Chapter I

Introduction

1.1 Background to the Study

Waste Electrical and Electronic Equipment (WEEE) or more popularly referred to as E-waste is an emerging global environmental issues that is steadily gaining prominence. This growing concern is due to rapidly increasing E-waste quantities, a trend that is expected to continue unabated for some time due to the rapid emergence of new technologies and affordable electrical and electronic products (Agamuthu & Dennis, 2013; Bowcock, 2011). Rapid innovation in consumer electronics coupled with limited incentives for designs that would increase opportunities for 3R (reduce, reuse, recycle) means that electronic products quickly becomes obsolete and are discarded more frequently (Bowcock, 2011).

The waste generated from discarded electronics is a rising concern because of the toxic substances they contain i.e. lead, nickel, cadmium, copper, chromium beryllium, lithium, mercury etc. Therefore, unsound handling of E-wastes can cause harm to both the human health and the environment due to its highly toxic components (Herat and Agamuthu, 2012; Lundgren, 2012).

There are varied definitions of E-waste. The Basel Action Network (BAN) refers to E-waste as “a wide and developing range of electronic appliances ranging from large household appliances, such as refrigerators, air-conditioners, cell phones, stereo systems and consumable electronic items to computers discarded by their users” (Basel Action Network, 2010; Gaidajis et al., 2010). According to United States

Environmental Protection Agency (USEPA), electronic products that are "near" or at the "end of their useful life" are referred to as "e-waste" or "e-scrap." Recyclers prefer the term "e-scrap" since "waste" refers only to what is left after the product has been reused, recovered or recycled. However, "E-waste" is the most commonly used term globally (Lundgren; 2012; UNEP, 2007).

In the European context E-waste is defined through the European Union's two related directives – Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) and Waste Electrical and Electronic Equipment (WEEE) – they define electrical and electronic equipment (EEE) as "equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1000 Volt for alternating current and 1500 Volt for direct current" (Logomasini, 2008; Sauder et al., 2010; UNEP, 2007).

In Malaysia, the Department of Environment (DOE) defines E-waste as "wastes from the electrical and electronic assemblies containing components such as accumulators, mercury-switches, glass from cathode-ray tubes and other activated glass or polychlorinated biphenyl-capacitors, or contaminated with cadmium, mercury, lead, nickel, chromium, copper, lithium, silver, manganese or polychlorinated biphenyl's" (Malaysia DOE, 2010).

1.1.1 Global E-waste Generation

Globally it is estimated that E-waste generation is between 20-50 million tonnes per year (Basel Action Network, 2010; Herat and Agamuthu, 2012; UNEP, 2006). This figure is more than 5% of the total Municipal Solid Waste (MSW) generation (Bowcock, 2012; SEPA 2011; UNEP, 2006, 2007). E-waste generation is further estimated to increase by 3-5% every year, which is nearly three times faster than the MSW generation annual growth rate (Agamuthu & Dennis, 2013; SEPA, 2011). Furthermore, in the USA, E-waste market researchers' project that global volume of E-waste generation is expected to reach 93.5 million tonnes in 2016 from 41.5 million tonnes in 2011 (Markets and Markets, 2011).

The emerging trend worldwide is that when consumers procure new electrical and electronic products, the old equipment immediately becomes obsolete or undesirable and are eventually being discarded, leading to generation of enormous amounts of E-wastes. In USA alone, it has been estimated that over 100 million cell phones and 30 million computers are being discarded every year in part because consumers are constantly upgrading their electronics (Cobbing 2008; SEPA, 2011). In the European Union it is estimated nearly 10 million tonnes of E-waste is generated annually and numbers from Japan indicate that in the year 2010, among others, 610 million mobile phones were disposed (SEPA, 2011). In China, it estimated that at least 70 million mobile phones, 4 million computers, 5 million TVs, 6 million washing machines and 4 million refrigerators have been abandoned annually since 2003 (Cobbing, 2008; SEPA, 2011). In India it also estimated that total annual electronic waste generation is between 146,000 and 330,000 tonnes, and is expected to reach 470,000 tonnes by

2011. Another estimate states that in 2007 India generated 380,000 tonnes of electronic waste from computers, televisions and cell phones only, and that figure is expected to reach 800,000 tonnes by 2012 (Herat and Agamuthu, 2012). Global generation of E-waste over the last decade is shown in Table 1.1.

Table 1.1 Global Generation of E-waste

Country	Tonnes	Year	Per capita generation (kg/person)
Germany	1,100,000	2005	13.3
United Kingdom	940,000	2003	15.8
Switzerland	66,042	2003	9
China	2,212,000	2007	1.7
India	439,000	2007	0.4
Japan	860,000	2005	6.7
Nigeria	12,500	N/A	N/A
Canada	86,000	2002	2.7
South Africa	59,650	2007	1.2
Argentina	100,000	N/A	2.5
Brazil	679,000	N/A	3.5
USA	2,250,000	2007	7.5
Kenya	7,350	2007	0.2

Source: (Herat and Agamuthu, 2012; IMRB International, 2010)

1.1.2 E-waste Generation in Malaysia

Malaysian DOE classifies E-waste generation among two categories that is Industrial Sector and Non Industrial (Households, Business and Institutions). The DOE reported that the amount of E-waste generated from the industrial sector in 2009 was 134,036 tonnes, 163,340 tonnes in 2010 and dropped to 152,722 tonnes in 2011. In the second category, combined E-waste generation by households, businesses and institutions amounted to 652,909 tonnes in 2006, 695,461 tonnes in 2007 and 688,068 tonnes in 2008 (Malaysia DOE, 2012). This scenario reflects that over 75% of E-waste generated in Malaysia is from households, commercial outlets and institutions.

In 2008, DOE projected that Malaysia E-waste generation would reach 1.1million tonnes per year by 2020. However, an E-waste inventory was conducted the same year with funding from Ministry of Environment of Japan and found that Malaysia actually generated 1.1 million tonnes of E-waste in 2008 (Agamuthu & Dennis, 2013; Herat & Agamuthu, 2012). Therefore, current E-waste generation levels have already surpassed the 10 year projections made by the DOE.

1.1.3 E-waste in Institution of Higher Learning

Institutions of higher learning (universities) contribute significantly to the rapidly growing threat of E-waste. Information and communication technology (ICT) equipment are the most widely used and most frequently replaced electronics in universities. And thus the bulk of E-waste generated in universities is from ICT equipment such as desktop and laptop computers, printers and photocopy machines. Industry experts estimate current average lifespan of ICT electronics to be at 3-4 years for desktop PC, 5 years for monitors, 2 years for laptop and 3-5 years for printers and copiers (Killick, 2007). However, in recent times most institutions have been replacing the older, more environmentally harmful Cathode Ray Tube (CRT) monitors with flat screens, thus increasing institutional E-waste generation.

1.1.3.1 E-waste Awareness and Management

More often than not the lack of awareness on E-waste has been cited as one of the major impediments to sustainable E-waste management. The European Recycling Platform (ERP) in a 2009 survey found that over 70% of E-waste recyclers cited poor public awareness as one of the biggest challenges holding back E-waste recycling (Incisive Media, 2013). In recent years, a number of environmentally proactive universities have engaged in sustainable campus initiatives to increase E-waste awareness and curb E-waste generation hence, reducing possible negative environmental and human health impacts.

The Macquarie University in Australia has put in place an E-waste Policy focused on environment and sustainability with regard to the disposal of unwanted and/or obsolete electrical and electronic equipment. The E-waste policy has increased E-waste awareness among university staff and diverted large amount of electronic waste that would have been destined for landfills by recycling 25 metric tonnes of E-waste in 2008 and over 40 metric tonnes in 2010 (Macquarie University, 2012).

At the Griffith University in Australia, the university Assets Team co-ordinates the disposal of University electrical and electronic equipment in accordance with the asset disposal policy which endorses the use of “Greenbox” for disposal and eCycling that ensures E-waste disposal is ethically handled. Griffith University is also a member of Solving the E-waste Problem (StEP), an initiative founded by various UN organizations and coordinated by the United Nations University. StEP's overall aim is to develop strategies to solve the E-waste problem based on a sound scientific basis (Griffith University, 2013).

In 2012, the Sustainable Electronics Initiative (SEI) at the University of Illinois – USA, ran an International E-waste Design competition that focused research and design in the area of product designs for environmentally responsible computing and entertainment. The entries were ideas that prevent electronic waste generation through life-cycle considerations and attracted international entries from Canada, Ireland, Chile, India, Hong Kong, Turkey, Bangladesh and the United States (Sustainable Technology Center, 2012).

In 2011 Auburn University – USA, in its sustainable campus initiatives collected nearly 62 metric tonnes of electronic waste, including items such as printers, fax machines, computer monitors and other computer parts. The University has other sustainable initiatives on campus such as the yearly dorm competition, "Sustain-a-Bowl," where dorms compete to reduce electricity use, recycle more and conserve water. Students can also attain a minor in sustainability. Established in 2005 the Auburn University Recycling Program has expanded to provide recycling bins in campus buildings, around campus grounds and at special events (Harding, 2012).

According to the Malaysia Ministry of Higher Education (MoHE) the country has 21 public universities, 43 private university and university colleges, 4 foreign university branch campus and 134 private colleges. This is a significantly large number of institutions that potentially contribute to E-waste generation however; there is no record of institutional policy on E-waste management in all these institutions of higher learning. Thus, the aim of this research is to establish if there are any institutional mechanisms for E-waste management in institutions of higher learning.

The research also conducts Material Flow Analysis (MFA) modeling for electronic equipment in the selected universities. The goal of the MFA modeling is to increase the understanding of university E-waste management systems, which leads to a better system analysis and practical recommendation (Chancerel, 2010). STAN (subSTance flow ANalysis) 2.5 software will be used as a tool for performing the MFA modeling, STAN 2.5 provides graphical models, data reconciliation, error propagation and gross error detection.

Furthermore, the research seeks to establish the level of E-waste knowledge among the university public and their E-waste disposal practices, how much E-waste these institutions generate, how it is disposed and what challenges are faced in E-waste management. The research focuses mainly on ICT E-waste management in universities in the Klang Valley.

1.2 Problem Statement

In Malaysia MSW contains 3% - 5% hazardous waste which includes E-waste. The growing concern over E-waste is due to rapidly increasing E-waste quantities which if unsoundly handled pose grave environmental and human health risks. This is exacerbated by the seeming lack of public knowledge/awareness on E-waste and thus in turn fuels the indiscriminate disposal of E-waste together with MSW. E-waste disposed of in landfills or illegal dump sites over time breaks down, releasing dangerous toxins i.e. lead, chromium, phosphor, mercury, barium, beryllium and bromated flame retardants and cadmium that leach into the groundwater, contaminating waterways and soil, ultimately poses health threats to both fauna and flora.

Furthermore, E-waste takes up significant amount of space in landfills. Space for less harmful biodegradable waste can be created or saved through proper management of E-waste using appropriate reduce, reuse and recycle (3R) technologies. E-waste components also contain precious and semi-precious metals, such as gold, copper, nickel, silicon and iron, which are needlessly squandered through careless disposal. Therefore, sound E-waste management in universities not only would reduce environmental degradation and associated human health threats but E-waste can also be potentially a revenue earner for these institutions of higher learning.

. 1.3 Research Objectives

1. To study and compare E-waste management in selected institutions of higher learning (private/public universities).
2. To analyze the flow of E-waste among selected institutions of higher learning using material flow analysis model (STAN).
3. To assess the level of knowledge on E-waste in institutions of higher learning.
4. To recommend potential programmes and/or projects in E-waste management based on findings.

Chapter II

Literature Review

2.0 Introduction

Chapter Two reviews various literature and institutional documentations on the subject of E-waste management. In this literature review the chapter endeavors to cover various categories of E-waste, concepts, principles and models used in E-waste management, gives an overview of global, regional and national perspectives of E-waste and the environmental impacts that result from unsound E-waste management practices. Furthermore, the chapter looks at institutions of higher learning and their contribution to E-waste generation and its subsequent management, covering case studies from both developed and developing countries.

2.1 Categories of E-waste

E-waste can be divided into the following categories presented in the table below:

Table 2.1 Categories of E-waste

E- waste categories	Examples
1. Large House hold Appliances:	Washing machines, Dryers Refrigerators, Air conditioners, etc
2. Small House hold Appliances:	Vacuum cleaners, Coffee Machines, Irons, Toasters, etc.
3. Office, Information & Communication Equipment:	PC's, Laptops, Mobiles, Telephones, Fax Machines, Copiers, Printers etc.
4. Entertainment & Consumer, Electronics and Toys, Leisure, Sports and Recreational Equipment, and Automatic Issuing Machines:	Televisions, VCR/DVD/DC players, Hi-Fi sets, Radios, etc, and Electric train sets, coin slot machines, treadmills etc and Vending machines, parking ticket equipment etc.
5. Lighting Equipment:	Fluorescent tubes and lamps, sodium lamps etc (Except Incandescent Bulbs, Halogen Bulbs)

6. Electric and Electronic Tools:	Drills, electric saws, Sewing Machines, Lawn Mowers etc
7. Security & health care equipment:	Surveillance and Control Equipment (e.g. CCTV cameras, scanning equipment), and Medical Instruments and Equipment (e.g. x-ray and heart lung machines) etc.

Source: (IMRB International, 2010)

2.2 Concepts and Principles in E-waste Management

In recent times with the ever increasing quantities of E-waste generation, a number of waste management concepts, principle and models have been used to formulate E-waste management strategies. The aims of the various concepts is to mitigate or reduce negative environmental impacts of waste, promote waste as a raw material through recycling, reuse or energy generation and to make companies, communities and individuals more responsible for the waste they generate. This research looks at (four) basic concepts, principles and models that are fundamental to E-waste management namely:

a) Concept of Waste Hierarchy (3R's)

b) Principle Of Extended Producer Responsibility (EPR)

c) Material Flow Analysis

d) Concept of Zero Waste

2.2.1 Concept of Waste Hierarchy (3R's)

The Waste Hierarchy Concept is a classification of waste management options in order of their environmental impacts. They can be classified as reduction, reuse, recycling and recovery and disposal. In Europe the waste hierarchy has five steps (Raina, 2010):

1. Prevention
2. Reuse
3. Recycling
4. Recovery, e.g. energy recovery
5. Disposal

The waste hierarchy has taken many forms over the past decade, but the basic concept has remained the cornerstone of most waste minimization strategies. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste (Raina, 2010; UNEP, 2007).

The Waste Hierarchy Concept of waste impact minimization, by reducing quantity of wastes, reusing the waste with simple treatments and recycling the wastes by using it as raw material to produce same or modified products is usually referred to as “3R”. As can be seen in Figure 2.1 prevention (reduce) is the most desirable in order of hierarchy, followed by reuse and recycling the least desired or favoured option.

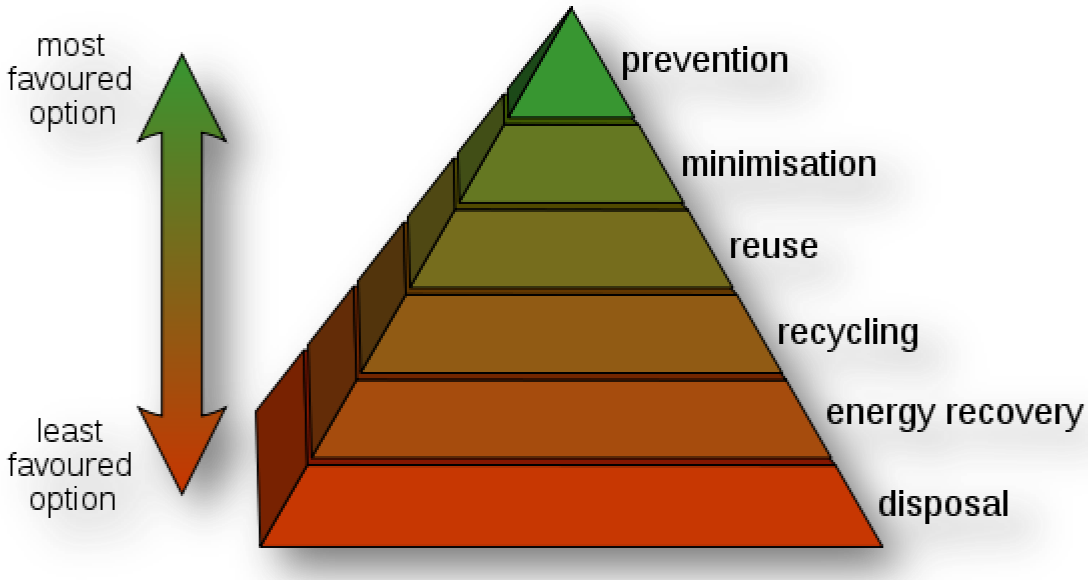

Figure: 2.1: Waste Hierarchy (Raina, 2010)

This concept is key to sustainable management of E-waste. Simply put the principle of 3R is for example, using resources with care can and will reduce the pace of consumption of resources, ultimately reducing waste significantly in waste streams. When products or consumables with long usable life span are reused over and over, it offsets harvesting of new resources to produce similar products. This reduces fresh resources exploitation and waste generation quantities. Some waste products can be used as raw materials for production of different goods or the same product, meaning recycling the same resource. This too saves fresh resource exploitation and offsets waste generation. All in all, the 3Rs individually or collectively reduce fresh resources exploitation, add value to the already exploited resources and very importantly minimizes the waste quantities generated and the resultant ill effects. Waste minimization efficiency is stated to be better achieved applying 3Rs in a hierarchical order – Reduce, Reuse and Recycle (Raina, 2010; UNEP 2007)

2.2.2 Concept Extended Producer Responsibility (EPR)

Extended producer responsibility (EPR), based on the "polluter pays" principle and entails making manufacturers responsible for the entire lifecycle of their products. One aim of EPR practice is to internalize the environmental costs of products into the product purchase price. Another is to shift the economic burden of managing products that have reached the end of their useful life from local government and taxpayers to the product producers and consumers (Lindhqvist, 2000; Lundgren, 2012; Sheehan & Spiegelman, 2006).

The concept of EPR was first formally introduced in Sweden by Thomas Lindhqvist in a 1990 report to the Swedish Ministry of the Environment.

> **Extended Producer Responsibility***: "a policy principle to promote total life cycle environmental improvement of product systems by extending the responsibilities of the manufacturer of the product to various parts of the entire life cycle of the product, and especially to the take-back, recycling and final disposal of the product" (Lindhqvist, 2000).*

One of the essential features of EPR is "take-back" of end-of-life products thus creating closed looped systems that prevent pollution and promotes efficient use of resources. By promoting a "cradle to cradle" responsibility, EPR demands a design strategy that takes into account the upstream environmental impacts inherent in the selection, mining and extraction of materials, the health and environmental impacts to workers and surrounding communities during the production process itself, and downstream impacts during use, recycling and disposal of the products (EPR Working Group, 2008).

2.2.3 Material Flow Analysis

Material Flow Analysis is a generic term in analyses of matter flows (chemical elements, compounds, materials or commodities) which are based on material balancing representing the law of material conservation (Streicher-Porte et al., 2005). The goal of a material flow analysis is to increase the understanding of a studied system, which may lead to a better system control and management (Steubing et al., 2008). The basic equation for material flow analysis is:

$$\Delta M = \Sigma F_{in} - \Sigma F_{out}$$ -----Equ 2.1: Material Flow Analysis

In Equation 2.1 ΔM represents the variation of the material stock in a process, ΣFin is the sum of flows entering a process and $\Sigma Fout$ is the sum of flows leaving a process (Steubing et al., 2008).

Material flow analysis has been widely used around the world as an E-waste management tool e.g. a study by Lui et al. (2006) in China, used MFA to predict the quantity of obsolete electronic products from urban households and to analyse the flow after the end of their useful phase. The quantity handled in 2005 was 885,354 units and is expected to double by 2010 due to consumption growth and the expansion of urbanization (Lui et al., 2006). The study estimated that the amount will increase to approximate 2,820,000 units by 2020: 70% of the obsolete appliances will be awaiting collection for possible recycling, 7% will be stored at the owner's home for one year on average and 4% will be discarded directly and enter the municipal solid waste collecting system (Lui et al., 2006). The remaining items will be reused for about 3 years on average after the change of ownership. The results of this study were aimed at assisting the waste management authorities of Beijing to plan the collecting system and facilities needed for management of E-waste generated in the near future. In Chile a study using MFA was used to comprehensively analyse E-waste in Chile, identifying relevant streams of E-waste and providing a basis for authorities and producers of electronic goods in order to take the necessary actions to establish an adequate recycling system (Steubing et al., 2008). In 2007, MFA was used in a research to quantifying the flows of small waste electrical and electronic equipment (sWEEE) in Germany and in the USA, as well as the flows of gold and palladium associated with the sWEEE (Chancerel, 2010).

2.2.4 Concept of Zero Waste

The concept of Zero waste is a waste management option borne out of material flow analysis. Zero waste postulates that the entire concept of waste should be eliminated, instead, waste should be thought of as a residual product or potential resource. Benefits such as reduced costs, increased profits, and reduced environmental impacts are gained when returning these residual products or resources are used as raw material to either natural and/or industrial systems. This may involve the redesigning of both products and processes in an effort to eliminate hazardous properties that make them unusable and unmanageable in quantities that overburden both industry and the environment (Zero Waste Organization, 2012; Lehmann, 2011). The (two) material flow diagrams (Figure 2.2 and Figure 2.3) represent the current waste flow. The current material flow for traditional production systems are one-way and linear, going from the extraction of resources, manufacturing of goods, product use and then ultimate disposal. Zero Waste seeks to redesign these systems to be cyclical, where there is no such thing as waste and discards are either designed out completely or fed back into the production cycle as raw material (Zero Waste Organization, 2012).

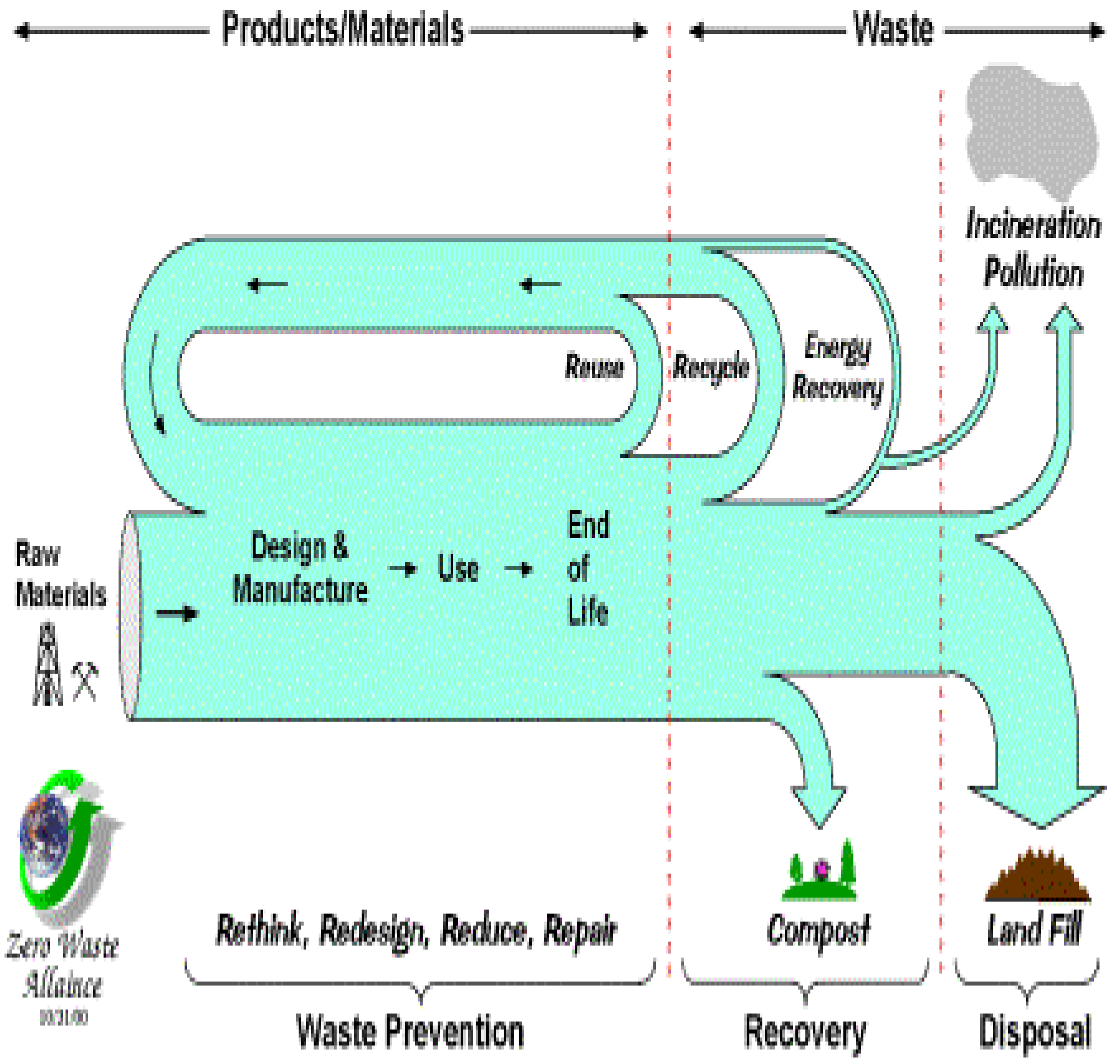

Figure 2.2 Current material flows *(Source: Zero Waste Organization, 2012)*

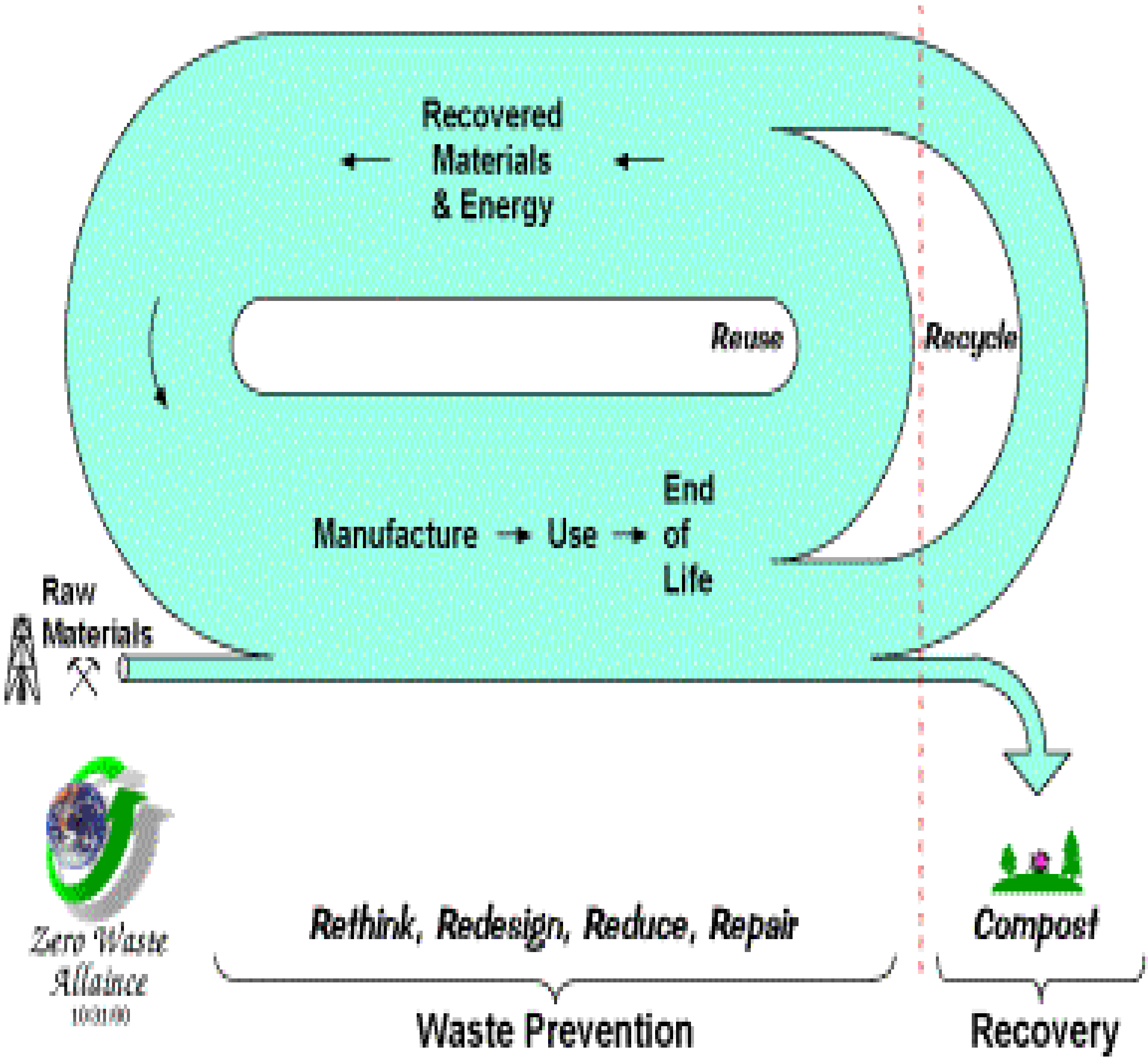

Figure 2.3: Improved material flows (*Source: Zero Waste Organization, 2012*)

In Japan, the town of Kamikatsu has embarked on a zero waste city campaign. The town has no garbage bins in any of the town's homes, and there's no dump site. Instead, the residents compost all waste from their food, and sort other trash into 34 separate categories, with sections for plastic containers, razor blades, Styrofoam, and various other paraphernalia (Hawkin, 2012). Although the Zero Waste Concept is highly ambitious and most likely not completely attainable, if the general principle is applied in the production of electrical and electronic equipment it could go a long way in sustainable management of E-waste.

