Chapter 5

Electronic Waste in Mexico – Challenges for Sustainable Management

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Additional information is available at the end of the chapter

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Abstract

The purpose of this chapter is to analyze the situation of the management of electronic waste in Mexico; it has been organized into four sections. In the first, a brief description of the problem of electronic waste based on the world vision presents the situation of transboundary movements of electronic waste from developed countries to developing countries or emerging stands out, in which it is done an incipient and inadequate management without concern about pollution, and health damage caused. In the second, the law applied to waste management in this country, concerning international, regional and national framework is presented. The third section, an analysis of the actors involved in the production, marketing, use, handling and disposal of electronic waste is presented; highlighting the role currently performed. A conceptual model of the life cycle of electrical-electronic equipment as a starting point for handling electronic waste and the model of management electronic that is now operating in Mexico, in which the actors involved in the value chain of electrical and electronic equipment waste (WEEE's), is presented. In the last section, efforts that Mexican environmental authorities have done on the management of electronic waste, and WEEE 's generation data are analyzed, a generic model is presented enhance the WEEE 's in Mexico as a first phase to move from an emerging electronic waste management to a management model.

Keywords: e-waste, handling, stakeholders, regulatory framework, Mexico

1. Introduction

The consumption of electrical and electronic equipment are increasing continuously all around the world, and therefore also the amount of waste electrical and electronic equipment (WEEE)

at the end of useful life. This is a consequence of rapid technological advance that make electrical and electronic equipment production in a shorter of useful lifetime and/or reduction using, due a substitution by costumer. Customers are motivated for new models, thus increasing the waste flow, so electronic waste volume increase faster than rest [1]. Actually growing is three times more faster than municipal waste and estimated worldwide grows between 3% and 5%. Without prevention, control and information strategies, this problem can cause and inadequate handling and disposal practices of WEEE. Lepawsky [2], mention that since more than a decade the problem of e-waste it focus on exportations of rich countries, particularly EE.UU., Canada and European Area, poor countries and/or emergencies economies to be processed in dangerous conditions for employees, that impact into health and environment.

According to Pickren [3], rapid growing of electronic equipment, it is consider an emergent problem. A study made for Yu, et al. [4], indicate that for 2017 developing countries will start generate more electronic waste than developed countries. An UNU report [5], predicts for 2020, countries like China and other of South Africa obsolete computer generation will grows from 200% generated in 2007 to a 400%, and to a 500% in India. Despite the high consumption in electrical and electronic equipment (EEE), markets still not saturated, this means that growing of electronic waste generation it overpass an adequate development infrastructure for collection, recycle and reuse [6,7].

Electronic waste problem, is a global problem, Ogondo et al., [8], research estimate that worldwide of e-waste generation was of 50 millions of tons annually approximately, and for 2017 estimate this will increase to 65.4 millions of tons per year [9]. This implicate that toxic wastes of electronic are multiplying with uncontrolled speed. Garlapati [10], indicate that current research shows that in next eight years developing countries will producing double of electronic waste than developed countries. Therefore, estimate for 2013 developed countries discard between 200-300 millions of obsoletes computers, while developing countries discard double of this amount [11]. According to [12], Mexico is between forty countries around the world. In first places was United States and China with just more than 7,000 million of tons first one and 6,000 second one, both countries contribute with 32% of total generated worldwide, 60% of electronic waste generated all around the world is from big and small home appliances. In terms of electronic waste generation per capita there is eight European countries that are in on top list: Norway, Switzerland, Iceland, Denmark, United Kingdom, Netherlands, Sweden and France. Consider this countries average generation for Norway is 28 kilograms of electronic waste per year and France with 22 kilograms.

At global level generation of electronics increase in 2014 to 41.8 Mt., from this volume only 6.5 million of tons of electronic waste was treated formally with data collection method which is establish in some developed countries. In European Union was deposited in garbage container 0.7 million of tons of e-waste. Electronic waste quantity that deposited in containers for other regions are unknown, in addition movement of electronic waste mostly comes from developed countries through developing countries is unknown. According to [13], data shows a flow to Nigeria in 2010 of 0.1 MT. In Asia, in 2014 generated 16 millions of tons of electronic waste. Generation per capita was 3.7 kg. Europe was the continent that had highest generation per

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capita (15.6 kg/capita). Oceania was the continent with less electronic waste generation (0.6 Mt.); however, quantity per capita was very similar to Europe (15.2 kg/capita). Less electronic waste per capita was generate in Africa (1.7 kg/capita). Throughout the continent generated 1.9 million of tons of electronic waste.

American continent generated 11.7 millions of tons of electronic waste, of this, North America generated most of the quantity (7.9 Mt); Central America 1.1 Mt and South America 2.7 Mt, generation per capita of continent was 12.2 kg/capita. From Latin American countries, there six that have highest generation, Brazil generate 1.4 million of tons of waste, Mexico follows this list with a million, Argentina, Colombia, Venezuela and Chile also are between in the 40 countries that generate more electronic waste.

In Table 1 shows largest electronic waste generation per capita in Latin American countries. Electronic waste generation per capita is high, therefore is important that establish strategies to handle electronic waste.

Country	Generation per capita
Chile	9.9
Uruguay	9.5
Mexico	8.2
Panama	8.2
Venezuela	7.6
Costa Rica	7.5
Argentina	7
Brazil	7
Colombia	5.3
Ecuador	4.6

Source: Modify of [14]

Table 1. Electronic waste generation in Latin American countries in 2014

According to [15] electronic waste are a source of material for metal recycling market because contain a lot of the metals that demand needs, between post-consumption electronic there are computers, mobile phones, screens and kitchen appliances include. In a recent survey, Cucchiella et al. [1] note that notebooks ant tablets, along with desktops and servers are the most valuable WEEE category, because of the high of metal content in some of its major subsystems. On the other hand, electronic waste generation is a problem that requires attention Premalatha, et al. [16] point out that few developed countries around the world are scientifically able to recycle or dispose electronic waste generated. In other developed countries just a fraction of e-waste is recycle correctly, the rest either incinerated or sent to landfills that causes severe secondary problems. Even worst, a significant part of waste flow generated worldwide

is exported to a developing countries where are dispose without any concern for the pollution that is causing.

