating an essential e-waste management system, Widmer *et al.,* (2005) has stated the following parameters that should be included in the design.

▪ Legal regulation, specifically on the operation management which deals with different stages of information/details in the legislation.

▪ Coverage with two types of responsibility allocated i.e. individual responsibility or collective responsibility. Covers with an all inclusive system that includes all the categories of products/components with a differentiated system that covers each product differently under the context of e-waste.

▪ The financing system which addresses the factors influencing financial resources will operate the system, external funding versus internal funding. Under external funding, the cost of recycling and collection are channeled to the producer or product user as well as the municipality. This could be done via supplies of funds for the end-of- life treatment of products. On the other hand, under internal funding the product generates funds for the collection and recycling (Basiye, 2008).

▪ Producer responsibility's plan in creating a system that takes in the amount of responsibility the producers should carry out. The points in the system that the responsibilities apply and the practical application of the responsibility to be carried out. The systems flexibility also allows both individual and collective responsibility (Basiye , 2008).

▪ Compliance can be achieved through having checks and balances in the system. This will prevent free riders, incorporate collection and recycling targets and have penalties in place for non- compliance. A system may have various measures ranging from high, medium and low or nothing at all in some cases (Guo *et al.,* 2010).

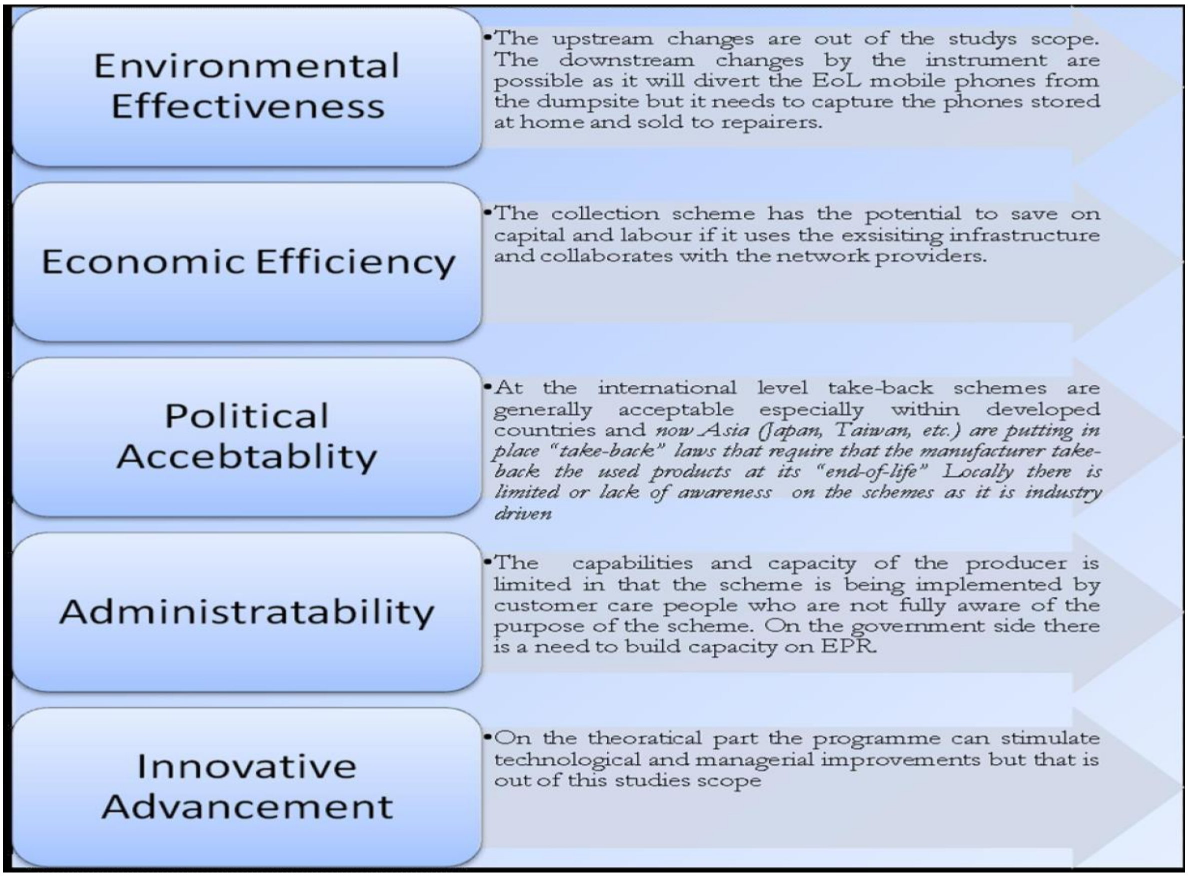
## 2.11 Take-back scheme

The policymakers have definitely created a significant interest towards the end-of-life (EoL) electronic products as they are bound to be a stream of waste with different characteristics (Herat, 2008a). The different stages of EoL electronics, also known as "e-waste", consists of hazardous materials such as mercury, lead and cadmium (Herat, 2008c). These have resulted in increasing environmental concern on the irregular disposal of the electronic components that have been on a rapid rise (Herat and Agamuthu, 2012). Next, the recovery of the valuable materials in e-waste can relieve mining of virgin materials (StEP, 2005). In many cases, the costs of e-waste recycling is much higher than the revenues generated from materials which are recovered(Herat 2008a). For example, EoL personal computers of a metric tonne contains more gold than the one recovered from 17 tonnes of gold ore. Primarily, this could be due to difficulty of separating highly combined constituents in complex products (United Nations University, 2007b)**.**

