Greening Information Technology: E-waste Management Approach

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Abstract

In recent years, as rapid growth and innovation occur in the technological sector of the economy, most business organizations have realized the need for greening their information technology for reasons both of social responsibility and reduction of the costs of operation. Also, government agencies have contributed to Greening Information Technology (GIT) by initiating programs and regulations that enforce it. The idea behind the GIT is to focus on ways of reducing the technological footprint on the environment. This is done by promoting new approaches in reducing pollution on the environment through effective disposal and recycling of defunct information technology (IT) products and factory waste. This paper presents electronic waste (e-waste) management from the manufacturer's and consumer's perspectives and by using statistical technique to determine the economic significance of revenue generated from recycling e-waste.

Keywords: GIT; E-waste Management; Recycling; Manufacturers; Revenue.

1. Introduction

Greening Information Technology (GIT) has been in practice since the launch of the Energy Star program by the Environment Protection Agency (EPA) in the United States in 1992, with the aim of saving money and protecting the environment through energy efficient products and practices. Other voluntary bodies have also joined in the campaign for green initiatives. Examples include: Climate Savers Computing Initiative, Green Electronics Council; Electronic Product Environmental Assessment Tool (EPEAT), United States Climate Action Partnership, US National Academies Board on Atmospheric Sciences and Climate (BASC); Local Governments for Sustainability, and the United Nations Environment Program (UNEP). All of these bodies have a similar mission which is aimed at promoting the development, deployment, and adoption of environmentally friendly IT technologies, as well as to both improve the efficiency of IT and reduce the health hazard threat posed by e-waste release in the environment.

Environmental pollution affects air, water, and soil; can have a devastating impact on all life; and the problem keeps accelerating with the accelerating pace of technological growth. An alarming new aspect of pollution is that which arises from the growth of electronic technologies. The global market for electrical and electronic equipment continues to expand exponentially, while the lifespan of these products decreases through increasingly rapid obsolescence. As a result, the burden of effectively controlling this e-waste is receiving considerable attention from policy makers. The objective of this study is to explore recycling techniques as an effective means of e-waste management aimed at curbing the problem of pollution that might result from improper disposal of e-waste. Recycling e-waste is not just a viable solution to eliminate the harmful effects of e-waste disposal, but a sound business proposition in itself.

2. GIT Initiatives

Since the launch of the Energy Star program in 1992 by the EPA, which marks the beginning of green initiatives, there have been remarkable green initiatives in IT. This program has expanded to include criteria on energy usage, ergonomics, and the use of hazardous materials in construction of IT products [1]. This means manufacturers create electronics in a way that positively reflects the triple bottom line (social responsibility, economic viability and the impact on the environment). Electronics sold to businesses or people are used in a green way by reducing power usage and disposing of them properly or recycling them. The idea is to make electronics a green product from beginning to end. The solution to greening IT is to create an efficient system that implements these factors in an environmentally friendly way. A good example would be IT managers' purchasing hardware that has been EPEAT approved, meaning that maintenance is reduced, the hardware's life is extended, and makes recycling the electronic appliance easy once it is no longer necessary. Organizations use the Greening IT initiatives lifecycle when designing and implementing green IT technologies. The stages in the life cycle include: Strategy, Design, Implementation, Operations and Continual Improvements [5].

Recently, greening initiatives have touched areas which include: Improving Data Center Cooling Methods, enhancing Efficient Servers usage by Virtualization, Alternative Storage Methods, Using Thin Clients, Strengthening Printer's Output Management, Exploring Alternative Sources of Energy, Energy saver initiatives, and Proper Disposal and Recycling: This is so important because it potentially eliminates the threat of harmful toxins being released into the environment and allows for the reuse of equipment thereby reducing the amount of hazardous waste in the environment. These initiatives exhibit the requirement of going green. Along with the above mentioned green IT initiatives, every sector and area of IT is practicing green strategy and policies because sustainable development of IT is the future need [1]. It should be noted that modern smart phones are also capable of greening IT. They have faster processors, more ram, faster wireless Internet connectivity and larger memories. Mobile Phones consume very low power. Overall the benefits of greening IT result in saving money, reducing costs, and conserving energy, along with helping the environment.