2.3 E-waste Management

2.3.1 E-waste Generation: a Global Perspective

In 2008 the United States generated 3.16 million tonnes of E-waste this was an increased from 3.01 million tonnes generated in 2007 (USEPA, 2009). E-waste constitutes from 2% to 5% of US municipal solid waste stream and is growing rapidly (Kang & Schoenung, 2005). The USEPA (2008) estimated that 29.9 million desktops, 31.9 million computer monitors and 12 million laptops were discarded in 2007; that is over 112,000 computers discarded per day. In a 2006 report, the International Association of Electronics Recyclers projected that with the current growth and obsolescence rates over 3billion consumer electronics would be E-waste by 2010 in the United States.

In 2008, around 10 million tonnes of E-waste was generated in the European Union (EU) and this volume is expected to increase by 3 to 5 percent a year (Deubzer, 2011). E-waste is the fastest growing waste stream in the EU, with estimates of between 1kg to 20 kg per person per annum and is increasing at about 3 times greater than normal MSW (Darby and Obara, 2005; Greenpeace, 2012). E-waste accounts for 8 percent of all municipal waste in Europe (Streicher-Porte, 2006)

Asia is estimated to discard 12 million tonnes of E-waste each year (Greenpeace, 2012). China after the USA (3 million tonnes) is the second largest producer of E-waste, with an estimated 2.3 million tonnes generated annually (Xin, 2012). By the year 2020, it is estimated that E-waste from computers in China will have grown by 200-400% and mobile phones will increase by 700%, while in India, computer waste is predicted to rise by 500% and E-waste from mobile phones will jump 1800 percent (Herat and Agamuthu, 2012; IMRB International, 2010).

2.3.2 E-waste Collection and Disposal

E-waste is a complex cocktail of hazardous and non-hazardous waste, which requires specialized collection, treatment and disposal (Bowcock, 2011). An efficient E-waste collection system ensures reuse, recovery, recycle and careful handling to avoid damage or breaking components that contain hazardous substances (UNEP, 2008). The following are some of the collection and disposal methods employed in various parts of the world.

2.3.2.1 E-waste collection and Disposal in United States

Currently, the U.S. E-waste collection and disposal focuses on two main methods: (i) E-waste collected as MSW and disposal in landfills and (ii) E-waste collected for recycling in US or exported (Kahhat et al., 2008).

Landfill Disposal

The US is the global leader in E-waste generation, more than 4.6 million tonnes of it entered U.S. landfills in 2000, and that amount was projected to grow fourfold in the next few years (USEPA, 2009). Between 2003 and 2005, approximately 80–85% of the E-waste ready for end-of-life management ended up in U.S. landfills (Kahhat et al., 2008; USEPA, 2008). This implies at the end-of-life most electronics are in discriminately thrown in trash bins where the E-waste is collected as MSW.

Whether E-waste disposed of in landfills is a threat or not to the environment and human health, the fact is there are major benefits that can be realized from reuse and recycling and thus discourage the disposal of E-waste via landfill (USEPA, 2008). Table 2.2 shows the E-waste retirement estimates by management method in the U.S. for the years 2003, 2004 and 2005. The results showed that 80% of all E-waste ended up in landfill disposal or incineration and only 20% was recycled.

Table 2.2: E-waste retirement estimates in US by management method (metric tonnes)

Year	Recycled		Landfill		Incinerated		Total	
2003	315.5	20%	1234.9	78%	35.1	2%	1585.5	100%
2004	326.5	20%	1281.9	78%	36.5	2%	1644.8	100%
2005	343.8	20%	1353.7	78%	38.5	2%	1736.0	100%

Source: (Kahhat et al., 2008; USEPA, 2008)

Recycling

Of the 3.16 million tonnes of E-waste generated in the U.S in 2008, only 430,000 tonnes or 13.6 % was recycled, the rest was trashed in landfills or incinerators. The year before in 2007, 3.01 million tonnes was generated and E-waste recovery rate then was also at 13.6% (USEPA, 2009). These figures compared to the results shown in Table 2.2 show a reduction in recycling within the US, this could be connected to exportation of E-waste to developing counties.

The Basel Action Network (BAN) and the Silicon Valley Toxics Coalition (SVTC) estimated that up to 80% of the U.S. E-waste initially collected for recycling purposes is being exported to developing countries for informal recycling procedures (Shelton, 2010). Millions of tonnes of US scrap electronics each year are shipped to developing countries i.e. China and Pakistan for recycling because of cheap labor and low standards of environmental protection (Priyadharshini & Meenambal, 2011)

2.3.2.2 E-waste collection and Disposal in Europe

The European Union has adopted a number of community level regulations related to E-waste, that are intended to "preserve, protect and improve the quality of the environment, protect human health and utilize natural resources prudently and rationally" (EU, 2003).

In January 2003, the European Commission-WEEE Directive (2003) adopted regulations related to five categories: (1) EEE product design, (2) E-waste collection, (3) E-waste recovery, (4) E-waste treatment and treatment financing and (5) EEE user awareness. The main considerations of the Directive included the recovery, recycle and reuse of E-waste. The regulation aimed to raise awareness of end-of-life factors during product design (EU, 2003; Lundgren, 2012).

These factors include dismantling of parts and recyclability of materials, proper collection systems that support separate collection of e-waste to reduce disposal in common municipal waste streams, and best practices for treatment, recovery and recycling of E-waste (Kahhat et al., 2008; Priyadharshini & Meenambal, 2011).

In addition, according to the type of E-waste, producers should comply with the minimum recovery rates (70–80% by weight) and “component, material and substances reuse and recycling” rates (50–80% by weight). Also, distinctions are made depending on the source of the E-waste: private household or non-private household, historical products or new products (Deubzer, 2011; EU, 2003).

In August 2012, European Commission-WEEE Directive (2003) was updated and approved by the European Parliament. The updated directive significantly strengthens a range of E-waste regulations and imposes new targets that will require member states to collect 45 percent of electronic equipment sold for approved recycling or disposal from 2016, rising to 65 percent of equipment sold or 85 percent of electronic waste generated by 2019, depending on which goal member states choose to adopt (EU, 2012; Herat & Agamuthu, 2012; Murray, 2012; UNEP, 2012).

European Parliament states (under the new regulations) better processing will help to recover more valuable raw materials and prevent harmful substances going to landfill. “The best recycling techniques should be used and products should be designed to be recycled more easily,” (ENS, 2012). In addition, under the updated directive all Member States of the EU must increase their collection of E-waste, whether or not they already meet the current flat-rate target of four kilograms per person per year. The current target represents about two million tonnes per year, out of an estimated 10 million tonnes of E-waste generated per year. Currently, the total amount of E-waste collected and appropriately treated is higher than the target at about one third of all the electrical and electronic waste generated across the European Union (EU, 2012; ENS, 2012).

2.3.2.3 E-waste collection and Disposal in Japan

E-waste collection and disposal in Japan follows E-waste Laws that require manufacturers and importers to take-back end-of-life electronics for recycling and waste management and are meant to ensure separation of E-waste from the MSW stream (Widmer et al., 2005; Kahhat et al., 2008).

The "Home Appliance Recycling Law", enacted in 1998 and fully enforceable by 2001, requires producers or importers to recycle four types of household E-waste: televisions, refrigerators, washing machines and air conditioners. In addition, consumers pay an end-of-life fee that covers part of the recycling and transportation expenses (Chung & Murakami-Suzuki, 2008; Herat & Agamuthu, 2012). The fees paid by consumers are between US$ 23 and US$46 (US$ 1 = JPY 107) that covers the recycling fee and an additional US$ 4 to US$ 19 (US$ 1 = JPY 107) collection fee to cover the transportation of the product to designated collection sites. The law also, obligates retailers to collect and transfer discarded products from consumers (Kahhat et al., 2008).

In April 2001, Japan began compulsory recycling of business personal computers (PCs) and expanded the requirement to residential PCs in the summer of 2003 with the "Law for Promotion of Effective Resource Utilization" (Chung & Murakami-Suzuki, 2008; Herat & Agamuthu, 2012; Kahhat et al., 2008). The system was initially managed by local authorities, but for PCs sold after October 2003, manufactures grouped in the PC3R Promotion Center are responsible for collection and recycling or reuse of computers (Kahhat et al., 2008). Computers under the PC recycling program have a "PC Recycling Mark" and include an invisible non-refundable recycling fee in the sale price, so no additional charges are required. However, for products purchased before October 2003 and with no mark, customers will need to pay a collection and recycling fee that ranges from US$ 29 to US$40 (Chung & Murakami-Suzuki, 2008; Kahhat et al. 2008).

2.3.2.4 E-waste collection and Disposal in South Korea

In 2003 South Korea enacted the Extended Producer Responsibility (EPR) Law which required local manufacturers, distributors and importers of consumer electronics such as air conditioners, TVs and PCs to achieve official recycling targets or face financial consequences (Kahhat et al., 2008). The local manufacturers, distributors and importers are required by law to set up an account with the government to deposit recycling funds, which are refundable in proportion to the actual volumes of waste recycled (Chung & Murakami-Suzuki, 2008). Manufacturers and importers can either outsource their waste recycling activities to industry cooperatives and professional recycling companies or establish their own recycling facilities to meet the EPR requirements. Retailers and suppliers are also required to collect and transport used equipment for free if the customer purchases a similar product (Kahhat et al., 2008).

In 2003, the year the EPR program was first introduced in South Korea, approximately 70% of E-waste was collected by producers. Furthermore, that same year, 12% of collected E-waste was reused, 69% was recycled, and the remaining 19% went to landfills or incinerators (Kahhat et al., 2008).. By sector South Korean local government collects an estimated 40% of the total collected E-waste and producers and retailers collect about 50% (Kahhat et al., 2008).

2.3.2.5 E-waste collection and Disposal in China

China's legislative process on the E-waste management is slow. A detailed article on defining the producers' and consumers' responsibilities, collection and recycling target, specific financial and subsidy plan is non-existent. Furthermore, trying to use one standard policy to implement the E-waste management for various regions and provinces in China is difficult, which has different economical and social situation across the country (Lundgren, 2012; Schluep et al., 2009). The current E-waste recycling system developed spontaneously and haphazardly in China and still lacks a coherent, overall strategy encompassing financially viable, environmentally benign and safe management methods (Li et al., 2012).

A study by the E-waste Civil Action Network, a Beijing NGO, revealed that convenience is the first priority most people take into consideration when disposing of their used electronic products (Li et al., 2012). Without convenient well established channels for the public to recycle E-waste, most people choose either to store or dispose of their discarded electronics together with other household trash. An estimated 60 percent of Chinese consumers, however, choose to sell the devices to reclaim waste collectors or secondhand markets, which are easily found in some neighborhoods (Xin, 2012). Discarded computers and other high-end appliances are then sent by truck to unlicensed workshops for illegal processing, mainly in Zhejiang, Hebei or Guangdong provinces, all hubs for the underground disposal market (Xin, 2012; Herat & Agamuthu, 2012;). Chinese informal recyclers use primitive methods to extract valuable material from the components, which poses great risk to the workers' health and local environment. In most cases basic working protection (i.e. gloves, masks) and medical insurance is non-existent (Schluep et al., 2009). For example, in Guiyu, recycling operations consist of toner sweeping, dismantling electronic equipment, selling computer monitor yokes to copper recovery operations, plastic chipping and melting, burning wires to recover copper, heating circuit boards over honeycombed coal blocks, and using acid chemical strippers to recover gold and other metals (Leung et al., 2006). Not all activities are related to recovery; some include open burning or dumping of unwanted E-waste.

For the formal recyclers of the national pilot projects, technologies and equipments from the developed countries are preferred and imported, which is not totally appropriate for China's local situation. Formal infrastructures like pyrometallurgical smelters for PWBs recycling, high-standard landfill for hazardous waste and incineration plants for specific waste streams are not fully installed (Schluep et al., 2009).

2.3.3 E-waste Treatment Technologies – Recycling, Reuse and Recovery

The composition of electronic waste consists of diverse constituents such as ferrous and non ferrous metals, glass, plastic, electronic components and various hazardous elements and compounds. While bulk materials such as iron, aluminum, plastics and glass account for over 80% of the weight, valuable and toxic materials are found in smaller quantities but are still of high importance (EMPA, 2009). Therefore, the major approaches or technologies used to treat E-waste are aimed at reducing the concentration of hazardous chemicals and elements through decontamination or dismantling, recycling and recovery of items of economic value and finally disposing E-waste fractions through either incineration or landfilling (UNEP, 2007).

2.3.3.1 Dismantling and Segregation

Manual dismantling and segregation is the first and more traditional way to separate hazardous materials from recyclable materials. In a pre-sorting process, the incoming electronic waste first is separated into the different categories, which are to be handled separately in the dismantling and segregation process. The dismantling process itself is performed with simple tools such as screwdrivers, hammers and tongs (EMPA, 2009; UNEP, 2007). Examples of manual dismantling and segregation of E-waste is shown in Plates 2.1 - 2.4.

Plate 2.1: Dismantling and segregation of computer parts in the formal recycling and most developed countries (source: Construction Week, 2011)

Plate 2.2: Dismantling and segregation of smaller PC part in formal recycling and most developed countries (source: The Hindu, 2011)

Plate 2.1: Dismantling of electronic parts in the informal recycling and most developing countries (source: Earth 911, 2013)

Plate 2.4: Dismantling CTR Monitor part in informal recycling and most developing countries (source: As You Sow Foundation, 2013)

Dismantling and segregation process can also be performed mechanically. Typical components of a mechanical dismantling plant are crushing units, shredders, magnetic separators and air separators (EPMA, 2009).

2.3.3.2 Refurbishment and Reuse

According to Microsoft (2008), the most environmentally responsible way to deal with discarded Personal Computers (PC) is to refurbish them so they can be reused. These refurbished PCs increase access to information technology for underserved populations that might not otherwise be able to afford a PC. The United States is the primary source of used PCs imported to a number of developing countries i.e. Peru, China and Pakistan (Kahhat & Williams, 2009; Lundgren, 2012).. Analysis of shipment value revealed that 87-88% of imported used computers had a price higher than the ideal recycle value of constituent materials (Kahhat & Williams, 2009). Therefore, the official trade in end-of-life computers is driven by reuse as opposed to recycling (Kahhat & Williams, 2009; Lundgren, 2012).

There are over 1,000 organization in 60 countries that are part of the Community Microsoft Authorized Refurbishers (Community MAR) programme (Microsoft, 2008). Through Community MAR, Microsoft provides genuine operating system (OS) and office productivity software at nominal cost to Refurbishers. The refurbished PC's with up-to-date software are sold at little or no cost to schools, non-profit organization or developing countries (Microsoft, 2008). In Colombia, the government has an initiative called "Computadores para Educar" translated "Computers for Schools" with the aim to supply public educational institutions (mainly schools) with information technology (IT), through the refurbishment and maintenance of computers (USEPA, 2012).

The approach to refurbish and send for reuse in less fortunate communities maybe seen as honourable since it helps bridge the technological divide between the rich and poor or developed and developing countries. However, the approach can also be argued as, developed countries merely shifting the burden of E-waste to developing countries because sooner than later these refurbished electronics will reach end-of-life and the burden of disposal then falls on to the less fortunate or developing countries. Considering the limited technology in developing countries and the crude method used in E-waste recovery and recycling, the environmental and human risk is far reaching (Lundgren, 2012). However, E-waste that cannot be refurbished and reused can still be dismantled and certain composite parts can be reused for other purposes or kept for spare parts and the remaining parts sent for recycling. This saves valuable raw materials, as well as the energy and water used in manufacturing process. Plates 2.5 – 2.8 show some uses of end-of-life electronics.

Plate 2.5: Discarded Apple Mac monitor reused as fish tank (source: Treehugger, 2012)

Plate 2.6: CRT monitor covers reused as waste paper bins (source: Treehugger, 2012)

Plate 2.7: Discarded keyboard reused as a pen/pencil holder. *(Source:* Earth 911, 2013)

Plate 2.8: General Motors and ABB – prototype back-up power storage unit that reuses discarded Chevrolet Volt batteries (Source: General Motors, 2012).

According to General Motors (GM) based on the company's new innovation in reuse technology, in the future it might be a common sight to see a group of homes or small commercial buildings being powered by an "off the grid" system made up of repackaged Chevrolet Volt batteries (See Plate 2.8). General Motors and ABB have partnered to produce a prototype back-up power storage unit that repackages five used Chevrolet Volt batteries into a modular unit that becomes an uninterruptable power supply and grid power balancing system (General Motors, 2012).

2.3.3.3 Recovery and Recycling

The benefit of carrying out manual dismantling is that after the disassembly of the equipment, it can be easily grouped into different fractions in its complete and intact forms, which could reduce the separation effort in the recovery and enable the reclaiming of the reusable parts. Notwithstanding eco-efficiency in manual dismantling most recycling process in the formal sector or developed countries use a mechanical process (EMPA, 2009; ITU, 2012).

In industrial large scale operation mechanical processing is used to obtain concentrates of recyclable materials from E-waste and also to further separate hazardous materials. Mechanical processing facilities include crushing units, shredders, magnetic- and eddy-current- and air-separators. The mechanical recycling process uses multiple stage shredding steps to reduce the E-waste in size. The different metal fractions are then extracted from the shredded E-waste using a magnetic belt to remove ferrous metals followed by an eddy current separator which removes non-ferrous metals. Using optical sorting, eddy current separation or vibration separation density separation among other methods, the non-ferrous material is further separated into aluminum, brass, copper etc. The remaining non-metallic material is then processed in order to separate circuit boards and wire, while the other remaining fractions are landfilled (EMPA, 2009; UNEP, 2007; ITU, 2012).

The next step in E-waste recycling is recovery. The three main technologies used in recovery are: (i) Pyrometallurgy (ii) Hydrometallurgy and (iii) Electrometallurgy.

i. **Pyrometallurgy** has been a traditional technology for recovery of precious metals from waste electronic equipment. The technology uses high temperatures that include smelting and roasting to chemically convert the feed materials and separate metals and impurities into different phases so valuable metals can be recovered. Pyrometallurgy involves heating in a blast furnace at temperatures above 1500°C to convert waste to a form that can be refined. The oxide waste is heated with a reducing agent, such as carbon in the form of coke or coal; the oxygen of the metal combines with the carbon and is removed in carbon dioxide gas. The waste material in E-waste (non-metallic parts) is called gangue; it is removed by means of a substance called a flux which, when heated, combines with it to form a molten mass called slag. Being lighter than the metal, the slag floats on it and can be skimmed or drawn off. Examples of technical hardware are submerged lance smelters, converters, rotary furnaces, electric arc furnaces etc (Cui & Zhang, 2008; UNEP, 2007).

ii. **Hydrometallurgy**, sometimes called leaching, involves the selective dissolution of metals from their waste. Hydrometallurgical processing techniques use strong acidic or caustic watery solutions to selectively dissolve and precipitate metals. Metal is recovered by electrolysis of the solution. If metal obtained from waste still contains impurities, special refining processes are required (Cui & Zhang, 2008; UNEP, 2007). In the informal sector or developing countries, precious metal recovery from E-waste usually employs wet chemical leaching processes using hazardous substances e.g. cyanide and nitric acid (Schluep, 2010).

A combination of unit operations from the different groups is often necessary to achieve optimal and efficient metal recovery. Biometallurgical methods using bacteria or fungi are in a research stage only and are currently not applied in the E-waste recycling chain (UNEP, 2007). Examples of informal and formal recovery methods are shown in Plates 2.9 - 2.10 and Plates 2.11 – 2.12 respectively.

Plate 2.9: Informal Recycler cooks PC motherboards over solder to remove chips and valuable metals – China (source: Blogs Indium, 2012)

Plate 2.10: Bonfires of electronic trash to scavenged valuable metals especially copper – Ghana (source: source: Blogs Indium, 2012)

Plate 2.11: State of the art Smelter for E-waste recycling plant (source: Gold International Machinery, 2012).

Plate 2.12: State of the art Refining Unit for E-waste recycling plant (source: Gold International Machinery, 2012).

Table 2.3 compares efficiency and sustainability of crude precious metals recovery technologies used in informal sector to those used in the formal sector.

Table 2.3: Efficiency and Sustainability of Gold Recovery by Technology (India)

Informal Sector	Formal Sector: State of Art Smelter
• only about 20% gets recovered • More than 60% loss due to the manual dismantling process • More than 50 % loss due to the wet-chemical leaching process • Emissions are dramatic: up to 400x the European thresholds	• Recovery rate of up to 95% Plus other metal, e.g. palladium, silver, copper etc, • High – tech off-gas control and treatment system

Source: (Schluep, 2010)

2.3.3.4 Treatment and Disposal

The final stage in E-waste Treatment Process is treatment/disposal that comes after recovery/recycling. After recovery/recycling the remaining E-waste is disposed of in landfill sites or sometimes incinerated (expensive), CFCs are treated thermally, PCB is incinerated or disposed of in underground storages, Mercury is often recycled or disposed of in underground landfill sites

- **Landfilling**: is one of the most widely used methods for E-waste disposal after the recovery or recycling process. In landfilling, trenches are made on the flat surfaces. Soil is excavated from the trenches and the waste material is buried in it, which is then covered by a thick layer of soil. Modern techniques like secure landfill are provided with some facilities like, impervious liner made up of plastic or clay, leachate collection trough that collects and transfer the leachate to wastewater treatment facility. The degradation processes in landfills are very complicated and run over a wide time span (EMPA, 2009).

- **Incineration**: It is a controlled and complete combustion process, in which the waste material is burned in specially designed incinerators at a high temperature (900-1000^{o}C). The advantage of incineration of E-waste is the reduction of volume of waste and the utilization of the thermal energy content of combustible materials. Some plants recover iron from the slag for recycling. By incineration some environmentally hazardous organic substances are converted into less hazardous compounds. However, the disadvantage of incineration is the emission into the atmosphere of harmful substances that escape flue gas cleaning and the large amount of residues from gas cleaning and combustion. E-waste incineration plants contribute significantly to the annual emissions of cadmium and mercury. In addition, heavy metals not emitted into the atmosphere are transferred to slag and exhaust gas residues and can reenter the environment on disposal. Therefore, E-waste incineration will increase these emissions, if no reduction measures like removal of heavy metals are taken (EMPA, 2009).

2.3.4 E-waste Trans-boundary Movement

The market for electrical and electronic equipment is increasing rapidly in developing countries or countries with economies in transition. The thirst for electrical and electronic equipment is giving an equally rapid rise in E-waste (Bowcock, 2012; Puckett, 2011). Currently, most used or second-hand electronic equipment, including

E-waste is exported from developed countries to developing countries, typically for re-use, repair or recovery of materials (Kahhat & Williams, 2009; Puckett, 2011). It must be noted that more often than not exports of E-waste take place to avoid costs of more diligent environmentally sound management at home, by allowing the waste management to be transferred to weaker economies that are not likely to possess the infrastructure, technology and societal safety nets to prevent harm to human health and the environment (Puckett et al., 2002; Widmer et al., 2005). Figure 2.4 below depicts the transboundary movement of E-waste around the world. Most of the E-waste from U.S is exported to China, South America and Africa and that from Western Europe is exported to Eastern Europe, Africa and Asia. Within the Asian regions large E-waste generators such as South Korea and Japan export their E-waste mainly to China and Australia mainly ships it E-waste to Asia.

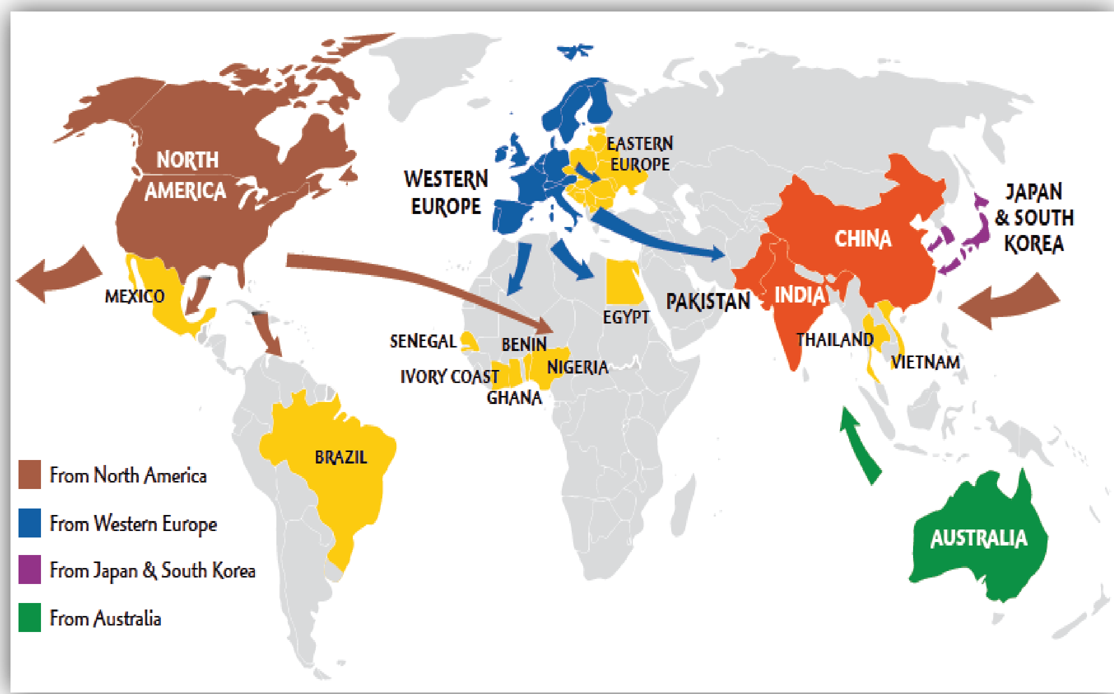

Figure 2.4: Transboundary Movement of E-waste *(Source: Lundgren, 2012)*

The transboundary movement of E-waste is practically impossible to quantify with a large component of this trade being concealed from the official radar (Laha, 2011). The Basel Action Network (BAN) and the Silicon Valley Toxics Coalition (SVTC) estimated that up to 80% of the U.S. E-waste initially collected for recycling purposes is being shipped to developing countries for informal recycling procedures (Kahhat et al. 2008; Puckett, 2011; Shelton, 2010). The E-waste is exported mainly to China and other East Asian countries for cheap recycling and final disposal or due to the low labour costs and less stringent environmental regulations in this region (Puckett, 2011).

According to a US Interagency Task Force on Electronics Stewardship (2011), a 2005 US Industry Report estimated recyclers export 74% of used electronics for reuse, refurbishing and recycling and much of this ends up in Asia, China to be specific. While the Chinese banned the import of E-waste back in 2000, the business has gone underground, creating a lucrative industry that profits from the dismantling of electronics and reselling of reclaimable materials (Barnes, 2011). The continued transboundary movement of E-waste has been linked to the complicit role of many US electronics-recycling centres, notorious for accepting waste under the pretence of responsible recycling and then quietly shipping it to China, India, Africa and other parts of the world, without proper oversight (Barnes, 2011; Lundgren, 2012).

The magnitude of illegal transboundary shipments of E-waste is growing; estimates from 2010 indicate that 40% of E-wastes from Europe alone are being exported to Asia and Africa (Olowu, 2012). In Ghana, Greenpeace documented E-waste from

USA, Japan and European which included brand names: Sony, Philips, Nokia, Microsoft, Canon, Dell and Siemens. Furthermore, labels revealed the equipment came from a range of organizations such as Den Kongelige Livgarde – the Danish Royal Guard and the US Environmental Protection Agency (Greenpeace, 2008).

Exporting hazardous electronic waste is illegal in the European Union, but the US Environment Protection Agency classifies it as legitimate recycling (Greenpeace, 2008). The export of used electronics to developing countries is often hailed as "bridging the digital divide" but, all too often this simply means dumping useless equipment on the poor. One estimate suggests that 25-75% of "second hand goods" shipped into Africa cannot be reused (Greenpeace, 2008). In Nigeria, estimates of the number of computer imports found to be non-functioning range from 75 to 95 percent of each shipment (Olowu, 2012).