OECD (2001) has pointed out that EPR take-back policy can be differentiated from other take-back schemes depending on the product system development's response. Adding to that, the voluntary nor mandatory product take-back has been the most active use of EPR in managing EoL electronics as listed by OECD (2001). However, the ultimate obstacle in dealing with take-back programmes is to make the consumers return EoL products for recycling which is against the inconsiderate disposal of the products. Van Rossem (2008) has also stated that the respective companies that take-back their own products are able to design cleaner and much more resource saving products.

The policy-makers on the other hand have insufficient practical experience and knowledge in designing a new take back system for EoL electronics (Townsend, 2011). The current systems are developing and most of it have grown simultaneously without learning from the existing practice (Empa, 2005). Therefore, this leaves the policy makers in position of creating an effective system that are fundamentally experimental in existence – they must use policy instruments that have not been well-tested or brand new(Townsend, 2011). This calls for them to execute and address issues on e-waste. However, there seems to be a mixture of various practice of e-waste take-back systems in many regions (StEP, 2005). When it comes to dealing with e-waste, there are different measures adopted in curbing the issue; one concept has been EPR. Most of the developing countries have taken up a set of measures in the management of e-waste to protect the environment and human health leading to sustainable development (Widmer *et al.,* 2005).

In evaluating the economic efficiencies of the take-back policy instrument, its economic efficiency, political acceptability, administratability and the innovative advancement in Figure 2.2 exposes the analysis of the criterion for the take-back policy scheme. In this way, the policy makers can utilize the criterias that would be best fitted to the existing needs and condition of an EPR policy instrument (Basiye, 2008).




Source : Basiye (2008)

Figure 2.2 : Evaluation of the voluntary product take-back programme

## 2.12 Environmental contaminants associated with e-waste

E-waste contains more than 1,000 different substances, which are toxic, such as lead, mercury, arsenic, cadmium, selenium, hexavalent chromium, and flame retardants (Nguyen, 2009). These substances create dioxin emissions when burned whereas heavy metals can cause brain damage, allergic reactions and cancer (Widmer et al., 2005). In addition, e-waste contains considerable potential environmental contaminants, particularly Polybrominated Diphenyl Ethers (PBDEs) and Polychlorinated Biphenyls (PCBs) (Qin *et al.,* 2011).

E-waste may contain complex mixtures of potential environmental contaminants that are even uncommon from other forms of waste (Sheehan and Speigelman, 2005). Examples including Ga and In which are used in Si chips and LCD monitors (Ladou and Lovegrove, 2008). It is difficult to give a generalized material composition for the entire waste stream, given that e-waste is very heterogeneous in nature (Robinson, 2009). Figure 2.3 indicates 7 similar composition found in the e-waste recycled in Switzerland. There are a total of 2.7% pollutants in the composition. This percentage may even be greater if the producers do not pay extra attention to the product design.