3. Composition of IT and impact on the environment

Continuously reducing environmental impact is more challenging. There is a consensus that serious negative environmental repercussions are the consequence of manmade pollution. From examining the atmosphere, soils and oceans, governments, partners, consumers and industry organizations want companies to have a more positive impact on the environment. The most common environmental impact measurement is labeled carbon footprint, usually measured in tCO2eq (metric tons of CO2 equivalent) based on the source of energy and amount consumed, manufacturing and logistics impact (often labeled embodied cost), as well as end-of-life (EOL) impact (e-waste, environmental externalities, and so on) [8]. Here, the global volume of discarded e-waste continues to increase each year, making it one of the most critical aspects of waste disposal today. The United Nations Environmental Program had estimated that over 20 to 50 million tons (metric tons) of e-waste is being generated yearly worldwide and this accounts for more than 5 percent of municipal waste stream [13, 14]. According to the Environmental Protection Agency [3], in the United States alone, out of 3.41 million tons (metric tons) of e-waste generated yearly, only 24.9 percent (around 850,000 tons) was recycled. Also Omar et.al (2009) predicted that by the year 2015 over 500 million units of e-waste will be disposed of and slightly over 113 million units will be recycled. The amount of global e-waste is expected to grow by 8 percent per year. A major driver of the growing e-waste problem is the fact that these electronic products sell more (as the consumers seek for advanced gadgets) and have a shorter lifespan – less than two years for computers and cell phones. The rest was sent to landfills or incinerators [16]. Figure 1 shows the percentage composition of electronic gadgets which includes metals, plastics, glass and other miscellaneous materials.

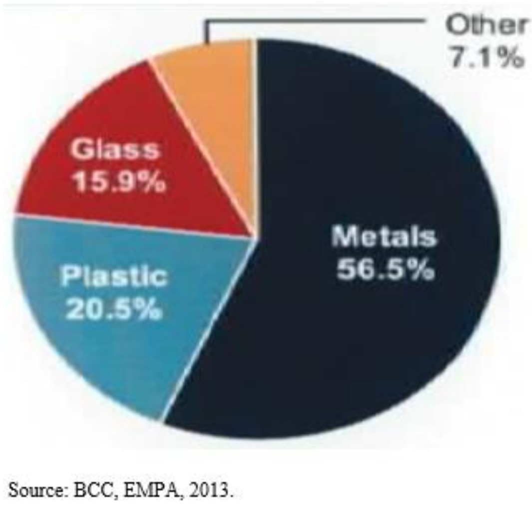


Figure1: Composition of EOL Electronics.

Unlike most solid municipal wastes, certain components of electronic equipment contain toxic substances, and their improper disposal generates a threat to the environment as well as to human health [18]. For example, electronic products such as monitors, Central Processing Units (CPUs), and printers which have components such as printed circuit boards (PCB), contains hazardous materials such as heavy-metal lead, mercury, barium, arsenic, antimony, cadmium, nickel, beryllium, zinc, etc.

Most of the materials incorporated into IT products are of concern due to known or suspected risks. When these products are placed in landfills or incinerated at end of life, they pose health risks due to the hazardous materials they contain. The improper disposal of IT products could lead to polluting the environment. As more e-waste is placed in landfills, exposure to environmental toxins is likely to increase, resulting in elevated risks of cancer and developmental and neurological disorders [11]. The EPA also reports that e-waste represents 2% of America's trash in landfills, but it equals 70 percent of overall toxic waste.

The extreme amount of lead in electronic devices alone causes damage in the central and peripheral nervous systems, the blood and the kidneys. Phasing out lead globally would mean 1.2 million fewer deaths per year, of which 125,000 are children [16]. Some health effects of e-waste materials on the human body include:

- Lead – The health effects of lead are well known; lead exposure in children affects nearly every system in the body and especially the brain and has already been banned from many consumer products.
- Mercury – Mercury is toxic in very low doses, and causes brain and kidney damage. It can be passed on through breast milk; just 1/70th of a teaspoon of mercury can contaminate 20 acres of a lake, making the fish unfit to eat.
- Cadmium – Cadmium accumulates in the human body and poisons the kidneys.
- BFRs – Brominated flame retardants (BFRs) may seriously affect hormonal functions critical for normal development. A recent study of dust on computers in workplaces and homes found BFRs in every sample taken. One group of BFRs, PBDEs, has been found in alarming rates in the breast milk of women in Sweden and the U.S. [12]. Due to the presence of these substances in IT products, recycling and disposal of e-waste becomes an important issue.

This paper presents e-waste management trends that have been in practice since the inception of the greening initiative, forecasts the revenue that will be generated by effectively recycling e-waste and suggests ways to further improve e-waste management. The paper is organized as follows: green manufacturing, e-waste management, economic significance of e-waste recycling and recommendations for e-waste management.

4. Green manufacturing

Green manufacturing stresses the need to minimize e-waste during the manufacturing of electronics and other subsystems to reduce the environmental impact of these activities.