2.3.4.1 International Legislation and Initiatives in E-waste Management

a. **The Basel Convention** on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was adopted in 1989 to regulate the transboundary movements of hazardous wastes and the provision of a scheme that would ensure the environmentally sound management of hazardous wastes. The Basel Convention does not place a ban on the transboundary movements of hazardous wastes and their disposal; it only attempts to control the latter. The convention requires an exporter/importer to seek and get the consent of the States through which the waste is to go through, as well as, that of the State of import before the actual movement of the hazardous waste. The

Ban Amendment to the Basel Convention (Basel Ban) seeks to strengthen the convention by prohibiting export of hazardous waste for any reason from Organization of Economic Cooperation and Development (OCED) member States to non-OECD States. The Basel Ban is yet to come in force (Azuka, 2009; BAN 2010; Basel Convention, 2011; Puckett, 2011).

After the Basel Convention Conference of Parties in 2006 hosted in Nairobi, Kenya, the conference adopted the Nairobi Declaration on the environmentally sound management of electrical and electronic waste in which parties declare that they will raise awareness, promote the exchange of information, promote clean technology and green design for electronic products and to recognize the Basel Convention as the main global instrument to guide the environmentally sound management of hazardous E-waste (Ecroignard, 2008).

b. **The Asian Network for Prevention of Illegal Transboundary Movement of Hazardous Wastes:** was established in 2003 at the initiative of the government of Japan and aims at facilitating the exchange and dissemination of information on transboundary movements of hazardous wastes and selected used/secondhand equipments among North-east and South-east Asian countries. The initiative also assists participating countries in formulating appropriate legislative response to such movements under each country's system, taking into consideration necessary procedures required by the Basel Convention. The Network also provides useful information that can contribute to capacity building of the participating countries for the implementation of the Basel Convention. The Participating countries are Brunei Darussalam, Cambodia, China, Hong Kong SAR (China), Indonesia, Japan, Republic of Korea, Malaysia, Philippines, Singapore, Thailand and Vietnam (Ministry of Environment-Japan, 2013).

c. **The StEP (Solving the E-Waste Problem):** started in 2004 after the publication of a book by the United Nations University investigating the environment and computers. The aim of the international initiative is to analyse the problem of electronics and the environment and create a dialogue on the issues. Together with members from various UN organizations, industry, governments, international organizations, NGOs and the science sector, the StEP initiative seeks to establish sustainable approaches to handling E-waste (Bowcock, 2011).

d. **The E-Stewardship:** is a project of the Basel Action Network. In 2003 BAN launched the e-Stewards Pledge programme, which certified recyclers that use only globally-responsible, safe and environmentally-friendly means to process E-waste. They must abide by a number of criteria for E-waste management, including:

- No disposal in landfill or incinerators.
- No prison labour
- No export to poor communities.

Without appropriate national or international legislature this community-led action aims to set a market incentive for recyclers to use only environmentally friendly methods (Bowcock, 2011).

2.3.5 Malaysian Perspective

According to the Malaysian Director General of the Environment, electrical and electronic waste (E-waste) is one of the emerging issues that have caught the attention of various parties including policy makers, non-governmental organizations (NGO) and the general public globally. This growing concern is due to the ever increasing volume of E-waste being generated resulting in activities such as collection, dismantling and disposal of E-waste that has caused environmental pollutions and adverse impact to public health (Malaysia DOE, 2010).

2.3.5.1 E-waste Policy

E-waste in Malaysia is regulated under the Environmental Quality (Scheduled Wastes) Regulations 2005, the inclusion of E-waste in the 2005 regulation is to adequately control the management of these wastes generated in the country as well as to enable Malaysia to disallow importation of used electrical and electronic equipment either for refurbishment or recovery only for short term usage, following which the equipment is disposed of (Malaysia DOE, 2010).

E-waste is categorized as scheduled wastes under the code SW 110, First Schedule, Environmental Quality (Scheduled Wastes) Regulations 2005. The SW 110 wastes are defined as wastes from the electrical and electronic assemblies containing components such as accumulators, mercury-switches, glass from cathode-ray tubes and other activated glass or polychlorinated biphenyl-capasitors, or contaminated with cadmium, mercury, lead, nickel, chromium, copper, lithium, silver, manganese or polychlorinated byphenyls (Malaysia DOE, 2010).

E-wastes are also listed as code A1180 and code A2010 under Annex VIII, List A of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal 1989. Malaysia being Party to the Basel Convention, the importation and exportation of such wastes must follow the procedures of the Convention. Importation or exportation of the wastes require prior written consent from the Department of Environment as mandated under Section 34B(1)(b)&(c), of the Environmental Quality Act, 1974 (Malaysia DOE, 2010).

2.3.5.2 E-waste Generation

Going by the Malaysia DOE classifications they are two categories of E-waste generators that are the Industrial Sector and Non Industrial (Households, Business and Institutions). The DOE reported that the amount of E-waste generated from the industrial sector in 2009 was 134,036 tonnes, 163,340 tonnes in 2010 and drop to 152,722 tonnes in 2011. The combined E-waste generated by households, businesses and institutions sector amounted to 652,909 tonnes in 2006, 695,461 tonnes in 2007 and 688,068 tonnes in 2008 (DOE Malaysia, 2012). The Malaysia

DOE (2011) projected that Malaysia E-waste generation would reach 1.1million tonnes per year by 2020 (Figure 2.5). However, an E-waste inventory for Malaysia was conducted in 2008 with funding from Ministry of Environment – Japan found that Malaysia generated 1.1 million tonnes of E-waste in 2008 (Herat & Agamuthu, 2012). Therefore, current E-waste generation levels have already surpassed the 10 year projections made by DOE in 2008.

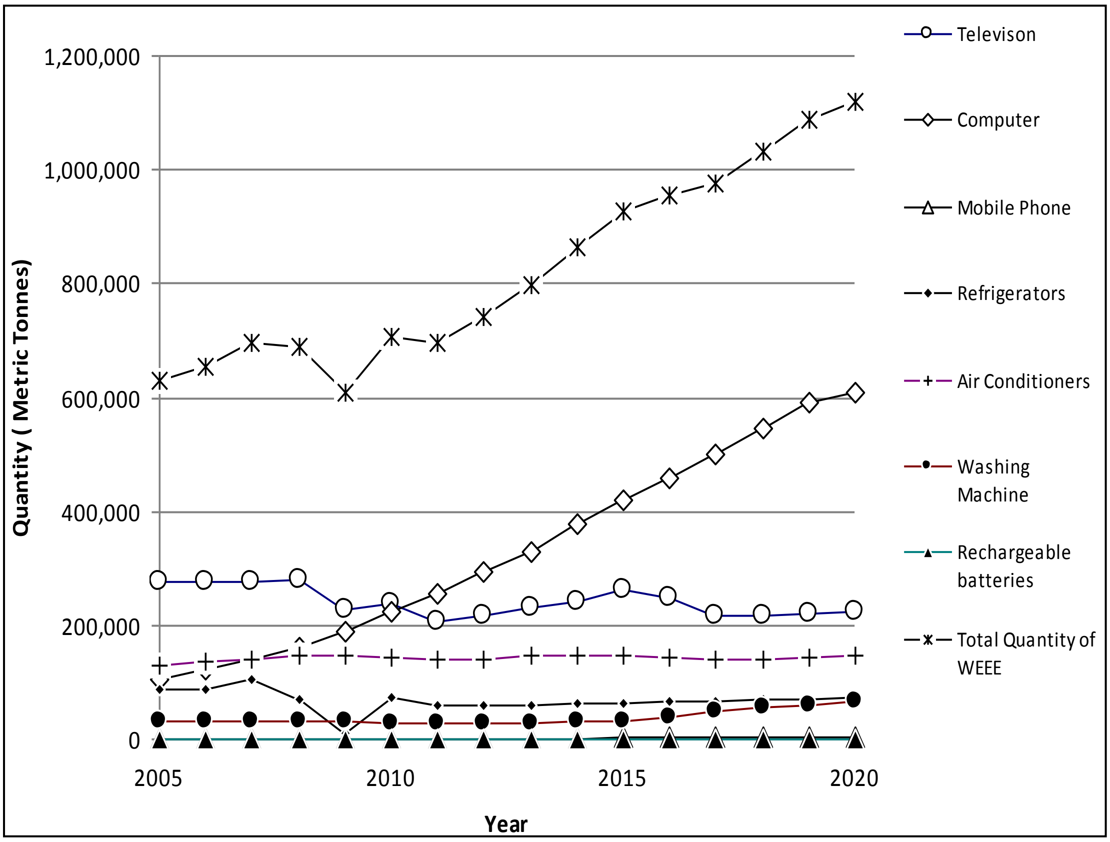

Figure 2.5: Estimated quantities of E-waste generation (Malaysia DOE, 2011)

2.3.5.3 E-waste Collection

In 2007, 400 recycling bins were placed by DOE at 200 sites such as supermarkets, universities, government offices around the Klang Valley and all DOE State Offices for the public to deposit used electronics (Malaysia DOE, 2011). However, this exercise was limited to used cell phones, cell phone batteries and other accessories, computers and their accessories, as well as television sets can be taken to the E-waste collection centres. At the end of 2007, DOE collected two tonnes of discarded batteries which were sent to local recycling facilities. The E-waste collection centres are managed by the solid waste concessionaires or local authorities (Malaysia DOE, 2011). In 2011, a pilot study on the collection of E-waste from households was carried in Penang, the outcomes were considered to be useful as inputs for the drafting of regulations on take-back for E-waste in Malaysia (Malaysia DOE, 2012).

In a study in Shah Alam by Kalana (2010) suggests E-waste produced by multinational electrical and electronic manufacturers and other large companies is collected by licensed E-waste contractors. The E-waste generated from individual households is not commonly collected, and only a limited number of E-waste contractors collect E-waste from the public. The reason for this Kalana (2010) says is because E-waste generated by household is in small amounts. Industry initiatives such as the "Recycle PC" campaign launched in 2005, spearheaded by the Association of the Computer and Multimedia Industry of Malaysia (Pikom) and Alam Flora Sdn Bhd a waste management company witnessed the collection 816 computers and peripherals between March 10 and April 30, 2005. This included 147 CPUs, 194 computer monitors, 428 printers, and 47 miscellaneous PC components (Hawari & Hassan, 2010). In general, electrical and electronic waste from industries and commercial centres are properly collected and sent to the recovery facilities, however collection of E-waste from household needs to be improved (Malaysia DOE, 2012)

2.3.5.4 E-waste Recycling

Under Environmental Quality (Scheduled Wastes) Regulations 2005, E-waste can only be transported by licensed contractors and delivered to licensed recycling facility or disposed off in the centralized scheduled waste treatment and disposal facility in Bukit Nanas, Negeri Sembilan. The E-waste shall be recycled and recovered at prescribed or licensed premises while disposal must take place at prescribed premises only and must be carried out in an environmentally sound manner (Kalana, 2010; Malaysia DOE, 2010)

Currently in Malaysia there are 155 E-waste recovery facilities licensed by DOE of which 135 facilities are "partial recovery" and another 20 facilities are "full recovery" (Malaysia DOE, 2012). The recovery facilities have a total capacity to handle 24,000 tonnes of E-waste a month (Kamar, 2012). The residue from the partial recovery facilities are still considered as scheduled wastes and need to be sent to full recovery facilities (Malaysia DOE, 2012).

The study by Kalana (2010) also revealed that the preferred methods of E-waste disposal by Shah Alam residents are storage and sale as secondhand equipment at 48% and 37%, respectively. Only a fraction of electronic waste (22%) finds its way to recycling facilities as there is no efficient take-back scheme for consumers. Most of the public do not know where and how to dispose of E-waste in a proper manner. Consequently, they resort to disposing electronic waste together with other household wastes. Therefore, a lack of proper management or collection method for

E-waste generated by household means large cumulative quantities of E-waste in Malaysia is indiscriminately disposed of into the MSW stream and ends up in landfill or dump sites posing great environment risk (Kalana, 2010).

2.3.5.5 E-waste Management Technologies

The main technology employed to recover E-wastes in terms of precious metals in Malaysia is still limited to wet chemical processes and electrolysis (Malaysia DOE, 2011). In most recycling facilities in Malaysia the two recovery techniques come after:

- **Dismantled and Segregated**: E-waste is manually dismantled and segregated into a “waste stream” of plastic, ferrous metal and electronic scrap.

- **Compacting**: Depending on the specialization of the recycler, E-waste in the form of plastic, paper packaging and ferrous metals are crushed and compacted for easy handling and transportation before being shipped to other recyclers that specialize in such materials.

- **Crushing:** Electronic components that may contain precious metal are stripped down and then crushed into smaller pieces in preparation for the chemical process.

- **Electrolysis:** The electronic pieces are dumped into an extraction tank where mineral i.e. copper, gold and other precious metals are separated by electrolysis.

- **Separator:** The processed electronic parts are crushed into powder for further processing. For example the Cycle Trend Industries recovery centre has separator facilities that separate dry materials according to weight or size, right down to particles as small as 1µm. The centre uses linear, circular and elliptical, vibrating and gravity separators depending on the material being processed.

2.3.5.6 E-waste Trans-boundary Movement in Malaysia

Malaysia is party to the Basel Convention on the Transboundary Movements of Hazardous Waste and Their Disposal 1989 and subscribes to the requirements of the Convention on the exportation and importation of electronic waste. Therefore, the transboundary movement of scheduled waste requires a prior written approval from the Director General of DOE and follows the Guidelines for the Classification of Used Electrical and Electronic Equipment in Malaysia as published in 2008 and amended in 2010 to facilitate the management of E-waste (Malaysia DOE, 2010):

- The guidelines spell out the category and characteristics of E-waste and the requirements of the importation of Used Electrical and Electronic Equipment for direct reuse;

- Used Electrical and Electronic Equipment (UEEE) older than 3 years is not allowed to be imported. This is to stop the importation of obsolete IT equipment;

- Importation of E-waste for recovery and disposal is not allowed;

- Starting from 2011, consideration for exportation of E-waste for recovery is only given on the case-to-case basis since there are already recovery facilities established in Malaysia to process and recover useful materials from E-wastes. Malaysia will only allow the exportation of E-wastes for recovery overseas, if the local recovery facilities do not have capability and capacity to carry out such activity and before DOE can allow E-wastes to be exported. The E-wastes generator/exporter must submit proof. The exportation of E-wastes for final disposal is totally not allowed (Malaysia DOE, 2011).

In the Asian region the main E-waste recycling markets are China, India and Pakistan. The region receives transboundary shipments of E-waste from all over the globe (USA, Europe, Australia, and Middle East) and intra-regional movement from OECD countries i.e. Japan and South Korea (Figure 2.6). Malaysia sits in the centre of what can be said is the transit route for E-waste from every corner of the globe making it a likely target for receiving and dispatching E-waste en route to various recycling sites around the region.

Figure 2.6: Transboundary Movement of E-waste – Asian Region (Source: BAN, 2010).

Malaysia is also the final destination for some transboundary movement of E-waste. According to Malaysia DOE despite the stringent regulation of transboundary movement of E-waste Malaysia's illegal importation of E-waste still persist. Between 2008 and 2011, Malaysian authorities' intercepted 38 containers containing E-wastes and returned them to the exporting countries (Malaysia DOE, 2012). And in 2009, a Malaysian company manager was sentenced to a one day jail and was fined RM 180,000.00 (US60, 000) for illegally importing of E-waste (Malaysia DOE, 2012).

Malaysia is also party to the regional initiative of The Asian Network for Prevention of Illegal Transboundary Movement of Hazardous Wastes.

2.3.2.7 E-waste Awareness

A review of various literature shows that there seems to be a gray area in what the level of knowledge on E-waste is in the country. A study by Kalana (2010) in Shah Alam reveals that the level of public awareness on E-waste as a recyclable material is relatively high. However, what is lacking is the knowledge on what to do or where to take the E-waste let alone the environmental and health risks associated with unsound management of E-waste. Kalana's view is also shared by Harman Shah et al., (2012).

Kalana goes on to state, most of the households do not know where and how to dispose of electronic waste in a proper manner consequently, they resort to storing the E-waste in their premises or dispose of it together with general waste (MSW). Therefore, there is a general lack of public knowledge on the environmental and health risk, this is a view also shared by the Minister of Natural Resources and Environment:

> *"I know some MPs who can't tell the difference. When you don't know, that's where the problem starts. People will dump food, wires, telephones and other items into rubbish bins."* Datuk Seri Douglas Uggah Embas – Natural Resources and Environment Minister (Yu, 2010)

There is however, an increase in awareness initiatives being undertaken by the government, non-governmental organization and private firm. The Department of Environment in Melaka will in 2013 launch a programme called Collection of E-*Waste 2013*. The aim of the initiative is to increase awareness on E-waste among the public, the DOE has since appointed Meriahtek (M) Sdn Bhd, Krubong Recovery Sdn Bhd and Victory Recovery Sdn Bhd to collect the E-waste at a few designated location (Federation of Malaysian Manufacturers, 2012). In 2011, a pilot study on the collection of E-waste from households was carried out in Penang, the outcomes are believed to be useful in promoting E-waste awareness (Malaysia DOE, 2012).

On 4th December 2010 The Malaysian National News Agency SIBU, reported members of the public in Sibu and Miri have become more aware of the importance of E-waste management, courtesy of E-waste recycling campaigns that were organized by Information Communication Technology (ICT) fair (Ling, 2010). The Association of the Computer and Multimedia Industry of Malaysia (PIKOM) together with the Department of Environment has embarked on an E-Waste Recycling Campaign with the aim of raising awareness on the need to recycle among the general public. Collection centres are located in Kuala Lumpur, Selangor, Putra Jaya and Pahang (Saleh, 2012).

2.4 E-waste Environmental and Health Risks

2.4.1 Health Impacts of E-waste

People at immediate risk of suffering from health complication associated E-waste are informal E-waste recyclers, especially in developing countries where worker are exposed to toxic or hazardous substances without any form of protective attire (Lundgren, 2012). Relatively small protective measures such as gloves and masks would easily make a big difference on the workers' health. Health risks are by no means only limited to E-waste recyclers as contaminants from E-waste enter the soil, water and air and can impact anyone who comes in contact with them (Table 2.4).

Table 2.4: Health Effects of E-waste Constituents

Source of E-Waste	**Constituent**	**Health Effects**
Solder in printing circuit boards, glass panels and gaskets in computer monitors	Lead (Pb)	Damage to the central and peripheral nervous system, kidney and blood system. Affects brain development in children.
Chip resistors and semi-conductors, batteries, toners	Cadmium (Cd)	Irreversible toxic effects to human health.
Relays and switches, printed circuit boards, fluorescent lamps, batteries	Mercury (Hg)	Accumulates in the kidney and liver. Cause neural damage.
Data tapes and floppy disks	Chromium (Cr)	Chronic damage to the brain. Respiratory and skin disorders due to bioaccumulation in fishes.
Cabling and computer housing	Plastic including PVC	Causes or aggravates asthma or bronchitis. DNA damage.
Plastic housing of electronic equipment and circuit boards	Brominated flame retardants (BFR)	Burning produces dioxin. It causes reproductive and development problems and immune system damage; interferes with regulatory hormones
Front Panel of CRT	Barium (Ba)	Disrupts endocrine system functions. Short term exposure causes muscle weakness, damage to heart, liver and spleen.
Motherboard	Beryllium (Be)	Carcinogenic (lung cancer). Inhalation of fumes and dust causes chronic beryllium disease or beryllicosis and skin diseases such as warts.
Batteries	Nickel (Ni)	Cause cancer of the lungs

Wiring in electronic and electrical devices	**Copper (Cu)**	**May amage liver, kidney and nervous system, and affecting protein metabolism in the brain causing Alzheimer disease.**
Batteries	Lithium (Li)	Corrosive to the eyes, skin and respiratory tract.
Chips, data storage disks	Aluminum (Al)	Affects brain and kidneys and may be associated with Alzheimer and Parkinson disease.

Source: (Chong, 2008; Lundgren, 2012; Tengku Hamzah, 2011)

2.4.2 Environmental Impacts of E-waste

Electrical and electronic equipment contain hazardous and toxic materials that cause environmental damage. For instance, Cathode Ray Tubes (CRT) contain significant amounts of lead; printed circuit boards contain plastic, copper, small amounts of chromium, lead, solder, nickel, cadmium and other heavy metals and another commonly disposed E-waste such a batteries contains lithium, cadmium and other heavy metal. These constituents of E-waste can contaminate soil, ground water and air, as well as pose great health to human being and other animals. The different E-waste disposal methods (incineration, open burning, landfilling) pose a variety of environmental impacts (Lundgren, 2012).

Incineration: is the process of destroying electronic waste through controlled burning. E-waste contains a cocktail of harmful substances; incineration is associated with a generating and dispersing contaminants and toxic substances into the atmosphere. This is especially true for incineration or co-incineration of E-waste that has not undergone prior treatment nor sophisticated flue gas purification. Studies of MSW incineration plants have shown that copper, which is found in printed circuit boards and cables, acts a catalyst for dioxin formation when flame-retardants are incinerated (EMPA, 2009). These brominated flame retardants when exposed to low temperature (600-800°C) can lead to the generation of extremely toxic polybrominated dioxins (PBDDs) and furans (PBDFs). Polyvinyl Chloride (PVC), which is found in E-waste in significant amounts, is highly corrosive when burnt and also induces the formation of dioxins that are released into the atmosphere (EMPA, 2009).

Open burning: is the most commonly used technique by informal E-waste recyclers in mineral recovery. In open burning E-waste is burn at relatively low temperatures and releases many more pollutants than in a controlled incineration process. Releasing of these pollutants contributes damage of the ozone layer, cause global warming and other negative atmospheric conditions (EMPA, 2009). . However, in open burning especially in informal recycling the immediate threat is posed on the recyclers, the inhalation of open fire emissions can trigger asthma attacks, respiratory infections, while chronic exposure to open fire emissions may lead to diseases such as emphysema and cancer (EMPA, 2009).

Landfilling: most of the world's E-waste finds itself in landfill whether by design or through indiscriminate disposal (EMPA, 2009). Landfills whether sanitary or open dumping produce leachate. The leachate often contains heavy metals and other toxic substances which can contaminate ground and water resources. Even state-of-the-art landfills which are sealed to prevent toxins from entering the ground are not completely leakage free in the long-term (EMPA, 2009). Of the constituent of E-waste mercury, cadmium and lead are among the most toxic leachates. Mercury, for example, will leach when certain electronic devices such as circuit breakers are destroyed and if it gets into a water supply, can accumulate in living organisms, including fish, mammals, and humans (Smith, 2008). Lead has been found to leach from broken lead-containing glass, such as the cone glass of cathode ray tubes from TVs and monitors. Other than leaching, vaporization is also other environmental concern in landfills with E-waste. For example, volatile compounds such as mercury or a frequent modification of it, dimethylene mercury can be released. In addition, landfills are also prone to uncontrolled fires which can release toxic fumes (EMPA, 2009).

The human and environmental risks posed by the ever growing E-waste stream can be minimized by producing less E-waste through the application of concepts i.e. green chemistry and design for environment. For example the development substitutes toxic raw materials with less toxic materials as in the case of Pb-free soldering or the development of halogen-free BFRs in electronics manufacture (Herat, 2011).

2.5 E-waste Management in Institutions of Higher Learning

E-waste is increasingly a growing problem for universities that are trying to reduce their environmental footprint. Institutes of higher learning are considered the cradle of research and development and are often held to higher standards for citizenship and ecological stewardship than are corporations. For these reasons, universities are shifting towards greater control and oversight regarding where their E-waste is directed and how it is disposed. The following are case studies of E-waste management initiatives pursued by various institutions of higher learning around the world (Bonhomme et al., 2008).

2.5.1 E-waste Management Strategy – University of Sao Paulo, Brazil

The University of Sao Paulo (USP) is the largest public university in South America. It has seven campuses and 80,000 students, faculty, and staff. The University has an arsenal of 15,593 printers, 37,420 microcomputers, and 3,998 network devices in use at any given time and it is estimated that 10% of which are taken out of service every year i.e. approximately 4,000 computers, 400 network devices, and 1,600 printers ((Bonhomme et al., 2008). The USP Electronic Computing Center (CCE) administration believed that the current system for dealing with E-waste at USP was insufficient and invited a team of experts from Massachusetts Institute of Technology, MIT Sloan School of Management – Sustainable Business Lab (S-Lab) to analyze the opportunities for transforming the system. The S-Lab team described the E-waste situation at USP prior to the project as backlog of electronics residuals from CCE and other places, an ad-hoc approach to E-waste processing and disposal and no upstream solution of E-waste management (Bonhomme et al., 2008).

After extensive site visit and interviews with various members of each CCE department S-Lab established the main challenges faced by CCE in E-waste management were:

- CCE had no centralized place for storage and sorting of E-waste.

- No sustainable end destination had been identified for certain E-waste (i.e. fiber optics).
- USP's online inventory system, Mercurio, did not currently reflect electronics inventory or E-waste generated.
- There were insufficient incentives or system in place to encourage re-use of electronics.
- There is no legislation in place in Brazil for E-waste treatment/processing nor a value-chain prepared to sustainably scrap the E-waste.
- CCE and USP's Agency for Innovation (Agencia Inovação) would need to be prepared for a larger role in centralizing electronics inventory and E-waste management

S-Lab Recommended Strategy Proposed to CCE-USP

After a review of the challenges the S-Lab team determined that in order to create buy-in among the stakeholders whose participation would be imperative, it was necessary to share a big-picture vision of where the future of E-waste management at CCE could lead. Therefore, the team presented a short-, medium-, and long-term outlook:

a. *Short-Term Target*: Collect and sort all current E-waste at CCE by Sustainability Week

b. *Medium-Term Target*: Create a system in equilibrium between E-waste generation and sustainably processing and use the CCE Success Case to expand to all USP Campus (1-2 years)

c. *Long Term Target*: Envision and work towards an optimal stage when e-waste regulation is in place and USP has a system-wide e-waste management solution—perhaps involving leasing and "take back" policies (Future)

2.5.2 Managing ICT Waste – Delta State University, Nigeria

A study by Ogbomo et al., (2012) on managing ICT waste at Delta State University Abraka, Nigeria established that there is inadequate management of ICT E-waste at the institution. The study concluded that this was as a result of lack of awareness and policy on ICT E-waste management and some other contributory factors. Furthermore, the study revealed that Nigeria has fast become a dump site for E-waste from all over the world thereby exposing the environment and citizenry to grave health and environmental degradation.

In recommendation the study proposed among other things that, university should draw up a policy on ICT waste management, the Government should make proper legislation to guide against indiscriminate influx of ICT waste into the country or place an outright ban on the importation of used electronics and conduct nationwide enlightenment campaign to educate the populace on the dangers associated with E-waste.

2.5.3 Reducing E-waste – University of Sydney, Australia

In 2006 the University of Sydney piloted an E-waste collection exercise at the main Camperdown and Darlington campuses. A total of approximately 20 metric tonnes of electronic materials were collected and in 2007 the program was extended to other University of Sydney campuses (University of Sydney, 2012). Since then around 120 metric tonnes of E-waste has been collected and stripped down to its various material components and recovered and recycled for reuse (University of Sydney, 2012).

2.5.4 E-waste Policy – Macquarie University, Australia

Macquarie University recognizes the significant role that electronic equipment plays in its activities across campus and the subsequent E-waste that comes with obsolete electronic equipment. Thus, the university has put in place an E-waste Policy focused on environment and sustainability in the workplace with regard to the disposal of unwanted and/or obsolete equipment. Electronic Waste is disposed of regularly using the University's service request system; the items are collected by security and taken to a storage facility, and then picked up by a recycler. The E-waste policy has diverted large amount of electronic waste that would have been destined for landfills by recycled 25 metric tonnes of electronic waste in 2008 and over 40 metric tonnes in 2010 (Macquarie University, 2012).

2.2.5 E-waste Policy – Griffith University, Australia

The Griffith University in Queensland has embarked on E-waste management initiatives where the university Assets Team co-ordinates the disposal of university equipment in accordance with the asset disposal policy, the university endorses the use of “Greenbox” for disposal and eCycling. The Greenbox is a large container, designed and used for free public disposal and recycling of E-waste. The Greenbox is ISO 14001 certified and has a zero landfill policy that ensures E-waste disposal is ethically handled. Griffith University is also a member of Solving the E-waste Problem (StEP), an initiative founded by various UN organizations and coordinated by the United Nations University. StEP's overall aim is to develop strategies to solve the e-waste problem based on a sound scientific basis (Griffith University, 2013).

2.5.6 Sustainable Electronics Initiative – University of Illinois, USA

In 2012, the Sustainable Electronics Initiative (SEI) at the University of Illinois ran an International E-waste Design competition that focused research and design in the area of product designs for environmentally responsible computing and entertainment. The entries were ideas that prevent E-waste generation through life-cycle considerations (E-Waste Prevention Category) or that incorporate E-waste components into a new and useful item (E-Waste Reuse Category). A total of 19 entries were submitted; 10 in the Reuse category and 9 in the Prevention category and attracted international entries from United States, Canada, Bangladesh, Canada, Chile, Ireland Turkey, Hong Kong and India (Illinois Sustainable Technology Center, 2012).