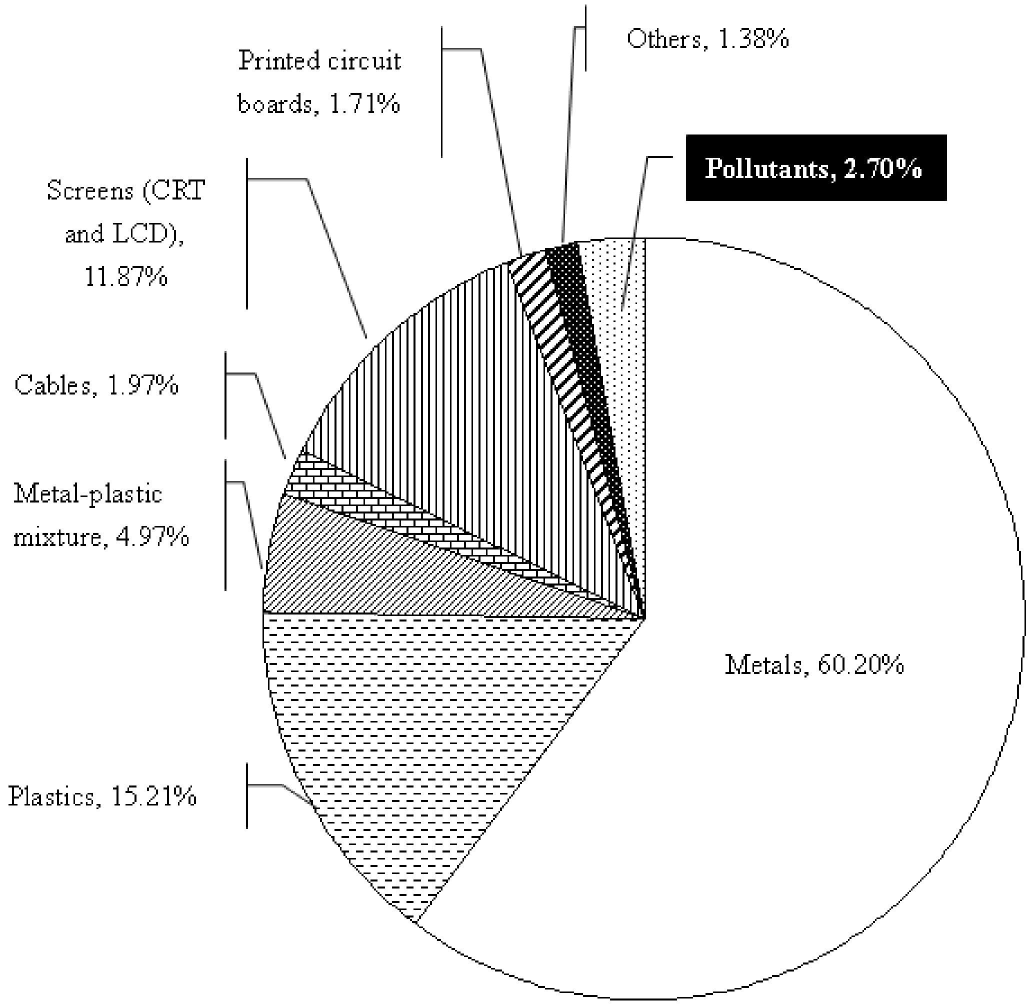



Figure 2.3 Material Fraction in e-waste

Source: Empa, 2005

As e-waste is chemically and physically distinct from other forms of municipal or industrial waste, it requires special handling and recycling methods. This to avoid environmental contamination and detrimental effects on human health (Priyadharshini and Meenambal, 2011). However, due to high labour costs, and stringent environmental regulations, developed countries tend not to recycle e-waste (Ladou and Lovegrove, 2008).

Instead, it is either landfilled, or exported to poor countries where it may be recycled using primitive techniques (Cobbing, 2008). Under the Basel Convention, although the exportation of e-waste is illegal, it continues through legal loopholes, and by countries that are not members under the convention (Basel Action Network, 2010). USA, which is a non-ratifying country has shipped around 50–80% of the collected domestic e-waste to destinations such as China (Puckett and Smith, 2002). Figure 2.4 shows the main e-waste traffic routes in Asia. China receives some 70% of all exported e-waste (Liu *et al*., 2006), while significant quantities are also exported to India, Pakistan, Vietnam, the Philippines, Malaysia, Nigeria and Ghana (Puckett *et al*., 2005).