Electronic products are made from valuable resources and highly engineered materials, including metals, plastics, and glass, all of which require energy to mine and manufacture. Reusing and recycling consumer electronics conserves our natural resources and avoids air and water pollution, as well as greenhouse gas emissions that are caused by manufacturing virgin materials [3]. Government regulatory authorities also actively work to promote this concept by introducing several voluntary programs and regulations for their enforcement.

In 2003, the Restriction of Hazardous Substances Directive (RoHS) was adopted by the European Union. This legislation restricts the use of hazardous materials in the manufacture of various types of electronic and electrical equipment. The directive is closely linked with the Waste Electrical and Electronic Equipment Directive (WEEE), which sets collection, recycling, and recovery targets for electrical goods and is part of a legislative initiative that aims to reduce the huge amounts of toxic e-waste. National Integrated Strategy for the Management of Waste Electrical and Electronic Equipment, which came into existence in 2007, gives a 10-year road map for WEEE/E-waste management till 2017. The major objectives of this strategy are:

- To manage domestic post-consumer WEEE in a scientific and systematic manner;
- To establish an efficient and sustainable WEEE management system with cooperation from every sector of society;
- To reduce hazardous wastes from EEE at the origin and to encourage environmentally friendly design and production;
- To enhance the competitiveness and negotiation power of the country in international trade; and
- To have nationwide efficient and effective integrated WEEE management by 2017.

Driven by these directives, VIA Technologies, a Taiwanese chip manufacturer, has implemented a set of internal regulations in order to develop products that are compliant with these accepted policies, including the use of nonhazardous materials in its production of chipsets, processors, and companion chips.

In 2001, the company focused on lead-free manufacturing, introducing the Enhanced Ball Grid Array (EBGA) package for power efficient. VIA processors and the Heat Sink Ball Grid Array (HSBGA) package for their chipsets. In traditional manufacturing processes, lead is used to attach the silicon core to the inside of the package and to facilitate integration onto the motherboard through tiny solder balls on the underside of the package. VIA's modern lead-free manufacturing technologies do not require a lead bead, and the solder balls now consist of a tin, silver, and copper composite [5].

5. E-Waste Managements

Ayesha and Anjum, (2013) describes “e-waste as old, end-of-life or discarded appliances using electricity.” It includes computers, consumer electronics, refrigerators, etc., which have been disposed of by their original users. “E-waste” is used as a generic term embracing all types of waste containing electrically powered components. It contains both valuable materials as well as hazardous materials which require special handling and recycling methods. This guide covers all categories of e-waste but emphasizes categories which contain problematic, scarce and valuable or otherwise interesting materials. For example, computers, LCD/CRT screen, cooling appliances, mobile phones, etc., contain precious metals, flame retarded plastics, carbon-fluoride-chloride (CFC) foams and many other substances. E-waste is categorized as large and small household appliances; office, information and communication equipment; entertainment and consumer electronics; lighting equipment; electric and electronic tools; toys, leisure, sports and recreational equipment; medical instruments and equipment; surveillance and control equipment; and automatic issuing machines.

E-waste management practices comprise various means of final disposal of end-of-life equipment which have different impacts on human health and the environment. It can be distinguished between state-of-the-art recycling technologies, which comply with high environmental and occupational health standards; and hazardous technologies that bears a great risk for both health and the environment, and are often used in countries where no strict standards exist. The United Nations Environmental Program (UNEP) Manual 3 (2011), summarizes the overall e-waste management system as three smaller systems:

- A collection system, which projects the mass of e-waste collected, cost of operating collection sites and the costs and environmental impacts of transporting e-waste as a function of the geo-economic context and the chosen number of available collection and processing points;
- A processing system, which calculates the amount of various materials recovered from the recycling process and the associated revenues and costs to the system;
- A management and financing system, which accounts for the overhead costs of operating an e-waste system.

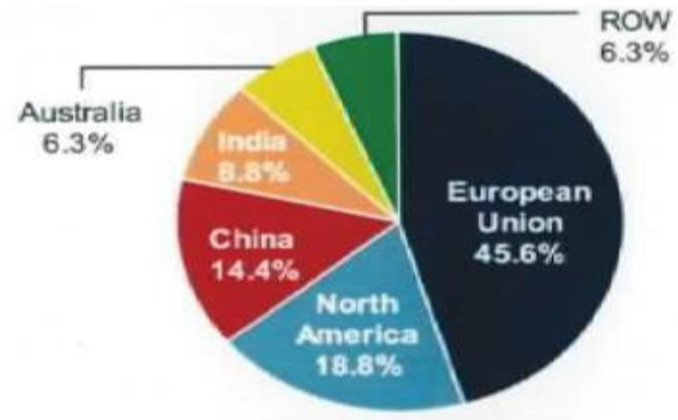
Ayesha and Anjum, (2013) described how e-waste usually ends up in a manner that might have negatively impact the environment:

