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Reducing the cost of wastes from electrical and electronic equipment

- A case in four cities of Ethiopia

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Abstract

Information communication technology (ICT) has a vital role for development, due to the fast growth of the sector there is high turnover of electrical and electronic products with short period of life time. This dynamics of the sector has higher contributions for the generation of wastes from electrical and electronic products resulted from short life time. The severity of wastes from electrical and electronic equipment insists the countries to create design and apply environmental friendly strategies, policies and choices on it. With the understanding of reducing and managing the rapid growing problem of wfeee to the economy, environment and human health, many developed and developing nations give high priority for the management of wfeee. Ethiopia has the general policies and strategies on the management of solid wastes, but not specifically on wastes from electrical and electronic equipment.

In this study, three economic incentive policies which are price-based for wfeee reductions are compared on the basis of the level of incentives and the related outcomes on the eee waste generations and its implementability in the developing nation context like Ethiopia: (i) credit/repayment, (ii) early disposal payment and (iii) reusing/recycling grant. This paper uses the simple partial equilibrium model of electronic waste removal using elasticity from researches and literatures which are done previously. The prices and quantities of computers, televisions, personal mobile phones and refrigerators are based on the 2011 Ethiopian electrical and electronics equipment inventories from four major cities of the country, from Ethiopian import office and primary information. This paper discovers the best from the stated economic incentive policy instruments to minimize wfeee through reductions from the source and increased reusing/recycling amount. The output of this work shows that the reusing/recycling grant economic incentive policy instrument has a better percentage weight in wfeee reduction.

Abbreviations

Br…….Birr, Ethiopian currency (currently1 USD ≈18 Birr)

CAC……..command and control

C/R……credit/repayment

CRT…….cathode ray tube

DfE……..design for environment

DP……disposal payment

EDP…….early disposal payment

EEE…….electrical and electronic equipment

EPA…….environmental protection agency

EPR…….extensive producer responsibility

EU……...European Union

GAO……government accountability office

ICT……..information communication technology

LCD……liquid crystal display

PAN……....pesticide action nexus

RG……..reused/recycling grant

SWICO……...organizational technology and information communication association for the Swiss

SENS…….Stiftung Entsorgung Scheweiz

US……..United States

Wfeee……...wastes from electrical and electronics equipment

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1. Introduction

1.1. Background

ICT, information communication technology plays an important role in the development areas, like education, health and other sectors. It is costly to get this technology like the software and hardware in the under developed nations. This directs these nations to use and to be dependent on the used products. Due to the increase in the need and accessibility of these products, legal and illegal business transactions of electrical and electronic commodities increased from time to time. This high supply and demand of electrical and electronic equipment causes to increase the electronic waste production. For instance, by the year 2015, 9.8 mill tons of wfeee will be produced from television sets, personal mobile phones and computers. This amount tells us that additional 4.2 million tons of wfeee will be generated from year 2010 – 2015 (Asiimwe, 2012). It also stated that, India and China which have the highest population in the globe have big informal recycling plants. For instance, India sends 99 percent of the total waste generated from the electrical and electronic equipment to the informal recycling plant. This shows that huge amount of the wfeee produced in the globe is not safely recycled.

The main problems in relation with the management of wfeee are its fast increasing quantity and its un-modernized controlling and environmentally non welcoming removal. The production of wastes from electrical and electronic equipment increases from time to time as the electronics manufacturing industry grows fast. For instance in India new 113.26 mill mobile phone customers added in 2008, which is 9.5 million on average customer increments in each month. Personal mobile phone markets increases from 168.11 Million (2003 – 2004) to 261.97 million (2007 – 2008). The quantity of sales of refrigerators from 2006 to 2007equals to 4.2 million and the production increases by 17 percent related to the previous years. The television sale grows by three fold by 2007 (Wath et al., 2010).

The consumer motivates recycling/reusing and the producer motivates output design to show economic, environmental and health concerns. The point of producers design for environment (DfE) is nowadays highly vital to the policy makers and the environmentalists to produce environment friendly products. This means the non-liquid waste policy diverts from the left over removal concerns to the producers product and deal with the outline concerns. This diversion of concerns is characterized by the idea of extended producer responsibility (EPR),

which makes the manufacturers financially and physically accountable for their outputs by the end of their life time. The EPR principles occasionally commands manufacturers take their products back for reusing and recycling for products like home appliances, electronics, automobiles and packaging (Calcott and Walls, 2005).

Ethiopia as part of the world and with a higher desire for development i.e. for the development of schools, health and research institutions, universities and for other infrastructure development need ICT materials. Electronic equipment is the second imported item in volume to the country. Though, there is no research done in the sector, particularly in the recycling area, it is obvious that from the level of import of the commodity (legal and illegal imports of eee), high amount of electrical and electronic wastes are generated.

Wastes from electrical and electronic equipment are used electronic and electrical materials that have finished the primary intended use. The term wastes from electrical and electronic equipment includes all parts, substitutes and non-durable products at the end life of service or discarding. It contains personal mobiles; computers and its accessories, refrigerators, television sets and etc. which have been discarded by the primary users (Roslim and Ishak, 2010).

Since wfeee is the amalgamation of both harmful materials (lead, mercury, cadmium, chromium, etc.) and non-harmful and rich materials (copper, gold, silver etc.), it has high toxic substances in it. Toxic substances with improper disposal management can cause problems to the environment and human health (Wath et al., 2010) and to the economy.

1.2. Aim of the study

The aim of this paper is to see and compare different economic incentive policy instruments on the basis of the same level of incentives and the related outcomes on the eee waste generations and its implementability in the developing nation context. The necessary level of wfeee reductions from these policy instruments increases efficiency by decreasing the volume of wastes generated from electrical and electronic equipment based on price applications. Credit/repayment, early disposal payments, reused/recycling grants policy instruments are compared to extract the effective system on the electronic waste reduction management for Ethiopia. To achieve the target of this study, this paper uses the following research questions: (1) what level of the economic incentive policy instruments are necessary to achieve different

reductions in wastes from electrical and electronic equipment? (2) Which policy instrument is best to implement for Ethiopia?

This study will help the Ethiopian policy makers to design a policy which is important to manage the electronic waste removals. It also helps to show the severity of the problem and directions for its management. Besides, this paper can contribute to the sector to serve as a resource document and as a ground work for future further researches.

1.3. Brief description of methodology

This study has constructed on a model developed by Palmer, Sigman and Walls (1997), using a data from the electrical and electronic equipment inventory from four major cities of Ethiopia, collected in 2011 and from the economic literature. Besides, the study is dependent on previous works to estimate price elasticity, and additional or further procedures are not included for estimation in the study. To achieve the aim of this paper: model, microeconomic analysis, tables and diagrams are used. The model used in this study is partial equilibrium model includes only electrical and electronic equipment like television, computers, personal mobile phones and refrigerators and wastes generated from this equipment. Environmental and human health outcomes are assessed to some extent. Due to the limitations of data, this study uses a static data, and it does not consider dynamic changes overtime. The target of this study is comparing the effective economic incentive policy instruments for the reduction of wfeee generation.

The types of electrical and electronic equipment included in this study are televisions, computers, personal mobile phones and refrigerators. This paper is organized based on the stated electrical and electronic equipment as follows: in the first chapter, it describes the introduction part on the size of the problems, the aim of the thesis, market for wfeee and the external effects of wfeee. In chapter two, conceptualizing of different policy instruments like credit/repayment, early disposal payment and reused/recycling grants is addressed. Chapter three describes methods and the model of the paper. Chapter four addresses the Ethiopian case study, and chapter five contains the data, here, quantities, prices and elasticity estimates discussed and source of the data are stated. Chapter six and seven contains the results and discussion parts of the paper and conclusions and recommendations respectively.

1.4. Supply and demand for eee

Markets are the determinant factor for the product to be produced and consumed. By the time of globalization, information communication materials are highly demanded by the consumers and supplied by the manufacturers to fulfill the needs. The issues of development is the concern of every nation and even a single individual, to assist and support this concerns the information communication technology plays a great role and makes this manufacturing sector to be very dynamic. The market should be regulated to be in the balance of supply and demand, any imbalance can cause the market to be volatile. Exporting countries export the electrical and electronic equipment whether it is primary or second hand product to the destination countries. The destination countries after importing these commodities: they can use them directly, or can use after getting reconditioned or dissembled. The final result from all these usages will be waste. The following diagram will explain it more.

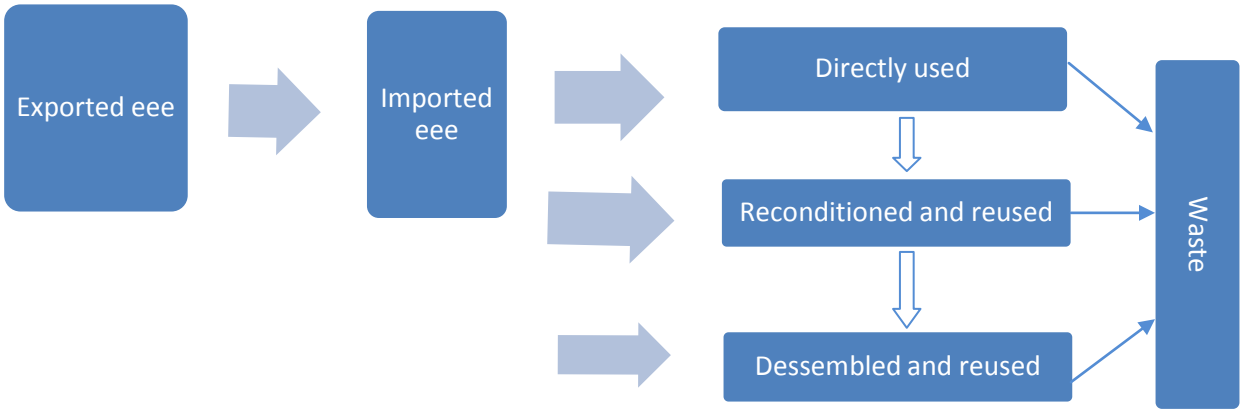

Figure 1: The General Trends of wfeee.