In Latin American countries there aren´t WEEE management systems, only started with initiatives to address problematic, but it is necessary to work with management systems in which stakeholders involved are committed and be responsible in the cycle. According to [17], at the end of life cycle, some electronics end up in common garbage. Contaminated fields around landfills by chemical substance and heavy metals such beryllium, chromium, cadmium, arsenic, selenium, antimony, mercury in electronic equipment and/or electronic that are hazardous and required a especial final disposition in order to not pollute the environment, for this reason collection and treatment sustainable of electronic equipment is indispensable.

Another alarming situation in terms of e-waste are transboundary movements, [18] suggest that developed countries are exporting their electronic waste to a developing countries as a practice of disposition. They state that much of e-waste sent it to countries such Africa or Asia, without authorization to export unnecessary good to poor countries for reuse o refurbish; in these cases, electronic equipment that does not work wrongly classified as "used goods". A significant flow of e-waste exportation is being sending from the European Union to Western Africa, causing environment pollution and significant risks to local population health [19].

In this sense [20], say that despite the Basel Convention, transboundary movements of hazardous waste is still high, mainly from countries such as United States, Canada, Australia, the European Union, Japan and Korea trough the Asian countries such as China, India and Pakistan. America, Brazil and Mexico are the countries, which serve as destination for this waste. According to [21], it is estimate that between 60-75% of e-waste collected in the European Union is sent to the countries of Asia and Africa for recycling or dismantling. Electronic waste in Pakistan are imported from United States, the EU, Australia, Saudi Arabia, Kuwait, Singapore and the United Arab Emirates, among many other countries. Dubai and Singapore also serve as centers of pre-distribution of e-waste from the European Union (EU) and United States through countries such South Asia as India and Pakistan as the main destinations [22]. This indicate that exportation of e-waste is a flow that is still practiced, in which there are transport processes of e-waste from one country to another, where do this imply the existing of partners, including countries of origin and recipients, multinational companies, handling agents and market intermediaries.

Currently electronic waste are exported to countries that are unlikely to obtain infrastructure and security networks to prevent damage to human health and to environment, this is due to factors such lower cost of exporting and manage waste in country of origin. Markets availability for raw materials or recycling facilities among other. However, there are examples of official recycling facilities in developing countries and with economy in transition that dedicate to repair, rebuild and recycle used equipment and electronic waste in environmentally sound manner.

Although the Basel agreement objectives, countries that been added to this agreement must be into the rules established for transboundary movements control of hazardous wastes, their still some gaps in some areas. Electronic waste are subject of interest or this agreement, one of

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it is major problems with authorities is to establish a clear definition in order to distinguish between secondhand equipment to be repair, refurbish or direct reuse and those they are an e-waste. In addition, there are controversies to determine which an e-waste is and what does not, therefore fall within the scope of the agreement. Therefore organisms in charge are vigilant for accomplishment of disposition of Basel agreement related to transboundary movements. Sometimes is difficult and complex to determinate.

2. Legal framework of electronic waste in Mexico

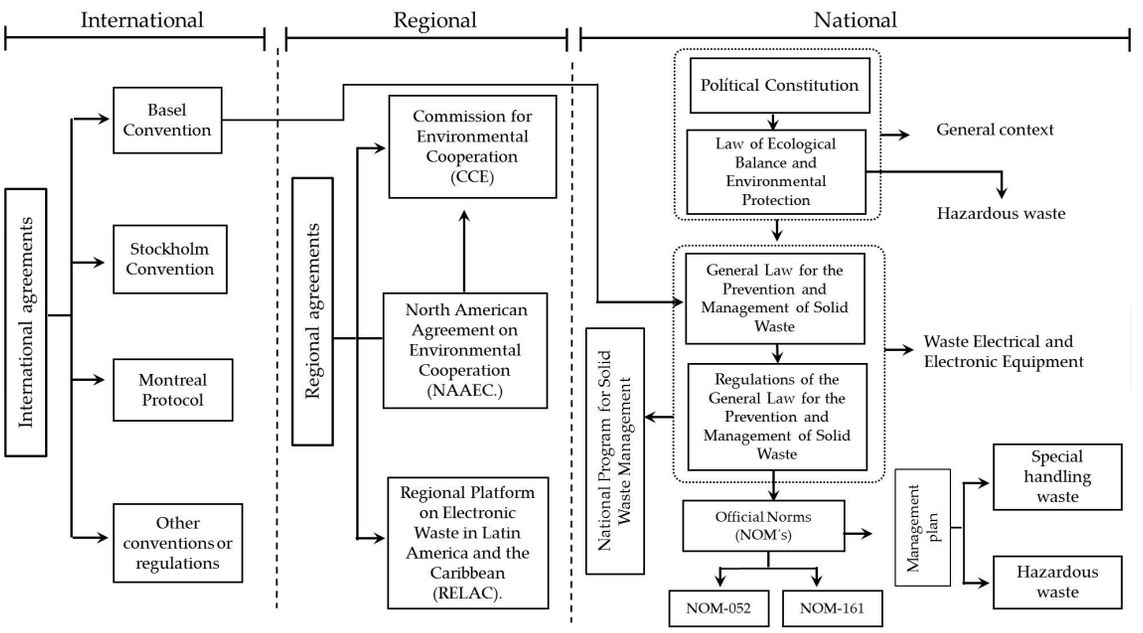
In Mexico, electronic waste begun having more importance, since that were included in the General Law for Prevention and Integral Management of Wastes (LGPGIR, by its acronym in Spanish). This law classify electronic waste in especial handling and establish obligation to make management plans and specific programs for disposition, because are this waste represents a high risk for population, environment and/or natural resources [23]. This waste contains persistence toxic substances and bioaccumulation, and materials can be recover.