- **Incinerator:** This is the process of destroying waste through burning. Because of the variety of substances found in e-waste, incineration is associated with major risk of generating and dispersing contaminants and toxic substances.
- **Open burning:** Since open fires burn at relatively low temperatures, they release many more pollutants than in a controlled incineration process. Inhalation of open fire emissions can trigger asthma attacks, respiratory infections, and cause other problems

such as coughing wheezing, chest pain and eye irritation. Often open fires burn with inadequate oxygen, forming carbon monoxide, which poisons the blood when inhaled.

- **Land filling:** Land filling is one of the most widely used methods of waste disposal. However, it is common knowledge that all landfills leak. The leachate often contains heavy metals and other toxic substances which can contaminate ground and water resources.

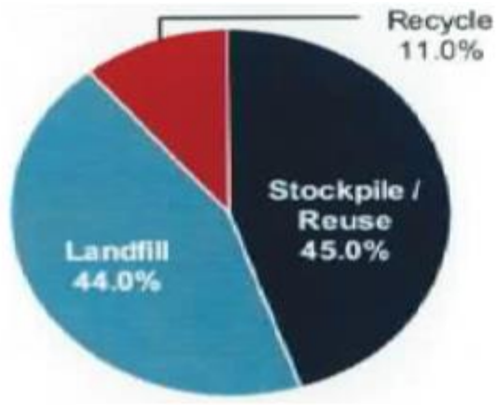
Figure 2 shows the distribution of global e-waste generated by region with European Union having the largest section followed by North America, China, India, Australia and the rest of the world (ROW) respectively.



Source: UNEP, European Commission, BCC, 2013.

Figure 2: Global E-waste Generated by Region

Figure 3 shows the distribution of global electronic recovery, recycling, and disposal practices with stockpile/reuse having the largest section, followed by landfill and recycling respectively.



Source: UNEP, European Commission, BCC, 2013.

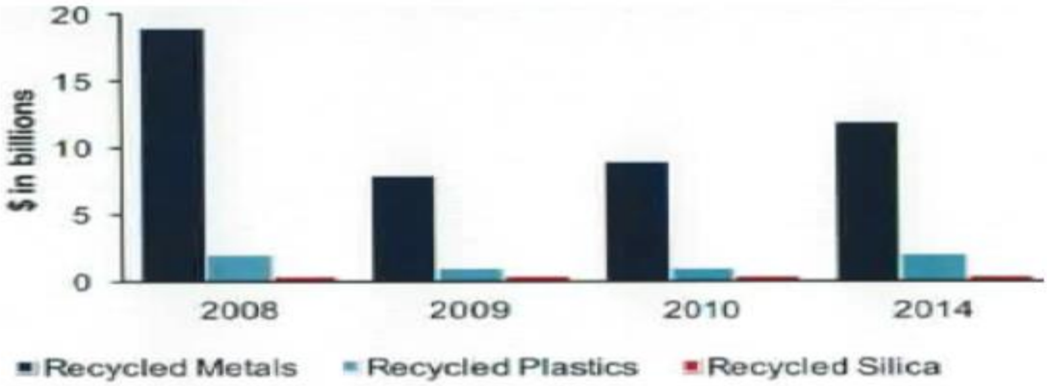
Figure 3: Global Electronic Recovery, Recycling, and Disposal Practices

The Federal Environmental Protection Agency (EPA) estimates over four million tons of e-waste is hitting landfills each year, with the numbers compounding every year. As more e-waste is placed in landfills, exposure to environmental toxins is likely to increase, resulting in elevated risks of cancer and developmental and neurological disorders. Much of this e-waste contains significant quantities of non-biodegradable toxic substances. Computers, servers, and other IT hardware contain mercury, lead, barium, arsenic, antimony, and cadmium. Flat-panel light displays contain mercury, and CRT monitors contain lead [9]. With this, there is a need to remake an existing computer or appropriately disposing of, or recycling, unwanted electronic equipment in an eco-friendly manner.

6. Economic Significance of E-waste Recycling Model

One of the most effective solutions to the growing e-waste problem in the environment is to recycle raw materials from end-of-life electronics. Electronic devices are composed of a variety of components, including metals that can be retrieved for future uses. The recycling chain for e-waste consists of three main subsequent steps: collection, sorting/dismantling and pre-processing (including sorting, dismantling, mechanical treatment), and end-processing (including refining and disposal) [14]. Recycling provides reuse possibilities, which allow natural resources to be conserved and also avoid the air and water pollution caused by improper disposal.