1.4.1. The supply of wfeee

Electrical and electronics manufacturing industry is the biggest and rapid growing area from the manufacturing sector in the world. Highest technological growth in combination with the higher turn off of product uselessness and unwanted electric and electronics are nowadays growing fast, and contributes 8% of the total municipal wastes in EU (Wath et al., 2010). With this fast outdating of electronic products due to the fast growing of the information

communication technology manufacturing sector, some of the developed nations are trying to use it for recycles as per their rules and regulations for proper handling, and some other find a place for disposal in developing nations in the form of aid and donation of second hand equipment. India, China, Pakistan and Nigeria are the main destination sites for wfeee from the developed nations for recycling purposes. As parties of the basal agreement which is applied for all members equally, but they use other rules to deploy the wastes. For instance, in Nigeria, Lagos ports are the main sites for importing secondhand electronic and electrical materials from different parts of the world including Europe, Australia, USA, Japan and South Korea. Between the periods March and June 2010, 10,567 kg of wfeee are imported to Lagos port (Ayodeji and Deubzer, 2011).

China is another developing country receiving high amount of wastes from electric and electronic equipment from the developed nations. The US wfeee reusing and recycling manufacture stating officially that about 80 percent of the wfeee they collect is transported into Asia, and from this 90 percent is transported into china (Liu et al., 2006). India is next to china in processing wfeee. 70% of the wfeee removed in India is assumed to originate from foreign with Delhi to its destination. India generates 400,000 tons of wfeee yearly.

Currently Ethiopia is not registered as the destination point for wastes from electrical and electronics equipment unlike Nigeria, China, India and others. But the flow of used and new branded electrical and electronic equipment to the country is becoming increasing from time to time, which can lead the country to be one of the destination points, if it is not regulated with proper policies.

1.4.2. The demand for wfeee

Due to the global increasing level of awareness to information communication technology, and the inclusion of these technologies to the development strategies, the need for electric and electronic equipment becoming increasing from time to time. Generally markets are there, for electric and electronic equipment. As the rate of the consumption of eee by the consumers increases, it is clear that the generation of wastes from this sector also increases. From the micro economic theory, economic resources are scarce and limited. Wfeee is the unutilized parts of economic resource. Maintenance with proper management cycles of wastes from these materials for recycling has its own advantages, since it has rich substances like gold, copper, silver etc. in it (Wath et al., 2010).

However, for some material parts (like plastics), one of the problems for reusing targets is the unavailability of demands for the secondary equipment by existing markets. This may be, because of volume, standard or legal restrictions, and thus availability of other alternative markets are important to safeguard the advantageous or better utilization of these equipment. For instance, the global production volume of cathode ray tube (CRT) glass is declining due to the production of flat board; this tells us that the market is not in a position to take the crt glass and results in diminishing market demand for this option (Ongondo et al., 2011).

For instance destination nations for wfeee often received the foreign currency paid from the senders. China, in the beginning of 1990s, welcomed containers of wfeee, the government receiving a payment of US$50/ton. Small and big business operators become established in the area of disposing wfeee without having the technology or material for proper processing. In most of the developing countries electronic equipment are highly demanded for consumption as a result of the development of their economy and the increase in the general global awareness level to the electronic technology. This shows that how the wfeee is needed for consumption and recycling in the recovery of economic resources.

In Ethiopia, the need for these electrical and electronics equipment is very high, in the second position next to oils, minerals, refinement products, etc. from all imports. All business companies engaged in import and export must be officially registered by the trade and industry minister to get a trading or business license. The ministry controls every procedure for imports and permit for foreign exchange are compulsory for all importers. By the year 2008, aggregate goods imported in to the country are more than $7.7 bln. Statements from the world trade center, the major five import items for Ethiopia during the year 2008 were:

Table 1: Major Five imported items for Ethiopia during the year 2008 by percentage.

1	Vehicles without considering rail way	6.1
2	Cereals	6.7
3	Machinery, boilers, nuclear reactors etc.	10.6
4	Electric and electronics equipment	11.7
5	Oils, minerals, refinement products etc.	23.7
6	Others	41.2
	Total	100

Source: (Hagmann and Abbink, 2011)

Informal business has the same age as the informal economy. Informal trade is the major area of source for most of the jobs created in Africa, absorbs 20 – 75% of the general employment in majority of the African nations, regardless of South Africa. The term informal business is

mostly used as a substitute for the informal activity (Feige and Urban, 2008). The same is happen to the country Ethiopia, though the Ethiopian government tries to control the informal businesses in the border areas, particularly in the area of electric and electrical equipment across the borders from the neighboring countries is still highly practiced.

To summarize this part, the motives of demand of the nations to import these electrical and electronics products are: countries that have recycling plant, to get raw materials for the recycling process, for dismantling and exploiting the rich minerals from the product and to use for the production of some other material, in the need for development like equipping schools and health institutions with information communication technology materials for the purpose of research and development processes, and to communicate with the rest of the world etc.

1.5. External effects of wfeee

The nature of wastes from electrical and electronics equipment are full of many hazardous substances. The effects of these toxic elements are very severe to the environment, human health and so on.

Environmental effects

In general, ruminants from the production process incorporate different substances that can serve as an input for another production activity if managed properly. In the process of economic activities, environmental resources are exploited and utilized, and residuals are thrown back to the environment. When this elements disposed to the environment without due care, affects the environment negatively. For instance, lead can disturbs the proper functioning of soil and water system. Cadmium can affect the atmospheric air when it gets burnt, affecting soil health and causing cancer to human being.

Developed nations have a variety of laws and rules on wfeee. Their production of wfeee presently accounts 2% of the general solid waste production and is estimated to rise more in the future. In the USA it contributes 1% to 3% of the aggregate municipal waste production. As the European community directive 2002/96/EC on waste from electrical and electronic equipment, wfeee is increasing three folds faster than the ordinary yearly municipal non liquid waste productions. It is approximated that the general amount of wfeee produced in the EU varies from 5 to 7 million tons per year or 14 to 15 kg per capita and is estimated to rise at a rate of 3 to 5 percent per annum. In under developed countries, it varies from 0.01 to 1

percent of the general municipal non liquid waste production. In India and China, however, where yearly production is less than 1 kg per capita, it is rising at a very fast pace.

Health effects

Before the introduction and rapid growth of ICT, mosquito born and infectious diseases were emerge as the basic recurrent health problems in the past decades in Africa (Nweke and Sanders III, 2009). By the time of globalization and the fast growing of ICT sector, wfeee are a rapid growing concern to the region. Substances from the discharge like tin, lead, beryllium, barium, mercury and cadmium can cause a major destruction in human health to the nerve, reproductive system and to the blood. In most of under developing nations eee are gathered, used and demolished to exploit useful elements for marketing (Takker, 2006). Dismantling wfeee is a new happening, resulting in making the peoples to expose themselves to these harmful toxic elements. It is approximated that cadmium 0.9 million kg, lead 0.55 billion kg and mercury 0.18 million kg released to the environment from 315 million all type computers with improper recycling procedures in India (Takker, 2006). Lead is one of the most hazardous substances available in television and computers CRT screens, cellular mobile phones (Schmidt, 2006). Cadmium is highly available in the CRT screens. There is no compiled data available on this new happening in Africa.

To conclude the chapter, the dynamic advancement of the information communication technology sector has its own contribution to the generation of wfeee in the globe. The economy, environment and the human health are adversely affected by the increasing production of electronic wastes. Ethiopia, as a country in the need of development imports new and second hand electrical and electronic equipment which can lead the country to one of the destination point for wfeee. The aim of this paper and the research questions are stated and addressed properly.

2. Waste policy instruments and their application

In this chapter, conceptualizing of economic incentive policy instruments like credit/repayment, early disposal payment, reusing/recycling grants and review of rules, regulations and principles from different country perspectives are assessed.

2.1. Conceptualizing economic incentive policy instruments

Understanding and application of proper policy instruments are very important to minimize or to solve the problems related to it. The application of Economic incentive policy instruments with regard to waste generated from electrical and electronic equipment is vital to manage and control the production of wastes from the sector. This paper addresses the credit/repayment, early disposal payment and reused/recycling grant policy instruments.

Credit/repayment

The credit/repayment system is a mixture of tax on the end product and a repayment during the recycling. This system is applied for the repayment of containers of beverages, bottles and cans from soft drinks and it can also applied in other types of containers like motor oil, lead acid batteries, tires, electronics and different dangerous materials and many more. The credit/repayment system has three possible merits on a Pigovian tax. It prevents dumping on the night, this is a problem related to the Pigovian tax and it becomes very serious when considering the dangerous waste removals. When the official waste removal is directly taxed, consumers and producers or firms find out different waste removal alternatives which includes night dumping and burning, if those alternatives are simple or with small penalties. The Pigovian tax has controlling and enforcement difficulties in many circumstances. For instance, directly litter taxing is not effective with the difficulty in controlling it, so a credit/repayment applied to packaging, plastic bags, bottles and other materials considered as litter are appropriate. Finally, tax circumvention and escaping is minor in the credit/repayment scheme than from the Pigovian tax (Walls, 2011).

The credit/repayment system takes a form of like material tax/recycling repayment. In such a system users pay a credit (tax) on the packaging or containers at the time of buying. This in theory is to mean, the setting of additional social cost of inappropriate removal of wastes on the net recycling expense. This implies that, if the waste material is inappropriately removed off, that consumer pays the external expense of inappropriate removal by missing the repayment which would exactly equal to the amount of the primary deposit. Most of the

theoretical researches argued that credit/repayment is the finest policy instrument in the presence of illegal waste removal. Palmer, Sigman and Walls (1997) modeled their work on materials (paper, plastics, glass, steel and aluminum). They found out that significant variation in the intervention amounts essential to get reductions in waste removal with the different policies. For example to get a 10% waste reductions from all trashes, it costs 45$/ton from credit/repayment, 85$/ton from early disposal payment and 98$/ton from reuse/ recycling grants (Palmer et al., 1997).