The regulation of waste in Mexico is supported by an international framework that includes agreements and treaties such as Basel convention, Stockholm and Rotterdam among others. As well as a regional approach that applied for North America situation and Latin America in terms of e-waste where Mexico has participation in different programs and agreements related to topic of both zones, such Commission for Environmental Cooperation (CCE) and Waste Regional Platform in Latin America and Caribbean. As well as the national legal framework establish since Political Constitution of the Mexican United States, General Law of Ecological Balance and Environmental Protection (LEGEEPA, by its acronym in Spanish), the General Law for Prevention and Integral Management of Waste that derives regulation of LGPGIR and official standards. Figure 1 shows the legal instruments in terms of environmental protection and waste management for Mexico and also international regulations and regionals agreement that Mexico has signed.

2.1. International legal framework in terms of waste

The inclusion of the international and regional framework for electronic waste management is important because it sets a benchmark in the development of public politics on waste in Mexico. Management of e-waste in our country has gained importance because of the presence of some contaminants found in waste and when they are disposal not properly, can be freely into the environment. Electronic industry growing and technological development in this country have contributed to equipment process substitution, increasing the number of electronic waste nationally [27].

Cano [28], suggest that electronic waste topic has gained international importance from its inclusion in the agendas of different agreement between countries seeking to promote actions for reduction environmental impacts such as the Basel and Stockholm Convention among others. These actions mainly for the identification of some persistent organic pollutants (POPs), such as brominated flame-retardants as well as of heavy metals. At the end of its life cycle,



Source: Prepared by the authors based in the [24-26]

Figure 1. International and national legal framework in terms of waste in Mexico.

these contaminants can be released and cause adverse environmental and health effects. Figure 2 presents a summary of the agreements to which Mexico has acceded to protection to the environment and where management of electronic waste is involved.

Convention	Date and place	Vigencia para México	Objective
Basel	Basel, Switzerland. March 22, 1989.	Approved in the Official Journal of the Federation (DOF) August 6, 1990 Entry into force in Mexico: May 5, 1992.	Control of Transboundary Movements of Hazardous Wastes and their Disposal.
Stockholm	Stockholm, Sweden, May 23, 2001.	Approved in the Official Journal of the Federation (DOF) december 3, 2002. Entry into force in Mexico: May 17, 2004	Limit pollution caused by the COPs. Among its provisions accurately controlled substances establishes rules of production, import and export of these substances
Rotterdam	Rotterdam, Netherlands, September 10, 1998	Approved in the DOF: march 2, 2005. Entry into force in Mexico: August 2, 2005	Promote shared responsibility and cooperative efforts of the parties in the international trade of certain hazardous chemicals, to protect human health and the environment from potential harm.
Montreal Protocol	Montreal, Canada, September 16, 1987.	Approved in the DOF: January 25, 1988. Entry into force in México: Junuary 1,: 1989	Protect the ozone layer by taking measures to control the production and consumption of substances that deplete it, to eliminate them, based on scientific knowledge and technological information.

Figure 2. International agreements which Mexico has signed in environmental terms.

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Mexico adheres to the Basel convention and considers that is an important advancement in environment protection, through the legal regulation of the transboundary movement of hazardous wastes, to establish a framework of general obligations for countries involved, seeking primarily to minimize generation of hazardous wastes and the transboundary movement of those. These ensure their environmentally management as well as promoting international cooperation to achieve this; establish mechanisms for coordination, monitoring and regulating the application of procedures for peaceful settlement of disputes. Also encourages their elimination, through environmentally proper management, more near from site where is generated. It also seeks to minimize the production of hazardous waste; this involves strong controls during storage, transport, treatment, reuse, recycling, recovery and disposal. Promotes substitution of hazardous substances in the production and the responsibility extended of producer (REP) from design and production of the product to the treatment of waste.

Currently, this agreement has included in its regulations, the transport of electrical and electronic waste, mobile phones and computers. Likewise, it contains fractions that specifically limit the export of electronic waste including metallic waste, electronic assemblies as circuits printed, accumulators and other batteries and cathode ray tubes glasses.

Based on the regulatory framework that provides for the LGPGIR and its rules of procedure, the Secretariat of Environment and Natural Resources (SEMARNAT, by its acronym in Spanish) applied provisions of agreement on the transboundary movement of hazardous waste. The Stockholm convention is an agreement on polluting organic persistent (POP), chemicals products with toxic and resistant to degradation, and cumulative properties in human skin, can be transported by air, water and migratory species, causing their accumulation in terrestrial and aquatic ecosystems, which makes them harmful to human health and the environment. Thus, since the problem is cross-border, it is essential to take measures at the international level.

Mexico, is committed to eliminating use of polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) in the country, for which there is a commitment to the elimination of products that contain them, including electrical and electronic waste. This agreement establishes a series of commitments and opportunities for signatory countries, such as Mexico. The obligations include formulation of a National Plan of implementation that meets objectives of convention, through an actions that will lead to the elimination or reduction of use and release into the atmosphere of pollutants.