Disposal of e-waste raises serious environmental and health issues. Recycling reduces the amount of greenhouse gas (GHG) emission caused by the manufacturing of new products. Recycling has environmental benefits at every stage in the life cycle of a consumer product—from the raw material with which it is made to its final method of disposal. Aside from reducing GHG emissions, which contribute to global warming, recycling, including composting also provides significant economic and job creation impacts [7]. Figure 4 shows the projected e-waste recycling materials global sales from 2008 to 2014.



Source: BCC, 2013.

Figure 4: Global Sales Projections for E-waste recycling by Type of Materials.

6.1.Closed Material Loop Manufacturing Model

Weck et al. (2013), researching ~~on~~ the trends in manufacturing technology innovation, described the inclusion of recycling in the advancement and impacts in manufacturing processes. The scarcity and apparent monopolization of some materials such as rare earth elements, the increases in transportation costs, the new environmental regulations, and customer perceptions promote more sustainability in manufacturing. These efforts center primarily on closing material loop cycles through reuse, remanufacturing and recycling of materials as well as the minimization of energy consumption during manufacturing. Figure 5 describes the closed material loop with recycling in advanced manufacturing processes. However, the lack of closing the material loop for electronic and electrical products manufacturing leads not only to significant environmental problems but also to systematic depletion of the resource base in secondary materials [14].

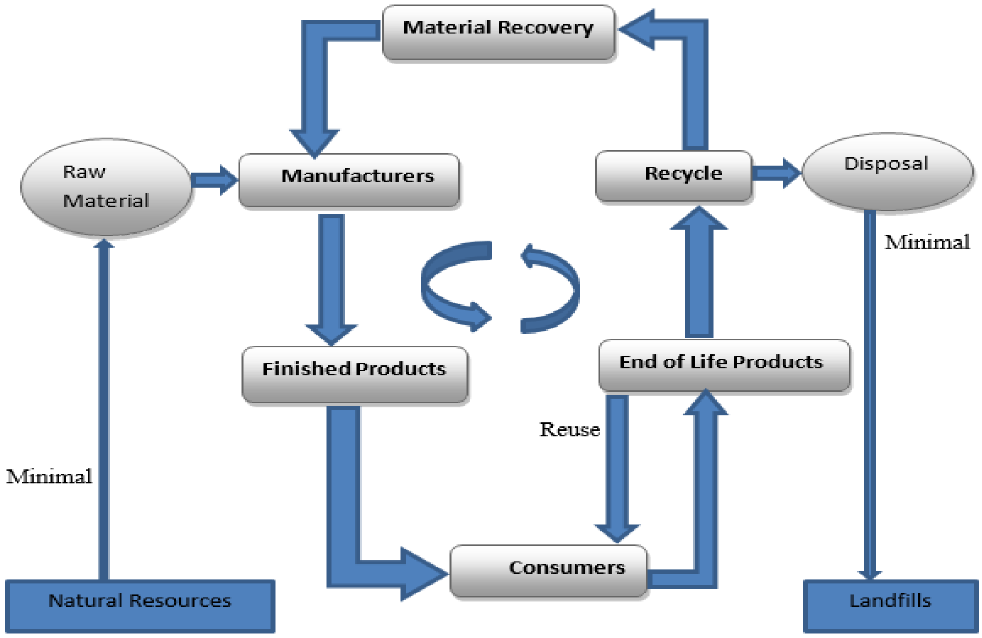
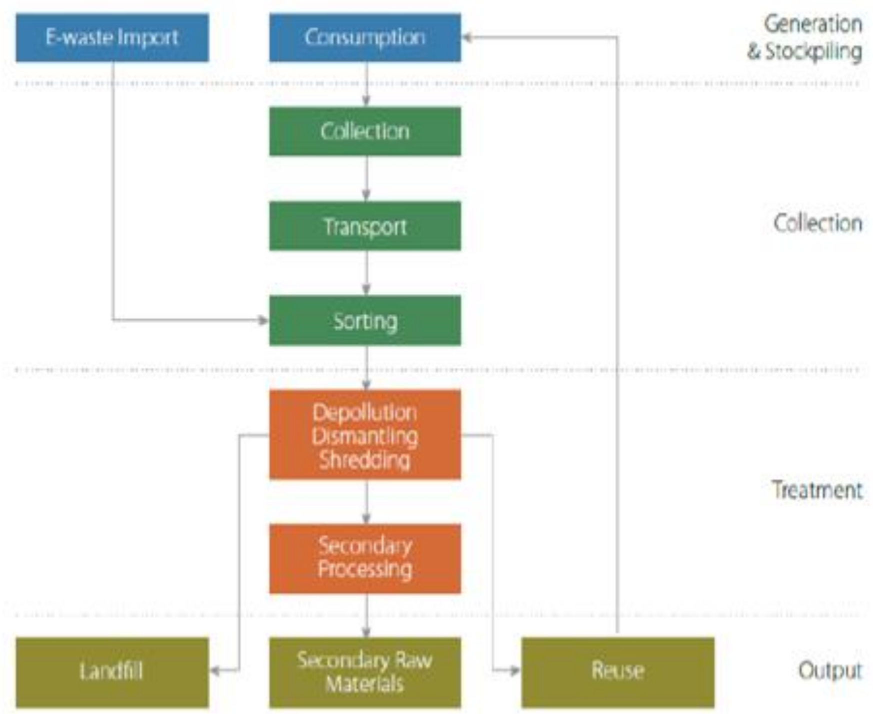