Merits of credit/repayment system

Every principles, laws and policies have their own advantages and disadvantages to the society, environment and economy, generally on the globe. As per the explanations of Palmer et al., 1997 the credit/repayment scheme has many benefits from the reduction of waste to the environment, economy and human health. Among the benefits: rising the recycling/reuse of equipment, minimizing the amount of littering, raising the use of refillables and evading dangerous substances circulating in the environment.

Early disposal payment

Disposal payments can be settled in two different scenarios: at the point of purchase, or at the point of disposal. From the Switzerland system of controlling and managing wastes, both the SENS and SWICO charges early disposal payment. The Swiss early disposal payment considers the periods where equipment purchased in the previous times and materials purchased at present time. The disposal payments settled at present is for the materials bought in the previous periods and being removed presently. Likewise, when the equipment purchased presently are removed some time in the future, their disposal expenses for reuse or recycling will be settled at the time of purchase. A criticism for the edp is that it penalizes instead of promoting materials with a design of environmentally friendly, this is to mean, as the edp reflects the expense acquired to pay for materials produced in the previous periods, no attention given to the newly produced materials that gives special considerations for environmentally friendly at the time of disposal during the end life of the product (Huisman, 2010).

Takayoshi Shinkuma classified the waste removal policies in to two: the disposal payment (DP) policy and the early disposal payment (EDP) policy (Shinkuma, 2007). There is difference among both in the situation of, who is responsible to pay for removal and the time preferences, when to be paid. In the disposal payment system, the users are required to settle

waste removal expenses when removing of the items. In the contrary, in the early disposal payment system the users are required to settle the removal expenses in early, when they purchase the products. Shinkuma after assessing economic researches on the waste removal policies stated that, the societal optimal utility can be achieved by disposal payment or early disposal payment policies, if illegal waste removal is not there. EDP is the preferred policy than the disposal payment, because, as Shinkuma explained disposal payment has a room for those who wish to remove their wastes illegally. On the other way, early disposal payment policy has been implemented in some areas especially for the reuse/recycling and left over removal of durable products at their end of life time. Durable and non-durable products are differed in at least two major respects: the deal in durable products is in the used product market, and users who have a property of durable goods have the options to repairing or removing of them when they become out of use. Consequently, the consumers using durable products has a variety of choices: to purchase a new product, to purchase or sell a second hand product, to maintain the material when it gets out of use, or to remove it. The payment is varied as per the type of the product that is going to be reused or recycled like, plastics, hazardous metals, glasses etc. In California consumers get additional charge of $6, $8 and $10 during purchasing electronic equipment which has screen like laptops, television sets, computer monitors, cathode ray tube, etc. as early disposal payment at the time of sale (Walls, 2011).

Reusing/recycling grant

Grants are used to provide constructive economic motivations to consumers and manufacturers who engaged to accomplish something that is assumed to be beneficial to the society from the outlook of the government side. Grant is as such the other side of charge or tax; it incorporates positive externalities than negative. Though the idea of grants has a disagreement with the “polluters pay principle”, it is yet one of the important waste policy instruments in conditions where there is imperfections in the market like monitoring and transaction costs rule out to apply the best policy instruments like waste removal payments. This system can have increased costs of administration, if it is applied for the first time as the only policy instrument (Khetriwal et al., 2009).

As Denne explained in the case of New Zealand, the reusing/recycling is granted by the local government. It is a contracted payment settled by the domestic government to companies who collects wastes for reuse/recycling. The grant stands for the variations between collection costs and the total income gained for the products collected. Preferably the collectors would

incorporate items that guarantee payments were completed at the level of the volume of recycled, indicating the amount to the local officials in minimized landfill waste removal costs (Denne, 2005).

The reusing/recycling grant is the same as the repayment part of the credit/repayment scheme. Under the reused goods market, the grants make a bridge between the price of demanded goods and the price of the second hand goods accepted by the suppliers. This means, the price of the second hand goods accepted by the suppliers is equal to the summation of the price of the demanded goods and the amount of the grant given. As a result, this leads to bring a change in the end products market. The grants minimizes the allocate price settled by the demanders of the end product who recycle it (Palmer et al., 1997).

2.2. Reviewing laws, rules and regulations in some country context

Most of the nations have understood the relevance of controlling mechanisms (laws, rules and regulations) to overcome the rapidly increasing quantity of wfeee, and designed different principles and rules to control the adverse effects of wfeee to the economy, environment and human health (Wath et al., 2010). The following table shows rules and regulations of some countries on the wfeee.

Table 2: Rules and regulations of wfeee in some countries,

Country	Rules and regulations	Descriptions	Effective date
China	-On the protection of environmental damage from non-liquid waste. - Rule from the controlling of waste household eee reuse and removal. - Administration procedures for the avoidance of damages from eee. - Guideline for the administration, reuse and removal for wfeee	-Removal of solid waste & use of solid wastes as raw material. -Obligatory reuse of wfeee based on epr, certification for used materials and recycling companies. -Ban on dangerous element uses, and environmental friendly product design. -produce controlling mechanism for the maintenance, reuse and removal of eee.	-1996, April 1. -included in the nation board legislation plan in 2006. -2007, March1. -2009, March 4.
European Union	-wfeee directives (2002/96/EC) (EU 2002a) - Control of use of known dangerous elements in eee directives (EU 2002b)	-Guidelines to help the manufacturers and customers in performing their responsibility to manage wfeee environmentally friendly. - Harmonize to the level of wfeee directives	-2004, August -2006, July 1.
India	-Guidelines for wfeee environmentally friendly manner -wfeee rules, 2010 draft	-directions for proper handling of wfeee - facilitate the maintenance and reuse of rich elements from wfeee & minimizes dangerous materials from disposal.	-2008, March 12. -2010, May 14.
USA	-Early disposal payment for dangerous wfeee -the Law of eee recycling chapter 70.95 N -wfeee program in Maine state -wfeee recycling in Hawaii state -Bill of manufacturer responsibility	-EDP applied at the time of purchase, charges from 6 – 10$US -producers to give unpaid service for recycling in Washington -costs for collection process shared by the municipals -producers are expected to design proper management for collection and recycling -Introduction of manufacturers responsibility bills	-2004, Sep 29 -2006 -2006, January -2010, Jan 1 -2007
South Africa	- The Polokwane statement 43, on managing and reducing the waste line.	-To reduce the production of hazardous waste elements.	-1997
Switzerland	-The law of taking back, return and removal of eee.	-All the proper wfeee management cycle from collection to removal is included	-1998, July

Source: (Wath et al., 2010)

Table 2 describes the rules and regulations on wfeee in some countries. This table contains countries from the developed and developing nations and the application of different policy instruments to manage and control wfeee. Most of the United States communities provide public waste gathering and removal services to the whole households around their localities. The expenses of delivering these facilities are covered by the domestic tax revenue or property and every household´s payment to these incomes is non-dependent on the size of wastes that it produces. In such a payment system households get a zero payment for every additional bag of wastes that they removed. The proposed solution for this challenge is to fix payments on households for every bag of waste, a system is often known as "unit pricing". Additional payment for additional bag of waste disposal may cause to increased illegal waste removal (Kinnaman and Fullterton, 1999).

In the stated countries, among the policy instruments that are applied to manage the generation of wastes from electrical and electronic equipment are command and control, early disposal payment, extended producer responsibility and credit/repayment. Country like China uses the command and control policy, the European Unions and the United States uses the extensive producer's responsibility, reusing/recycling and other economic instruments like early disposal payments and credit/repayment. India has developed the guidelines for using wfeee in environmentally friendly manner and Switzerland added the taking back policy.

2.2.1. Managing and controlling system of wastes from electrical and electronic equipment in Switzerland

Switzerland is the primary nation in the globe to design and practice a well-developed and proper wfeee controlling system, follow the procedural flow of the management cycle, from collection to disposal. The foundation of the official and functional frame is the representation of extended producer responsibility sets the financial and physical accountability for environmentally friendly caring, reused and removal of wfeee from the industry and trader of this equipment. *Organizational technology and information communication association for the Swiss (SWICO) and Stiftung Entsorgung Scheweiz (S.E.N.S)* are taking responsibilities for the controlling and functioning of the process by representing the member manufacturers (Wath et al., 2010).

The necessary fund for the continuous performing of the process (the management cycle i.e. from collection to disposal) is collected from early disposal payment which is received from

the buyers of first hand electronic equipment during the period of purchase. The final product consumers or a user pays the reused or recycling payments, which is equal to the amount of the variations among the final price of the product and the recycled price of the commodity from wfeee. This system protects the illegal disposal of wfeee as the users are willing to be charged some amount of money as early disposal payment (Wath et al., 2010).

2.2.2. Management trends of wastes from electrical and electronic equipment in India

Issues associated with wfeee in India have begun to occur since 1990 at the first part of economic liberalization. The national wfeee work group proposed that in 2005, 146 000 tones/year was generated. Another study by 2007 and 2009 forward the estimates to 330 000 and 420 000 tons per annum but, by the year 2010 the wfeee generation from refrigerators, personal computers, televisions, printers and mobile phones is 100 000, 56 300, 275 000, 4 700 and 1 700 respectively. Besides, from the increased need for development, India will generate wfeee 500% from computers, 18 times increases from mobile phones, 2 and 1.5 times higher from refrigerators and televisions by 2020 in respective of the year 2007 levels (Arora and Ahmed).

The wfeee management scheme in India is not well developed and organized unlike Switzerland, rather it is badly defined. According to the study from the Indian wfeee situation, the management of wfeee in India can be categorized in to three parts, the first one is; the eee generation section. In this part the introduction of electronic and electrical products, sub-assemblies, assemblies and raw materials to India by the manufacturers. At this level there is no management problem because the process is organized and follows the normal import process of the country. The second part is wfeee generation part. In this part the second hand and the new brand users of eee are the actual users. The waste generation starts here and the poor management as well. The last part is the wfeee re-processing part which has many management problems (Wath et al., 2010).