Mexico government restricted, since 1992, the use of the PCBs, one of the compounds subject to the Stockholm Agreement, whose management began in 1988 with publication of the LGEEPA and its regulations on hazardous waste and, later, with elaboration of the NOM-133-SEMARNAT-2000, environmental protection, management of polychlorinated biphenyls (PCBs) [29], some of the electronic waste contain PCBs; in addition, incineration environment frees heavy metals such as lead, cadmium and mercury, as well as dioxins and furans, polluting the air, soil and on occasions, reaching aquifers and introducing in trophic chains; for this reason, the Stockholm Agreement represents an opportunity for signatory countries to reduce effects to health and the environment through the control of POPs [26]. With regard to the

management and handling of WEEE, this agreement includes the PCBs contained in some capacitors equipment.

The Rotterdam Agreement promotes shared responsibility and joint efforts of the countries adhering to the Convention in the field of international trade of certain hazardous chemicals in order to protect human health and environment against possible damage and contribute to their environmentally rational use, facilitating the exchange of information on their characteristics, establishing a national process of decision-making about their import and export and disseminating these decisions among members.

The Montreal Protocol was signed for the purpose of standardizing on substances depleting the ozone layer, in which established deadlines for removal and consumption of the major substances that are depleting the ozone layer. Protocol establish a restriction on trade with countries that are not part of the Protocol, by prohibiting the import or export of depleting substances or products that contain them. It also gives importing countries the media and information they need to recognize potential hazards and exclude chemicals products that cannot handle safely. If a country consents the import of chemicals products, the Agreement promotes the use of this chemicals without risks according to standards of labeling, technical assistance and other forms of support.

Mexico is part of the 190 countries that are committed to the goals of production of gases chlorofluorocarbons (CFC), halons and methyl bromides which are used in industry and domestic application in cooling systems and air conditioners among others that are causing thinning of the ozone layer. The Montreal Protocol is an example of the success that may have the adoption of measures at the international level, provided there is the technological development needed to replace substances which have adverse effects on our environment, as well as the willingness of governments to cooperate in terms of transfer and exchange of information.

2.2. Instruments on waste in regional scope

At the regional level, in 1994 Mexico signed the North American Agreement of Environmental Cooperation (NAAEC). This agreement reflects the commitment of Mexico, Canada and United States to environmental improvement in the region. As a result of the NAAEC, arises the Environmental Cooperation of North America Commission, integrated by three federal environmental agencies of the signatory countries of the North America Free Trade (NAFTA) signed by the three countries.

Since 2004 the three countries have worked within the framework of the CEC to develop proper management of electrical and electronic waste projects. Commission considers that electrical and electronic waste represent an environmental and commercial issue both waste generated by flows with use and destination unknown to other regions such as Africa or Asia. So the problem of electrical and electronic waste in North America must be addressed in a way joint given the geographical vicinity and the permeability of borders. The differences in national laws and complex institutional coordination represent significant challenges that may be faced

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in the context of the CCA to contribute to the control of illegal electrical and electronic waste flows and efficient application of local laws to improve its management, among others.

In relation to the Regional Platform on electronic waste in Latin America and the Caribbean (RELAC by its acronym in Spanish), it is not itself a normative instrument, but a partnership project, non-profit, its aim is promotes, articulate and disseminate initiatives that promote solutions for prevention, proper management and proper final e-waste treatment in Latin America (LAC). The scope of project is prevention, reuse and recycling, its foundation focuses on identifying the social, economic and cultural peculiarities of Latin America and the Caribbean and respond to them in the initiatives of e-waste that are implemented in the LAC countries, its foundation focuses on recognize, highlight and respond to the social particularities economic and cultural of Latin America and the Caribbean in treatment of e-waste that are implemented initiatives. Undertakes overhaul initiatives to reduce the digital divide, promote social business, and promote equal access to initiatives of market for the treatment of e-waste (Figure 3).

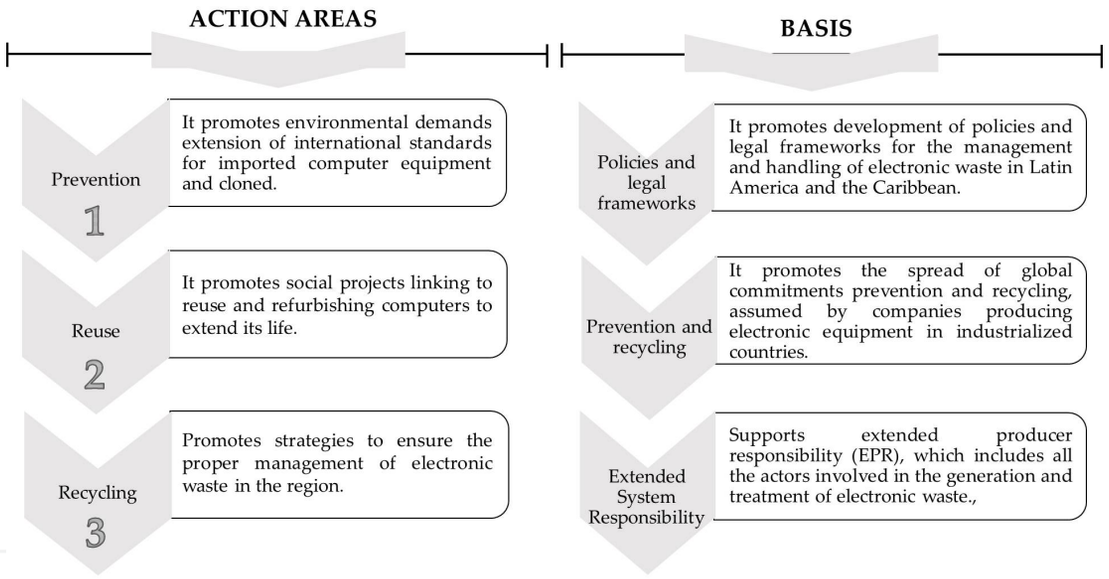

Figure 3. Basis and action areas of RELAC.