2.5.7 Secure and Responsible Recycling – Kansas University, USA

The Kansas University (KU) provides university departments a secure and responsible way to recycle obsolete, unused or unwanted electronic equipment or data storage devices. All sensitive and proprietary university or customer information is completely removed from computer and thumb drives before disposing of them in an environmentally safe manner; this service is only for university-owned equipment. Recycled items may include computers, servers, external drives, mobile phones, tapes, printers, monitors, fax machines etc. Electronic equipment from research labs may also be recycled once the department removes any hazardous materials or chemicals (Kansas University, 2013).

2.5.8 Collection Days Event – Indiana University, USA

The Indiana University Office of Sustainability (IUOS) has recognized the health and an environmental issue associated with E-waste disposal and has decided to take the lead on developing better E-waste practices. Through the Indiana University Collection Days Event, IUOS in coordination with Apple Inc. has collected and properly recycled over 635 metric tonnes of electronic waste (Knudsen, 2010).

The first Indiana University Collection Days Event in 2009 collected in a total of 378 metric tonnes of E-waste, this event took place on the Indiana University Bloomington (IUB) and Indiana University-Purdue University (IUPU) campuses and involved many different campus entities and was deemed a huge success. The following year 2010 saw another successful E-waste Collection Days programme at Indiana University Bloomington and Indiana University South Bend where approximately 272 metric tonnes of E-waste were collected (Knudsen, 2010).

2.5.9 Sustainable Campus – Auburn University, USA

The Auburn University (AU) prides itself in being a sustainable campus and recognizes that electronic waste if thrown in a landfill could leach lead, mercury or arsenic into the ground, air or water and plastic, metal and glass components would never degrade and would remain in the landfill forever (Harding, 2012).

2.5.10 Environmental Stewardship – Columbia University, USA

The Columbia University Environmental Stewardship Office has an E-waste collection programme where the university picks up old electronics equipment for a small charge at the Morningside Campus, and for free at the Medical Center. The electronic equipment is taken to a central area where it is collected by Northeast Lamp Recycling; in 2011 the University recycled over 36 metric tonnes electronics and the Morningside Campus recycles approximately 4.5 metric tonnes of this hazardous or potentially hazardous waste, including lamps and other mercury-containing devices, each year (Columbia University, 2012).

Table 2.5 shows E-waste generation by some select institutions of higher learning from different part of the world.

Table 2.5 Generation of E-waste by Universities around the World

Institution	Country	Year	Total generation (kg)	Campus Population	Per Capita Generation (kg)
University of Sao Paulo,	Brazil	2007	124,000	80,000	1.55
University of Sydney	Australia	2007	20,000	40,000	0.50
Macquarie	Australia	2010	40,000	40,000	1.00

University					
Auburn University	USA	2011	62,000	30,000	2.07
Columbia University	USA	2011	40,500	31,000	1.31
Indiana University	USA	2010	272,000	57,000	4.80

Chapter III

Research Methodology

3.1 Introduction

In this Chapter the research methodology employed in the study is documented. The chapter highlights the location of survey sites; the study design, the population and sample. Furthermore, the instruments used in data collection, including methods implemented to maintain validity and reliability of the instruments and data analysis methods are described.

3.2 Research Approach and Design

In this research a quantitative approach was followed. Quantitative Research is a formal, objective, systematic process to describe and test relationships and examine cause and effect interaction among variables. Surveys may be used for descriptive, explanatory and exploratory research. A descriptive survey design was used in this study, this involves collecting numerical data to test hypotheses or answer questions concerning current status which is then conducted either through self-reports collected through questionnaires, interviews or through observations. In this research primary information was collected through self-administered questionnaires and interviews of various stakeholders. The descriptive survey was employed because it provides an accurate portrayal of characteristics, e.g. behaviour, opinions, beliefs, awareness and knowledge level of a particular individual, situation or group.

3.3 Study Area

The Klang Valley of the Central Region of Malaysia covers Kuala Lumpur and its surrounding areas has a total of five (5) Public and (24) Private universities (MoHE, 2013). In the study 14 (4 public and 10 private) universities were approached and invited to take part, eight of the selected universities responded positively and subsequently took part in the study (Table 3.1). The location of the eight selected universities is shown in Figure 3.1.

Table 3.1 List of Selected Universities in the Klang Valley

No.	Name	Institution Type	Population (Staff + Students)
1.	University of Malaya (UM)	Public	29,000
2.	Universiti Putra Malaysia (UPM)	Public	34,000
3.	HELP University College (HUC)	Private	11,000
4.	Mahsa University	Private	8,000
5.	SEGi University College	Private	12,000
6.	Universiti Kuala Lumpur (UniKL)	Private	15,500
7.	Universiti Tun Abdul Razak (UniRAZAK)	Private	900
8.	Universiti Tunku Abdul Rahman (UTAR)	Private	4,000

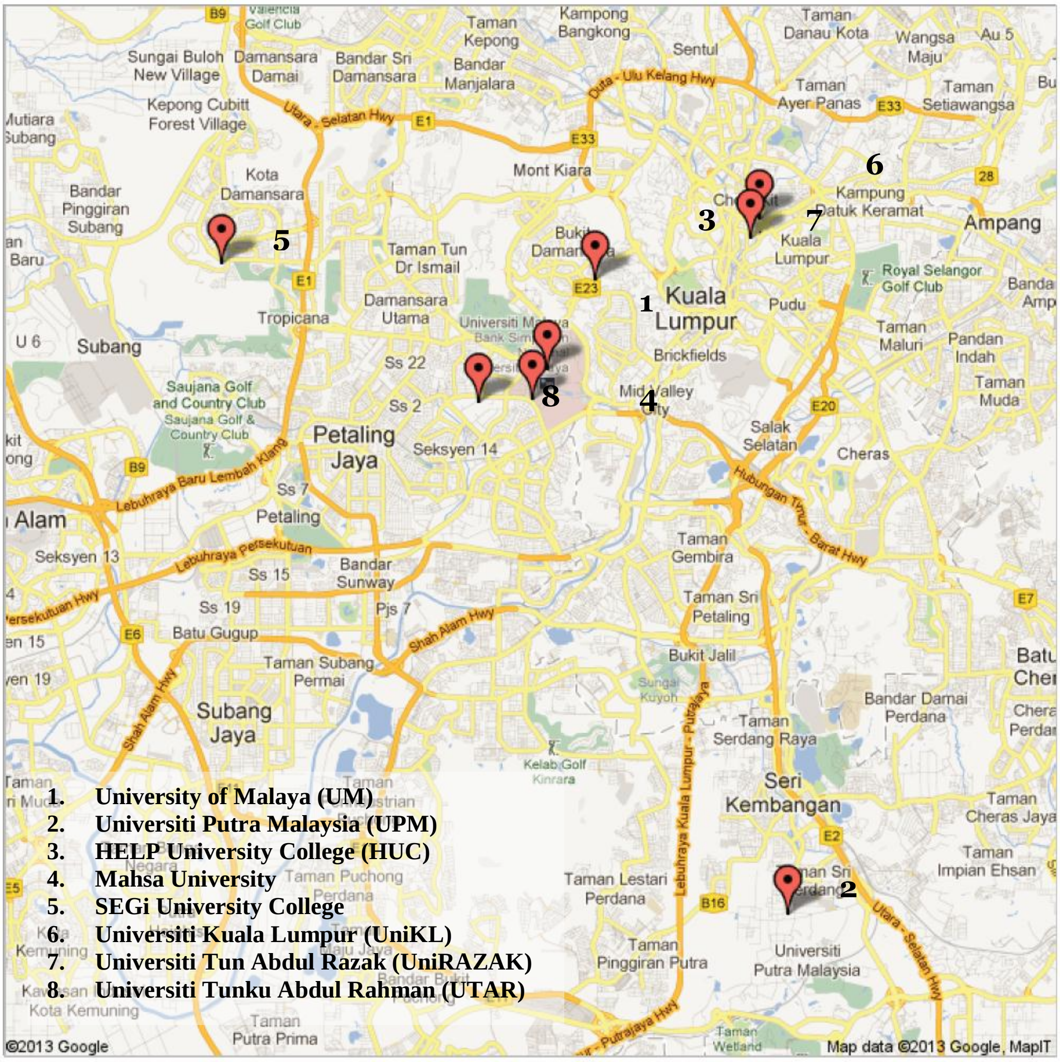

Figure 3.1 Location Map for Selected Universities (Source: Google Map, 2013)

3.4 The Study Population and Sample

The sample size is a key feature of any experimental study in which the objective is to make assumption about a population from a sample. Based on three values such as maximum error of estimate, the population standard deviation, and the degree of confidence, the sample size can be generated to provide answers representative of the population. The sample size was derived from the maximum error of estimate and calculated from the mathematical formula (Equ 3.1):

$$n = \left(\frac{z_{\alpha/2} \cdot \sigma}{E}\right)^2$$ ---------Equ 3.1: Sample Size Equation

The study target population is university communities that include students, academicians and auxiliary staff. The estimated study population size is 110,000 and using the statistical method of simple random sampling (SRS) a sample size of 400 respondents was interviewed. Simple random sampling method was used because of the homogeneity of the study population. The sample size was derived at using online sample size calculating software based on mathematical formula for sample size (Table 3.2).

Table 3.2 Sample Size Calculator

Population Size	110,000
Margin of Error (Confidence Interval)	5%
Confidence Level	95%
Sample Size	**400**

(Source: www.raosoft.com/samplesize.html)

3.5 Data Collection

In the primary data collection, questionnaires and face-to-face interviews were used. The questionnaires were in two sets (i) Institutional Survey Questionnaire (ii) Public Survey Questionnaire (Appendix A and B respectively):

i. **Institutional Survey Questionnaire:** targeted at university administrators or departments responsible for E-waste management in the respective selected institutions. This included university departments in charge of maintenance of electrical and electronic equipment such as computers, printers, photocopiers, laboratory equipment etc. The questionnaire was divided into three sections; Section (a) Institutional Information – name, type and category of institution; Section (b) Respondent Information – name, designation, department and contact details; Section (c) E-waste Management – covered E-waste generation (stock piles), collection, disposal, recycling and also included assessment of purchasing practices for EEE and any other waste management policies at the institution, (Appendix A).

ii. **Public Survey Questionnaire:** targeted general university community (student, lecturers, and support staff). The questionnaire was designed to evaluate university's community knowledge and awareness on E-waste. The questionnaire was divided into two sections; Section (a) General Information – included demographic variables such as gender, nationality, race, age, occupation, education level and residence and Section (b) focused on the respondents E-waste knowledge. This included E-waste generation, disposal method and perceptions. Respondents were not required to fill out their names to ensure confidentiality and anonymity, (Appendix B).

Both Public and Institutional questionnaires were translated into Bahasa Malaysia (BM) to enable respondents with little or no command of English to complete the questionnaire as accurately as possible. In addition to the institutional questionnaire, face-to-face interviews with university staff were conducted to acquire greater understanding of the asset management policies of the institution i.e. procedure followed in the disposal of end-of-life electronics. It must be noted that of the selected eight universities, UTAR had a change of heart and was later unwilling to take part in the institutional survey but however, responded favourably to the public survey allowing the interview of students and university staff.

3.5.1 Data Collection Procedure

Initial contact with stakeholders was made via email and phone calls. However, responses were very slow. A more proactive approach was employed using the official letter from University of Malaya. The researcher physically went to institutions and requested audience with relevant institution authorities. This approach proved successful and stakeholders were more than cooperative in person and in some cases went out of their way to administer questionnaires on behalf of the researcher.

In the administration of public survey, the researchers first sought permission from university authorities to conduct the survey, thereafter the university's community was engaged at different location in the university i.e. offices, faculties, bus stop, residence, restaurants, library, recreation halls, walkways etc. In many instances there was assistance with distribution and collection of questionnaires from colleagues and university staff at the various universities.

3.6 Reliability and Validity

3.6.1 Reliability

Reliability of the data collection instruments was tested using internal consistence. The "*Internal consistency reliability*" measures how well an instrument addresses different constructs and delivers reliable results by measuring two different versions of the same item within the same test (MacCrae et al., 2011; Williams, 2006). In this study, Cronbach's Alpha was used to measure internal consistence reliability. Cronbach's Alpha gives a score of between zero and one, with 0.7 generally accepted as a sign of acceptable reliability. The research instrument scored 0.85 on Cronbach's Alpha, which is well above the acceptable (0.7) reliability (Santos, 1999).

3.6.2 Validity

The validity of a questionnaire is the degree to which the instrument measures what it is intended to measure. To achieve content validity, questionnaires included a variety of questions on respondents' knowledge/awareness about E-waste and its management. Questions in the instrument were based on information gathered during the literature review to ensure that they were representative of what respondents should know about E-waste. To further ensure content validity, questions in the questionnaire were formulated in simple language and translated into Bahasa Malaysia for clarity and ease of understanding.

3.7 Pre-test of Questionnaires

A pre-test of the data collection instruments was carried out before distribution to stakeholders. A total of 15 respondents were randomly selected and administered the initial questionnaires. Respondents were requested to make note of any questions they had difficulty understanding and any other inconsistencies in the instrument they observed. After pre-testing, corrections to the instruments were made to simplify language used and questions were rephrased to ensure ease of understanding.

3.8 Data Analysis and Modeling

After the data was collected it was organized and analyzed. In the material flow analysis model used in this research computer software STAN 2.5 was employed. STAN (subSTance flow ANalysis) 2.5 is a software that facilitates performing material flow analysis (= modeling and quantifying material flows and stocks) significantly (IWR, 2012). It supports graphical modeling of arbitrary complex systems (e.g. processes, companies, sectors, regions, countries, continents and global systems) as well as data management and calculation under consideration of units and data uncertainties. STAN also features data reconciliation, error propagation, gross error detection and displays the results in a clear Sankey style (visualization) (IWR, 2012). In both institutional and public survey data analysis SPSS 21 was used. Responses to the questionnaires were initially coded before data entry into the software (e.g. Gender: Male = 1, Female = 2; Nationality: Malaysian = 1, Non Malaysian = 2). Once all responses were entered into the database, the data was analyzed by using descriptive statistics, correlations and multiple response measurements. The analyzed data was presented in tables and graphs. Furthermore, Pearson's r and Test of Significance were used to determine the strength of the relationship/correlation between variables in the survey (Statistics Help for Students, 2008). Pearson's r shows the degree of correlation between two variables and ranges between 1 for high positive correlation to -1 for high negative correlation, with 0 indicating a weak relationship between the two variables. In determining correlation using Test of Significance (ToS) if the value is greater than 05 it can conclude that there is no statistically significant correlation between two variables and when the value is less than or equal to 0.05 it can concluded that there is a statistically significant correlations between two variables (Statistics Help for Students, 2008).

3.9 Flow Chart for the Research

Figure 3.2 represents the procedures that will be followed in the execution of the research.

Figure 3.2: Process Flow of the Research

Chapter IV

Results and Discussion

4.1 Introduction

This study carried out quantitative and descriptive research to explore various aspects related to E-waste management in institutions of higher learning in Klang Valley. Eight institutions took part, two public universities (University of Malaya (UM) and Universiti Putra Malaysia (UPM)) and six private universities namely Help University, Mahsa University College, Segi University, Universiti Kuala Lumpur (UniKL), Universiti Tun Abdul Razak (UniRazak) and Universiti Tunku Abdul Rahman.

The research data collection was aimed at determining the amount of E-waste generated in institutions of higher learning and the management policies, mechanism or practices in place to manage this E-waste generation as well as determining the level of E-waste knowledge and awareness among the general university populace i.e. students, lecturers, support and staff.

The method of data collection and data analysis used in the research have been discuss in Chapter III (refer to section 3.5). In this chapter, the research findings are analyzed and discussed and furthermore used to formulate recommendations for environmentally sound management (ESM) of E-waste generated in or by institutions of higher learning.

4.2 E-waste Management in Selected Universities in the Klang Valley

Eight universities located in Klang Valley were approached and agreed to take part in the research however, only 7 universities subsequently took part. This is despite the UTAR administration having approved the request to take part in the survey but the department in charge of ICT equipment was unable to undertake the institutional survey therefore, yielding an effective response rate of 88% for this institutional survey.

The seven universities that took part include two public universities (UM and UPM) and five private universities (Help, Mahsa, Segi, UniKL and UniRazak). Other than ensuring both public and private universities were selected to take part in the survey the institutions were randomly selected. The two public universities are primarily research universities while the private universities are either comprehensive universities (offering various fields of study) i.e. Help, Segi and UniKL or focused universities e.g. Mahsa which is a medical university and UniRazak a boutique university which is focused on business, entrepreneurship and governance. This also gives a varied representation of E-waste management in institutions of higher in the Klang Valley.

Universities have many different types of electrical and electronic equipment used in the day to day running of these institutions. This includes ICT equipment i.e. computers, printers, copiers etc. or laboratory equipment i.e. refrigerators, ovens, incubators, various electronic meters etc. and teaching aids i.e. projectors, televisions, sound systems etc. Most of all this electronic or electrical equipment is considered E-waste when it reaches its end-of-life and thus categorized as hazardous waste under DOE regulations.

4.2.1 ICT Equipment Stock

The public universities UPM and UM were found to have the largest stockpile of desktop computers (includes CPU and monitor) at 10,190 and 9,776 units, respectively (Table 4.1). UPM and UM being public and research universities outweigh private institution in number of faculties, students and staff (Table 3.1) therefore, it is expected that these two institutions boast larger consignment of ICT equipment. The smallest stock of desktops was found at UniRazak with 240 units, this also because the institution is small with only 33 academic staff and 900 students at Kuala Lumpur City Campus (Table 3.1).

However, it was observed that laptops are the more preferred computer type in private institutions. This could be that private universities are limited for space and in many case have to rent the floor area in which they operate i.e. Help, UniKL, UniRazak and UTAR. Desktop computers are more or less fixed/stationary equipment and take up more space than laptops thereby, making laptops more preferable. UniKL has the largest consignment of laptops with 820 units followed closely by Help University with 800 laptops while smallest consignment of laptops was found at UniRazak with 20 units. Only Help University recorded a higher laptop to desktop stockpile ratio with 500 desktops to 800 laptops. Printers, plotters and photocopy machines (output devices) where grouped as one as most of these equipment have multifunction options i.e. they may come with scan, print, photocopy and/or fax functions. The largest consignment of ICT output devices is found at UniKL with 1,100 units and the smallest consignment of 16 units is found at Mahsa University. It is unclear why UniKL has such a large number of printers/copiers compared to the rest of the institution surveyed (Table 4.1).

Table 4.1: Total ICT Equipment Stock – 2012

Institution	Desktop PC	Laptop	Printer/Copier	Total
UM	9,776	377	186	10,339
UPM	10,190	442	239	10,871
Help	500	800	30	1,330
Mahsa	452	40	16	508
Segi	530	305	160	995
UniKL	3,200	820	1,100	5,120
UniRazak	250	20	40	310

4.2.2 ICT E-waste

The University of Malaya has the largest stockpile of discarded ICT E-waste among the selected institutions with 1,776 desktop computers and smallest collection was found at UniRazak with only 10 desktop computers on the institutions end-of-life electronics inventory. Both public universities recorded well over 1000 obsolete desktop computer unit while the private universities range only between 10 to 200 units. UniRazak has the lowest In Use/Discard desktop computer ratio at 24:1 while Help University has the highest ratio at 4:1 (Table 4.2).

Plate 4.1: Discarded ICT Equipment at UM

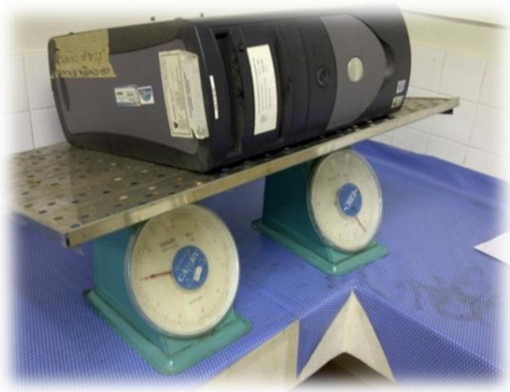

Plate 4.2: Plate 4.4 Measuring average weight of Desktop CPU at Solid Waste Lab - UM

Help University has the largest consignment of discarded/obsolete laptop computers with 300 units on the institutions E-waste inventory while UniRazak has no discarded laptops on record. Of all the institutions that recorded a inventory of discarded laptop, Segi University has the lowest In Use/Discarded laptop ratio at 60:1 and Help University has the highest ratio of 2:1 (Table 4.2).

UniKL has the largest consignment of discarded Printer/Copier on record with 100 units while both Help University and UniRazak have none of record. And of those institutions that reported having discarded Printer/Copier, Segi University has the smallest In Use/Discarded ratio at 15:1 and University of Malaya at 4:1 shows the highest ratio (Table 4.2).

In terms of In Use/Discarded comparison of ICT E-waste management, Segi University, UniKL and UniRazak performed better keeping the ratio at 20:1 or less for each type of electronic equipment while Help University did not fare so well in the In Use/Discarded ratio in some case recording as high as 4:1. Furthermore, between the two public universities, UPM performed better than UM in In Use/Discarded ICT waste ratio however, in terms of actual stockpile of ICT waste by sheer numbers UM tops the list.

Table 4.2: ICT E-waste Stockpile and In Use/Discarded Ratio – 2012

Institution	Desktop PC			Laptop			Printer/Copier		
	In Use	Discard	Ratio	In Use	Discard	Ratio	In Use	Discard	Ratio
UM	8,000	1,776	5:1	340	37	9:1	150	36	4:1
UPM	9,090	1,100	8:1	411	31	13:1	223	16	14:1
Help	400	100	4:1	500	300	2:1	30	-	
Mahsa	432	20	14:1	30	10	3:1	14	2	7:1
Segi	500	30	17:1	300	5	60:1	150	10	15:1
UniKL	3,000	200	15:1	800	20	40:1	1,000	100	10:1
UniRazak	240	10	24:1	20	-	-	40	-	-
Total	21,662	3,236	7:1	2,401	403	6:1	1,607	164	10:1

4.2.3 ICT E-waste by Quantity

The seven selected universities have a combined total of over 98.5 metric tonnes of ICT E-waste. The two public universities contributed over 82.8 metric tonnes of the total 95.5 metric tonnes of ICT E-waste. The larger part of this E-waste tonnage is contributed by desktop computer (90.8 metric tonnes), printer/copier (6.56 metric tonnes) and laptop (1.41 metric tonnes).

Plate 4.3 Measuring average weight of CRT Monitor at Solid Waste Lab - UM

Plate 4.4 Measuring average weight of Printer at Solid Waste Lab - UM

In the desktop computer category UM makes up more than half the tonnage with 49.7 metric tonnes and the lowest is UniRazak with only 0.28 metric tonnes. Under the laptop category Help University makes up 1.05 metric tonnes of the total 1.41 metric tonnes of laptop waste while UniRazak contributed nothing and under printer/copier category UniKL recorded 4.0 metric tonnes of total 6.5 metric tonnes while Help University and UniRazak both contributed nothing (Table 4.3). The University of Malaya has the highest per capita E-waste generation at 1.77kg and Mahsa University has the lowest per capita generation at 0.08kg.

Table 4.3: Quantities of ICT E-waste in the Selected Institutions (kg) – 2012

	Desktop PC	Laptop	Printer/ Copier	Total (kg)	Total Population	Per Capita (kg)
UM	49,728	130	1,440	51,298	29,000	1.77
UPM	30,800	109	640	31,549	34,000	0.93
Help	2,800	1,050	-	3,850	11,000	0.35
Mahsa	560	35	80	675	8,000	0.08
Segi	840	18	400	1,258	12,000	0.10
UniKL	5,600	70	4,000	9,670	15,500	0.62
UniRazak	280	-	-	280	900	0.31
Total	**90,608**	**1,411**	**6,560**	**98,579**	**110,400**	**0.89**

The overall average per capita E-waste generation for the selected universities is 0.89kg. Thus, the Klang Valley universities generally have a lower per capita E-waste generation compared to the global case studies i.e. University of Sao Paulo – 1.55kg, Indiana University – 4.8kg, Macquarie University – 1.0kg, Auburn University – 2.0kg (Bonhomme et al., 2008; Harding, 2012; Macquarie University, 2012). The reason for this could be that universities in developed countries such as USA and Australia replace electronic equipment more often than universities in developing countries i.e. Malaysia.

4.2.4 Value ICT E-waste by Quantity

A market survey of E-waste recyclers/traders that buy obsolete computers/printers found the best going price at RM3.00/kg depending on the condition of E-scrap while some recycler/traders will pay as little as RM0.50/kg or offer nothing other than collecting the E-waste. Based on the best price case scenario Table 4.4 shows the estimated worth of ICT E-waste stored for each of the seven selected institutions of higher learning. It was estimated that the annual ICT waste from the selected universities is worth RM295,735 (US$98,578). University of Malaya accounts for more than half of the total ICT E-waste stock at an estimated value of RM153,892 (US$51,297) while UniRazak’s inventory of ICT E-waste is only worth RM840 (US$280). Other than being a much smaller university than UM, UniRazak has a more streamlined electronic waste management system.

Table 4.4: Monetary Value ICT E-waste by Quantity – 2012

Institution	**Quantity (kg)**	**Estimated Value**	
		Malaysian Ringgit (RM)	US Dollar
UM	51,298	153,892.50	51,297.50
UPM	31,549	94,645.50	31,548.50
Help	3,850	11,550.00	3,850.00
Mahsa	675	2,025.00	675.00
Segi	1,258	3,772.50	1,257.50
UniKL	9,670	29,010.00	9,670.00
UniRazak	280	840.00	280.00
Total	**98,579**	**295,735.50**	**98,578.50**

In the worst case scenario this institutional ICT E-waste maybe given away to recyclers/traders for free although research has shown that when refurbished and sold as second hand products these used ICT electronics can fetch top dollar (Kahhat & Williams, 2009; Lundgren, 2012). Furthermore, if this ICT electronics cannot be refurbished it provides a source of raw material for the lucrative industry of electronic waste recycling (Barnes, 2011; Puckett, 2011).

In hindsight, institutions of higher learning that are storing huge stockpiles of hazardous electrical and electronic waste are sitting on a potential gold mine worth thousands of Ringgits/Dollars. Needless to say this E-waste is notorious for taking up large amounts of floor space in storage. Therefore, selling this E-waste may earn the institutions a few coins as well as getting rid of the storage consuming hazardous burden.

4.2.5 Mode of Purchase of ICT Equipment

The mode of purchase of ICT equipment is a factor worthy of note. Globally, there is a general growing emphasis on EPR when it comes to E-waste Management. Take-back is the most effective practice in EPR as it transfers the responsibility of E-waste disposal from the consumer/public onto the manufacturer. However, depending on the mode of purchase it may prove difficult to practice the take-back option e.g. if a computer is purchased in a local retail store, the retailer is not obliged to take-back the said computer from the customer once it reaches its end-of-life. Direct import of electronics also poses a challenge in practicing take-back by the consumer/end users as the manufacturer to whom to return the used electronics is based overseas thus shipping back the electronic waste would be considered transboundary movement of hazardous waste (Malaysia DOE, 2008). Therefore, the ideal mode of purchase for electronic equipment is though local manufacturers who also practice take-back as part of their EPR activities.

Findings of the survey show that all the selected institutions in the study purchased ICT equipment through local manufacturer/supplier and local retail store, only Mahsa University purchased ICT equipment from Local Retail Store thus posing a challenge when it comes to practicing take-back when the equipment has reached its end-of-life (Figure 4.1). Further investigation at Mahsa University revealed that to overcome this challenge of not having the take-back option with retail stores, end-of-life electronic equipment at the institution is sold to secondhand electronics dealers.