To conclude, the importance of waste policies to manage and control the production and removal of wfeee through the application of different economic incentive policy instruments has discussed. Among the economic instruments, credit/repayment, early disposal payment and reused/recycling grants have covered by this chapter. Besides, this chapter also reviewed the laws, rules, policies and regulations in the developed and developing countries context,

Switzerland and India are among the countries this chapter discussed in detail representing the developed and developing nations respectively.

3. Methods and the Model

Under this chapter, the research methods and the model, theoretical explanations and market places for the reusable and reused products are stated. Different types of electronic waste policy instruments and their implementations are discussed. The aggregated baseline data from the four major city of Ethiopia are explained. Quantity, price and elasticity estimates are stated and discussed.

3.1. Research methods and the model

The research methodology in its comprehensive definitions can be grouped in to the qualitative and quantitative techniques. In qualitative techniques, the researcher uses a descriptive presentation of narrations and explanations to address the facts in a quality details. Above all a researcher using qualitative research methods is much more rolled as the first hand data collector. The information can be collected with interview, beneficiary observation and focus group discussions. Qualitative research technique is targeting to achieve the general structure of the subject matter and then taking further deep understanding, instead of playing with numerical data. On the other hand, quantitative research methods are dependent on and targeting numerical data and findings. In this category numerical data will be analyzed by the help of a variety of mathematical, statistical and microeconomic model etc. to address different kind of relationships of the phenomena.

In this paper, both quantitative and qualitative research methods are applied to investigate, describe and produce an effective model on wastes from electric and electronic equipment by using economic incentive policy instruments. This paper uses a simple partial equilibrium model developed by Palmer et al., 1997 for analysis of alternative policy instruments for solid waste reduction. This paper uses this model to electronic waste management in Ethiopia, using Ethiopian electronic waste statistics in combination with data from the economic literature. In the remainder of this chapter, the simple partial equilibrium model used by Palmer et al., 1997 for solid waste is presented to analyze the wfeee.

A simple partial equilibrium in the production and utilization equation accesses us in using the market information to evaluate the properties of electronic waste policies. The quantity of electronic waste removed, W, will be the difference of the total production consumption, Y, and the quantity reused, U.

$$W = Y - U \quad \text{(a)}$$

With this simple partial equilibrium model, the application of proper policy instrument will minimize this problem either by increasing the ability of reusing the products or decreasing the source of production, which this paper define to mean, increasing in U and decreasing in Y. In the above stated model the application of proper policy instrument affects the balance of the production consumption markets and the reused product markets. Let me start by stating the framework of both markets, then figure out the different types of economic incentive policies.

3.2. Theoretical Perspectives of the Model

The model this paper uses, the partial equilibrium is defined as a situation in which economic stability is taking in to account only a specific part of the economic transactions, all other things remain constant to get balance in the economy. The demand and supply representation is a partial equilibrium, where the market clearance on specific product is achieved without the dependence of other quantities and prices in any of the markets other than that specific market. Here it is to mean that, the value of the complement and substitute products and the level of income of the consumers are fixed.

3.2.1. Assumptions of the model

In the partial equilibrium model, the application and belongings of economic incentive policy instruments are investigated in the transactions that have direct relations and affections. The demand and supply function helps to show the effects of prices in these policies. The following assumptions are taking in to consideration on the market structure: the market is perfectly competitive, depends only on the fixed parameters and allocated price for the primary product and the second hand (reused) products, because of the nature of the model (partial equilibrium) and since the users or consumers of the second hand product and the primary final products are different, the demand for the second hand product is not dependent on the amount of the primary final product that serves as an input for the second hand product at the time of the product end life.

3.3. The value of reusable products

There is a different taste or need for reusable products than the primary products because of the differences in the quality, durability, commodity prices etc. each commodity has its own

production, administration, transport and other costs when passing through the production process to the final consumers. When these products arriving to the market, the price is set or adjusted as per the production process costs plus profit margins from the product. This material price may vary or not within the reuse or non-reuse products. When the product is targeting not to reuse at the time of production, its allocated value will be the market buying price p_y. But to the contrary, when the product is targeting for reuse at the time of production, its allocated value will be p_y minus the leftover price of the product. The leftover price of the product is the value of the reuse equipment p_u. The product demand function appears to be the amalgamation of the above two allocated prices.

$$Y = D(p_y, p_y - p_u) \quad \text{(b)}$$

3.4. Equating wastes from electrical and electronic equipment

The fast dynamics of the ICT sector makes the electrical and electronic equipment outdated in a very rapid way before finishing the life time of the product. Because of the availability of hazardous substances and some rich elements in the electronic equipment, the market is there, first to reuse the rich elements and second to dispose the hazardous substances properly. The maintenance rate of the reused product R_r is the division of Y_u (the quantity of reused product) to the total product Y. The amount of the reused maintenance rate R_r increases as the increase in the value of the reused product p_u. Suppliers of the used products will make increase the amount they provide to the market as the value they get from the sale increases. So, it has the following functional forms:

$$R_u^s = R_r(p_u)(D(p_y, p_y - p_u)) \quad \text{(c)}$$

Where, R_u^s is the supply of the reused electrical and electronic equipment and R_r is the maintenance rate of the reused product. From the microeconomics analysis, demand and prices has an inverse relationship. As the price of the secondary commodity increases, the demand for that specific commodity will decline, assuming that all other things remain constant. The amount of reused products demanded by the secondary product processing firms differs with the price it has. So, demand is dependent on the price of the commodity and has the following relationships.

$$R_u^d = R_u^d(p_u) \quad \text{(d)}$$

Where R_u^d is: the demand for the reused electrical and electronic equipment. In a competitive market, before the application of any policy instrument assumed that the market supply and demand for the reused equipment or product is balanced.

$$R_u^s = R_u^d \qquad \text{(e)}$$

Taking together equation (c), (d) and (e)

$$R_u^d(p_u) = R_r(p_u)(D(p_y, p_y - p_u)) \qquad \text{(f)}$$

By taking equations (a), (b) and (f) above, in to consideration and aggregate together, the new electronic waste removal equation can be derived as follows: From the beginning W = $Y - U$ and $Y = D(p_y, p_y - p_u)$ in equation (a) and (b) respectively. The supply equation for the reused material is $R_u^s = R_r(p_u)(D(p_y, p_y - p_u))$ in equation (c).

As stated above in equation (d), $R_u^d = R_u^d(p_u)$ that means the demand for the reused product is dependent on the price of the reused product, substituting these two demand functions to the original equation in (a) results in:

$$W = D(p_y, p_y - p_u) - R_u^d$$

Here considering equation (e) will help us to substitute R_u^d by R_u^s because they are equal at the equilibrium and re-writing the equation gives us:

$$W = D(p_y, p_y - p_u) - R_r(p_u)(D(p_y, p_y - p_u))$$

Under this equation, $D(p_y, p_y - p_u)$ is common for both functions and re-writing the equation for simplification and results:

$$W = (1 - R_r(p_u))\,(D(p_y, p_y - p_u)) \qquad \text{(g)}$$

3.5. Economic incentive policy instruments for the reduction of wfeee

Currently, many kinds of public policies are designed to minimize electronic waste removal and to enhance reusing/recycling. Parts of these policies are based on payments, incorporating credit/repayment, early disposal payment and reusing/recycling grants. Recent experiments identified that these policies addresses economic efficiency or to minimize the negative drawbacks that emerges from not being efficient by setting payments for waste removal (Palmer et al., 1997).

3.5.1. Credit/repayment

Credit/ repayment system syndicates a tax on item consumed with a refund when the item or its container is resumed to reusing/recycling for proper disposal. Assume that the credit c, equals the repayment (settlement) s. a credit/repayment system modifies the functional equations to the end product and the reused product markets. In the first place the credit considered as the tax on the end product, and increasing the value of the product to the consumers by the amount of the credits. When the constant supply value of the end product is p_y, the demand value in the credit/repayment system will become p_y + c. Consumers who reused the product will get the repayment back. Finally, they will not experience an increase in the effective price. In the second place, the credit/repayment gives benefit from reused the product, modifies the equilibrium or balance in the reused product market. Hence the price amount gained by the reused product providers will be p_u + c. Under this policy instrument the market balance in the end product is:

$$Y = D\big(p_y + c, (p_y + c) - (p_u + c)\big)$$

$$Y = D(p_y + c, p_y - p_u) \qquad \text{(h)}$$

The credit/repayment policy instrument then as stated above changes the balance of the reused product market by increasing p_y and p_u with the amount of c, and results in:

$$R_u^d(p_u) = R_r(p_u + c)(D(p_y + c, p_y - p_u)) \qquad \text{(i)}$$

Reformulating the first equation by combining the above two market equilibrium conditions gives:

$$W = Y - R_u^d(p_u)$$

Where, W is the waste generated from electrical and electronics equipment, Y is the amount of the end product of eee and $R_u^d(p_u)$ is the demand for the reused equipment under the credit/repayment policy. The direct substitution of equations (h) and (i), the amount of end

product of eee and the demand for the reused equipment respectively to the waste equation above gives us:

$$W = (D(p_y + c, (p_y + c) - (p_u + c))) - (R_r(p_u + c)(D(p_y + c, p_y - p_u)))$$

$$W = (D(p_y + c, p_y - p_u) - (R_r(p_u + c)(D(p_y + c, p_y - p_u)))$$

$$W = (1 - R_r(p_u + c))\,(D(p_y + c, p_y - p_u)) \quad (j)$$

3.5.2. Early disposal payment

The early disposal payment like the credit part of the credit/repayment system increases the value of the end product to all consumers, including the re-users and non-re-users. The balance in the end product market will become $p_y + e$ (e is the amount of the payment). Then the balance in the end product market is:

$$Y = D(p_y + e, p_y + e - p_u) \quad (k)$$

This policy instrument affects the wfeee market indirectly for the reused products since it minimizes the level of the product supplied to be reused. Early disposal repayment system increases the selling price of the end products to the consumers, and the market equilibrium will be affected in the following form:

$$R_u^d(p_u) = R_r(p_u)(D(p_y + e, p_y + e - p_u)) \quad (l)$$

By rearranging the first equation, equation (a) will be:

$$W = Y - R_u^d(p_u)$$

Where, W, Y and $R_u^d(p_u)$ has the same interpretation as above in the credit/repayment system. In the early disposal payment system, only the end product purchasing price is affected and the allocated value or the effective price is increased by e amount.