The RELAC also promotes and participates in research projects focused on solutions for management of e-waste in LAC; supporting Latin American electronic waste management projects and initiatives. Manages different sectors (public, private, academic) and from civil society the articulation in management of WEEE. It also offers legal and technical tools for dissemination of knowledge on management of e-waste, turning it into an important broadcast channel for the problem of electronic waste.

2.3. National framework on waste issue

Wastes are standard since the constitution, in its article 115, which is attributed to the municipalities' the responsibility the responsibility for providing the public service of cleaning,

collection, transfer, transportation, treatment and final disposal of solid waste, this is the general framework of the issue of waste. The first environmental law that regulated specifically to hazardous waste, is the LGEEPA, this was the first specific legislation of environmental protection in Mexico, there are established specific guidelines to waste handling, as well as the distribution of powers in the three levels of government, so the e-waste generated in homes, in public and private institutions, one of the natural destinations is in the municipal waste stream, even though there are regulations which confer you the responsibility of its management to the states or to the federation, this situation makes more complex the management of e-waste, depending on the source that generates it and the composition can be an urban waste, special handling or hazardous [26].

The General Law for the Prevention and Integral Management of Wastes (LGPGIR, by its acronym in Spanish) as an instrument of environmental policy establishes a general classification for waste: hazardous, special handling and solid urban waste [23]; the first and last classification are waste whose identity has no doubt however, as regards handling special waste, has not been very clear definition and understanding, which makes more complex the management of WEEE in Mexico.

The LGPGIR set environmental policy instruments to regulate plans of waste management that need it, this official Mexican norms laying down criteria for development of management plans. The LGPGIR classified the WEEE as special handling waste, defined as technological waste from industries of computer science, electronics manufacturers and others that require a specific management after its useful life [23]. It establishes a framework of shared responsibility among various players in the industry, as well as general principles for waste management, appraisal, and shared responsibility and integrated, under the criteria of environmental, technological, economic and social efficiency management.

The regulation of the General Law for the Prevention and Integral Management of Waste defines the implementation of plans for special handling waste which represent an environmental hazard and seeks to promote the recovery of materials. It also indicates that to classify a residue of especially management in terms of the LGPGIR, it will be established in accordance with the Mexican Official Norms (NOM, by its acronym in Spanish). Regulation drives the management plans of priority trends of waste including e-waste. By NOM are defined special handling waste listings inclusion and exclusion of waste criteria and requirements for the handling plans formulation through responsibility plans [30].

Mexican Official Norm (NOM-052-SEMARNAT-2005) for management of hazardous waste, set properties, the procedure of identification, classification and includes some electronic components in the list of hazardous waste, because some of the substances contained in these possess properties of corrosively, reactivity, flammability or toxicity [31]. Official norms (NOM-161-SEMARNAT-2011) establishes criteria to classify special handling waste and to determine what are subject to management plan, the procedure for the inclusion or exclusion of special handling waste; as well as the elements and procedures for formulation of management plans. This standard lists in normative annex products which in the course of its useful life should be subject to a management plan: technological waste from computer industries and electronics manufacturers; desktop personal computers and accessories, personal laptops

and their accessories, cell phones, monitors with cathode ray tubes (including TVs), screens of liquid crystal and plasma (including TVs), portable audio and video players, cables for electronic equipment and printers, copiers and multifunctional [32].

Other instruments that are framed in legislation are management plans, it aims to minimize the generation and maximize the recovery of the waste, with specific steps looking for environmental, technological, economic and social efficiency designed on principles of shared responsibility and integrated management, which considers the set of actions, procedures and viable means and involves producers, importers, exporters, distributors, traders, consumers, users of by-products and large generators of waste, as appropriate, as well as to the three levels of government.

The LGPGIR, indicates that management plan should be designed under the principles of shared responsibility, where the integral management of waste is a social co-responsibility and requires the joint participation, coordinated and differentiated producers, distributors, consumers, users of by-products, and the three orders of government, as appropriate, under a scheme of the feasibility of market and environmental efficiency technological, economic and social in Mexico the federal entities, have the power to formulate, lead and evaluate state policy as well as the programmers in e-waste topics. They are also responsible to authorize the comprehensive management of these, and identify those who may be subject to management plans.

3. Actors involved in management of electronic waste

Interest in problems associated with generation and management of e-waste has led the authorities to carry out studies to measure the problem and identify the level of participation of the actors involved in the life cycle of electronic.

In Figure 4 a diagram shows how is the release into the environment of hazardous substances, as well as the exposure of human beings and organisms of the terrestrial, and aquatic biotic in any of the stages of the product life cycle processes, services, from production to disposal [33].

Figure 5 shows a conceptual model about cycle of life EEE, proposed by United Nations Environment Programme (UNEP) by establishing the flow of materials from production, stage in which turns recycled until the final disposition or virgin material. This model is important for any electronic waste management system, because it allows establishing the flow of materials and identification of networks and chain that connects the different stages of the cycle of life of EEE and stakeholders, as well as interest groups associated with the management in the country, which is to be proposing the model.

Identifying the string sets the flow of materials; identify inputs, outputs at each stage, to quantify the WEEE in the analysis of the life cycle of the EEE. According to [34], the inventory of the WEEE in a city, region or country is the basis for management, in the model that proposes, start from the stippled line (Figure 5) from this model will identify the chain that connects the different phases of the cycle of life of the EEE and the actors involved.