Figure 5: Closed material loop manufacturing with recycling.

Figure 5 shows materials flow cycle from manufacturers to consumers and back to manufacturers when effective adherence to the close material loop is maintained. Here, manufacturers convert the raw materials into finished products, which are ready to transport to consumers for use. The consumers then purchase these finished products and tend to use them through to their EOL. At EOL of products, they are reused or recycled. Here at the recycling stage, three main steps are involved: collection, sorting/dismantling and pre-processing (including sorting, dismantling, mechanical treatment), and end-processing (including refining and disposal). At end-processing, important materials are refined and recovered as recovery materials while less important materials are discarded or disposed to landfills. End-of life management options for e-waste include reuse of functional electronics, refurbishment and repair of electronics, reuse and recovery of electronic components, end-processing for recovering metals, and disposal.

6.2. E-waste Recycling Processing

Figure 6 shows the e-waste processing steps which consist of three major steps: collection, sorting/dismantling/mechanical processing (including shredding, magnetic separation, etc.), and end-processing.



Source: InfoDev (The World Bank Group), 2009.

Figure 6: E-waste Processing steps.

Collection is generally achieved through take-back programs sponsored by retailers and manufacturers of electronics, municipal drop-off collection centers, and non-profit and for-profit collection programs.

- Sorting/Dismantling and Mechanical Processing generally has the end goal of separating device streams into material streams: primarily metals, glass, and plastics, for end-processing. This stage is to upgrade the valuable material content, and remove and safely dispose of hazardous materials. It should be noted that the optimal level of pre-processing is dictated by the quality of feed requirements for end-processing. Excessive pre-processing not only adds cost, but also may lead to significant losses of precious metals. Therefore there is an optimal level of preprocessing that needs to be achieved.
- End-Processing is dictated by the material stream and generally aims to recover valuable components (i.e., precious metals), which form the secondary raw materials, and remove impurities. Sampling and assaying is necessary in order to determine the composition and content of precious metals in the e-waste stream, and to ensure that the optimum process is used to recover precious metals [7]. An EPA report reveals that recycling one million cell phones, can recover more than 9,000 kg (20,000 lb) of copper, 9 kg (20 lb) of palladium, 250 kg (550 lb) of silver, and 24 kg (50 lb) of gold.

6.3.E-waste Recycling Data Collation

Table 1 describes the growing rate of e-waste and the recycling rate from years 1999 through 2012. The e-waste products are selected consumer electronics which include products such as TVs, VCRs, DVD players, video cameras, stereo systems, telephones, and computer equipment. It can be seen that e-waste recycled continually increased as e-waste generated while the e-waste disposed fluctuates over the given years.

Table 1: E-waste generated, disposed, and recycled for year 1999 through 2012

Year	Total e-waste generated Tons(000)	Total e-waste disposed Tons(000)	Total e-waste recycled Tons(000)	Total percent recycled Tons (%)
1999	1,056	899.2	157	14.9
2000	1,282	1092	190	14.8
2001	1,447.6	1237.6	210	14.5
2002	1,634	1384	250	15.3
2003	1,944.7	1654.7	290	14.9
2004	2,043.5	1723.5	320	15.7
2005	2,630	2,270	360	13.7
2006	2,930	2,440	490	16.7
2007	3,010	2,460	550	18.3
2008	3,160	2,600	560	17.7
2009	3,190	2,590	600	18.8
2010	3,320	2,670	650	19.6
2011	3,410	2,560	850	24.9
2012	3,420	2,420	1,000	29.2

Data source: EPA, 2014

Table 2 shows the increasing quantity of e-waste recycled and the rate of recycling alongside the revenue generated. As the recycling figure increases, so does the revenue generated from the activities. It can be seen that in the year 2011 the e-waste revenue generated reached 5billion dollars [4], with an increase in the total e-waste recycled of 200,000 tons compared to year 2010.