Figure 2.4 Asian e-waste traffic

Source : Schwarzer *et al*., (2005)

## 2.13 Environmental and public health impacts associated with e-wastes

### 2.13.1 Disposal

Most e-waste is landfilled. Using the Toxicity Characteristic Leaching Procedure (TCLP), Dagan *et al.*, (2007) demonstrated the chemical that leached from various consumer electronics using TCLP was toxic. Therefore, landfilling the e-waste may contaminate the underground water. Prior to landfilling, imcineration may increase the mobility of heavy metals, particularly Pb (Guo *et al.*, 2010). This imposes health impacts to humans through inhalation. With other influencing factors, the leaching of toxins from e-waste may be even worse (Herat and Agamuthu, 2012).

### 2.13.2 Recycling

E-waste recycling involves the disassembly and destruction of equipments to recover new materials (Zhang *et al.*, 2010). According to the waste management hierarchy, recycling is always more favourable than landfilling or incineration and has a lower ecological impact (Schwarzer *et al.*, 2005). At present, most developed countries export their e-wastes to other developed countries for recycling. In poor countries, there is a risk that children may be employed to separate e-waste components (Ladou and Lovegrove, 2008). Guiyu, located at the Guangdong region of China, is one of the largest e-waste recycling sites in the world. Nearly 80% of families, have members who have engaged in e-waste recycling operations (Li *et al.*, 2008). Children there had significantly higher blood Pb (Huo *et al.*, 2007; Li *et al.*, 2008) levels and lower cognitive abilities than children from a nearby town (Li *et al.*, 2008) presumably as a result of long exposure of e-waste. Therefore, it is evident that using primitive methods to recycle e-waste can result in serious widespread environmental and human contamination (Manomaivibool, 2009).

### 2.13.3 Storage of e-waste

Prior to landfilling or recycling, e-waste with their bulky size are normally stored in open sites (Mayers, 2007). Many of these sites do not have shelters. E-waste may be exposed to the environment and lead to the seepage of heavy metals which will eventually cause pollution (Environment Bureau, 2010).

## 2.14 E-waste management in Developing countries

The current issue is to export e-waste to developing countries, in which workers often disassemble electronics which has been discarded without any protective gear (Gaidajis *et al.*, 2010). The Waste Electrical and Electronic Equipment as well as the Restriction of Hazardous Substances directives has set their stringent guidelines for producers or manufacturers to consider recycling phase while designing their products (Townsend, 2011). As far as health and environment problems are concerned, hazardous contents in electronics forces other neighbouring countries around the globe to look into their practices of e-waste management (Guo *et al.*, 2010).

The e-waste management of three countries are reviewed. Japan, Taiwan and Korea are selected because they showed a good example of dealing with the growing e-waste problems though EPR with different approaches. The countries are also reviewed because of similar situation and background as European countries (Environmental Protection Agency, 2008).

## 2.15 E-waste recycling in Japan

When it comes to legislation, Japan manages e-wastes using 2 ways of method. There is Law for Promotion of Effective Utilization of Resources (LPUR) which increases solution for products recycling and reduces generation of e-wastes. This is followed by second Law for Recycling of Specific Kinds of Home Appliances (LRHA), which is the second law that focuses on responsibilities upon producers, manufacturers and consumers on process of recycling of used home equipments (Chung *et al.*, 2008).

When these two laws are compared, both the laws have a tangible difference where the LPUR instils efforts voluntarily among the group of producer while the LRHA sets conditions which are imperative on manufacturers (Chung and Zhang, 2011). It also states that consumers are responsible for recycling costs of home equipments which include transportation costs and recycling fees (Kojima *et al*., 2009). In such case, consumers are required to pay the retailers to take up e-waste. They would then send it for recycling and make payment of fees to the consumer. In making the system more balanced, the retailers would take it back to manufacturer in which a system is set up by the manufacturers to recycle electronic wastes (Zhao *et al.*, 2008).