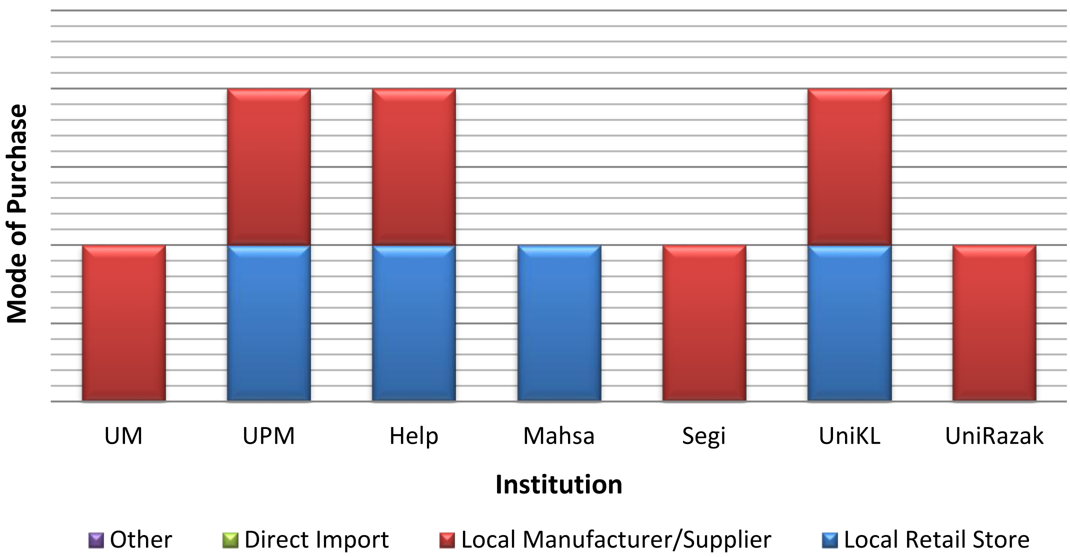

Figure 4.1: Mode of Purchase of ICT Equipment – 2012

Another method of acquiring ICT equipment that has proved successful to E-waste management in some universities is the option of leasing equipment as opposed to outright purchase. In this arrangement ICT equipment is leased for 2-4 years by the university from reputable brand name suppliers or manufacturers and returned thereafter to the manufacturer/supplier for upgrade, refurbished, recycling or disposal. Some renowned manufacturers found to be offering ICT equipment lease services to universities in the Klang Valley are Dell, Hewlett-Packard and Ricoh.

A comparison between the two public research universities (UM and UPM) shows that despite UPM having a larger consignment of ICT equipment than UM at 10,190 and 9,776 units respectively, UPM recorded a smaller In Use/Discarded equipment ratio than UM at 8:1 and 5:1, respectively. This can in part be attributed to UPM's policy of leasing 25% of its equipment while UM had nothing on record as leased (Table 4.5). The University of Sydney in Australia has embarked on reducing E-waste through lease purchasing policy of Electronic Equipment(University of Sydney, 2012). In the past, the institution purchased electronic equipment that gets stockpiled once obsolete; this policy now promotes the leasing of computer equipment, including a product take back service (University of Sydney, 2012).

Table 4.5: Leasing of ICT Equipment and In Use/Discarded Ratio – 2012

Institution	Percentage of Leased Equipment	Total No. In Use	Total No. Discarded	In Use Ratio/Discarded Ratio
UM	-	8,490	1,849	5:1
UPM	25%	9,724	1,147	8:1
Help	30%	930	400	2:1
Mahsa	-	476	32	15:1
Segi	-	950	45	21:1
UniKL	-	4,800	320	15:1
UniRazak	10%	300	10	30:1

4.2.6 Average Lifespan of ICT Equipment

The average lifespan of electronic equipment is important as it determines when or how soon electronic equipment is expected to reach its end-of-life and hence, become E-waste or E-scrap. The electronic equipment may reach its end-of-life as a result of being obsolete because it can no longer meet the users requirements for instance the equipment becomes incompatible with the latest software or programme. This is common with computers or electronic equipment which may reach its end-of-life as result of damage or wear and tear through ordinary usage. At the end-of-useful life electronic equipment pose the challenge of disposal in an environmental sound manner. Therefore, by knowing the average lifespan of ICT electronic equipment this information can be used in future planning on how to manage the resultant institutional E-waste.

The institutional survey found that ICT equipment for four of the selected universities (UM, UPM, Masha and UniKL) has an average useful lifespan of more than 5 years while the shortest average in-service life of 3 years was recorded by Segi University (Figure 4.2).

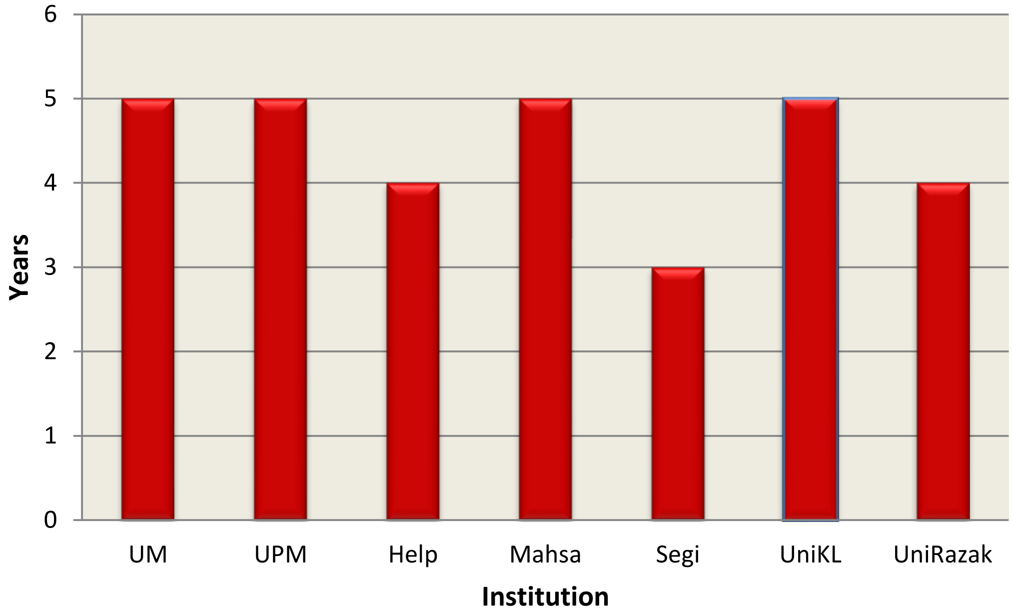

Figure 4.2: Average Lifespan of ICT Equipment

Therefore, Segi University generates ICT E-waste more frequently than any other of the surveyed institutions however; the institution does not store the E-waste but sells it to ICT equipment traders within a period of 3 months. Thereby, the university receives a token value for end-of-useful life equipment and also transferring the burden of E-waste disposal onto the trader. Industry experts estimate current average lifespan of to ICT electronics to be at 3-4 years for desktop PC, 5 years for monitors, 2 years for laptop and 3-5 years for printers/copiers and often it works out cheaper to buy a replacement printer than to replace consumables i.e. ink cartridges (Killick, 2007). At this rate of obsolesce it would be more prudent for universities to lease ICT equipment and thus reduce the responsibility of end-of-life electronic waste management. The advantage of leasing electronics can be seen through a comparison of UM and UPM. UPM practices a 25% lease option (Table 4.5) as a result UPM generated less E-waste compared to UM which does not lease any ICT electronics.

4.2.7 Management of End-of-Life ICT Equipment

The research also attempted to establish how universities deal with ICT equipment when it is no longer useful. Results of the survey show that all the selected universities initially place E-waste in storage, some for the short-term (3 – 6 months) prior to disposal while others store it for the long-term (2 year +) as a management option. The most practiced E-waste management option among universities is selling the waste to recycler or second-hand electronics traders/vendors; this was practiced by all institutions surveyed except Mahsa and UniKL (Figure 4.3). Selling of E-waste has two distinct advantages to the university, firstly proceeds of the sale add a little money to the university kitty and secondly it takes away the responsibility of managing E-waste from the institution.

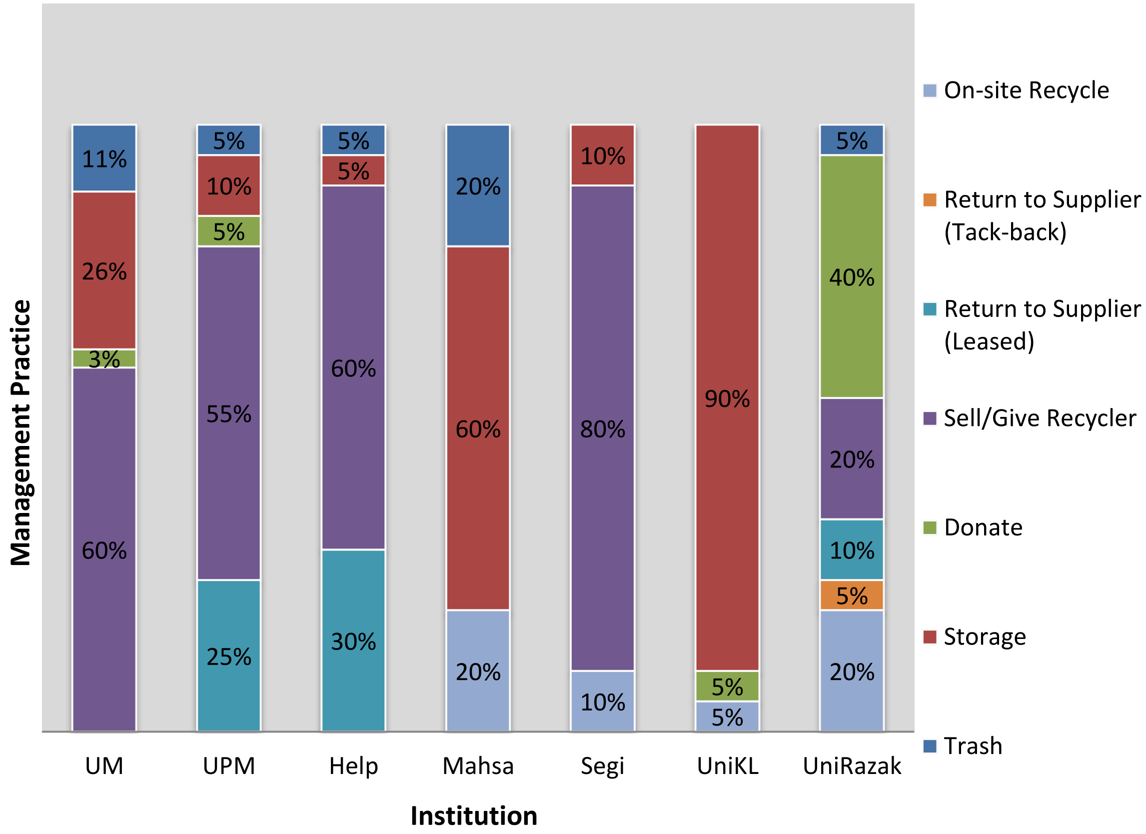

Figure 4.3 Management Practices for End-of-Life ICT Equipment – 2012

The second most practiced management option is storage of E-waste, UniKL stores 90% of the E-waste generated and Mahsa University keeps in storage up to 60% of the institutions E-waste. University of Malaya, Universiti Putra Malaysia, Segi University and UniRazak are the only institutions that donated their discarded ICT equipment to charity i.e. school, vulnerable groups or employees (Figure 4.3). The practice of donating used electronics to the less fortunate is considered honourable and enhanced the institution's image in terms of corporate social responsibility (CSR). However, the practice can also be argued that universities are merely shifting the burden of E-waste onto the recipient as such electronics are usually near their end-of-life and would not be useful for very long. However, for the universities which do give used ICT equipment to charity they "kill two birds with one stone" as they enhanced the institutions CSR image by donating used equipment to the underprivileged and also avoid the responsibility of ICT E-waste management.

A worrying method of ICT E-waste disposal practiced by all of the universities except Segi and UniKL is that of discarding E-waste in the thrash (MSW). The E-waste disposed includes among others obsolete printers, used printer/copier cartridges, monitors and various PC parts. Mahsa University discards 20% of its 0.65 metric tonnes into MSW, although this is significantly less compared to UM which discards 11% of its over 50 metric tonnes E-waste into MSW. The E-waste from universities enters the MSW stream and ends up in landfills or dump sites and poses grave environmental and human health hazardous as the components degrade or disintegrate releasing toxic constituents such as lead, nickel, beryllium, mercury, cadmium, chromium, copper, lithium etc (Table 2.4; Figure 4.3).

The only institution on record to be practicing the take-back of end-of-life electronics is UniRazak. Consumer electronics giants Dell, Hewlett-Packard and Samsung have a take-back program with UniRazak as part of the company's EPR portfolio. This means at the end-of-life of university ICT equipment it is returned to the manufacturer for disposal at no cost to the institution. Take-back is an efficient but underutilized E-waste management option available to universities. Electronics giant Toshiba Sales and Services Sdn Bhd and Tele Dynamics Sdn Bhd in collaboration with the Department of Environment (DOE), Shan Poornam Metals Sdn Bhd (official recycler) and a total of 14 selected retailers in the Klang Valley, Johor Bahru and Penang are providing voluntary take-back programme(Toshiba, 2013). The programme involves the take-back of electronic waste of products sold by Toshiba such as refrigerators, televisions, washing machines and computers. The participating retailers also accept E-waste material of other brands (Toshiba, 2013).

4.2.8 Material Flow Analysis for ICT E-waste

A material flow analysis (MFA) model for the selected universities in the Klang Valley was developed to investigate the flows of E-waste from purchase to disposal. The goal of the MFA is to increase the understanding of a studied system, which may lead to a better system control and management (Figure 4.4).

The material flow analysis shows that the selected universities have ICT equipment stock of over 777,799kg of which 679,220kg is 'in-use' stock and 15% (98,579kg) is obsolete or at the end of its useful life stock. Of the close to 100 metric tonnes of E-waste in the system 7.7% (7.5 metric tonnes) is discarded into the MSW stream. This practice of indiscriminate disposal of E-waste into MSW stream by universities is as a result of these institutions not having proper institutional E-waste management policy in place; this is further exacerbated by the low level of knowledge among university staff on environmental and human health hazards posed by E-waste (Figure 4.4). Thus, university staff tasked to manage E-waste disposal may throw E-waste into trash bin ignorant of the environmental damage this may cause.

Over half of the E-waste in the MFA at 52.2% (51,502kg) is either sold or given to recyclers (partial/full) who are responsible for its ultimate disposal in an environmentally sound manner or in accordance with relevant environmental law (Figure 4.4).

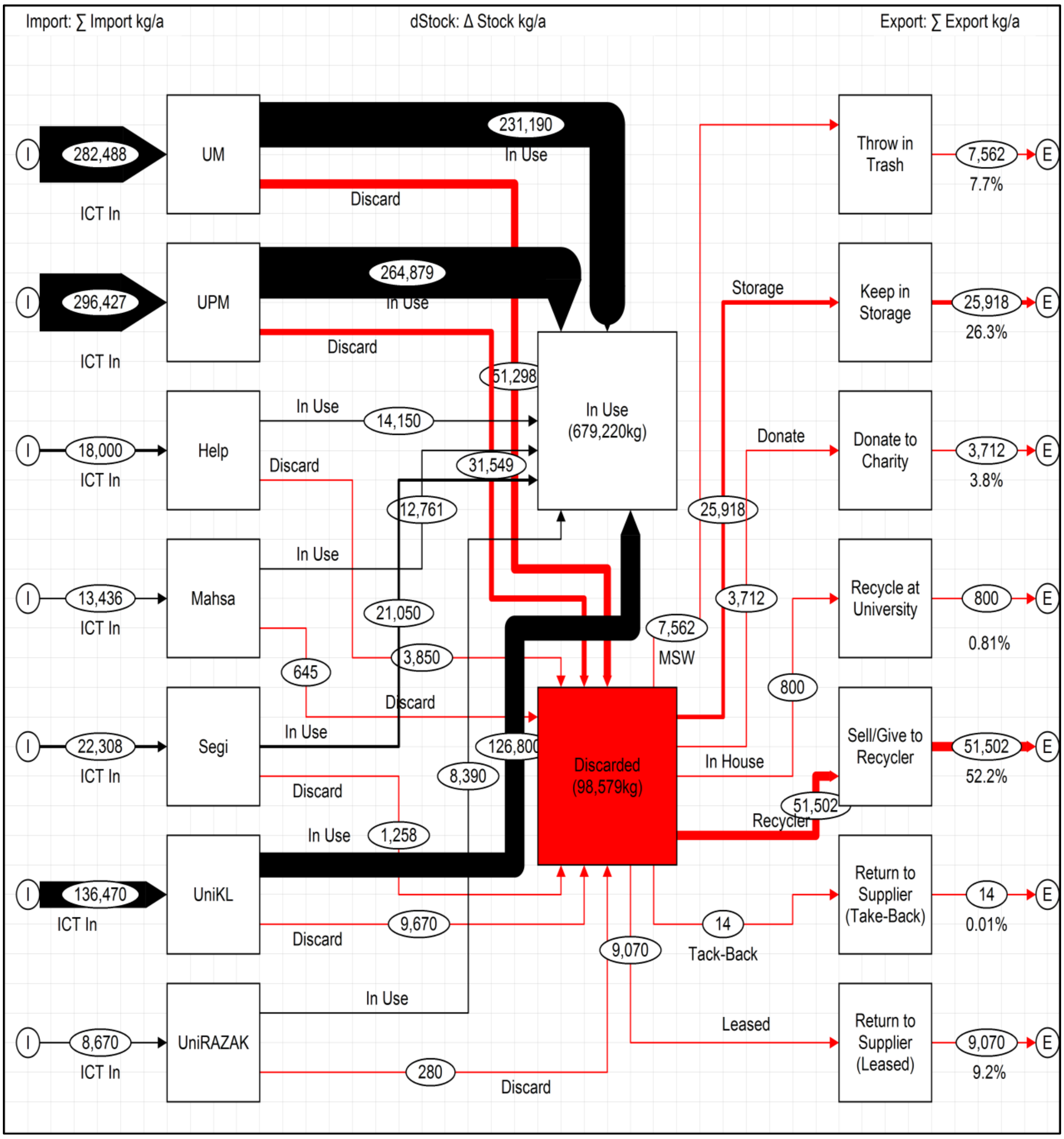

Figure 4.4 MFA for ICT Electronics in Klang Valley Universities – 2012

They are 155 E-waste recovery facilities are licensed by DOE, of which 135 facilities are "partial recovery" and another 20 facilities are "full recovery" (Malaysia DOE, 2012). The recovery facilities have a total capacity to handle 24,000 tonnes of E-waste a month (Kamar, 2012). However this is not always the case as some E-waste is illegally shipped out of Malaysia by unscrupulous recyclers to destinations i.e. Indonesia and Myanmar contrary to the Basel Convention (Young, 2012).

A study by Babington et al., (2010) found that in Selangor State, universities contribute only 5% of E-waste recycled in both partial and full recycling facilities. The combined total of E-waste recycled (52.5 metric tonnes) by the universities in the study compared to other international institutions shows that E-waste recycling is still very low. For instance the Columbia University alone collected 40.5 metric tonnes of E-waste which was recycled through by Northeast Lamp Recycling while Indiana University E-waste Collection Days Event in coordination with Apple Inc. has collected and properly recycled over 635 metric tonnes of electronic waste since 2009 (Knudsen, 2010).

Mahsa University, Segi University, UniKL and UniRazak of the selected Klang Valley universities practiced on-site/in-house 3R (Figure 4.3). However, in MFA this only represents 0.81% of discarded outflow since the institutions stores selected broken or dysfunctional electronic and uses them as sources of spare parts in the in-house repair of similar electronic products. At the Indian Institute of Technology students have spearheaded the in-house recycling as a social responsibility initiative where they collect used/old computers and donate them to people who could get some use out of them while preventing the pile up of E-waste at the institution (Ramya, 2012).

The MFA also reveals that there was insignificant take-back practice among the Klang Valley universities which accounts for only 0.01% of total E-waste out flow, (Figure 4.4), despite a number of brand name consumer electronics giant i.e. Dell, HP, Toshiba and Samsung offering free voluntary take-back programmes.

4.2.9 Storage Life of ICT Equipment

Storage of end-of-life ICT equipment is the initial step/practice in E-waste management in all the universities. It may be in the interim (short-term) before final disposal or for the long haul if there is no defined plan to dispose it. Results of the survey showed that Segi University stores E-waste for the shortest period of time (3 months) while Help University stored E-waste for more than 5 years (Table 4.6).

Table 4.6 Storage Life and Quantity of ICT E-waste

	Maximum Storage Life	**Quantity Stored (metric tonne)**
UM	3years	53.7
UPM	3years	33.1
Help	More than 5year	3.8
Masha	2years	0.7
Segi	3months	1.3
UniKL	1year	9.9
UniRazak	1year	0.3

The institutional survey found that there is less red-tape or bureaucracy in private universities when it comes to condemning and discarding of unwanted assets such as end-of-life electronics. For example at the University of Malaya, the Department of Development & Estate Maintenance (JPPHB) is responsible for end-of-life electronics once condemned but cannot dispose of the E-waste without the permission of the original owner e.g. the faculty, department, office etc that purchased or was using the discarded equipment. This unfortunately means JPPHB may hold onto discarded assets for long periods of time awaiting further instruction on final disposal from the "owners."

One of the major issues with disposal of institutional ICT E-waste is that it raises security concerns. For instance a desktop or laptop may be condemned because it is broken and cannot be fixed but the storage device component (i.e. hard drive) can still be in proper working order thus if sold or given away the would be recipient can access institutional or personal data by removing the hard drive and plugging it into another functioning device. Some of the information stored on discarded ICT equipment may be of confidential nature and in the wrong hands can be used for fraudulent or criminal activities. However, they are recyclers (i.e. Apex Computer Services Sdn.Bhd, Green Heaven Metal Sdn Bhd, TES-AMM Malaysia Sdn. Bhd and Dell Malaysia) on the market that offer and guarantee data destruction and hard drive shredding services for E-waste considered to have confidential data.

4.2.10 Challenges to Institutional E-waste Management

University employees responsible for E-waste management were asked their opinion on what they considered as some of the challenges or drawbacks to E-waste recycling in their institutions. The two most prominent challenges cited were "lack of institutional policy" and "lack of awareness" on E-waste. Segi University and UniRazak cited no challenges in their E-waste management operations and findings of the survey also support this opinion as both institutions recorded the lowest In Use/Discarded ratio of ICT Equipment at 30:1 and 21:1, respectively (Table 4.5; Table 4.7). Franklin & Feldman (2011) and Egwali and Ekong (2011) in studies on E-waste management in businesses and institutions in Wisconsin – USA and Benin City – Nigeria, respectively stated potential obstacles for E-waste management include cost, data security, awareness, convenience, limited choices, or transportation. Both studies cited cost and data security as the most significant obstacles to proper E-waste disposal.

Table 4.7: Challenges to Institutional E-waste Management

Challenge	UM	UPM	Help	Masha	Segi	UniKL	UniRazak
1. Cost of Recycling	✓						
2. Lack of institutional policy	✓	✓		✓		✓	
3. Lack of Awareness	✓	✓	✓			✓	
4. No Challenges					✓		✓
5. Other	✓	✓	✓			✓	

4.2.11 E-waste at University of Malaya

A more detailed inventory of E-waste management was conducted at the University of Malaya. This inventory included other electronic products such as projectors, servers, mobile phones, televisions and refrigerators; including ICT equipment the institution was found to have a stockpile of over 61.7 metric tonnes of E-waste (Table 4.8). Needless to say the quantity of E-waste in UM must be much higher if the inventory was to also include other specialized electrical and electronic equipment i.e. laboratory equipment, air conditioners, sound systems etc (Plate 4.5-4.6). Material flow analysis was also conducted for UM individually and included data for all other electronic equipment in the UM inventory.

Plate 4.5: Obsolete electronic laboratory equipment at UM

Plate 4.6: Obsolete electronic laboratory equipment at UM

A Survey of current market price for E-waste ranged between RM0.50-RM3.00/kg while mobile phones are fetching between RM0.80-RM5.00/piece depending on the age, model and condition. Based on the highest possible value UM E-waste is estimated to be worth RM185,142 (US$61,714). However, depending on the condition of the E-waste and the buyer, its value could be considerably less or possibly worth nothing to the institution if given away for free as a means to clear considerably large stockpile (Table 4.8).

Table 4.8: E-waste at University of Malaya for 2012

E-waste	**In Use**	**Discard**	**Ratio**	**Quantity (kg)**	**E-waste Estimated Value**	
					Ringgit	**US$**
Desktop PC + Monitor	8,000	1,776	5:01	49,728	149,184.00	49,728.00
Laptop PC	340	37	9:01	130	390	130
Printer/Copier	83	36	2:01	1,440	4,320.00	1,440.00
Projector	150	-	-	-	-	-

Server	120	27	4:01	945	2,835.00	945
Mobile Phone	40	26	2:01	4	12	4
Television	552	232	2:01	7,192	21,576.00	7,192.00
Refrigerator	379	65	6:01	2,275	6,825.00	2,275.00
Total	**9,664**	**2,199**	**4:01**	**61,713**	**185,142.00**	**61,714.00**

The large stockpile of E-waste at UM can be in part attributed to the institutional asset disposal procedure (condemning assets takes long time) and the low level of knowledge or awareness on E-waste, as well as, cost of recycling as cited by UM-JPPHB. At the rapid rate electronic products are becoming obsolete, this E-waste stockpile is expected to grow significantly if no immediate measures are taken to address these pitfalls.

4.2.12 Material Flow Analysis for UM E-waste

The MFA for UM found that the institution has a stock of over 390,000kg of electrical and electronic equipment of which 15.8% (61,713kg) is E-waste. They are currently only four E-waste disposal streams/flows employed at UM. The bulk of the E-waste generated in the MFA flows is into disposal by "sell to recycler option" at 60% (37,028kg), followed by storage at 26% (16,045kg), disposal as MSW at 11% (6,788kg) and donations at 3% (1,851) (Figure 4.5).

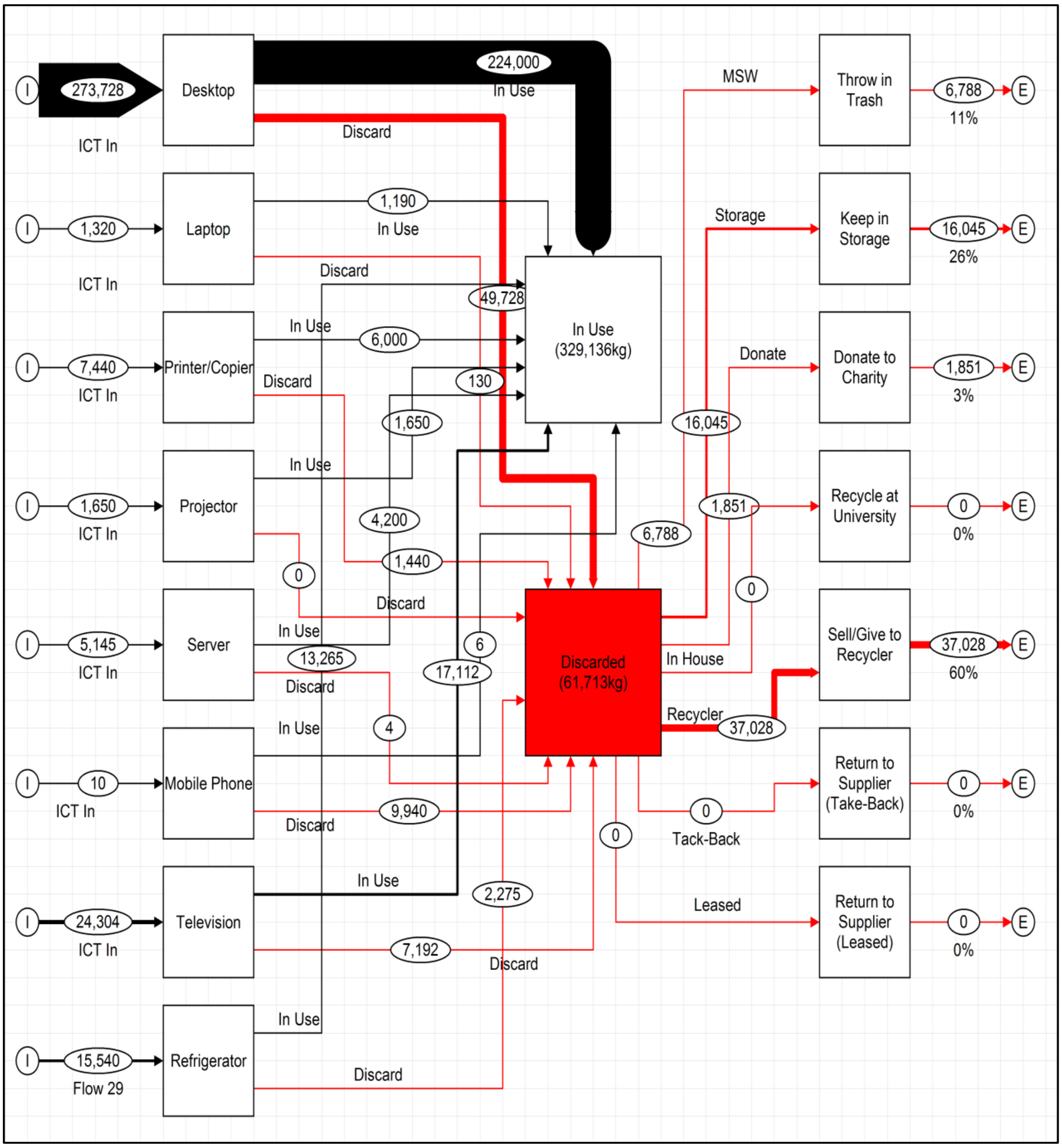

Figure 4.5 MFA for UM E-waste – 2012

A major concern with UM MFA, as was found with the MFA for the Klang Valley universities is the large amount of E-waste that flows into the MSW stream and the inherent environmental consequences. If no deliberate E-waste management policy is effected which should also include increasing university public knowledge/awareness of E-waste the amount of E-waste disposed into the MSW stream is certain to grow and cause even greater environmental damage. University of Malaya despite being the premier research university in Malaysia is lagging behind in adopting new innovation in E-waste management such as take-back or in-house E-waste 3Rs as part of enhancing the institutions sustainable campus profile.