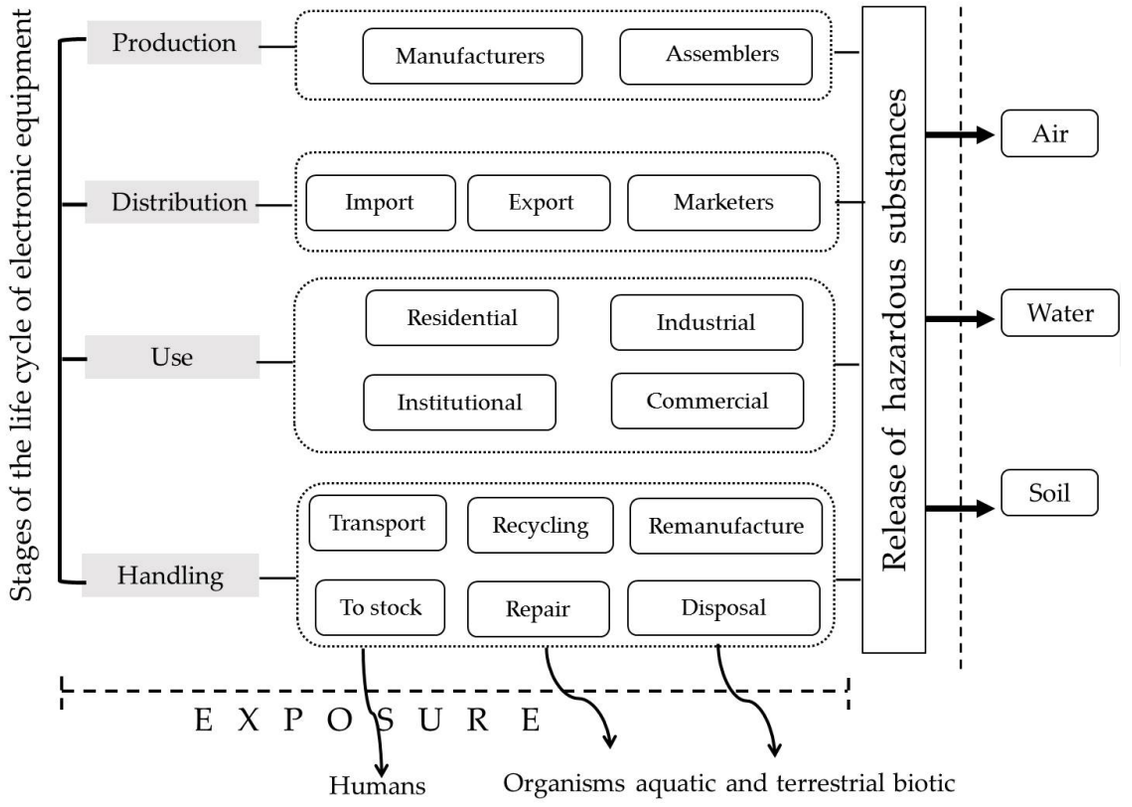

Figure 4. Environmental impacts and human exposure in life cycle of EEE.

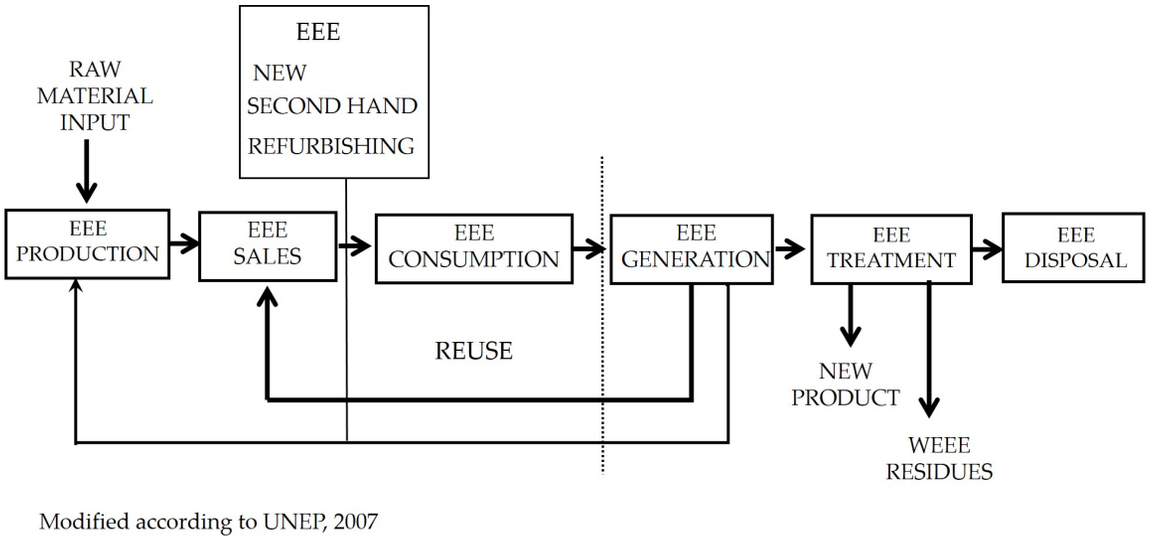

Figure 5. Conceptual Life Cycle of Electrical and Electronic Equipment.

Electronic devices that are discarded, obsolete and/or not be functional, can be repaired, reused, or recycled. In Mexico there is a both formal and informal market for devices repaired and reused, mainly near the border between the United States and Mexico, which generates a

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large volume of used electronic products (used electronic products UEP), which eventually end up in the final disposal sites or are recycled inadequate way, presenting risks for public health and the environment. In Mexico, formal recycling of electronic waste, which is mostly limited to disassembly, is a new activity. Traditional metal recycling industry has discovered the WEEE recycling market; however, the recycled quantities are very small, since the political framework, nor the infrastructure allow larger quantities. Most of these companies do not offer a complete service; concentrate on the valuable components, such as printed circuit boards, neglecting the adequate disposal of other components such as cathode ray tubes (CRT) that have no economic value, but represent a risk to health and the environment.

Recycling of electronic products in Mexico market is mainly composed of three groups: small and medium-sized companies exclusively dedicated to the recovery and valorization of materials from collection or low tax of team programs; the scrap metal dealer, scavengers or local small that ordered recovery of components considered valuable, such as cables and printed circuits cards.