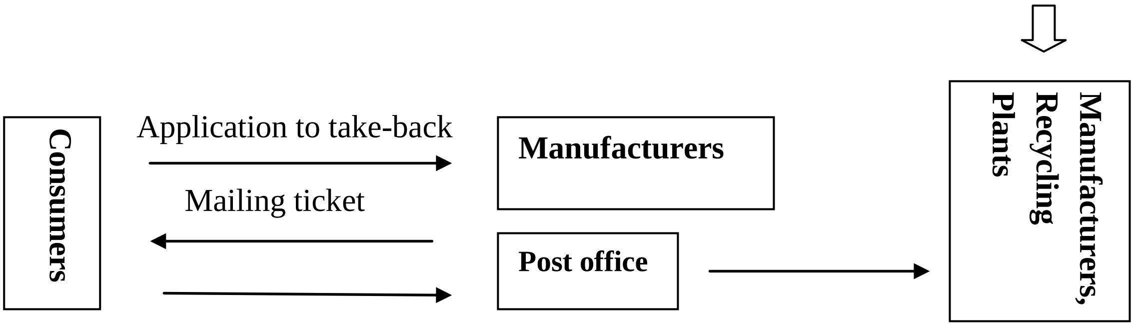
This is in order to sustain a certain portion of usage from these resources (Zhao *et al.*, 2008). However, one stage of the process which acquires a recycling facility that also shows how the recycling is carried out is not regulated by government. Therefore, the manufacturers are given the authority to hire anyone suitable in building the facility in which electronic waste recycling could be done in their selective ways (European Recycling Platform, 2012). Hotta *et al.,* (2008), has stated that manufacturers would prefer to recycle their products in the cheapest way available which leaves ample of space for improvement. The only thing is to retain the amount of utilization from each component or devices that is brought into the facility (Mazzanti, 2009).

Moreover, both the laws play a concrete role in addressing costs increase for the disposal of e-waste. Insufficient sites of waste disposal has also been rising over recent years (Zhang *et al.*, 2010). In terms of costs settings and segregation for collection of used equipments and computers, the manufacturers have been involved in recycling and assembly of e-wastes since 2003 (Kojima, 2005).

Currently, the utilization of electronic waste resources in Japan is around 50% and is expanding rapidly (Kojima *et al.*, 2009). Therefore, a proactive approach has been taken by the Japanese government in e-waste management. This is due to lack of empty affordable space available for landfill sites (Manomaivibool, 2008). There are four major factors influencing them such as : 1) upgrade of technology in incineration 2) upgrade of technology in recycling 3) specific labeling production-side recycle stream package and 4) comprehensive participation of consumer/household participation in recycling and separation of waste material separation (Jain, 2009).

Based on Japan's National Institute for Environmental Studies, in April 2005, over 7 million PCs were discarded (Lifset and Lindqvist, 2008). About 37 percent of them being disposed or recycled, while 37 percent were reused within Japan alone and 26 percent being exported externally (Khetriwal *et al*,. 2011) . Thus, Yuichi Moriguchi, Director of the Institute's Research Centre for Material Cycles and Waste Management, has stated that besides the Home Appliance Recycling Law, Japan needs an efficient plan or scheme for recycling (Khetriwal *et al.*, 2009). This is in particular with current existing scheme of further collection of used PCs and batteries and a well managed system to take back small household electronics and cell phones

(Akenji *et al.,* 2011). Figure 2.5 below shows general flow of used computers from households in Japan




Source : Banerjee (2007)

Figure 2.5: General Flow of Used computers from Households in Japan.

### 2.16 E-waste recycling in Taiwan

Taiwan, being the centre in world's production of electronic products, has the capability in trying to build and expand on its existing manufacturing hub to develop suitable technicality on know-how (Terazono, 2008). In that process, Taiwan's well-trained manufacturers should be able to design products that are environmentally friendly in reducing their total cost required (Hotta *et al.,* 2008). E-waste recycling relatively first began in Taiwan about a decade ago (Huang, 2009). Before then, many would have thought the unwanted parts of computer could be converted into something beneficial when three decades ago, e-waste was either only incinerated or deposited into landfills (Hotta *et al.,* 2008).