Table 2: E-waste recycled for year 1999 through 2012 with the revenue generated

Year	Total e-waste recycled Tons(000)	Total percent recycled Tons (%)	Total recycled revenue generated Billion Dollars ($)
1999	157	14.9	0.5940
2000	190	14.8	0.6980
2001	210	14.5	0.8197
2002	250	15.3	0.9587
2003	290	14.9	1.1320
2004	320	15.7	1.3301
2005	360	13.7	1.5778
2006	490	16.7	1.8283
2007	550	18.3	2.1948
2008	560	17.7	2.6865
2009	600	18.8	3.2642
2010	650	19.6	4.0200
2011	850	24.9	5.0000
2012	1,000	29.2	6.4600

Data source: EPA, ERI, 2014

6.4.Data Analysis

Linear regression is a statistical method used to find a predictive model from the observed data. In this study, the first model used the simple linear regression to investigate any significant relation between the wastes over the years. The second model is the multiple regression model used to investigate the relation between the cost "revenue" as the dependent variable, and the wastes and the years both as independent variables, to predict the total recycled revenue generated in billions of dollars, the dataset starting from 1999 up to 2012. SAS software was used to estimate the parameters of the simple and the multiple regression models. The results showed a significant relationship between the years and the wastes, and also between the dependent variable (revenue) and the independent variables (years and wastes).

The first model which is the linear regression. A relationship

$$Waste = \beta_0 + \beta_1 \times Year + \varepsilon$$

Between wastes and the years using the least square estimation (regression) is

$$Waste = -117659 + 58.9 \times Year$$

Where the R Square is equal to 0.9306 and adjusted R Square is equal to 0.9248. Table 3 shows the statistics analysis of the variance output of the data using the first model.

Table 3: Analysis of variance output using first model

ANOVA	*df*	*SS*	*MS*	*F*	*P-value*
Regression	1	789216	789216	160.8	<0.0001
Residual	12	58895	4908		
Total	13	848111			
	Coefficients	*Standard Error*	*t Stat*	*P-value*	
Intercept	-117659	9315	-12.63	<0.0001	
Year	58.9	4.64	12.68	<0.0001	

The model fits the data very well at the .01 significance level (F=160.8, p<.0001). R Square of .9306 says that this model accounts for 93% of the total variance. The model has the intercept of -117659 (T= -12.63, p<.0001) and the independent variables of 58.9 (T=12.68, p<.0001) the estimated parameters are significant at 0.01 level.

The second model, which is the multiple regression model, was used to predict the revenue using the years and wastes as independent variables. Transformation was used for the normality and the heterogeneity in the residual errors. The log transform is applied to the dependent variable.

A relationship

$$\log(revenue) = \beta_0 + \beta_1 year + \beta_1 waste + \varepsilon$$

Between the revenue and both wastes and the years is developed using least square regression and the model is found to be

$$\log(revenue) = -285.601 + 0.143 \times Year + 0.000622 \times waste \, .$$

It is desired to calculate the amount of revenue for years 1999 through 2012 in the case of using all waste instead of part of the waste (recycle part). Where R Square is equal to 0.9982 and the adjusted R Square is equal to 0.9979 (fragment). Table 4 shows the statistical variance analysis of the output data using the second model.

Table 4: Analysis of variance output using the second model

ANOVA	*Df*	*SS*	*MS*	*F*	*P-value*
Regression	2	7.32945	3.66472	3114.46	<0.0001
Residual	11	0.01294	0.00118		
Total	13	7.34239			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-285.601	17.245	-16.56	<0.0001
Year	0.14256	0.00863	16.52	<0.0001
Waste	0.00062236	0.00014	4.4	0.0011

The model fits the data very well at the 0.01 significance level (F=3114.46, p<.0001). R Square of 0.9982 says that this model accounts for 99.82% of the total variance. The model has the intercept of -285.601 (T=-16.56, p<.0001) and the two independent variables of 0.14256 (T=16.52, p<.0001) and 0.00062236 (T=4.4, p=.0011); all the estimated parameters are significant at 0.01 level.