WEEE recycling is a source of employment and income for the informal sector composed of recyclers and brokers, operating in streets, small shops, disposal sites, as well as their own homes [35]. Processes carried out by the various actors, both formal and informal, in the value chain are collection, manual dismantling, refurbishment, recycling, mainly recovering, plastic, metals, cables and printed circuit boards contained in the WEEE. This process finally transformed into secondary resources for chains of production, while the unusable components, and frequently hazardous are discarded and thrown away or left on sidewalks vacant lots and illegal dumps.

In Mexico, as in other countries of Latin America collection, a network of complex and diverse actors and processes are formed for recovery, recycling and disposal of the WEEE´s. The specific legal framework for environmental management and socially sustainable of the EEE ´s at the end of its life cycle, has not been defined, there are instruments which establish very generic guidelines added to this is the lack of financing for managing post-consumer of WEEE, manufacturers/importers, consumers and others involved in the chain. So the management of WEEE, is emerging, there is a differentiated and heterogeneous management by region according to the efforts that have been made by actors involved in the chain of recovery. Once an EEE life cycle, whether functional or not, in Mexico, involved an important network of actors by value electronics such as printed circuit cards, as well as materials that constitute the devices. Figure 6 shows actors involved in the value chain of e-waste.

The chain begins with the actors who manage the electronic equipment in the stages of production and use, in Mexico the producers of EE are the manufacturers of original equipment (OEM), which may be national or transnational and companies providing services manufacturing (Electronics manufacturing Services EMS) ; according to the Ministry of Economy [36], Mexico is one of the leading exporters and assemblers countries in the world, it is located nine of the 10 largest transnational companies manufacturing service. Our country is the leading exporter of flat panel TVs, the computer room and eighth in cellular globally. The flow of the EEE, are presented in two directions, can be manufactured in Mexico for export or sold on the domestic market, there is also a flow of electronic equipment that are acquired primarily in

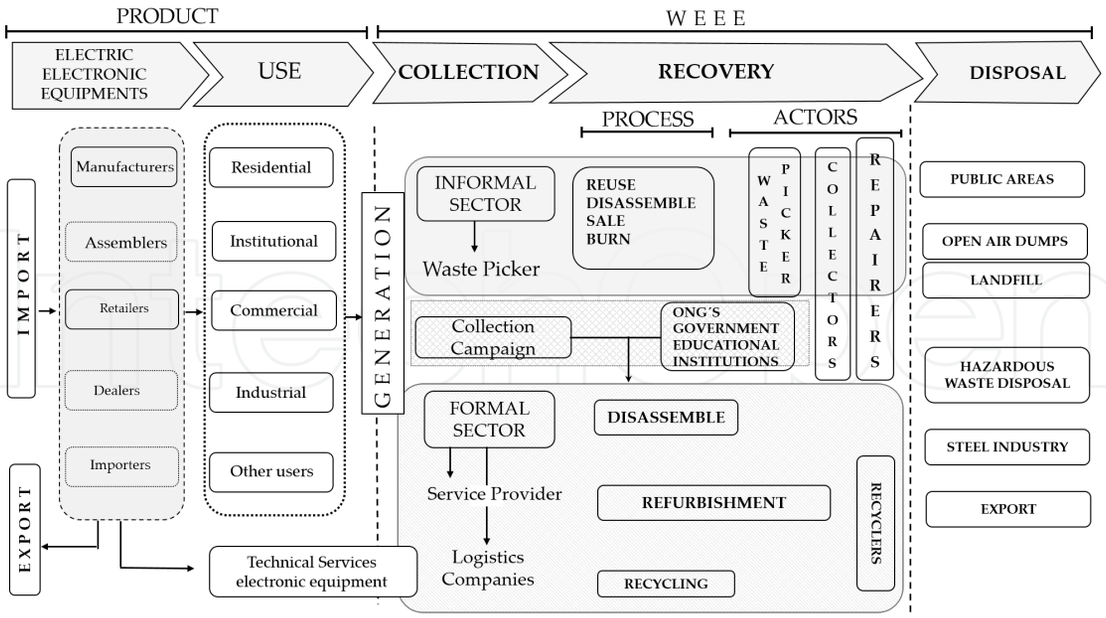

Figure 6. Actors involved in the value chain of electronic waste.

the United States, the actors involved in the flows described are retailers, distributors and importers.

The next step is to use, in which the actors belonging to the sectors shown below this stage (Figure 6), buy the US for use, so they are also generators of WEEE´s, from this time the waste flow continues to be valorized. Among the collection and use stage it is inserted the actor who have called technical, some are distributors, retailers of electronic equipment and simultaneously perform repair functions, so that also generate electronic waste.

In the collection stage involving both the informal sector and formal; in the first are the street scavengers who separate the waste from the streets to segregate materials and / or components which have market value; to retrieve the value the disassembled, sell them to collectors and / or recyclers; when the EE still works sell at outdoors markets or reuse; it is also common to burn cables to recover metals. The materials that have no market value dispose them in open dumps or abandoned in vacant lots.

The formal sector is also involved in the collection stage through companies dedicated to providing the collection service WEEE's service sectors, commercial and industrial which by law must prove that has been prepared in accordance with the regulations logistics companies that are contracted by companies engaged in recycling electronics and provide service including users in the sector also participate residential who can request to collect at home electronic equipment in use, it is important to clarify that it is not a common practice. In the collection stage also involved NGOs, government institutions, educational institutions and some companies dedicated to the recovery of WEEE, through collection campaigns, in which citizens can bring their obsolete electronics. Which are sent to companies that are formally registered to provide treatment and proper disposal of the WEEE, components with value are sold and e- scrap is disposed at authorized sites.