$$W = (D(p_y + e, p_y + e - p_u)) - (R_r(p_u)(D(p_y + e, p_y + e - p_u)))$$

$$W = (1 - R_r(p_u))\,(D(p_y + e, p_y + e - p_u)) \quad (m)$$

3.5.3. Reusing/recycling grants

The reusing/recycling grant is like the repayment part of the credit/repayment system. In the reused product market, the grant urges fixing among the demand value and the price gained by providers of the used products. If the demand value of the reused product is assumed to be equals p_u and the amount of the grant is g, the price gained by the providers is p_u + g. Then the balance in the end product market is:

$$Y = D(p_y, p_y - (p_u + g)) \quad \text{(n)}$$

Here we can appreciate a shift in the demand of the final product market resulting from the gains from the grants. The grant minimizes the allocated price paid by the consumers of the end product who reuse it and the equilibrium with the grant in the reused product market results in:

$$R_u^d(p_u) = R_r(p_u + g)(D(p_y, p_y - p_u - g)) \quad \text{(o)}$$

In the inclusion of the grant the electronic waste removal equation becomes:

$$W = Y - R_u^d(p_u)$$

Where, W, Y and $R_u^d(p_u)$ has the same interpretation as above in the credit/repayment and early disposal payment. In the reuse/recycling grant, only the reused product purchasing price is affected, and the reused price is increased by g amount.

$$W = \left(D\left(p_y, p_y - (p_u + g)\right)\right) - (R_r(p_u + g))\left(D\left(p_y, p_y - (p_u + g)\right)\right)$$

$$W = (1 - R_r(p_u + g))\left(D\left(p_y, p_y - (p_u + g)\right)\right) \quad \text{(p)}$$

The function below is the parameterized demand function suggested by Palmer et al., (1997).

$$Y = D(p_y, p_y - p_u) = a_1(p_y)^{e_y^d} + a_2(p_y - p_u)^{e_y^d} \quad \text{(q)}$$

Where e_y^d and e_u^d is the own price elasticity of demand with a negative value for the primary and used product respectively. The parameters $a_1$and a_2 are the output share of the primary and the reused/recycled product Y and Y_u respectively. So, the demand equation has the following functional form for the stated economic incentive policy instruments respectively.

$$Y = D\,(p_y + c,\, p_{y-} p_u) = a_1(p_y + c)^{e_y^d} + a_2\,(p_y - p_u)^{e_y^d} \qquad (r)$$

$$Y = D\,(p_y + e,\, p_y + e - p_u) = a_1(p_y + e)^{e_y^d} + a_2\,(p_y + e - p_u)^{e_y^d} \qquad (s)$$

$$Y = D\,(p_{y,}\, p_{y\,-}\,(p_u + g)) = a_1(p_y)^{e_y^d} + a_2\,(p_y - (p_u + g))^{e_y^d} \qquad (t)$$

By substituting the second functions from equation (j) with equation (r), the final waste equation from the credit/repayment policy instrument is:

$$W = (1 - R_r(p_u + c))\,(a_1(p_y + c)^{e_y^d} + a_2\,(p_y - p_u)^{e_y^d}) \qquad (u)$$

Substituting the second functions from equation (m) with equation (s), the final waste equation from the early disposal payment policy instrument is:

$$W = (1 - R_r(p_u))\,(a_1(p_y + e)^{e_y^d} + a_2\,(p_y + e - p_u)^{e_y^d}) \qquad (v) \text{ and}$$

By substituting the second functions from equation (p) with equation (t), the final waste equation from the reusing/recycling policy instrument is:

$$W = (1 - R_r(p_u + g))\,(a_1(p_y)^{e_y^d} + a_2\,(p_y - (p_u + g))^{e_y^d}) \qquad (w)$$

4. Ethiopian case study

4.1. Background

Ethiopia is found in the eastern parts of African continent, usually called as the horn of Africa with a total area of 1.1 square kilometers. Ethiopia is a country primarily dependent on agricultural activity. This sector contains more than 80% of the country's total population. More than half of the country's GDP and 85% of the export is gained from this sector and the most vital product from the sector for export contribution is coffee.

The manufacturing and industry sector has an important contribution to the economy in supplying goods to the consumers and generating foreign currency from export. Mostly this sector involved in the production of materials for construction, chemicals and metal goods, clothing, textile and leather products, food and beverages.

The Ethiopian government constitution of 1995 has formed a federal state incorporating local sub governments curled on the base of ethnic and language criterion. The federation incorporates nine local states based on the identified local common traits. It contains Afar, Tigray, Somali, Oromia, Amhara, SNNPR, Benishangul, Harrari and Gambella states. Dire Dawa and Addis Ababa are federal administrative states (Assefa and Egziabher, 2007).

4.2. General waste policies in Ethiopia

As the responses from forum for environment Ethiopia assessment study proposes that the nation's scientific and technical capability for the safe way of controlling the waste from any source is unorganized. Trained and skilled personnel are required to manage the wastes especially from the industry, health institutions, municipal solid wastes and some other sectors. Some types of waste items like the electronic wastes are not regulated, and there are no scientific and proper ways of controlling, monitoring and correcting actions.

Ethiopia has an official municipal solid waste policy with proclamation number 513/2007. Under this article, solid waste defined as a matter that is neither gas nor liquid and is removed as undesired. Here also solid waste management is addressed as the process of all steps from the proper ways of collection to the disposals. The urban administration has the responsibility to create a favorable condition to facilitate investment on the delivery of solid waste management sector. There is the involvement of the lower level of government authorities and their local residents in the management cycles, from designing to implementation.

When comes to wastes from electrical and electronic equipment, internationally it is known that there is shortage of reliable information on the production, collection, export & imports of wfeee. Economic trades, health and environmental concerns in relation to electronic wastes at domestic, regional and global level leads many countries specially the under developed nations to incorporate proper policy interventions to tackle the problems arising from this area. Ethiopia is of the country that has indorsed the Basal convention (proclamation No. 674/2010) to apply the right and proper way of managing electronic wastes. According to the forum for environment (Ethiopia) and the Ethiopian federal government's waste policy, there is no specific policy, regulation and principle in the area of electronic waste removal in Ethiopia. This area is the area that needs deep concentration and attention for action.

5. Data

The level of electronic waste production in Ethiopia is not yet well studied and documented, pesticide action nexus (PAN) (a nongovernmental organization working in Ethiopia) in collaboration with and under the general principles and supervision of the federal environmental protection agency Ethiopia made an inventory of eee in four of the major cities of the country. The cities are, Addis Ababa, the capital of Ethiopia and the seat for African Union located at the center of the country. Bahir dar, which is the city for the amhara regional state located at the northern part of the country and the region is bordered with Sudan. Dire dawa, which is one of the federal cities of Ethiopia, located at the eastern part of the country and bordered with Djibouti and Somalia. Hawassa, which is the city for the southern nations and nationalities regional state located at the southern part of the country, the region is bordered with Kenya. These cities are from the top five cities relative to the other cities of the country and assumed that there is high consumption of electrical and electronic equipment in the area.

Generally, the data is collected from different sectors or stakeholders from the stated cities. These stakeholders are the household, governmental and nongovernmental organizations, academic and research institutions, wholesalers and retailers of electronic equipment, electronic equipment maintenance shops and other businesses (like restaurants, cafeteria, hotels…).

In this study only some basic categories of electronic equipment is addressed which are assumed to be highly consumed by the society. Among them, computers and its accessories, television sets, personal mobile phones (cellular phones) and refrigerators of different brands are the dominant.

Figure 2: Map of Ethiopia Source: http://www.mapsofworld.com/ethiopia/ethiopia-political-map.html

In this paper the Ethiopian electrical and electronics equipment inventory data has taken from the stated cities; Bahir Dar, Hawassa, Addis Ababa and Dire Dawa summarized in table 11, 12, 13 and 14 respectively (PAN-Ethiopia, 2012), (see appendix). In the tables, some of the products are described including the accessories (like computers and televisions) and the rest described by the different product brands (like personal mobile telephones and refrigerators). But, because of the unavailability of data to calculate and the difficulty to find from the previous researches for elasticity of each of the accessory and different branded products of eee, this paper uses the accessories and different brands to include in the main product. The circulation of eee and the contribution on the generation of wfeee from the stated cities are described in the tables. Because of the volume, similarities and characteristics of the data from the inventory and by targeting to get a better result and conclusions, this paper uses the summarized aggregate quantity of eee for the calculations from the entire four cities under Table 4 which will help this paper to see the urban set up of wfeee production in the country.

Under table 3, the total consumed, reused/recycled, residue amounts and the maintenance rate are described. The consumption and reused/recycled amounts are the summations of products from each city under table 11, 12, 13 and 14 (see the appendix).