Using both models to predict the amount of money for 2016, 2017 and 2018, the first model (Linear Regression) predicts the waste for the three years. The second model (Multiple Regression) predicts the revenue for the same years. Table 5 shows the prediction of revenues expected to be generated on years 2016, 2017 and 2018 as 28.84, 34.52, and 41.31 in billions of dollars respectively.

Table 5: Prediction of revenue for year 2016 to 2018

Year	E-waste recycled Prediction (first model)	Revenue Billion Dollars ($) Prediction
2016	1083.4	28.84321548
2017	1142.3	34.51902426
2018	1201.2	41.31172674

If the industrial recycle industry recycles a 100% or 50% of the e-waste using the multiple regression model, the revenue could increase. Table 6 shows the generated revenue using the second model. Note that column one through six on Table 6 are excerpt from Table 1 and 2.

Table 6: Revenue generated using second model

Year	**e-waste generated Tons (000)**	**e-waste disposed Tons (000)**	**e-waste recycled Tons (000)**	**Percent recycled Tons (%)**	**Dollars ($) (Billions)**	**Prediction using regression on the total waste**
1999	1,056	899.2	157	14.9	0.594	2.493861
2000	1,282	1092	190	14.8	0.698	3.311509
2001	1,447.60	1237.6	210	14.5	0.8197	4.235101
2002	1,634	1384	250	15.3	0.9587	5.486815
2003	1,944.70	1654.7	290	14.9	1.132	7.679876
2004	2,043.50	1723.5	320	15.7	1.3301	9.422091
2011	3,410	2,560	850	24.9	5	59.9805

Statistics for Table 6 are based on the prediction model used for all the wastes compare to the recycled part. For example, in 2002, if it is possible to recycle up to 50%, the revenue could be increased by approximately 2.75 billion dollars, and by recycling 100% the revenue could increase by 5.5 billion dollars. Since the variable year was significant on the multiple regression model, in 2004 if it is possible to recycle up to 50%, the revenue could be increased by approximately 4.7 billion dollars, and by recycling 100%, the revenue could be increased by 9.4 billion dollars.

7. Conclusion

Overall, the effects of GIT through effective use of e-waste management are all positives. Implementing e-waste management in the environment provides society's needs in ways that do not damage or deplete natural resources. Mainly this means creating fully recyclable products, reducing pollution, proposing alternative technologies in various fields, and creating a center of economic activity around technologies that benefit the environment. This study indicates the significant relationship between e-waste generated, recycled and revenue generated over years. By using the statistical approach to predict revenue expected from e-waste recycling, we indicate the significant economic benefits expected from adopting effective e-waste management in the future. GIT demonstrates fundamental economic as well as environmental sense, so it is understandable why organizations are exploring green computing options with such intense interest across the IT industry.

8. Recommendations for e-waste management

Despite current legislation aimed at minimizing e-waste pollution, vast amounts of e-waste are disposed of in landfills. Future efforts to minimize the impact of e-waste pollution on the environment will undoubtedly include aggressive legislation on the effective use of recycling by both the consumers and the manufacturers and also increase public awareness and/or education. Also, the manufacturers have a more important role to play in the e-waste management process. Some of the recommended approaches manufacturers need to consider in planning and implementing e-waste management include:

- The incorporation of the logo “Think green” on every electronic product produced.
- Motivate the consumers in the return - back process for recycling after end of life through incentives. Incentives should range from one through three percentage (1-3%)

of the cost of purchase and should be given to the consumers on return of end of life products.

- Collection sites should be designated and accessible at all times. Manufacturers should outsource the end of life collection to agents who will cover a wide area of the society.
- Continue investment in research to find less harmful materials in the manufacture of electronic products.
- Increase the awareness of the consumers through societal marketing. This increases customer loyalty if they gain a reputation for recycling e-waste. A survey by Landor Associates (2012) found that 77% of consumers say it is important for companies to be socially responsible. Companies that recycle E-waste appropriately and communicate their progress to customers in Corporate Social Responsibility reports demonstrate their commitment to protecting human and environmental health, which could result in an increase in business [17].

There is a huge market for recycling e-waste and extracting raw materials. As the supply from primary production is getting scarcer by the day, the only possible alternative, if we are to keep using metals for production, is to recycle. Apart from e-waste being a commodity, there is also substantial supporting evidence to show it significant. The world is mining metals at a rapid rate. Demand is increasing, but supplies are decreasing. The most effective way to keep using metals on earth is to start to recycle. Governments are realizing this; and policy makers tend to stress sustainable development when faced with the scarcity of resources. Investment in recycling will be a significant step toward fully implementing social policy of sustainable development.

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