With this, Taiwan holds the highest potential of becoming one of the world's renowned electronic waste recycling center. Provided that the country has long, concrete working bonds with the world's leading technology based companies (Hayashi *et al.*, 2009). Among the listed companies are the Super Dragon Technology and Jiin Yeeh Ding Enterprise Corp., involved in this industry, and both have both their own recycling facilities in Chinese mainland (Williams, 2005). However, in practice, the international treaty is required to restrain hazardous waste being transported across national borders. The accumulating e-wastes transported from other countries ranges between 50 and 70 percent in mainland China, as it is produced by local manufacturers (ENHESA, 2005).

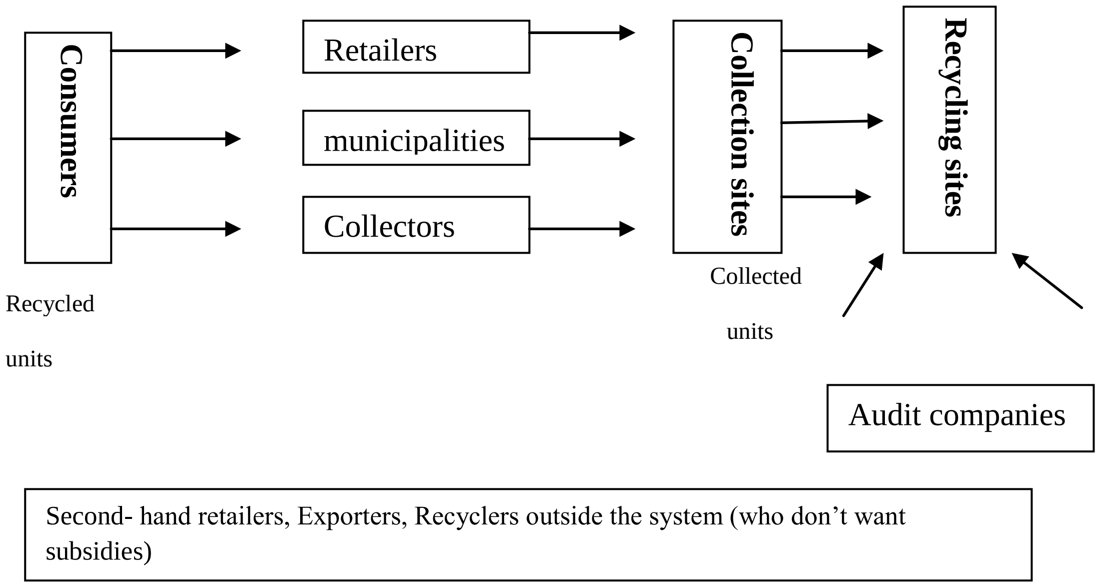
Moreover, the spokesperson of Super Dragon Technology, Kenny Lin, stated in maintaining a healthy relationship with the local government by keeping up with their capacity that has authority over their clients (Greenpeace International, 2008). Apart from that, despite the heavy load of wastes being generated in the country, the challenge is to secure a persistent source of used electronics for their plant in Suzhou, Jiangsu Province. Plus, many local manufacturers tend to ship e-waste to scrap yards for incineration since the laws and regulations are still insufficient in mainland of China (Kojima *et al.,* 2009).

E-waste management has become an important issue that even Taiwan has difficulty in controlling some of the higher technologies involved in recycling of e-wastes (Wang *et al.*, 2009b). The country's lack of suitable processing technologies is vital in achieving cost efficiency through merge of supply chains (Wang *et al.*, 2009b). As Taiwan plays an essential role in the industry, it is necessary for the community in sustaining its economy and environment (Yu *et al.*, 2010). In recent years, Taiwan has seen an increase in volume of e-waste products. Following several years of implementation and making recycling goals easily achievable through EPR system, the Environmental Protection Administration (EPA) is actively guiding manufacturers in creating self-managed recycling, clearance and treatment systems (Electronics Take back Coalition, 2010). According to EPA, half of its e-waste is now recycled by Taiwan, much higher than the world average between 15 and 30 percent (Environmental Protection Agency, 2008).