Table 3: Production, maintenance and removal of wfeee in 2011,

Product	Amount utilized (in thousand Kgs)	Amount maintained in tones	Maintenance rate (%)	Amount of residue in tones
Urban Ethiopia (Bahir Dar + Hawassa + Addis Ababa + Dire Dawa)				
Computers and accessories	**1795.94**	**1201.44**	**0.67**	**594.502475**
- Desktop comp.	1655.16	1140.57	0.69	514.59
- Laptop comp.	27.53	17.50	0.64	10.04
- Printers	110.36	65.35	0.59	45.01
- Palmtop comp.	0.17	0.10	0.59	0.07
- Notebook comp.	0.31	0.16	0.52	0.15
- External Hard disk	2.41	0	0	2.41
Television and accessories	**362.90**	**271.63**	**0.75**	**91.27**
- Television	359.42	284.23	0.79	75.19
- CD/DVD/VCD Player	1.20	0.77	0.66	0.39
-Video deck	2.33	1.81	0.78	0.52
Mobile Telephone	**2.09**	**1.36**	**0.65**	**0.73**
- Different brands	2.09	1.36	0.65	0.73
Refrigerator	**351.36**	**257.53**	**0.73**	**93.83**
- West point	44.1	35.94	0.82	8.16
- LG	38.43	29.17	0.76	9.26
- Hitachi	34.65	26.37	0.76	8.28
-Samsung	39.93	28.99	0.73	10.94
- Ocean	27.37	19.39	0.71	7.98
- Konka	7.63	5.01	0.66	2.62
- Philips	21.35	14.83	0.69	6.52
- Others	137.9	107.01	0.78	30.89

Source:(PAN-Ethiopia, 2012)

The weight and volume of the disposed eee is calculated by assuming the average weights of the products under study. The following table tells us the unit final price of the primary product, the unit price of the used product, the unit estimated weights of different types of electrical and electronic equipment, the price per ton value for the primary and used product respectively.

Table 4: Unit price of products, weight/unit/kg and price per ton of products, as of 2011

Product	2011 final price (in Br/unit)	2011 after utilization price (in Br/unit)	eee weight/unit/ kg	2011 final product price/ton	2011 after utilization price/ton
Computers and accessories					
– Desktop comp.	13000	500	30	433333	16667
– Laptop comp.	10500	600	3	3500000	200000
– Printers	2600	100	8	325000	12500
– Palmtop comp.	3000	200	0,7	4285714	285714
– Notebook comp.	7000	250	2	3500000	125000
– External Hard disk	360	0		0	0
Television and accessories					
– Television	9300	1000	35	265714	28571
– CD/DVD/VCD Player	3000	270	3	1000000	90000
– Video deck	2800	120	5	560000	24000
Mobile Telephone					
– Different brands	3200	200	0,1	32000000	2000000
Refrigerator					
– West point	7300	1100	70	104286	15714
– LG	7000	1100	70	100000	15714
– Hitachi	6200	1100	70	88571	15714
– Samsung	6950	1100	70	99286	15714
– Ocean	5690	1100	70	81286	15714
– Konka	5400	1100	70	77143	15714
– Philips	6300	1100	70	90000	15714
– Others	5100	1100	70	72857	15714

Table four contains the unit/Br purchasing price of primary and used products, the unit product weights in Kg, and the purchasing price per ton of primary and used products in Br respectively. The data for the unit price of products is obtained from the retailers for primary product and from maintenance shops for the used products through telephone and from the

Ethiopian import office. These prices are directly applied on the calculations in each economic incentive policy instruments.

Due to the information constraint, it is difficult to calculate elasticity in this paper for the given commodities or products in this specific country case Ethiopia. Table 5 is totally based on the elasticity estimates from the previous other countries case work. In this paper, the payments on the credit/repayment, early disposal payment and the reused/recycling grant is labeled as c, e and g respectively based on equations (u), (v) and (w).

Table 5: Demand and supply elasticity by product[1]

Product	End product demand elasticity	Reused product demand elasticity	Reused product supply elasticity
Computers	-6,3	- 0,805	1,1
– Desktop comp.	-6,3	- 0,805	
– Laptop comp.	NA	NA	NA
– Printers	NA	NA	NA
– Palmtop comp.	NA	NA	NA
– Notebook comp.	NA	NA	NA
– External hard disk	NA	NA	NA
Television	-1,51	- 0,805	1,1
– Television	-1,51	- 0,805	1,1
– CD/DVD/VCD Player	NA	NA	NA
– Video deck	NA	NA	NA
Mobile Telephone	-2,011	- 0,805	1,1
– Different brands	-2,011	- 0,805	
Refrigerator	-2,5	- 0,805	1,1
– West point	NA	NA	NA
– LG	NA	NA	NA
– Hitachi	NA	NA	NA
– Samsung	NA	NA	NA
– Ocean	NA	NA	NA
– Konka	NA	NA	NA
– Philips	NA	NA	NA
– Others	NA	NA	NA

[1] Sources, estimated elasticity of demand for computer: STAVINS, J. 1997. Estimating demand elasticity in a differentiated product industry: The personal computer market. *Journal of Economics and Business*, 347-367.; estimated elasticity demand for television: estimated elasticity of demand for mobile phones: IIMI, A. 2005. Estimating demand for cellular phone service in Japan. *Telecommunications policy 29*, 3-23.;JOHN, W. M. & YASUJI, O. 1991. Deman pricing and regulation: evidence from the cable TV industry. *RAND Journal of Economics*. Refrigerator :GALARRAGA, I., DEL VALLE, D. H. & GONZÁLEZ-EGUINO, M. 2011. Price Premium for High-Efficiency Refrigerators and Calculation of Price-Elasticities for Close-Substitutes: Combining Hedonic Pricing and Demand Systems.: reused product demand and supply elasticity: (Palmer, et al., 1997)

Table 5 explains the demand and supply elasticity of the eee products. As this paper stated above, due to the constraint of data, all the elasticity results are taken from the previous researches. The demand and supply elasticity of all the used electrical and electronic materials are the same across the products.

Table 6: Calculated Parameter Values in ratio and price per ton.

Eee products	Calculated parameter values by product and price per ton						
	a_1/prod	a_2/prod	R_r/prod	e_y^d/prod	P_y/ton	P_u/ton	c=e=g Br/tone
Computers	0.7148	0.6936	0.67	-6.3	433333	16667	3333
Televisions	0.1444	0.1568	0.75	-1.51	265714	28571	2857
Mobile phones	0.0008	0.0007	0.65	-2.011	32000000	2000000	1000000
Refrigerators	0.1398	0.1486	0.73	-2.5	104286	15714	1428

Figures in table 6 are applied for the calculations of the results and discussions part.

6. Results and discussions

6.1. Findings of the research

This chapter presents the calculations and results of wastes from eee reduction policy instruments based on equations (u), (v) and (w) in chapter three. The elasticity, price and quantities of the eee products stated in the previous chapters are applied to regulate the model. In this chapter, solutions for the policy instruments are achieved from the calculations of credit/repayment, early disposal payment and reusing/recycling grants that give a percentage decrease in the total wfeee removal. The outcome of these policy instruments on the reductions of wfeee from the source and reusing has discussed in this part. The wfeee reduction policy instruments are compared from applying the same level of payment on each. This paper uses the same payments for all the policies, which is 100ETB/unit of products to see the impacts of the policies only on their applications regardless of the price differences. The reason that this paper uses 100ETB/unit is as stated in section 2.1 in this paper above, the payment for wfeee for reused/recycling purpose is $6, $8 and $10 per unit in the United States. This paper considers the minimum payment which is $6 which is approximately equivalent to the Ethiopian currency 100 birr. The difference in the volume of reductions is achieved from the application of the system on equation u, v and w.

From Table 5 above, the end product demand elasticity for all the stated eee is price elastic. Computer is the highest elastically demanded equipment chased by mobile phones, television and refrigerators respectively. Policies on reductions from the source are more useful for products with larger demand elasticity. In the categories of reused product demand elasticity, because of the absence of elasticity data for the secondary product of eee and since this paper uses data for the elasticity of reused products of eee from other similar product's secondary demand elasticity, all the eee products have similar elasticity demands, that is price inelastic. The results in the following table are calculated by using equation u, v and w.

Table 7; Reductions in wfeee generation in percentage weight from different policy instruments

Product	Credit/Repayment	Early disposal Payment	Reusing/recycling grants
computers	4,57E-32	3,81E-32	4,92E-32
televisions	4,94E-05	4,49E-05	5,07E-05
mobile phones	3,46E-10	2,31E-10	3,35E-10
Refrigerators	1,25E-09	1,14E-09	1,33E-09
Total	4,94E-05	4,49E-05	5,08E-05

Table 7 represents reductions in electronic waste generations in percent after applying credit/repayment, early disposal payment and reusing/recycling grant economic incentive policy instruments. The results in the table are calculated based on the model this paper applied in each policy from equations (u), (v) and (w) respectively. Television, refrigerators, mobile phones and computers have better wfeee reductions in sequence from the stated policy instruments. Generally, television has high reductions and computers have the lower reductions in all the policy instruments. But when considering the total reductions in all the items from the three economic incentive policy instruments; reusing/recycling grants have a higher wfeee reductions and early disposal payment has the least wfeee reductions. The percent wfeee reduction results look not significant because of the size of data. But it has still a positive response from the application of these economic incentive policy instruments to the reduction of electronic wastes.