4.3 Public Survey for University Staff and Students

4.3.1 Demographic Information

The public survey collected data on demographic variables of the sample population that may influence E-waste knowledge/awareness and management practices. The basic demographic variables considered in the public survey are gender, nationality, race, age, occupation, education and residence. The total number of respondents was 400 representing a confidence interval of 0.05 and confidence level of 95% representative reliability.

An overview of the demographic data of the respondents used in this research is presented in Table 4.9. In terms of gender, they were 58% females and 42% males with 80% and 20% of respondents being Malaysians and Non-Malaysians respectively. Race was divided into 4 categories Malay, Chinese, Indian and Others, Malay's recorded the highest race representation at 40% and Indian was least at 11 percent. More than 50% of respondents were between 21 to 25 years of age and 4% above 40 years. In reference to occupation of respondents, students made up 79% and 21% were university staff. The majority (68%) of the university public interviewed had or was pursuing undergraduate degree; 15% have STPM/Diploma, 10% have Master or PhD accounted and 8% have achieved only Secondary school education.

Finally, over 60% of respondent reside in private accommodation, 27% off-campus college and 12% reside on-campus.

Table 4.9: Demographic Data of Respondents

Gender				
	Frequency	Percent	Valid Percent	Cumulative Percent
Male	168	42	42	42
Female	232	58	58	100
Total	400	100	100	
Nationality				
	Frequency	Percent	Valid Percent	Cumulative Percent
Malaysian	321	80	80	80
Non Malaysian	79	20	20	100
Total	400	100	100	
Race				
	Frequency	Percent	Valid Percent	Cumulative Percent
Malay	163	41	41	41
Chinese	119	30	30	71
Indian	45	11	11	82
Others	73	18	18	100
Total	400	100	100	
Age				
	Frequency	Percent	Valid Percent	Cumulative Percent
Less than 20	73	18	18	18
21 - 25	208	52	52	70
26 - 30	60	15	15	85
31 - 35	33	8	8	94
36 - 40	12	3	3	97
Above 40	14	4	4	100
Total	400	100	100	
Occupation				
	Frequency	Percent	Valid Percent	Cumulative Percent
Student	316	79	79	79
University Staff	84	21	21	100
Total	400	100	100	

Education				
	Frequency	Percent	Valid Percent	Cumulative Percent
Secondary School	30	8	8	8
STPM or Diploma	59	15	15	22
Degree	270	68	68	90
Masters or PhD	41	10	10	100
Total	400	100	100	
Residence				
	Frequency	Percent	Valid Percent	Cumulative Percent
On Campus Housing	50	13	13	13
Off Campus Housing	109	27	27	40
Private Accommodation	241	60	60	100
Total	400	100	100	

4.3.2 Knowledge of E-waste

E-waste is gaining prominence as the term used to refer to electrical and electronic waste. In this vain the survey sought to establish how familiar the public is with the term "E-waste." Establishing this is important because even though much of the public have an idea what type of waste "electronic waste", many drew a blank when it is coined as "E-waste" during the pilot study to test for the sampling instrument.

Findings of the survey shows that university public in Klang Valley are largely unfamiliar with the term as 60% did not know what E-waste refers to and only 40% knew (Figure 4.6). A similar survey by Kalana (2010) of residents of Shah Alam found that 57% of the respondents were knowledgeable about E-waste and the rest have no idea on what E-waste entails (43%). Another study at Universiti Teknologi Malaysia concluded that knowledge about E-waste amongst the university public was "severely low" although exact figures were not indicated (Yosuf, 2008).

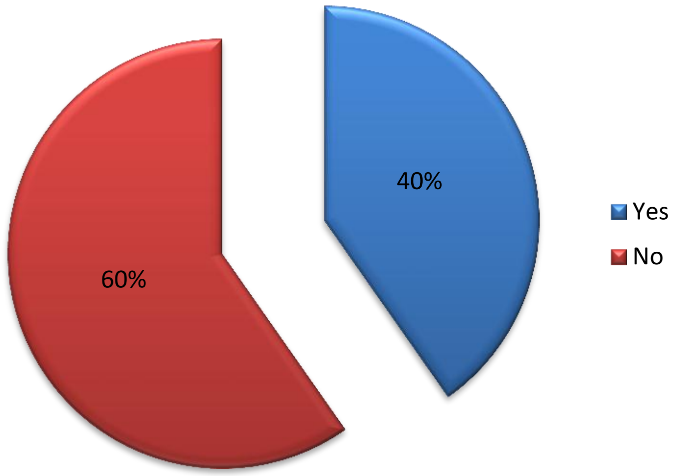

Figure 4.6 Knowledge of E-waste

4.3.2.1 Knowledge on E-waste by Institution

A closer look at university public knowledge of E-waste by institution revealed that UM and UPM communities were more knowledgeable on what E-waste referred to compared to the rest of the other institutions which are all private owned. However, UM (staff and students) is the only institution to have recorded above 50% correct understanding of E-waste at 56% and the lowest recorded was by UniKL with 26% (Figure 4.7). Furthermore, the Test of Significance (0.006) shows that there is a significant correlation between understanding of E-waste and institution type (public/private). Therefore, it can be concluded that public university communities are more likely to be knowledgeable on E-waste compared to private university counterparts.

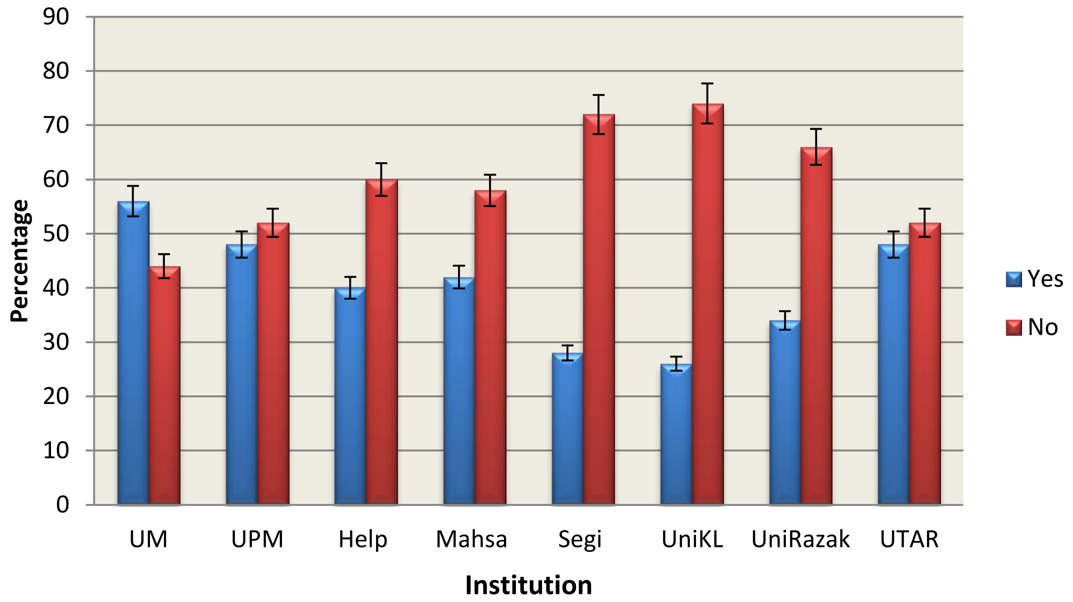

Figure 4.7 Knowledge of E-waste by Institution

University Of Wisconsin System - Solid Waste Research Program in 2011 carried out a research to assess level of E-waste awareness in business and institutions. The study found that 86% of respondents reported being familiar with the term E-waste and 14% reported either never hearing of or not being able to define the term (Franklin and Feldman, 2011). Compared to the findings of this study Malaysia's awareness levels on E-waste are extremely low. This can also be said for other developing countries e.g. in Kenya the Jomo Kenyatta University of Agriculture and Technology (JKUAT) reported in the institutions E-waste Policy Report that public E-waste awareness at the institution and national level was extremely poor (JKUAT, 2009).

4.3.2.2 Knowledge of E-waste by Age

Analysis of survey results on the knowledge of E-waste by age shows that the older the person is the more likely they are to know what E-waste is as shown in Figure 4.8. Test of significance showed strong significant correlation between age and understanding of E-waste at (0.007). The age range that recorded highest knowledge levels on E-waste was 36-40 years with 75% and the lowest with 34% was respondents less than 20 years. The higher the age goes can imply the greater the exposure to knowledge through academics and/or general every day to day activities.

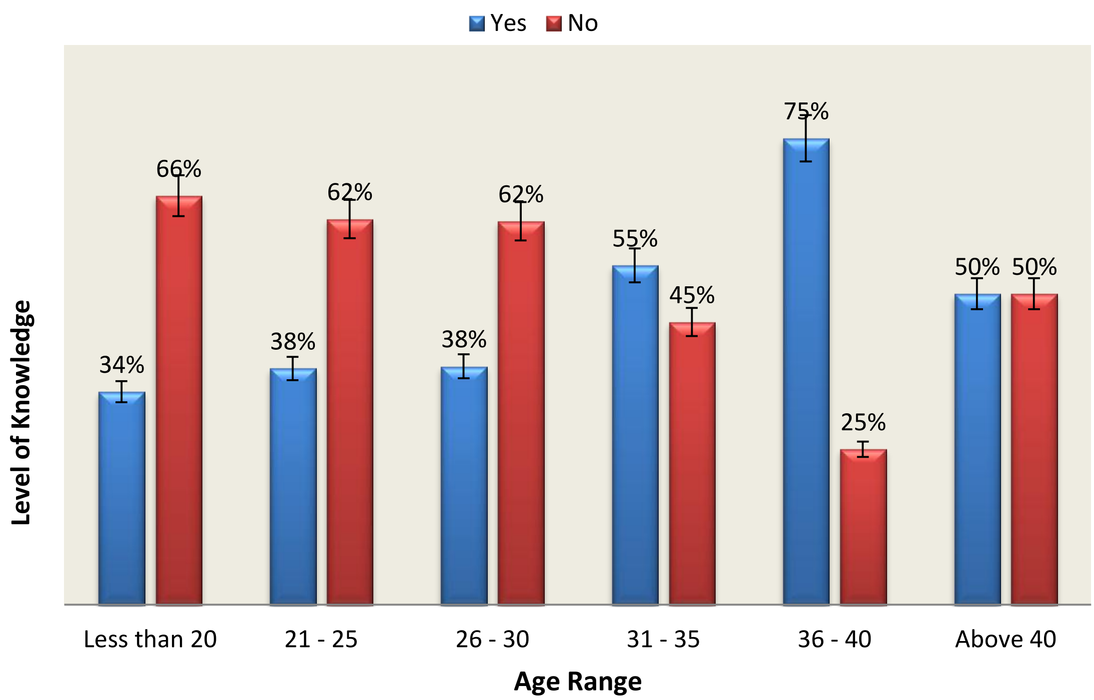

Figure 4.8: Knowledge of E-waste by Age

Age is of great concern in E-waste management especially in the informal recycling of E-waste; children unknowingly expose themselves to hazardous conditions. At Agbogbloshie an E-waste site in Ghana for example, children (mostly boys, sometimes as young as 5 and mostly between 11 and 18 years old) are involved in E-waste recycling burning activities and manual dismantling and young girls aged between 9 and 12 have been observed working as E-waste collectors (Prakash & Manhart, 2010). Although, there is no documented evidence of Malaysian children involved in informal E-waste recycling it is important to encourage E-waste awareness among younger citizen (in Pre-school, Primary and Secondary Schools) even before they reach tertiary education age.

4.3.2.3 Knowledge of E-waste by Education Level

Knowledge of E-waste by level of education found that respondents with postgraduate qualifications (Masters or PhD) had the highest level of knowledge at 56% and lowest recorded was 31% under STPM/Diploma category. Both Pearson r correlation test (-0.06) and Test of Significance (0.233) found no correlation between level of education and knowledge of E-waste. (Table 4.9). Similar to the finding of the research, Egwali and Ekong (2011), in a study on E-waste awareness and disposal practices in Benin City, Edo State, Nigeria found that education level is a significant factor in E-waste awareness. The more educated respondents were the more knowledgeable on E-waste.

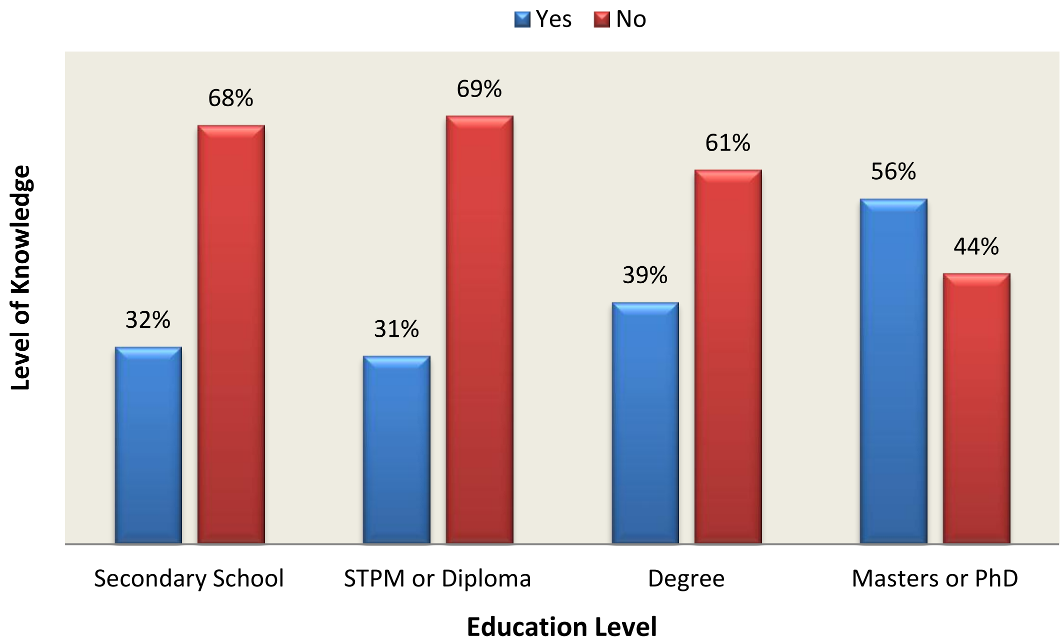

Figure 4.9: Knowledge on E-waste by Education Level

4.3.2.4 Knowledge of E-waste by Occupation

Knowledge of E-waste by occupation of respondents showed that University Staff have higher knowledge level on E-waste as 46% responded YES to knowing what E-waste refers to, while students recorded a 36% YES response (Figure 4.10). Though, it was found that university staff had a higher knowledge, the Pearson's r correlation test (-0.06) shows that there is no significant link between occupation of respondent and knowledge on E-waste. Therefore, any attempt to increase awareness on E-waste in universities should not discriminate but target both student and staff alike. Franklin and Feldman (2011) in a study on E-waste awareness in Wisconsin – USA, found that 50% of staff in government/institutions had an idea and 50% knew exactly what E-waste referred to, this shows a higher level of awareness in US compared to Malaysian staff who over 50% having no idea what E-waste refers to (Figure 4.10).

The Auburn University in an effort to increase E-waste awareness among students gives them the option to attain a 15-credit-hour minor in sustainability. The sustainability program includes initiatives in which students compete to reduce electricity use, conserve water and recycle more though various on campus activities i.e. E-waste collection day, dorm competitions and environmental awareness seminars (Harding, 2012). The initiative employed by Auburn University can be introduced or adopted in institutions of higher learning in the Klang Valley and Malaysia at large to increase knowledge on sound E-waste management practices.

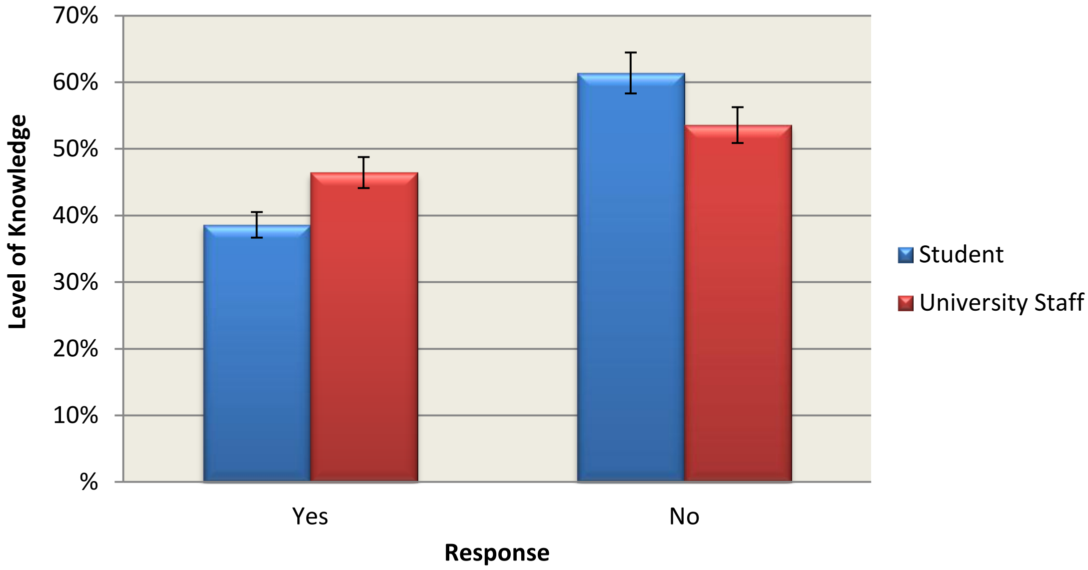

Figure 4.10: Knowledge of E-waste by Occupation

4.3.3 Knowledge on E-waste Recycling

In determining respondent's level of knowledge on E-waste recycling, the term "E-waste Recycling" was not used but it was rather coined as "Electrical and Electronic Waste Recycling." In section 4.3.1 of this study it was found that the term "E-waste" was familiar to only 40% of respondents. However, when referred to as "Electrical and Electronic Waste" recycling 67% of the respondents were aware of E-waste recycling. This shows that the term "E-waste" is foreign to a significant percentage of the public as many did not know that E-waste refers to "waste of electrical and electronic equipment" even though they may be knowledgeable on the topic of E-waste.

Findings of the survey show that when the university public was asked if they were aware of electronic waste recycling 67% responded positively and 33% claimed to have no idea what electronic waste recycling was (Figure 4.11). A study comparing

E-waste recycling awareness between Universiti Kebangsaan Malaysia (UKM) and Shah Alam City found that 80% of UKM campus community was aware of E-waste recycling while Shah Alam City public recorded a 42% awareness level (Chibunna, et al., 2010). The two surveys showed that the university public in Klang Valley is generally well aware of electronic waste recycling. However, despite the high level of awareness of E-waste recycling most of the public are unwilling to engage in the practice for varying reasons i.e. lack of knowledge on where to take E-waste for proper handling, unwilling to burden the cost of disposal, lack of knowledge on inherent danger posed by environmental unsound disposal of E-waste etc. (Kalana, 2010; Chibunna, et al., 2010).

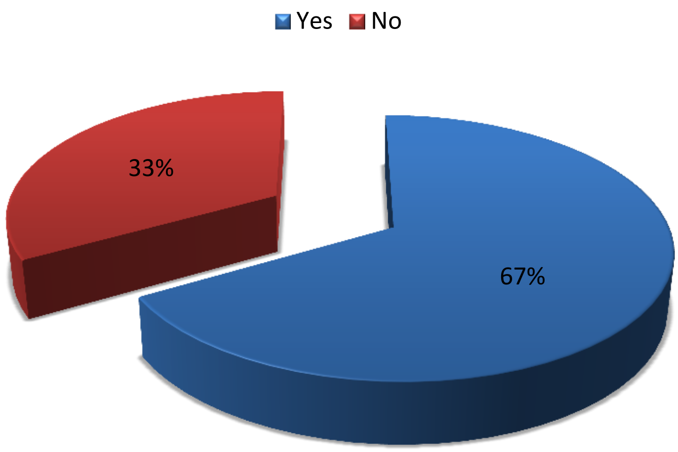

Figure 4.11: Knowledge on Electrical and Electronic Waste Recycling

4.3.3.1 Knowledge on E-waste recycling by Institution

An assessment of knowledge on E-waste recycling by institution found that UPM has the highest level of knowledge at 78% followed by UM with 72% while the lowest knowledge levels were recorded at Segi University with 62%. Yet again public universities (UPM and UM) were found to have higher E-waste recycling knowledge as compared to private universities that recorded below 70% knowledge levels (Figure 4.12). However, correlation tests Pearson's r (0.72) and Test of Significance (0.153) show no significant link between type of institution and awareness on E-waste recycling. Despite the relatively high level of E-waste recycling awareness in institutions of higher learning Babington et al., (2010) states that universities in Malaysia only contribute a mere 5% to E-waste recycled. This shows that despite university public knowing about E-waste recycling their institutions are not actively engaged in E-waste recycling practices.

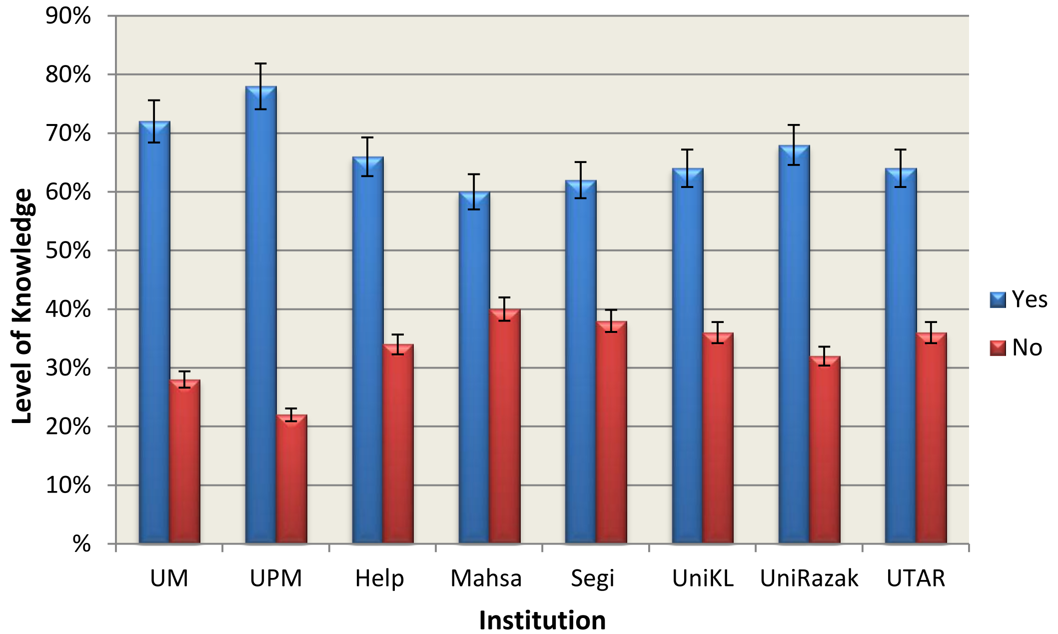

Figure 4.12: Knowledge on E-waste recycling by Institution

4.3.3.2 Knowledge on E-waste recycling by Education Level

Level of knowledge on E-waste recycling by educational status was recorded highest among respondents with postgraduate qualifications at 76% which was 10% higher than respondents with degree qualification at 66% while STPM/Diploma and secondary school qualification holder were at par with 63% each (Figure 4.13). Pearson's r correlation test (-0.06) for the two variables shows no correlation between level of education and knowledge on E-waste recycling. This is contrary to finding of similar studies in other part of the world, i.e. a study by Lee (2009) in the Bay Area of California (USA) found that public stakeholders with higher educational backgrounds were more knowledgeable about E-waste issues and the necessity of recycling. Similar findings are also stated by Egwali and Ekong (2011). Thus awareness campaigns on E-waste recycling in the Klang Valley should target all levels of educational background.

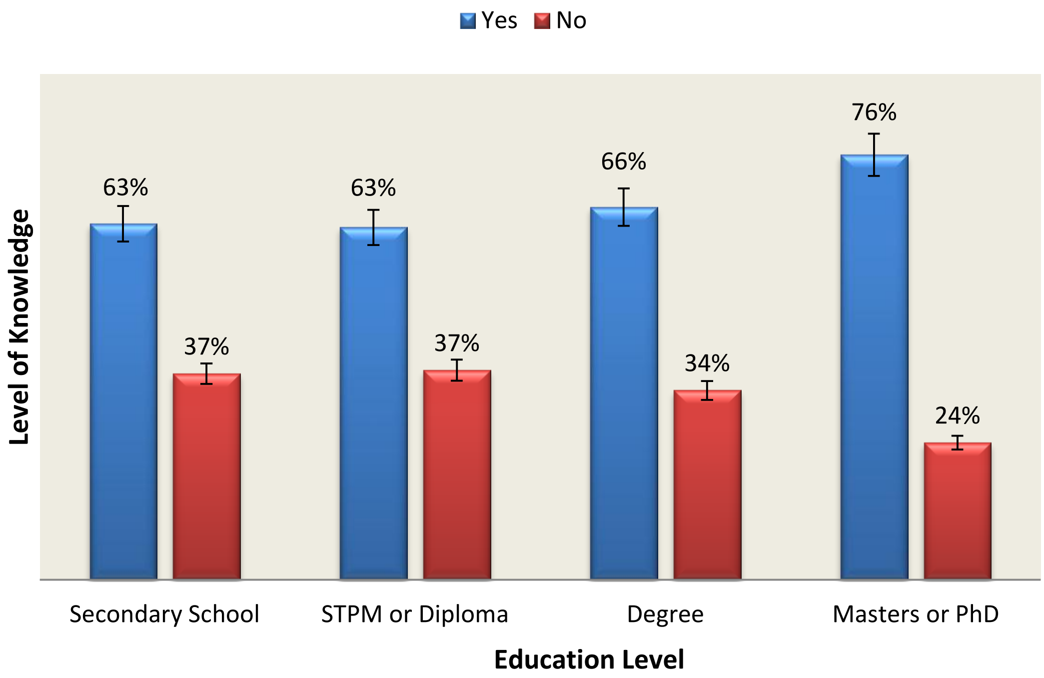

Figure 4.13: Knowledge on E-waste recycling by Education Level

4.3.3.3 Knowledge on E-waste recycling by Occupation

Findings of the survey showed a rather even distribution of knowledge on E-waste recycling among students and university staff at 67% and 65% knowledge levels respectively (Figure 4.14). Correlation test Pearson's r (0.01) also revealed that knowledge on E-waste recycling and occupation of respondent are not strongly correlated. Therefore, any awareness campaigns on E-waste recycling should target both occupational categories in a university community.

In 2010 a campus survey at Dalhousie University, Canada found that about 60% of students knew batteries could be properly recycled, indicating that a substantial 40% of the student population is unaware of the possibility of recycling their batteries (Marcus at el., 2012). This shows a similar trend in E-waste recycling awareness with Klang Valley universities.

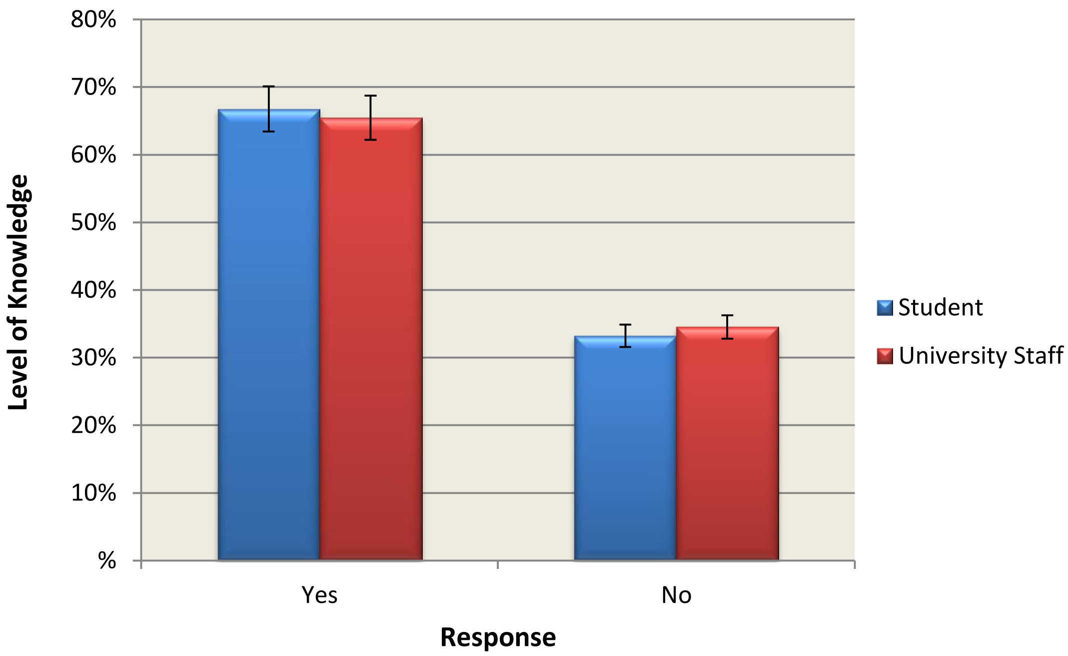

Figure 4.14: Knowledge on E-waste recycling by Occupation

4.3.4 Knowledge on Environmental Hazards Caused by E-waste

The research found that the level of knowledge on environmental hazards posed by E-waste is extremely low among the university public. Over 60% of the university populace sampled had no knowledge on what environmental hazards may arise from E-waste if not disposed of in proper manner (Figure 4.15). There is generally poor public knowledge on the environmental hazards in Malaysia as stated by Datuk Seri Douglas Uggah Embas – Natural Resources and Environment Minister (The Star Online, 2010). Low levels of knowledge of harmful effects of E-waste are also common in other parts of Asia, in India for example IMRB International (2010) states there is low level of public awareness regarding harmful effects of E-waste. Therefore, greater efforts are required on the part of government, business and NGO's to make E-waste knowledge widespread. This high level of ignorance on the environmental hazards of E-waste can contribute significantly to indiscriminate disposal of E-waste together with MSW.