However, electronic products have a lifespan of between two and ten years, which makes the volume of the materials difficult to be recycled and discarded (Environment Bureau, 2010). This in turn causes impacts towards the environment which makes it troublesome to assess the overall management of recycling of products (Environmental Protection Agency, 2008). In overcoming this, EPA has taken action by putting in more effort into current evaluation scheme of overall environmental costs of pollution prevention, costs regeneration, and disposal costs of wastes (Yu *et al.*, 2010). EPA also adopts supply management in promoting green production and green design, as a method of reducing degree of environmental impact and management complexity (Widmer *et al.*, 2005).

From that, the Waste Disposal Act and Resource Recycling Act has indicated on the scope of Taiwan's recycling policies. The Acts are in similar level with international standards and its performance of reuse facilities which has led to the development of similar systems in China and Japan (Yoshida *et al.*, 2009). This is entirely based on the principles of competitiveness and EPR on recycling (Osibanjo and Nnorom, 2007). Experts from Germany, Japan, the Netherlands, Republic of South Africa and some countries in Central America and South America have also come to Taiwan to observe on how recycling facilities operates efficiently (Ongondo *et al.*, 2011).

Moreover, the recycling operating models particularly the domestic ones require full participation of the public. It is a four-in-one system which is exclusive and universal that comprises of public, recycling funds, recycling and treatment organizations and local refuse collection crews (Yu *et al.*, 2010). This is to ensure the waste of electrical and electronic products are recycled, reused and discarded in a friendly manner. Taiwan's technology industry is indeed a high growth, profitable and a developed green industry (Nnorom and Osibanjo, 2007). Figure 2.6 below shows the general flow of E-waste in Taiwan.




Source: Luo *et al.,* (2011)

Figure 2.6: General Flow of E-waste in Taiwan

## 2.17 E-waste recycling in Korea

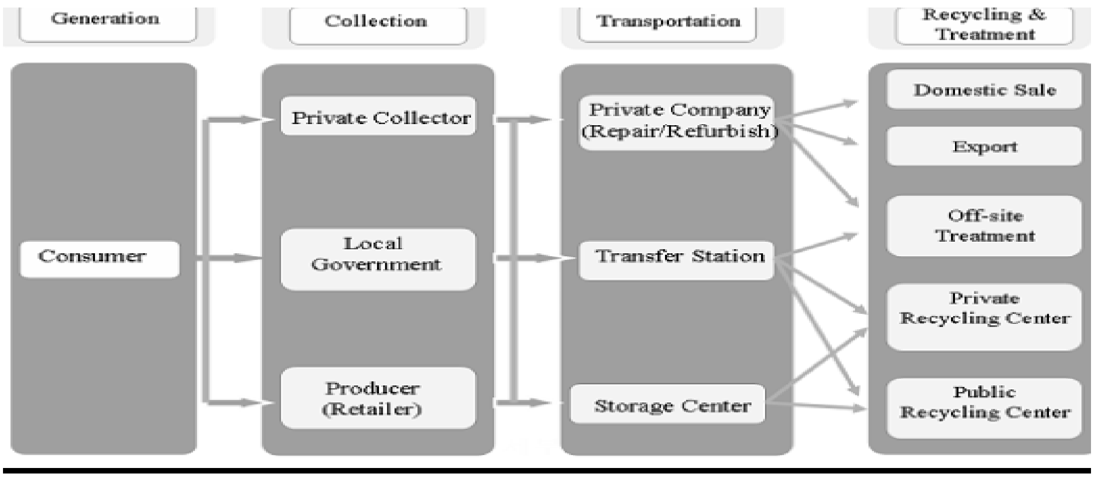
The generation of electronic waste (e-waste) has been growing rapidly over the past decade in Korea (Lopez *et al.,* 2011). Although, the recycling of e-waste is highly beneficial in terms of economic status, e-waste contains hazardous constituents (Manomaivibool, 2009). However, the current practices and management of e-waste in Korea focuses more on the generation rates, collection systems, regulations and recycling practices of e-waste. With the context of EPR, suggestions and challenges have been associated with the problems likely to occur to e-waste recycling and management in Korea (Manomaivibool, 2008).