Table 8: wfeee reductions from the source and increasing in reusing amount after policy implementation

Descriptions under each Policy instruments	eee products				
	Computers in tones	Televisions in tones	Mobile phones in tones	Refrigerators in tones	Total percentage reduction
Credit/Repayment					
Reduction from the source	7,2002E-29	0,0166	1,4541E-09	4,1870E-07	0,0166
Increased reusing amount	4,8168E-29	0,0124	9,4325E-10	3,0689E-07	0,0124
Total reduction in wfeee	1,2017E-28	0,0291	2,3974E-09	7,2560E-07	0,0291
wfeee reduction percent	2,0214E-29	0,0318	3,2638E-07	7,7334E-07	**0,0581**
Early disposal. payment					
Reduction from the source	7,1537E-29	0,0166	1,4540E-09	4,1605E-07	0,0166
Increased reusing amount	4,788E-29	0,0124	9,4320E-10	3,0495E-07	0,0124
Total reduction in wfeee	1,1945E-28	0,0289	2,3973E-09	7,2100E-07	0,0287
wfeee reduction percent	2,0093E-29	0,0317	3,2648E-07	7,6845E-07	**0,0577**
Reused/recycling grants					
Reduction from the source	7,2161E-29	0,0166	1,4546E-09	4,2055E-07	0,0166
Increased reusing amount	4,8274E-29	0,0124	9,4353E-10	3,0825E-07	0,0124
Total reduction in wfeee	1,2044E-28	0,0291	2,3981E-09	7,2879E-07	0,0292
wfeee reduction percent	2,0258E-29	0,0319	3,2648E-07	7,7675E-07	**0,0582**

Table eight describes the level of wfeee reductions from the source, reusing amount, total reductions and percentage reductions after policy implementation in the stated four eee. The table illustrates the policies significant differences in their dependence on the increase in reusing/recycling amount and the source reductions. The first, second and third part of table eight describes the wfeee reductions from the credit/repayment, early disposal payment and the reusing/recycling grant policy instruments. The reusing/recycling grant takes over to both the increase in reusing/recycling amount and wfeee reductions from the source among the policies. The reusing/recycling grant motivates reusing/recycling and reductions from the source. The credit/repayment policy instrument takes part next to the reusing/recycling grant with the same characteristics on the reductions from the source and reusing/recycling motivation. Early disposal payment takes the last part, but encourages the reductions from the source and increasing reusing/recycling amount, like the same to the credit/repayment and the reusing grants.

Reductions from the source and increasing reusing/recycling amount by product, the amount of reductions from the source and reusing occasions are different among the electrical and electronics products. At the reflection from table eight, removal of computers, televisions, personal mobile phones and refrigerators is achieved both by decreasing consumptions and increasing reusing/recycling amount among all the described policies. Under table eight, it is also illustrated that there is variations in the reductions among the products. The last row in each of the policy instruments indicates the wfeee reductions in percent by product type. Generally, from the product category television, refrigerator, personal mobile phone and computers have higher wfeee reductions in percent respectively. In aggregating the wfeee reductions in percent, this paper has achieved results from the stated eee and policy instruments. In general, in the total wfeee percent reductions reusing/recycling grants have the highest and early disposal payment has the lowest wfeee reductions.

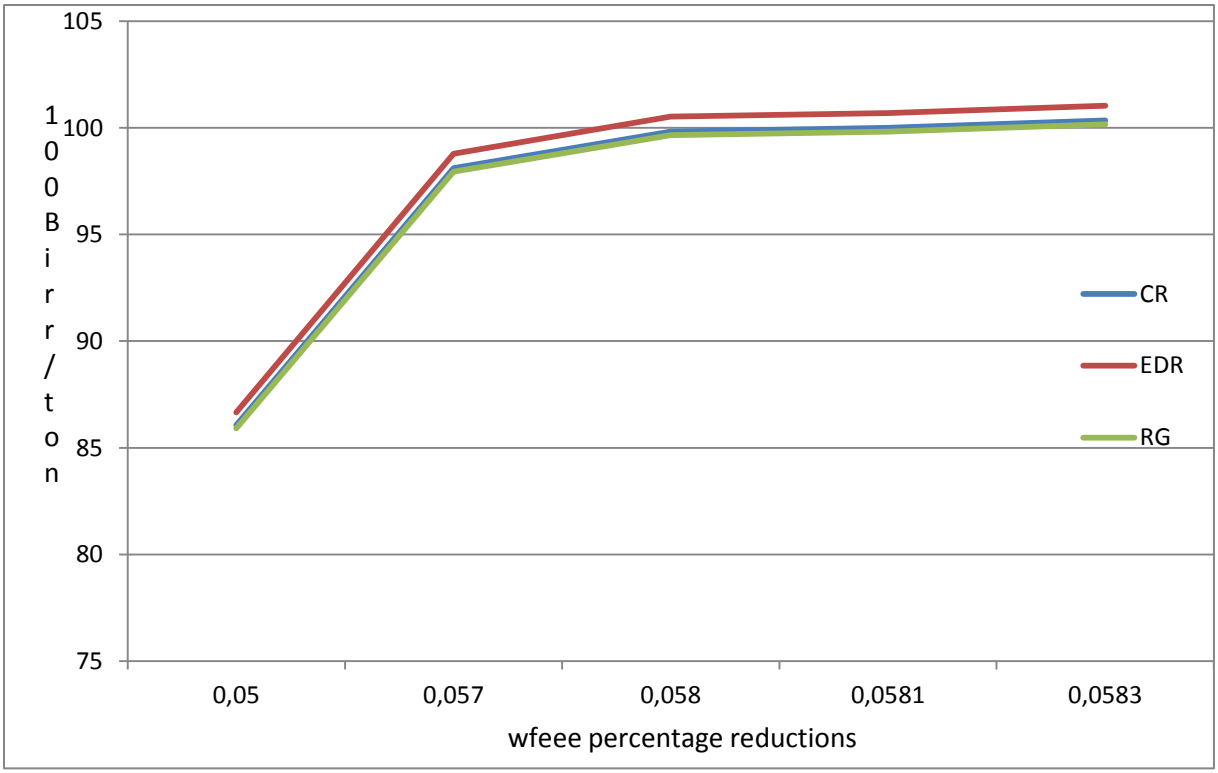

Figure 3: Percentage wfeee reductions respective of price changes

The above figure explains the relationship between the percentage wfeee reductions and the payment across the three economic incentive policy instruments. They are directly related, as the payment goes up the percentage reductions also goes up and the vice versa. It is shown that, the payments for a given percentage reductions is almost the same, but still the reusing/recycling grant has the higher wfeee reductions in all the electrical and electronic equipment under study.

The results from this paper are so close among the stated policy instruments and different from the result of the Palmer et al. (1997), which this paper used as the basic reference. This difference may happened due to the following reasons: First, this paper uses a one time period data and covers very limited areas that resulted from constraint in data volume. Second, regular prices are applied for the calculations for both the primary and used electrical and electronic products. Third, in this paper only electrical and electronic equipment are targeted for the calculations of these policy instruments. Whereas in the Palmer et al., 1997 paper, different kinds products like, paper and paperboard, glass, aluminum, steel and plastics are targeted which have their own characteristics that can affect the results on the policy instruments. Fourth, this paper uses elasticity from the previous works and elasticity from similar products. Fifth, since there is no such policy instrument for electrical and electronic equipment in Ethiopia, this paper uses the same payment 100Br/unit for all the economic

incentive policy instruments. In addition the study of Palmer et al., 1997 is used to obtain data for elasticity of similar products.

6.2. Sensitivity Analyses

The mathematical computations explained in this paper uses the elasticity estimates from the previous researches for various types of electronic products. To discover the sensitivity of results, this paper uses a 10% increase to each of the value of elasticity of the different electronic products separately. This analysis has done based on the elasticity of electrical and electronic products on table 5. In table 9 below, the reductions in wfeee after a 10 % increase in the elasticity from the different policy instruments has different results from the base line result. Computers, personal mobile phones and refrigerators generally has decline in waste reductions with different levels of percent. When considering the percentage changes in the wfeee reductions from different policy instruments under different scenario after a 10% increase in the elasticity of products results in different outputs (table 10). The increases in the elasticity of demand on the end product have a positive effect on the reduction of wfeee from all the stated electrical and electronic equipment under all the policy instruments. Similarly, a 10% increases in the demand elasticity of the reused product have the same effect on all products under the policy instruments.

Generally, a 10% increase in the elasticity of end and reused products under the stated scenario in the all product category resulted in either a positive or neutral effect on the wfeee reductions from all electronic products under the three policy instruments.

Table 9: Reductions of wfeee in percent from different policy instruments after 10% increase in elasticity

Product	Policy instruments		
	C/R	EDP	RG
Computer	1,11E-35	1,10E-35	1,11E-35
Televisions	7,01E-06	6,99E-06	7,02E-06
Mobile phones	4,07E-11	4,07E-11	4,07E-11
Refrigerators	6,80E-11	6,76E-11	6,83E-11
Total	7,01E-06	6,99E-06	7,02E-06

Table 10: Percentage change of total wfeee under the three policy instruments

Product	Scenario (10 % Increased in)	% change of total wfeee under C/R	% change of total wfeee under EDP	% change of total wfeee under RG
Computer	Elasticity demand of end product	1	0,99	0,99
Television	Elasticity demand of end product	0,85	0,85	0,85
Mobile Phones	Elasticity demand of end product	0,94	0,94	0,94
Refrigerators	Elasticity demand of end product	0,94	0,94	4,33
All Products	Elasticity demand of end product	**3,73**	**3,72**	**7,11**
Computer	Elasticity demand of reused product	1,02	1,02	1,02
Television	Elasticity demand of reused product	1,97	1,97	1,97
Mobile Phones	Elasticity demand of reused product	0,84	0,84	0,84
Refrigerators	Elasticity demand of reused product	1,74	1,74	1,74
All Products	Elasticity demand of reused product	**5,57**	**5,57**	**5,57**
Computer	Elasticity supply of reused product	1	0	0
Television	Elasticity supply of reused product	0	0	0
Mobile Phones	Elasticity supply of reused product	0	0	0
Refrigerators	Elasticity supply of reused product	0	0	0
All Products	Elasticity supply of reused product	**1**	**0**	**0**

6.3. Implementability of the policy instruments

Small and large scale industries and manufactories produce different kinds of products to address the demand of the consumers. These products are produced using natural and manmade resources as an input for the production process from the environment. During this process, many harmful solid and non-solid substances are produced. Rules, principles and regulations are designed to tackle and control properly the damages from these hazardous substances. The same is happening in the wfeee sectors. Ethiopia as a country has these rules, principles, regulations and experience of applications and implementation for the solid wastes in general, but specifically not for wfeee, except signing the Basal agreement. This may happen because; the severity of the problem from wfeee was minimal and may be with lack of deep awareness to the sector and some other additional reasons like economic reasons. Since there is no economic incentive policy instruments in the electronic waste sectors, all the three instruments described and compared in this paper has a positive response for the reduction of wfeee (by assuming all other things constant). But when comes to implementation, all the stated policy instruments have their own pros and cones, in demanding additional resources like money, man power, establishing reusing/recycling plants and others, and results in to some extent increased in transaction costs, and can end up with failure of the instruments unless proper management is applied.