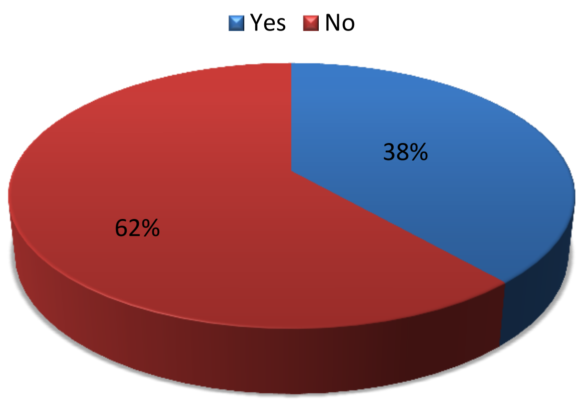

Figure 4.15: Knowledge on Environmental Hazards Caused by E-waste

The 38% of university public that had an idea of what environmental hazard arise from E-waste gave a wide array of answer as to what they perceived these hazards to be; Table 4.10 shows responses given by the public and divides them into two categories (Environmental and Human Health hazards). The question on knowledge on environmental hazards was posed as an open-ended question and as can be seen some of the responses given were very vague showing that though respondents had an idea that E-waste was an environmental hazard many do not know exactly how it affects the environment or human health. In a study by Kalana (2010) in Shah Alam also states that even though the public in the area are aware of the environmental consequences of the disposal of E-waste, most of them do not know or are unsure of the actual consequences. Therefore, knowledge on environmental and health effects associated with E-waste among the public is limited and more awareness initiatives have to be undertaken.

Table 4.10: Environmental and Human Health Hazards Caused by E-waste

Environmental	Human Health
• Contamination • Toxic hazard to the land and river • Water Pollution due to dumping near water pipes • Water pollution due to surface runoff • Water table contamination • Heavy metal leaching into the land and soil as housing erodes. • Silicone doesn't degrade easily • Non biodegradable components take up space permanently • Deplete landfill area • Release hazardous gas • Causes air pollution when burnt • Release of CFC's into the atmosphere • Cause greenhouse effect and destroy ozone layer • Radioactive waste • Breeding of Mosquitoes • The parts in electronic items are toxic to the environment • Ecosystem disruption	• Radioactive waste • Lead and Mercury causes damage to nerves system and developing fetus • Arsenic causes damage to the digestive system • Brain damage • Cancer

4.3.4.1 Knowledge on Environmental Hazards by Institution

The UM public showed the highest level of environmental knowledge on the dangers posed by E-waste with 56% while the lowest 22% was recorded by UTAR (Figure 4.16). The other public university UPM also recorded lower knowledge levels confirming the Pearson r test (0.058) and Test of Significance (0.287) that there is no correlation between knowledge on environmental hazards and type of institution (public or private). Henceforth, both public and private university should be encouraged to sensitize their public on the environmental and human health hazards posed by electrical and electronic waste. Initiatives such as the 2006 Joint Awareness Campaign by Toxics Link, UNEP and Maharashtra Pollution Control Board can be emulated. The campaign targeted both private and public schools & colleges in Mumbai – India with the aim to create awareness on the hazards of E-waste, the importance of safe and environmentally friendly management (UNEP, 2006).

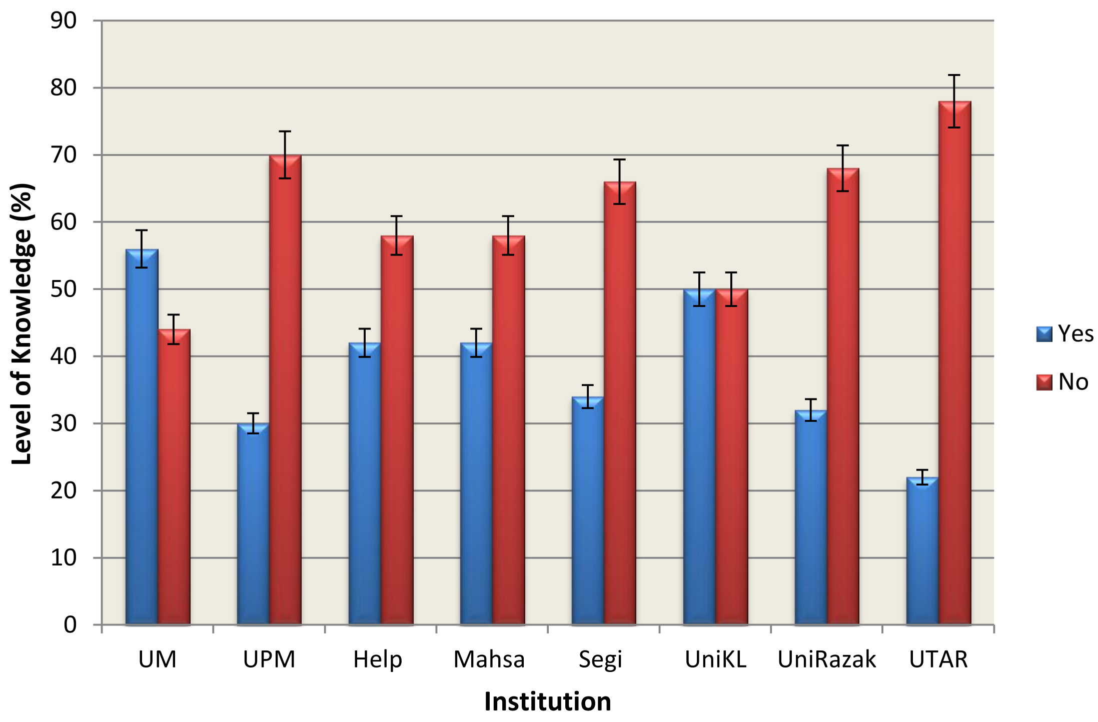

Figure 4.16: Knowledge on Environmental Hazards by Institution

4.3.4.2 Knowledge on Environmental Hazards by Age

The university public survey found that knowledge on the environmental hazards of E-waste increases with increase in age of public respondents. The highest knowledge levels was recorded under the 36-40 years age bracket and the lowest under less than 20 years age at 58% and 33% respectively as shown in Figure 4.17. Test of significance (0.033) shows correlation significance between age and knowledge on environmental hazards. The larger percentage of the (less than 20 years) age bracket of university public is undergraduates, fresh from high school who need to carry out early orientation where emphasis on E-waste is given when joining the university.

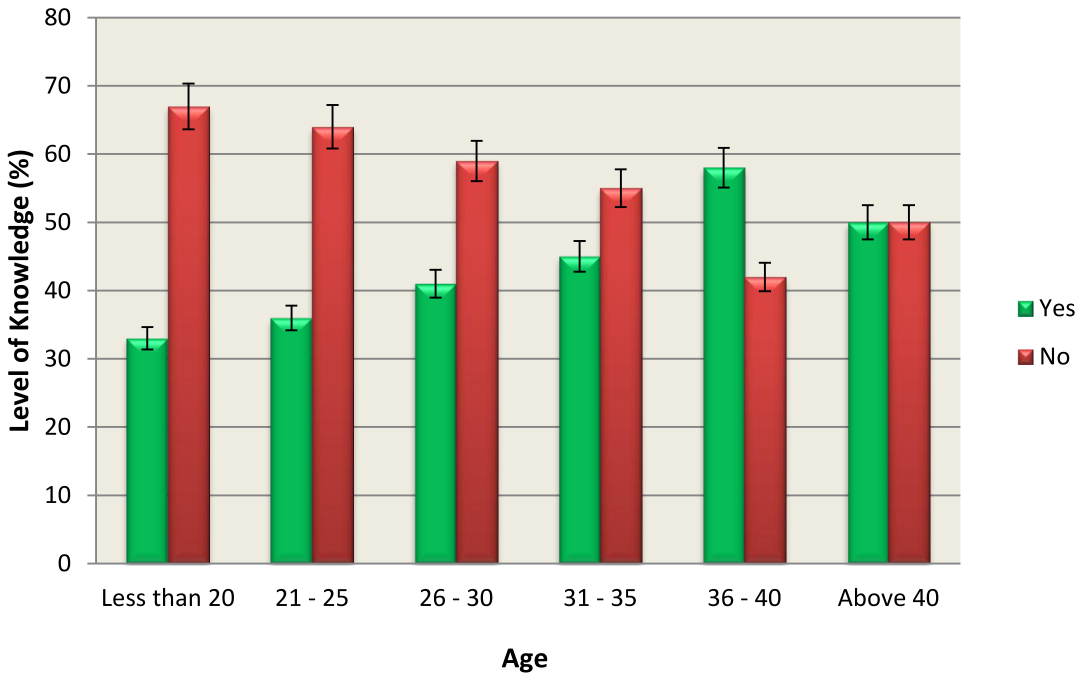

Figure 4.17: Knowledge on Environmental Hazards by Age

4.3.4.3 Knowledge on Environmental Hazards by Education Level

Level of knowledge on environmental hazards of E-waste by educational status shows that the higher the qualification the more knowledgeable one is, Postgraduate qualification recorded 49% compared to STPM/Diploma that recorded 22% (Figure 4.18). Test of Significance (0.031) shows a strong correlation in the two variables, level of education and knowledge on environmental hazards. Regardless of the level of education, knowledge on environmental hazards posed by E-waste are low and hence any deliberate policy to increase knowledge levels should endeavor to target all the university public regardless of levels of education. Ogbomo et al., (2012), postulated that ignorance which usually goes in tandem with level of education is a major contributing factor to poor knowledge of the danger of E-waste. In an effort to increase knowledge and awareness through education the Government of Delhi has engaged in awareness initiatives for school children and teachers regarding environmentally sound E-waste management also citing that schools can play an important role to raise awareness among the community at large (Government of Delhi, 2012). This shows education (primary, secondary and tertiary) can be a major conduit of increase awareness on hazards posed by E-waste.

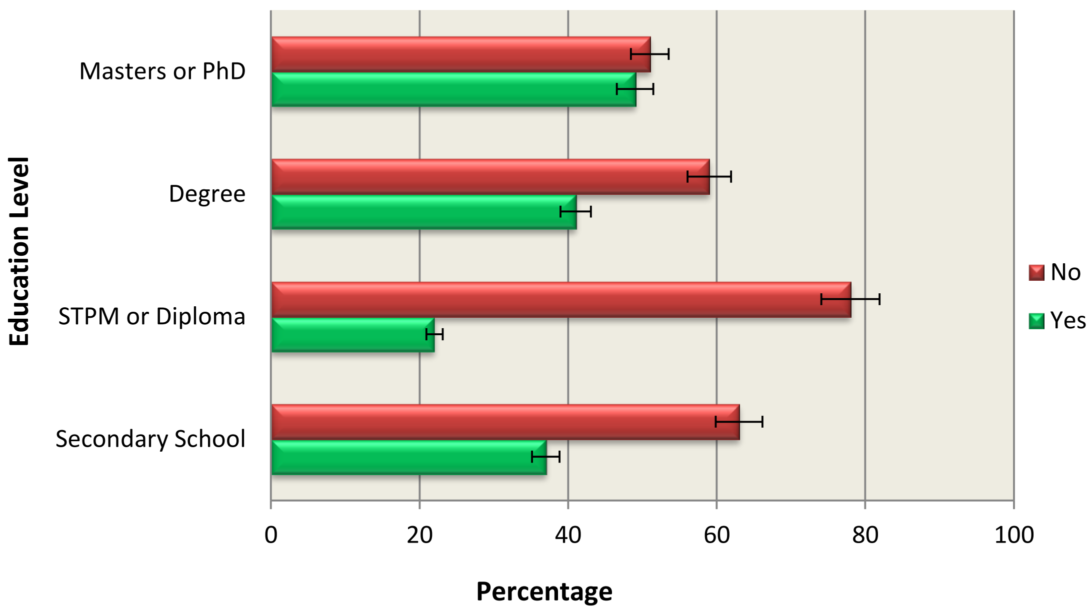

Figure 4.18: Knowledge on Environmental Hazards by Education Level

4.3.4.4 Knowledge on Environmental Hazards by Occupation

The occupation of respondents (student or staff) had no significant correlation to knowledge on environmental hazards of E-waste (Figure 4.19). Both correlation tests, the Pearson's r (-0.021) and Test of Significance (0.676) verify this lack of correlation. Therefore, any awareness campaign to increase knowledge on environmental hazards of E-waste should target both university staff and students alike. Florida Gulf Coast University has formulated a framework called "research to education to action" to increase knowledge and awareness on environmentally sound management of E-waste. The framework impacts the university and local community by researching the topic (E-waste), disseminating the information through various educational practices, and motivating students, faculty, administration, and the community to take action. These non-traditional education experiences not only bring environmental awareness to both students and staff at the institution but also support action (Mendes, 2011).

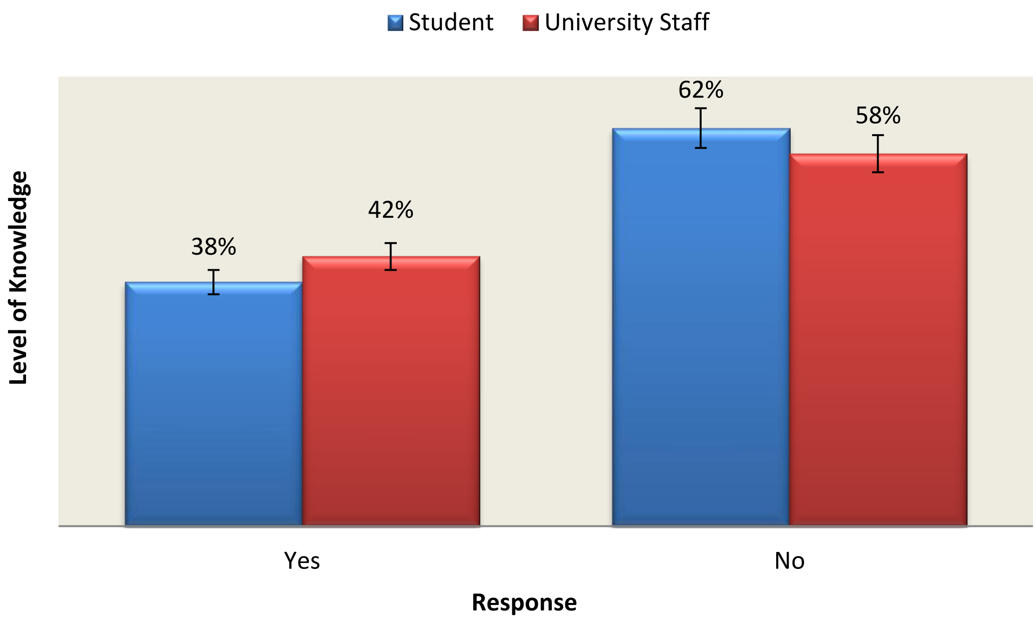

Figure 4.19: Knowledge on Environmental Hazards by Occupation

4.3.5 Willingness to Learn about E-waste

University communities sampled in the Klang Valley showed an eagerness to learn more about E-waste and its environmental impacts. Over 85% of the public showed a willingness to acquire greater knowledge on E-waste. The most popular preferred method of communication among those willing to learn is through mass media with 30%, this includes programmes such as documentaries, television shows, current affairs reports etc., while 18% advocate that E-waste learning should be incorporated in education programmes. About 1% (other) suggested that social networking platforms i.e. Facebook, Twitter, Blogs and Linkedin be employed to raise awareness and with the high and ever increasing popularity of social networking this could be one of the most effective ways of information dissemination considering that the very electronic gadgets used in social networking (i.e. smartphones, Tablet PCs, Laptops etc.) contribute heavily to E-waste generation (Figure 4.20).

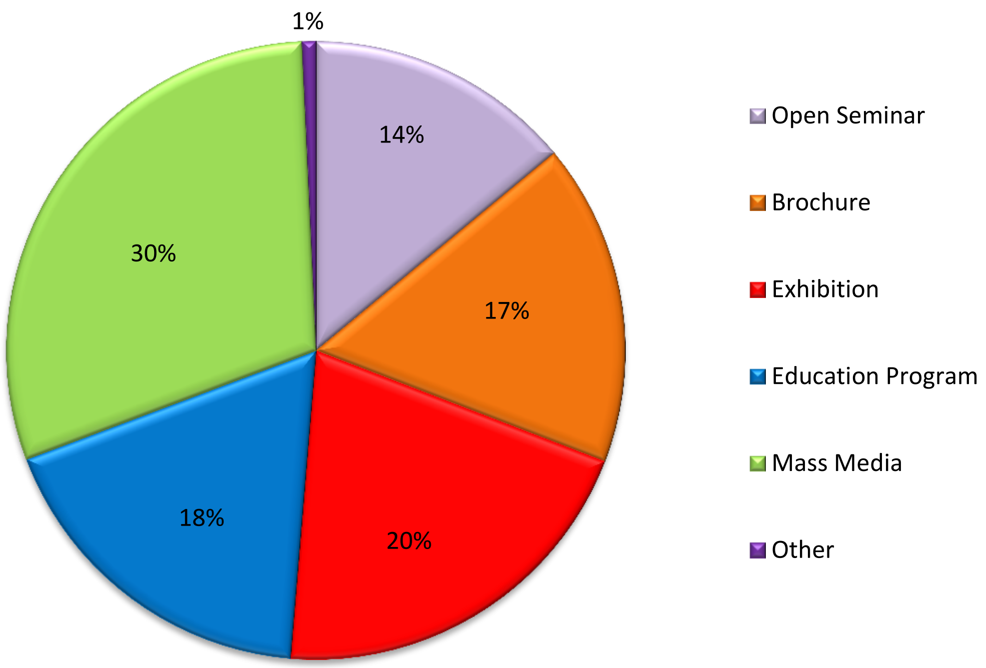

Figure 4.20: Willingness to Learn about E-waste

Universities around the globe have used various other mediums not highlighted in Figure 4.20 to disseminate information or increase E-waste awareness. In New Delhi workshops have been conducted by the government engaging both university students and staff to increase awareness and establish E-waste collection mechanisms (Government of Delhi, 2012). The Indiana University Office of Sustainability (IUOS) apart from utilizing radio and television to educate citizens about the importance of E-waste recycling also runs an art competition and exhibition called IUB Electronic Waste Art Competition to raise awareness (Knudsen, 2010). In Canada, the Queens University has used games and competitions as a tool for E-waste information dissemination and to encourage E-recycling at the institution (Queens University, 2013)

4.3.6 E-waste Management Practices by University Public

E-waste management practices in university communities show that the most preferred method of discarding electrical and electronic waste is putting it in storage or disposing of it together with municipal solid waste (Figure 4.21). This preference by the public to store E-waste comes as a result of them knowing that electronic waste has some inherent value although it may have reached its end-of-life, 80% of respondents agreed to this assertion. The other reason for storing E-waste or disposing of it together with the trash is that most of the public are unaware of where to take end-life-life electronics. This coupled with lack of knowledge on environmental dangers results is indiscriminate disposal E-waste (Babaington et al., 2010). A study on E-waste management practices in Shah Alam also found that most residents preferred “to store” E-waste on their premises or sell the electronic products (Kalana, 2010).

In recent years, Malaysia has seen an increased emphasis on extended producer responsibility (EPR) encompassing activities such as consumer take-back of used electronic and electrical products. The findings of the study show that only 5% of university public engages in take-back practices. Take-back practice removes the burden of E-waste disposal from the public, placing it on the manufacturer. However, at this low practice rate (5%) the initiative is still foreign to much of the university public. Whereas, 16% of the university public practice trade-in, where they give a retail/seller a functioning used electrical or electronic product for a reduced price on a new and/or similar product (Figure 4.21). A small percentage of the university public (1%) practiced other methods of electronic waste disposal such as burning and/or burying it, both of which pose considerable human health and environmental risk (Figure 4.21).

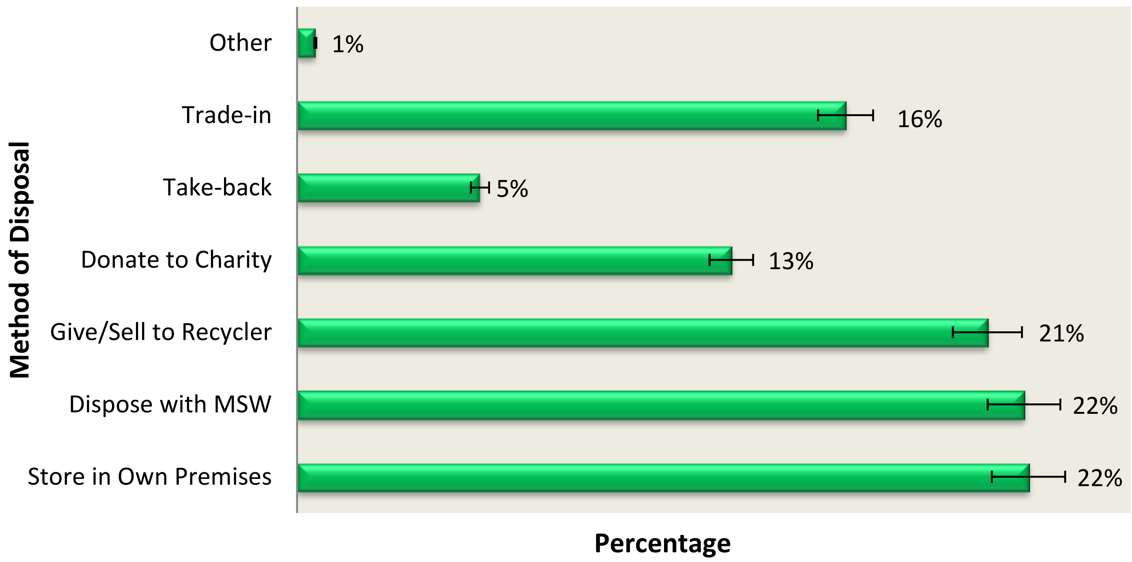

Figure 4.21: E-waste Management Practices by University Public

According to a DOE (2010) report in 2007, 400 recycling bins were placed by DOE at 200 sites such as supermarkets, universities, government offices around the Klang Valley for the public to deposit their discarded mobile phones and mobile phone accessories for recycling and environmentally sound disposal. However, this survey found that only 10% of the university public has seen an E-waste collection points in or around their institutions or places of residence. Placing of recycle bins in strategically relevant points was a step in the right direction to ensure environmentally sound management of E-waste but they are by far insufficient. This insufficient number of E-waste recycling bins is contributing to public disposal of E-waste with trash.

4.3.7 Willingness to Practice Environmentally Sound Management (ESM) of E-waste

The public survey also attempted to gauge the willingness of the university communities to engage in some ESM practices of E-waste by asking respondents if they would be willing to give away their end-of-life electronic products for free or if they would be willing to pay for the collection of their electronic waste products. A total of 69% of the public are willing to give away their used or obsolete electronics for free. This is an encouraging factor if universities in the Klang Valley were to implement policies such as E-waste Collection Days where the university community can be encouraged to bring their E-waste and offload it on the institution which in turn can engage a reputable recycler to dispose of it in an environmentally friendly manner. The case studies reviewed in Chapter 2 show that E-waste collection days at institutions of higher learning around the world have proved to be some of the most successful method of collecting E-waste for recycling, thereby, significantly reducing the amount of hazardous waste that would have possibly made it into landfills.

However, 64% of respondents were not willing to pay for the service of collection of E-waste. This may also contribute to why most of the public prefer to keep their end-of-life electronics in storage or dispose of them with normal household and hence cause environmental degradation. Therefore, an introduction or increase in E-waste collection points within universities would encourage the public to dispose of their end-of-life electronics at minimal or no cost or possibly the waste can be bought from the public at a small token.

4.3.8 University Public's Perception of E-waste Management in Universities

The survey found that public perception on collection and disposal of E-waste in universities is low with 38% of the public sharing this opinion (Figure 4.22). The negative perception is supported by earlier findings in section 4.3.6 that show that only 10% of university public has spotted an E-waste collection point.

Babaington et al., (2010) found that universities and schools only contribute 5% of the E-waste treated by both partial and full recyclers in Selangor. This implies that there is very little or no activities in terms of deliberate policy to sustainability manage E-waste generated by institutions of higher learning.

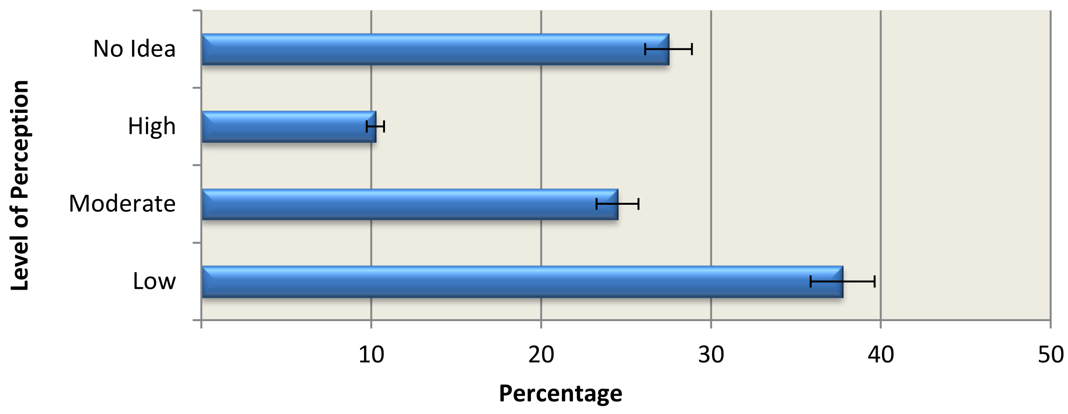

Figure 4.22: University Public Perception of E-waste Management in Universities

When asked what sort of intervention measures can be implemented in the immediate and long-term to remedy the shortcomings of current E-waste management practices in universities, over 65% of respondents agreed or strongly agreed to the suggestion that E-waste collection points should be set up in universities. While in the long-term over 75% of respondent agreed or strongly agreed that E-waste awareness programmes be promoted in universities (Table 4.11). Though, increasing or introducing E-waste collection points maybe viewed as an immediate response ultimately when incorporated with awareness programmes E-waste recycling bins can offer long-term sustainable management options for E-waste.

Table 4.11: Ways to Improve E-waste Management in Universities

	Strongly Disagree	**Disagree**	**Not Sure**	**Agree**	**Strongly Agree**	**Total**
E-waste collection points should be set up in universities	5%	7%	22%	32%	36%	100%
E-waste awareness programmes should be promoted in universities	4%	4%	15%	36%	41%	100%

Chapter V

Conclusion and Recommendations

5.1 Conclusion

The research found that the Klang Valley universities generated a significant amount of E-waste in 2012, the bulk of which was generated by public universities. Furthermore, all the universities in the study had no deliberate policy dedicated to the management of this E-waste. However, asset (including E-waste) disposal practices were more efficient in private universities as compared to public universities. The MFA model established that universities sold much of their E-waste to recyclers however; the institutions also disposed large quantities of E-waste as MSW. Universities were also not actively embracing the new innovations in E-waste management i.e. take-back scheme or in-house recycling. The level of knowledge on E-waste among the university public (staff and students) was found to be very low.

5.2 Recommendations

The recommendations postulated below are generated from the careful analysis of the research findings and are aimed at suggesting plausible ways to improve E-waste management by the university public and institutions of higher learning alike.