One of the most progressive country would be Korea in the field of electronics and information technology (IT) (Hicks *et al.,* 2005). More than 25 millions PCs were being used in Korea, and from there, more than 60% of the population were internet users (Herat, 2008a). Thus, due to the development of information technology and increasing demand from consumers, there is a significant amount of obsolete device which have been discarded in Korea. This includes computers and peripherals, TVs, telephones, fax machines and video/audio devices (Tojo, 2004).

When it comes to e-waste recycling, from an environmental and economical point of view, it is an important subject area that has not been well-constituted in Korea. Only small number of these wastes are refurbished and recycled as the costs of recycling has increased and consumer incentives have also become less (Manomaivibool, 2008). Many of these devices ends up in landfills or incineration for valuable materials to be extracted (Manomaivibool, 2009). As such waste contains hazardous heavy metals and polybrominated biphenyl ethers, it could could pose a significant threat towards humans and environment (Cobbing, 2008)

In Korea, the e-waste generated is collected by three major pathways. Figure 2.7 below displays flow of present collection system of consumer's electronics in Korea. The process starts with retailers and suppliers collecting an old product from consumers (Cobbing, 2008). It is mandatory for them to accept the product and constantly transport the item to the producer's storage centers. The next option for disposal involves a local government in taking back the consumer electronics at specific areas with MSW near residential complex (Masanet and Horvath, 2007).

The electronics discarded will be collected on a weekly basis by public collectors. In this e-waste collection system, private collectors play a vital role in managing them and sometimes pay for malfunctioned consumer electronics (United Nations University, 2007b). This could eventually increase on the revenue from sales of electronic appliances collected as well as charges made upon the producers. The recent increase over the years has called for the implementation of EPR program (United Nations Environment Programme, 2007 a).




Source : United Nations University, 2007b

Figure 2.7 : Collection system of e-waste in Korea

However, many efforts have been made in Korea towards a better management of e-waste from consumers. Ever since, the measures have been initiated by MOE of Korea, evaluation of output will be difficult to assess (Townsend, 2011). Guidelines and regulations have been implemented in order to create an integrated system of e-waste management. Thus, several suggestive options can be assessed to enhance the practice of present e-waste recycling and management ethics of electronic products in Korea (OECD, 2008).

First and foremost, the urge for waste minimization through reuse, recycling, and source reduction has to be reckoned among the public (Ongondo *et al.*, 2011). Next, would be a need to establish a structured collection system for a balanced store of electronic products to be recycled (Liu *et al.*, 2006). This is compulsory to have an ongoing and flexible demand for recycled components. Third is followed by EPR program with a rise in amount of recycling rate (Morf *et al.*, 2007). This is stable and is needed in giving out incentives. To date, e-waste recycling requires recovery and recycling of constituents or materials which is restricted to e-waste streams (Barba Guttierrez, 2008).

In Korea, waste minimization and recycling are not well publisized that it leads to significant amount of e-waste to be discarded (OECD, 2008). The electronic waste is still in preliminary stage of evaluation for the program (Morf *et al.*, 2007). As incineration and land disposal of e-wastes are not applicable anymore, more efforts including incentives for technicality as well as collectors have to be encouraged in reducing and recycling e-waste (Ladou and Lovegrove, 2008). Plus, polybrominated biphenyl ethers, dioxin, and lead emissions should be monitored closely to reduce potential threats to humans in the environment. E-waste collection is somehow linked to a lack of awareness on potential hazards among consumers and local government (Shinkuma and Managi, 2010).Many developed countries have also shown their interest in generating recycling processes in reducing amount of e-wastes (Robinson, 2009). This is very much essential in reading physical characteristics of waste stream to structure a cost-effective and environmentally friendly recycling (Widmer *et al.*, 2005). Other e-waste collection activities such as special collection events by local governments are still limited because e-waste is commonly viewed as a potentially valuable resource by consumers (StEP, 2005).

In the past, electronic waste was often mixed with waste of household and those disposed of at landfills (Tang *et al.*, 2010a). As number of electronic devices has been increasing over the years in Korea, generation of e-waste has been rising in abundance as well (Qin *et al.*, 2011). This has led to a move by the Korea Ministry of Environment with more stringent and systematic rule over the public concern from the inefficient disposal of e-waste (United Nations University, 2007b).