Under the reusing/recycling grant, additional money is necessary that serves as a grant for the waste collecting groups or agents. This additional money or cost covered by the government is getting from the revenue generated from the additional payment gained during the time of purchase of the equipment. The government can decrease its burden by increasing the awareness of the people towards the sector and participating the private companies and investors to the area. By doing so, the government can control and monitor the system and administers the revenue properly. This revenue shouldn't go to the government budget; the revenue should be recycled and used for handling wfeee. If the country applies and implements the reused/recycling policy instrument, the society can practice to wfeee environment friendly, creates additional job spaces for the people from private companies and investors by opening facilitating offices. Once the system is established, there is a very minimal transaction cost.

In this chapter, this paper had a look on the elasticity of products and its usefulness in the reduction of wastes from electrical and electronic equipment. Mathematical calculations and results on percentage wfeee reductions from the three economic policy instruments, source reductions and increases in the reusing amount on each economic instrument have discussed. The effects of these policies on the reduction of wfeee from the source, increasing reusing amount, total reductions in wfeee and the reduction percentages of wfeee among the different types of eee products have addressed. Besides, sensitivity analysis from a 10% increment in the elasticity and its changes in the percentage reductions are also discussed. Finally, the implementation of this economic policy instrument has explained.

7. Conclusions and recommendations

7.1. Conclusions

EEE export countries are benefited from exporting new brand and second hand electrical and electronic equipment from the dynamics of information communication technology sector. The eee importing countries also benefited from importing electrical and electronic equipment for the expansion of development and in creating a smooth and fast networking to the external world. Importing the second hand electrical and electronic equipment particularly happened in the economically poor countries because of the cheap price and getting it in the form of donation and support from the economically rich countries which results in accumulation of wastes from eee. Though, Ethiopia is not one of the wfeee destination countries, the volume of eee import is the second largest commodity for the country. Some of the imported materials applied directly for consumption and some getting reconditioned and consumed after importing, but the final destination of these materials is removed as a waste. Different policies and economic incentives can be applied to minimize the volume of wfeee.

This paper discusses and analyzes different policy instruments and basically gives emphasis on the three economic incentive policy instruments for minimizing the removal of wastes from electrical and electronic equipment in the Ethiopian context: the credit/repayment, early disposal payment and the reused/recycling grant. This paper finds out that all the three economic incentive policies have almost similar percentage wfeee reductions under the stated set up (Ethiopia). However the reusing/recycling grant policy instrument takes advantage over the credit/repayment and early disposal payment in the case of Ethiopia.

7.2. Recommendations

It is known that Ethiopia as a nation has so many laws, principles and policies for different sectors. The country has also a strong policy on the solid waste disposal; however, this solid waste disposal policy has not included specifically the wastes from electrical and electronic equipment. Unless there are rules and regulations applied in this sector from the process of wfeee collections up to disposal, it will be a problem to the economy, the environment and human health. Finally after passing through all this process, this paper would like to recommend the following points: since the country has no specific policy regarding the wfeee, it should be designed and applied to the electrical and electronic products. In this paper all the three economic incentive policies have almost equal percentage reductions in wfeee to this

specific country, but the reusing/recycling grant is more advantageous than the other two. Agencies or companies should be established to collect wfeee and to settle the necessary payments for the reimbursed amount, motivating the involvement of the private sectors to the establishment of reused/recycling plants, providing capacity building trainings and activities for professionals who are working in wfeee management cycles and launching proper mass awareness creation programs to the society about the proper disposal, damages and benefits from wfeee.

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Appendices

Table 11: Production, maintenance and removal of wfeee in Bahir Dar by 2011,

Product	Amount utilized (in thousand Kgs)	Amount maintained in tones	Maintenance rate (%)	Amount of residue in tones
Bahir Dar				
Computers and accessories	**431.53**	**295.17**	**0.68**	**136.36**
- Desktop comp.	411.39	281.39	0.68	130.00
- Laptop comp.	5.70	3.47	0.61	2.22
- Printers	14.33	7.74	0.54	6.60
- Palmtop comp.	0	0	0	0
- Notebook comp.	0	0	0	0
- External Hard disk	0.12	0	0	0.12
Television and accessories	**50.44**	**32.83**	**0.65**	**17.6**
- Television	49.84	33.94104	0.681	15.89896
- CD/DVD/VCD Player	0.36	0.20	0.55	0.16
-Video deck	0.24	0.15	0.63	0.09
Mobile Telephone	**0.32**	**0.06**	**0.19**	**0.26**
- Different brands	0.32	0.06	0.19	0.26
Refrigerator	**75.42**	**52.79**	**0.7**	**22.63**
- West point	2.94	1.97	0.67	0.97
- LG	9.24	6.56	0.71	2.68
- Hitachi	4.76	2.81	0.59	1.95
-Samsung	14.24	10.54	0.74	3.7
- Ocean	7.28	5.10	0.7	2.18
- Konka	1.82	0.89	0.49	0.93
- Philips	1.61	0.90	0.56	0.71
- Others	33.53	26.49	0.79	7.04

Source: (pan Ethiopia)

Table 12: Production, maintenance and removal of wfeee in Hawassa by 2011,

Product	Amount utilized (in thousand Kgs)	Amount maintained in tones	Maintenance rate (%)	Amount of residue in tones
Hawassa				
Computers and accessories	**171.53**	**144.09**	**0.84**	**27.44**
- Desktop comp.	150	130.5	0.87	19.5
- Laptop comp.	4.86	3.75	0.77	1.12
- Printers	15.19	10.25	0.68	4.94
- Palmtop comp.	0.0028	0.0012	0.42	0.0016
- Notebook comp.	0	0	0	0
- External Hard disk	1.47	0	0	1.47
Television and accessories	**67.36**	**50.52**	**0.75**	**16.84**
- Television	66.54	54.56	0.82	11.98
- CD/DVD/VCD Player	0.50	0.35	0.71	0.14
-Video deck	0.33	0.25	0.77	0.075
Mobile Telephone	**0.34**	**0.24**	**0.70**	**0.10**
- Different brands	0.34	0.24	0.70	0.10
Refrigerator	**77**	**61.83**	**0.80**	**15.17**
- West point	11.83	9.82	0.83	2.01
- LG	8.75	7.09	0.81	1.66
- Hitachi	10.99	8.9	0.81	2.09
-Samsung	4.48	3.49	0.78	0.99
- Ocean	7.14	5.71	0.80	1.43
- Konka	0.35	0.28	0.80	0.07
- Philips	6.23	4.98	0.80	1.25
- Others	27.23	23.42	0.86	3.81

Source: (pan Ethiopia)

Table 13: Production, maintenance and removal of wfeee in Addis Ababa by 2011,

Product	Amount utilized (in thousand Kgs)	Amount maintained in tones	Maintenance rate (%)	Amount of residue in tones
Addis Ababa				
Computers and accessories	**1089.98**	**730.28**	**0.67**	**359.69**
- Desktop comp.	997.41	688.21	0.69	309.20
- Laptop comp.	15.92	9.87	0.62	6.05
- Printers	75.87	45.52	0.60	30.35
- Palmtop comp.	0.17	0.10	0.60	0.07
- Notebook comp.	0.18	0.12	0.68	0.06
- External Hard disk	0.43	0	0	0.43
Television and accessories	**175.46**	**166.68**	**0.95**	**8.77**
- Television	173.92	168.7	0.97	5.22
- CD/DVD/VCD Player	0.20	0.19	0.93	0.014
-Video deck	1.34	1.29	0.96	0.05
Mobile Telephone	**0.86**	**0.82**	**0.95**	**0.043**
- Different brands	0.86	0.82	0.95	0.043
Refrigerator	**116.06**	**99.81**	**0.86**	**16.25**
- West point	24.85	21.87	0.88	2.98
- LG	13.58	11.68	0.86	1.90
- Hitachi	13.51	11.69	0.87	1.82
-Samsung	10.92	9.5	0.87	1.42
- Ocean	5.53	4.65	0.84	0.88
- Konka	2.94	2.53	0.86	0.41
- Philips	6.09	5.24	0.86	0.85
- Others	38.64	34.78	0.90	3.86

Source: (pan Ethiopia)

Table 14: Production, maintenance and removal of wfeee in Dire Dawa by 2011,

Product	Amount utilized (in thousand Kgs)	Amount maintained in tones	Maintenance rate (%)	Amount of residue in tones
Dire Dawa				
Computers and accessories	**102.90**	**31.9**	**0.31**	**71.00**
- Desktop comp.	96.36	40.47	0.42	55.89
- Laptop comp.	1.05	0.4	0.38	0.65
- Printers	4.97	1.84	0.37	3.13
- Palmtop comp.	0.0014	0.0004	0.28	0.001
- Notebook comp.	0.31	0.04	0.31	0.09
- External Hard disk	0.4	0	0	0.4
Television and accessories	**69.65**	**21.59**	**0.31**	**48.06**
- Television	69.13	27.03	0.39	42.10
- CD/DVD/VCD Player	0.11	0.03	0.30	0.08
-Video deck	0.42	0.12	0.28	0.30
Mobile Telephone	**0.57**	**0.24**	**0.42**	**0.33**
- Different brands	0.57	0.24	0.42	0.33
Refrigerator	**82.88**	**43.10**	**0.52**	**39.78**
- West point	4.48	2.28	0.51	2.20
- LG	6.86	3.84	0.56	3.02
- Hitachi	5.39	2.98	0.55	2.41
-Samsung	10.29	5.45	0.53	4.84
- Ocean	7.42	3.93	0.53	3.49
- Konka	2.52	1.31	0.52	1.21
- Philips	7.42	3.71	0.50	3.71
- Others	38.5	22.33	0.58	16.17

Source: (pan Ethiopia)