5.2.1 Institutional policy on E-waste management

Institutional policy on E-waste management should be introduced in all universities. The institutional E-waste management policy would aim to raise awareness on environmental and human health hazards posed by E-waste as well as raise awareness on recycling at universities targeting faculty, college, university staff, and students.

Furthermore, the policy would endeavor to implement strategies to enhance campus-recycling systems if any or introduce such systems if non-existent at the institution. The campus-recycling systems would include a process for proper and responsible disposal that ensures data security, environmental safety, worker's safety, and consumer responsibility.

a. Awareness Campaign

Institutions of higher learning can introduce marketing campaigns to raise university campus awareness on E-waste through already existing sustainable campus initiatives such as UMCARES at University of Malaya. The campaign can also include seminars on E-waste management as part of the orientation process for new students as well as on-going initiatives that engage existing student to practice sound E-waste management (i.e. E-waste Collection Days).

b. E-waste Collection Days

Initiatives that encourage consumer/public responsibility may include E-waste collection days. E-waste collection days will not only target the university public but also bring in other stakeholders such as recyclers, second-hand electronics traders or manufacturers. Thus depending on the condition of their discarded electronics the public can either sell for a token value or return to manufacturer (take-back) their obsolete electronics.

c. E-waste Collection Bins

In a number of institutions of higher learn it was found that they have waste separation bins for MSW although this is only limited to paper, plastic and metal. An initiative already initiated by DOE of placing E-waste collection point at universities can be stepped up by increasing the number or introducing E-waste collection points in universities.

d. Efficiency and Data Security

Decentralization of the E-waste disposal procedure especially in public universities, allowing authorities such as UM-JPPHB to dispose of E-waste immediately it has been certified as condemned. However, the department (i.e. UM-JPPHB) must ensure that data security is not compromised. In ensuring data security the department can have a small team that ensures all instructional data storage devices are formatted of all memory or hard drives removed and shredded before being sent for recycling or alternatively send E-waste to a recycler that also offers data destruction.

5.3 Areas for Future Research

The research generally focused on ICT E-waste generated by selected institutions of higher learning and thus did not cover all types of electronic waste generated by universities. Therefore, there is need for further research that encompasses all forms of E-waste generated in or by institutions of higher learning and this future research can also endeavour to extend beyond the Klang Valley and include the rest of

Malaysia thus giving a holistic/national view on E-waste management in instructions of higher learning.

5.4 Limitations of the Study

The major limitation to this study is that being of survey nature or desktop research and limited to the Klang Valley. The study was not provided any research grant from the university. Thus the study was purely funded by the researcher and conduct within a smaller study area.

References

Agamuthu, P. and Dennis V. (2013). Policy trends of e-waste management in Asia. *Journal of Material Cycles and Waste Management*, pp 1-11. DOI 10.1007/s10163-013-0136-7

As You Sow Foundation, (2013*). E-waste Initiative*. Retrieved February 14, 2013, from: http://www.asyousow.org/sustainability/ewaste_initiative.shtml

Azuka, A. I. (2009). 'The Influx of Used Electronics into Africa: A Perilous Trend', *Journal of Law, Environment and Development*, 5(1), 92-104

Babaington, J., Siwar, C., Fariz, M. A., Rawshan, A. B. (2010). Bridging the Gaps: An E-waste management and recycling assessment of material recycling facilities in Selangor and Penang. *International Journal of Environmental Sciences*, 1(3), 383-391

Barnes, A. (2011). New War on E-waste. Retrieved October 3, 2012, from: http://www.chinadialogue.net/article/show/single/en/4456-New-war-on-e-waste-

Basel Action Network. (2010). *The Globally Responsible Way to Recycle your Electronics.* Retrieved September 22, 2012, from: http://www.e-stewards.org/

Basel Convention. (2011). *The Basel Convention Ban Amendment*, Secretariat of the Basel Convention. Châtelaine, Switzerland. Retrieved September 24, 2012, from: http://www.basel.int/implementation/legalmatters/banamendment/tabid/1484/default.aspx

Basel Convention, (2010). *Environmentally sound management of used electrical and electronic equipment (e-waste) in Asia-Pacific*. Secretariat of the Basel Convention, Geneva, Switzerland. (p. 1-4)

Basel Convention, (2008). *Basel Convention: Parties to the Basel Convention.* Retrieved October 24, 2012, from: www.basel.int/ratif/convention.htm

Blogs Indium. *E-waste Images*. Retrieved November 20, 2012 from: www.blogs.indium.com

Bonhomme, G., Castro, F., and Clarke, A. (2008). *Final Report: E-Waste Initiative at University Of São Paulo*. MIT Sloan School of Management. Massachusetts Institute of Technology. Cambridge. (p. 1-31)

Bowcock, H. (2011). *Electronics and E-Waste a Guide for Management*. Balkan E-waste Management Advocacy Network and Metamorphosis Foundation, Prague. (p. 3-45)

Chancerel, P. (2010). *Substance flow analysis of the recycling of small waste electricaland electronic equipment - An assessment of the recovery of gold and palladium*. Institut für Technischen Umweltschutz Band. Berlin. (p 8)

Chibunna, J. B., Siwar, C., Mohamed A. F. and Rawshan Ara Begum R. A. (2013). The Role of University in E-Waste Recycling: Case of Universiti Kebangsaan Malaysia. *Research Journal of Applied Science*s, 8: 59-64

Chibunna, J. B., Chamhuri, S., Begum, Rawshan, Ara B. and Fariz, M. A. (2010). E-Waste Management for sustainable campus: Case Study of Universiti Kebangsaan Malaysia. *Journal of Solid Waste Technology & Management*, 36 (3): 537-546

Chong, T. L. (2008). *E-waste Management. IMPAK Issue 1 / 2008*. Malaysian DOE, Kuala Lumpur.

Chung, S. and Murakami-Suzuki, R. (2008). *A Comparative Study of E-waste Recycling Systems in Japan, South Korea and Taiwan from EPR Perspective: Implication for Developing Countries.* Institute of Developing Economies, Japan External Trade Organization (IDE-JETRO). Chiba, Japan. Retrieved September 26, 2012, from: http://www.ide.go.jp/English/Publish/Download/Spot/pdf/30/007.pdf

Columbia University. (2012). *E-waste*, Office of Environmental Stewardship, Columbia University. New York. Retrieved August 30, 2012, from: http://www.environment.columbia.edu/

Cobbing, M. (2008). *Toxic tech: not in our backyard, uncovering the hidden flows of e-waste.* Greenpeace International. Amsterdam, Netherlands. (p. 3-10)

Construction Week. (2011). *Bee'ah launches e-waste treatment facility*, Retrieved February 14, 2013, from: http://www.constructionweekonline.com/article-14657-beeah-launches-e-waste-treatment-facility/#.UO5UOOScf-Y

Cui, J. & Zhang L. (2008). Metallurgical recovery of metals from electronic waste: A review. *Journal of Hazardous Materials*, 158: 228–256

Darby, L. and Obara L. (2005). Household recycling behaviour and attitudes towards the disposal of small electrical and electronic equipment. *Journal of Resources Conservation and Recycling* 44(1): 17-35.

Deubzer, O. (2011). *E-waste Management in Germany*. United Nations University – Institute for Sustainability and Peace (UNU-ISP). Bonn, Germany.

Earth 911, (2013). *E-waste*. Retrieved November 23, 2012, from: http://earth911.com/?s=e-waste

Ecroignard, R. C. (2008, October 6). Transboundary Movement of E-waste. *Proceedings of the Waste Management Conference (WasteCon2008)*. Durban, South Africa. (pp. 1-7)

Egwali, A. O. and Ekong, V. E. (2011). E-Waste Awareness and Disposal Practices: An Empirical Investigation. *World Journal of Applied Science and Technology*, 4(1): 104-1-09

EMPA, (2009). *Hazardous Technologies*, Retrieved September 30, 2012, from: http://ewasteguide.info/node/10

Environmental News Services. (2012). *Europe Expands Electronic Waste Collection, Recycling Law*. Retrieved December 3, 2012, from: http://ens-newswire.com/2012/01/20/europe-expands-electronic-waste-collection-recycling-law/

EPR Working Group, (2008). *Extended Producer Responsibility – A Prescription for Clean Production, Pollution Prevention and Zero Waste.* Retrieved March 14, 2013, from: http://www.eprworkinggroup.org/

European Union. (2012). Directive 2012/19/EU of the European Parliament and of The Council of 4 July 2012 on Waste Electrical and Electronic Equipment (WEEE). *Official Journal of the European Union,* 55:1-9.

European Union. (2003). Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on Waste Electrical and Electronic Equipment (WEEE). *Official Journal of the European Union,* 37:24-37.

Federation of Malaysian Manufacturers, (2013). *Increasing Public Awareness on E-Waste*. Wisma FMM, Kuala Lumpur. (p. 1-2)

Franklin, K. and Feldman, J. W. (2011). *E-waste Awareness and Practices Among Wisconsin Businesses and Institutions*. University of Wisconsin, Oshkosh. (p. 3-10)

Gaidajis, G, Angelakoglou, K, and Aktsoglou, D., (2010). E-waste: Environmental Problems and Current Management. *Engineering Science and Technology* Review 3(1): 193-199.

General Motors, (2012). *GM, ABB Demonstrate Chevrolet Volt Battery Reuse Unit – World's first use of electric vehicle batteries for energy storage nears grid testing*. Retrieved November 22, 2012, from: http://media.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2012/Nov/electrification/1114_reuse.html

Gold International Machinery, (2012). NEW Precious Metal Recovery from E-Waste & I-Waste. Retrieved November 20, 2012, from:

http://goldmachinery.com/machinery/i-waste.htm

Google Maps, (2013). *Map of Klang Valley, Malaysia*. Retrieved February 12, 2013, from: https://maps.google.com.my/maps?q=google+map+malaysia&ie=UTF-8&hq=&hnear=0x3034d3975f6730af:0x745969328211cd8,Malaysia&gl=my&ei=TQ8NUvPCHuLQ7Aau44CQAg&ved=0CC0Q8gEwAA

Government of Delhi, (2012). *Awareness Workshop Establishing E-waste Collection Mechanism in Schools & colleges*. Retrieved November 13, 2012, from: http://www.igep.in/live/hrdpmp/hrdpmaster/igep/content/e48745/e49028/e49649/SchoolWorkshopwithDoE.pdf

Greenpeace International. (2008). *Poisoning the Poor Electronic Waste in Ghana* Retrieved October 25, 2012, from: http://www.greenpeace.org/international/Global/international/planet-2/report/2008/9/poisoning-the-poor-electonic.pdf

Griffith University. (2013). E-waste. Retrieved from November 5, 2012, from: http://www.griffith.edu.au/engineering-information-technology/e-waste-research-group

Harding, K. (2012). *Auburn University's E-Waste Recycling Efforts Prevent Computers from Going in the Garbage*. Auburn University. Alabama Retrieved October 15, 2012 from: http://ocm.auburn.edu/featured_story/terra_blight.html#.UPZebR2cf-Y

Harman Shah. A. H., Mohamed. A. F., Junaidah. A.K. and Abdul Samand. A.H. (2012). *Awareness and community participation for e-waste recycling: Determining factors for sustainability*. Paper presented in conference Proceedings of 'International Association for People-Environment Studies (IAPS)', Glasgow, Scotland.

Hawari, M. and Hassan, M. H. (2008). E-Waste: Ethical Implications for Education and Research. *IIUM Engineering Journal*, 9(2): 11-26

Hawkin, K. (2012). *The Town without Trash: Kamikatsu*, Japan, Retrieved February 14, 2013, from: http://gimundo.com/news/article/the-town-without-trash-kamikatsu-japan/

Herat, S. (2011). *Major Threats from E-Waste: Current Generation and Impacts*. Wiley-VCH Verlag GmbH & Co. KGaA. Retrieved November 3, 2012, from: http://www.chemistryviews.org/details/ezine/1037973/Major_Threats_From_E-Waste_Current_Generation_And_Impacts.html

Heart, S. and Agamuthu, P., (2012). Review on Challenges and Issues in E-waste Management in Asian Countries. *Waste Management and Research* 30: 1113-1129.

Illinois Sustainable Technology Center. (2012). *2012 International E-Waste Design competition Winners Announced.* Retrieved September 10, 2012, from: http://www.sustainelectronics.illinois.edu/

IMRB International. (2010). *E-waste Assessment in Kolkata Metropolitan Area, Indian Chambers of Commerce Kolkata.* West Bengal Pollution Control Board and Gtz. Kolkata, India. (p. 6-40)

Incisive Media Investments Limited. (2013). *Poor Awareness Holding Back E-Waste Recycling.* Retrieved January 8, 2013, from: http://www.computing.co.uk/ctg/news/1861141/poor-awareness-holding-waste-recycling

International Telecommunications Union (ITU). (2012). *End-Of-Life Management for ICT Equipment.* Retrieved from: www.itu.int/ITU-T/climatechange/ess

Institute for Water Quality, Resource and Waste Management (IWR), (2012). *STAN2WEB*. Retrieved April 2, 2013, from: http://www.stan2web.net/

Jomo Kenyatta University of Agriculture and Technology (JKUAT). (2009). *E-waste Management Policy*. Retrieved August 3, 2012, from: http://www.jkuat.ac.ke/

Kahhat, R., Kim J., Xua M., Allenbya B., Williams E. and Zhang P. (2008). Exploring e-waste management systems in the United States. *Resources, Conservation and Recycling* 52: 955–964

Kahhat, R. & Williams, E., (2009). Product or Waste? Importation and End-of-Life Processing of Computers in Peru, *Environmental Science & Technology* 43 (15): 6010–6016

Kalana J. A., (2010). Electrical and Electronic Waste Management Practice by households in Shah Alam, Selangor, Malaysia, *International Journal of Environmental Sciences,* 1(2): 132-144

Kamar, P. (2012). Good Response to E-waste Project. *The New Straits Times Press* Retrieved February 14, 2013, from: http://www.nst.com.my/nation/general/good-response-to-e-waste-project-1.111833

Kang, H. Y. and Schoenung J. M. (2005). Electronic waste recycling: A review of US infrastructure and technology options. *Resources Conservation and Recycling* 45(4): 368-400.

Kansas University. (2012). *E-waste Recycling*. Retrieved September 24, 2012, from: http://technology.ku.edu/ewaste-recycling

Killick, M. (2007), *ICT Replacement Strategy*. Retrieved November 12, 2012, from:

www.ictknowledgebase.org.uk/replacementstrategy

Kissling, R., Fitzpatrick C., Boenia H., Luepschen C., Andrew S. and Dickenson J., (2012) Definition of generic re-use operating models for electrical and electronic equipment. *Resources, Conservation and Recycling*, 65: 85–99.

Knudsen, L., (2010). *Electronic Waste Solutions - Electronic Waste Collection Days Event and Other Initiatives*. Retrieved Sepember 30, 2012, from: http://www.indiana.edu/~sustain/programs/internship-program-in-sustainability/docs/final-reports/AY09-10/Knudsen-AY9-10.pdf

Laha, S. (2011). *Transboundary Toxic E-Waste Flow: Environmental Injustice Through Neo-ecological Imperialism.* Retrieved Septmeber 13, 2012, from: http://www.iss.nl/fileadmin/ASSETS/iss/Documents/Conference_presentations/NatureInc_Somjita_Laha.pdf

Lee, H. (2009). *Electronic Waste Recycling in the Bay Area, California: What Do People Really Know*? Retrieved September 10, 2012, from: http://nature.berkeley.edu/classes/es196/projects/2009final/LeeH_2009.pdf

Lehmann, S. (2011). Resource Recovery and Materials Flow in the City: Zero Waste and Sustainable Consumption as Paradigmsin Urban Development. *Sustainable Development Law & Policy*, 11(1): 28-37

Leung L., Cai Z. W. and Wong M. H. (2006). Environmental Contamination from Electronic Waste Recycling at Guiyu, Southeast China. *Material Cycles and Waste Manage*, 8: 21–33.

Li J., Liu L., Ren J., Duan H. and Zheng L. (2012). Behavior of urban residents toward the discarding of waste electrical and electronic equipment: a case study in Baoding, China, *Waste Management and Research*, 30: 1187-97.

Lindhqvist, T. (2000). *Extended Producer Responsibility in Cleaner Production Policy Principle to Promote Environmental Improvements of Product Systems*. International Institute for Industrial Environmental Economics. Lund, Sweden. (p i-vi)

Ling., S. (2010). *E-waste keeps piling up, laments Ismail*. Retrieved on January 13, 2013, from: http://www.thestar.com.my

Liu, Xi., Tanaka M., Matsui Y. (2006). Generation amount prediction and material flow analysis of electronic waste: a case study in Beijing, China. *Waste Management Research*, 24: 434 – 445.

Logomasini A. (2008), *Electronic Waste, National Research and Testing Unit, Borås, Sweden.* Retrieved September 13, 2012, from: http://www.cei.org

Lundgren, K. (2012). *The global impact of e-waste: Addressing the challenge*. International Labour Organization. Geneva, Switzerland. (p. 9-64)

Macquarie University, (2012). *E-waste*, Macquarie University, Sydney Australia Retrieved September 5, 2012, from: http://www.ofm.mq.edu.au/ewaste.html

Malaysia DOE. (2012, July 19). *Management of Household Hazardous Waste.* Paper presented at the 10th Annual Waste Management Conference & Exhibition 'Waste To Opportunities'. Sime Darby Convention Centre, Kuala Lumpur, Malaysia.

Malaysia DOE. (2011), *E-Waste Management: Malaysia's Experience*, Retrieved September 13, 2012, from: http://www.doe.gov.my

Malaysia DOE. (2010). *Guidelines for the Classification of Used Electrical and Electronic Equipment in Malaysia.* Department of Environment, Malaysia.

Marcus, G., Childs A., Hristow, C., Williams, H. and Wilson, M. (2012). *E-Waste and Battery Recycling at Dalhousie University*. Retrieved September 3, 2012,from: http://environmental.science.dal.ca/Files/ENVS_3502_projects_212/EWaste_and_Battery_Recycling.pdf

Market and Market, (2011). *Global E-Waste Management Market (2011 – 2016).* Retrieved December 4, 2012, from: http://www.marketsandmarkets.com/Market-Reports/electronic-waste-management-market-373.html

McCrae, R. R., Kurtz, J.E., Yamagata, S. and Terracciano, A. (2011) Internal Consistency, Retest Reliability, and their Implications For Personality Scale Validity. *Pers Soc Psychol* 15(1): 28–50.

Mendes, J. E. (2011). *Electronic Waste at Florida Gulf Coast University: Research to Education to Action.* Florida Gulf Coast University. Florida. (p. 3-27)

Microsoft (2008). *Microsoft Partners Promote Reuse of Computers and Cut Electronic Waste.* Retrieved September 16, 2012, from: http://www.microsoft.com/unlimitedpotential

Ministry of Environment Japan, (2013). *The Asian Network for Prevention of Illegal Transboundary Movement of Hazardous Wastes* Retrieved September 13, 2012, from: http://www.env.go.jp/en/recycle/asian_net

Ministry of Higher Education (MoHE). (2013). *List of Institutitons of Higher Learning*. Retrieved March 23, 2013, from: http://www.mohe.gov.my/educationmsia/search.php#institution

Murray J. (2012). EU *Amps Up E-Waste Collection Rules For Companies, Consumers, Green Business.* Retrieved September 23, 2012, from: http://www.greenbiz.com/news/2012/08/15/eu-amps-up-ewaste-rules

Ogbomo M. O., Obuh A. O. and Ibolo E. (2012). Managing ICT Waste: The Case of Delta State University Abraka. Nigeria, *Library Philosophy and Practice*, Paper 736

Olowu D. (2012), Menace of E-Wastes in Developing Countries: An Agenda for Legal and Policy Responses', *Journal of Law, Environment and Development*, 8(1): 61-75

Prakash, S. and Manhart, A. (2010), *Socio-Economic Assessment and Feasibility Study on Sustainable E-Waste Management in Ghana.* Öko-Institut, Freiburg.

Priyadharshini, S. and Meenambal T., (2011). A Survey on Electronic Waste Management in Coimbatore. *International Journal of Engineering Science and Technology*, 3 (3): 2099-2104

Puckett, J. (2011). *Draft Technical Guidelines on Transboundary Movements of Used Electronic and Electrical Equipment and E-Waste, In Particular Regarding the Distinction between Waste and Non-Waste under the Basel Convention*. Basel Action Network. Seattle, USA. (p 5-17)

Puckett, J., Byster, L., Westervelt, S., Gutierrez, R., Davis S., Hussain, A. and Dutta, A. (2002). *Exporting Harm: The High-Tech Trashing Of Asia*. The Basel Action Network (BAN) and Silicon Valley Toxics Coalition (SVTC). Retrieved September 27, 2012, from: http://www.ban.org/E-waste/technotrashfinalcomp.pdf

Queens University. (2013). *University Games for E-waste Recycling*. Queens University. Ontario. Retrieved September 14, 2012, from: http://www.queensu.ca/news/articles/university-game-e-waste-recycling

Raina, M. (2010, October 4-6). *3Rs for Green Economy - Country Presentation*. Presentation at the 2nd Meeting of the Regional 3R Forum in Asia. Kuala Lumpur, Malaysia

Ramya, M. (2012). *IIT Students Make Systems Out of E-Waste*. Retrieved January 29, 2013, from: http://timesofindia.indiatimes.com

Rosoft, (2012). Sample size calculator. Retrieved October 24, 2012 from: http://www.raosoft.com/samplesize.html

Saleh, S. M. (2012). *Green IT Shaping the Industry*. Persatuan Industri Komputer dan Multimedia Malaysia (PIKOM). Selangor Darul Ehsan, Malaysia. (p. 1-8)

Santos, J. R. A. (1999). Cronbach's Alpha: A Tool for Assessing the Reliability of Scales. *Extension Journal*, 37:2 ISSN 1077-5315.

Sauder, K., Schilling, S. and Hamburg, O. G., (2010). *Transboundary Shipment of Waste Electrical and Electronic Equipment / Electronic Scrap – Optimization of Material Flows and Controls.* Federal Environment Agency. Germany. (p. 49-58)

Schluep, M. (2010, November 2-3). *E-Waste Management in Developing Countries – with a focus on Africa.* Presentation at ITU Symposium on ICTs and the Environment & Climate Change in Cairo. Cairo, Egypt.

Schluep, M., Hagelueken, C., Kuehr, R., Magalini, F., Maurer, C., Meskers, C., Mueller, E. and Wang, F. (2009). *Sustainable Innovation and Technology Transfer Industrial Sector Studies: Recycling- From E-Waste to Resources.* Retrieved December 23, 2012, from: http://www.cyrcle.it/resources/090630_UNEP_eW2R_finalreport_publication_screen_rvsd4-FIN.pdf

Sheehan, B. and Spiegelman, H., (2006*). Extended producer responsibility policies in the United States and Canada: history and status*. Greenleaf Publishing. Sheffield, U.K. (p. 202-204)

Shelton, R. (2010). Recycling E-waste. *Innovation and Empowerment. SNU-Tulsa Research Journal* 3 (1): 1-8

Smith, T. (2008). Toxic TVs and Poison PCs. Retrieved March 1, 2013, from: http://svtc.org/wp-content/uploads/ppc-ttv1.pdf

Statistics Help for Students, (2008). *How do I interpret data in SPSS for Pearson's r and scatterplots?* Retrieved December 25, 2012, from: http://statistics-help-for-students.com

Steubing, B., Ludwig, C., Böni, H. and Silva, U. (2008). *E-waste Generation in Chile: Analysis of the Generation of Computer Waste using Material Flow Analysis*. Swiss Federal Institute of Technology (EPFL) / Swiss Federal Laboratories for Materials Testing and Research (EMPA). Switzerland.

Streicher-Porte, M., Widmer, R., Jain, A., Bader, H. P., Scheidegger, R. and Kytzia, S. (2005). Key drivers of the e-waste recycling system: Assessing and modeling e-waste processing in the informal sector in Delhi. *Environmental Impact Assessment Review*, 25: 472-491.

Sustainable Technology Center, (2009). *Strategies for Improving the Sustainability of E-Waste Management Systems*. Champaign, Illinois. (p. 2-9)

Swedish Environmental Protection Agency (SEPA), (2011). *Recycling and Disposal* *of Electronic Waste - Health Hazards and Environmental Impacts*. SEPA. Stockholm, Sweden.

Tengku Hamzah, T. A. A. (2011). *Making Sense of Environmental Governance: A Study of E-waste in Malaysia*. Retrieved October 24, 2012, from: http://etheses.dur.ac.uk/670/

The Hindu. (2011). Renewing E-waste. Retrieved Setember 30, 2012 from: http://www.thehindu.com/

The Star Online (2010), *Uggah: E-Waste Poses a Serious Threat to the Environs.* Retrieved December 28, 2012, from: http://thestar.com.my/metro/story.asp?file=/2010/10/25/sarawak/7290398&sec=sarawak

Toshiba Malaysia. (2013, Feb). *Toshiba Voluntary E-Waste Take-back Scheme.* Retrieved March 25, 2013, from: http://toshiba.com.my/news/toshiba_ewaste/

Treehugger, (2012). E-waste reuse. Retrieved October 24, 2012, from: http://www.treehugger.com/tag/e-waste/page/4/

UNEP. (2012). *New European Union Directive on E-waste Comes into Force*. Retrieved January 29, 2012, from: http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=2692&ArticleID=9254&l=en

UNEP, (2008). *Manual 3: WEEE / E-waste "Take Back System" (DRAFT).* UNEP / DTIE / IETC

UNEP, (2007). *E-waste: Volume 1, Inventory Assessment Manual*. UNEP. Osaka, Japan.

UNEP. (2006, Nov). *Press Release, "Basel Conference Addresses Electronic Wastes Challenge."* UNEP. Retrieved September 24, 2012, from: http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=485&ArticleID=5431&l=en

University of Illinois, (2009). *Strategies for Improving the Sustainability of E-Waste Management Systems.* Retrieved September 13, 2012, from: http://www.sustainelectronics.illinois.edu/concept_paper.pdf

University of Sydney. (2012). *What Is Sydney University Doing?* University of Sydney. Sydney, Australia Retrieved September 13, 2012, from: http://sydney.edu.au/facilities/sustainable_campus/waste/university.shtml

USEPA. (2012). *Municipal Guide for Comprehensive Management of E-waste in the*

Northeast of Mexico. El Colegio de la Frontera Norte. Retrieved October 24, 2012, from: http://www.epa.gov/border2020/reg6/txcoahnltaum/docs/municipal-guide-ewaste-2012-02-english.pdf

USEPA. (2009). *Municipal Solid Waste Generation, Recycling, and Disposal in the United States: Facts and Figures for 2008*. Retrieved October 24, 2012, from: http://www.epa.gov/epawaste/nonhaz/municipal/pubs/msw2008data.pdf

USEPA. (2008). *Electronic Waste Management in the United States, Approach 1*. Retrieved October 24, 2012, from: http://www.epa.gov/osw/conserve/materials/ecycling/docs/app- 1.pdf

US Interagency Task Force on Electronics Stewardship. (2011*). National Strategy For Electronics Stewardship*. Retrieved September 12, 2012, from: http://www.epa.gov/wastes/conserve/materials/ecycling/taskforce/docs/strategy.pdf

Van der Voet, E., Guinee, J. B., Udo de Haes, H.A., editors. (2000). *Heavy Metals: A Problem Solved?* Dordrecht7 Kluwer Academic Publishers.

Widmer R., Oswald-Krapf H., Sinha-Khetriwal D., Schnellmann M. and Boni H. (2005). Global perspectives on e-waste. *Environmental Impact Assessment Review* 25: 436–458

Williams, G. (2011). *Indiana University Electronic Waste Initiatives*. Retrieved September 13, 2012, from: http://www.indiana.edu/~sustain/programs/internship-program-in-sustainability/docs/final-reports/AY10-11/E-Waste_Williams.pdf

William, M.K. (2006). *Types of Reliability*. Retrieved January 24, 2013, from: http://www.socialresearchmethods.net/kb/reltypes.php

Xin, Z. (2012). *Fortune Squandered Without Recycling*, Retrieved January 25, 2013 from: http://www.chinadaily.com.cn/cndy/2012-08/06/content_15645939.html

Yosuf, N. (2008). *A Study on Electronic Waste (E-waste).* Retrieved September 3, 2012, from: http://www.efka.utm.my/thesis/images/3PSM/2005/4JKAS/Part4/noraidaca020044dttp.pdf.pdf

Young, L. (2012). *Global Trade in Electronic Waste*. Retrieved March 3, 2013, from: http://www.pbs.org/frontlineworld/stories/ghana804/map/map.html

Yu, J. (2010, October 25), *Uggah: E-Waste Poses A Serious Threat To The*

Environs. Retrieved December 23, 2012, from: http://thestar.com.my/metro/story.asp?file=/2010/10/25/sarawak/7290398&sec=sarawak

Zero Waste Organization, (2012). *Creating a Prosperous and Inclusive Future without Waste.* Retrieved September 26, 2012, from: http://www.zerowaste.org/