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In the recovery stage the formal sector makes disassembly processes, equipment refurbishing and recycling of components. The actors involved are the assemblers, repairers and recycling companies. Some of the collectors and repairers are part of the informal sector because they are not registered to provide those services, but there is also a group that works in formality compliance with the standards established.

The waste recycling companies that have a presence in Mexico, most of them limit their operations to the dismantling of equipment, recovery of useful parts, grinding and separation of materials. As a result, the national recycling activity focuses on the reprocessing of plastic, glass and copper, while the valorized material is sent abroad for the recovery of precious metals [37].

As for marketing, unlike developed countries, recovery is an activity in which the informal sector is actively involved in the chain coexisting with actors that have made e-waste business. There is a significant flow of secondhand electronic equipment that are marketed, so in the recovery chain is an important link repairer who perform activities of repair, refurbishing and reselling used equipment. All this impacts on a significant prolongation of the life cycle of the equipment. As shown in Figure 6, there are chain actors who share working spaces in formality and informality. Depending on the sector involving the final disposal has several streams in the informal sector the actors have in public places such as vacant lots and open dumpsites, also arranged in the flow of urban waste to be disposed in the landfill, whereas the formal sector, must dispose compliance with regulations, the waste is hazardous they must be disposed in an approved this site, components and parts that have market valorize are sent to companies that buy metals, plastics or exported for processing in raw material.

Figure 7 shows the flow of the life cycle of electronic waste and the participation of stakeholders to long cycle is presented. EEE production, begins with the use of virgin materials to produce them subsequently is marketed for sale and consumed by various actors. From generation stage becomes WEEE, when the equipment is discarded and still works, re-enter the market with secondhand equipment to be marketed and consumed again. When the WEEE enters the treatment stage

In the management of WEEE's, the recovery chain starts when a user and owner of an electrical or electronic equipment (EEE), intends to dispose of WEEE, for several reasons:

1. Obsolescence of EEE, which may be for functionality, underperformance compared with recent patterns, fashion, technological, etc.

2. Technological replacement of all or part thereof, change of systems, software requirements or updates.

3. Break, damage or loss of function in this factor are included from producers, assemblers, importers, distributors, corporate users and government, to private consumers of EEE.

One of the purposes of the stage of recovery of WEEE's, is the recovery of disused equipment functions in this activity involved from remanufacturing or multinational technical services to NGOs promoting the reuse of EEE disused even work. Among the functions reclaims, highlights companies specializing in maintenance and updating which exclude or receive

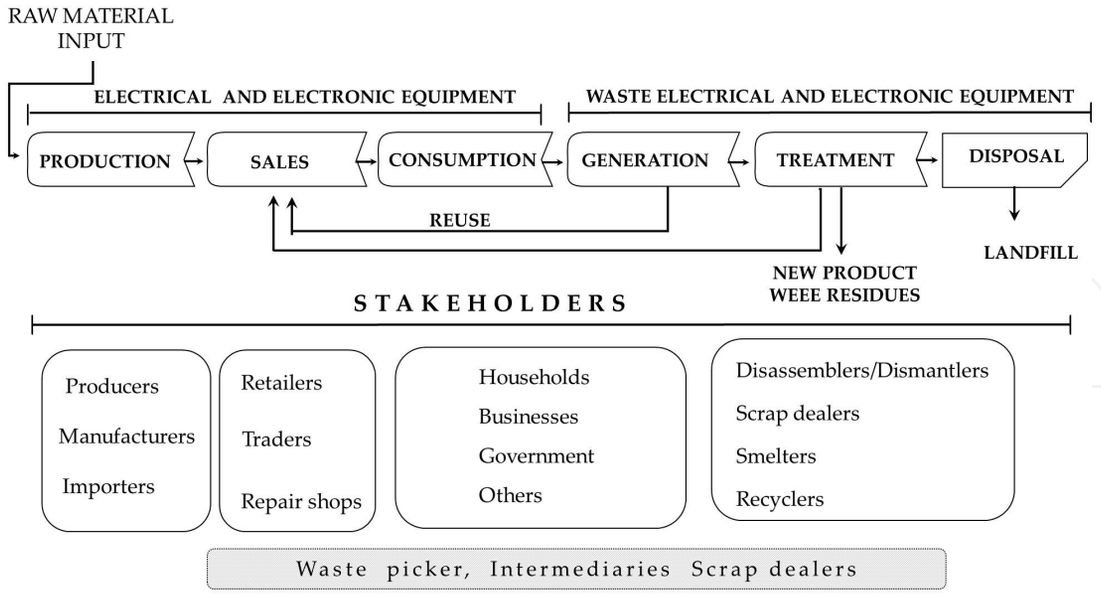
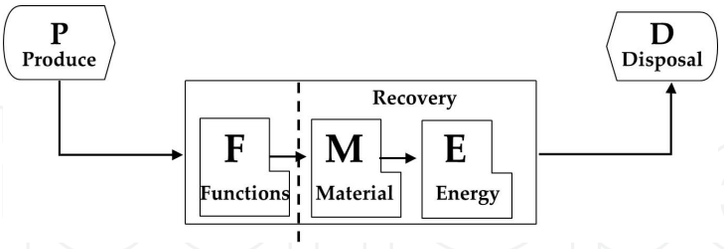


Figure 7. Stakeholders in the life cycle of e-waste.

equipment market and sloughed them or incorporate new devices to prolong its life. One of the problems associated with the recovery of functions is that the actors involved refurbishing EEE to incorporate them back into the market, as repairers or waste pickers, not considered parts of EEE as potentially hazardous substances since the usually they handled without caution, with low technological support without concern that accumulate debris discard obsolete equipment or parts. In this sense it is important to consider the Swiss model for electronic recycling in which they propose three principles, recovery function, material and energy. (Figure 8).



Source: [38]

Figure 8. Principles for the recovery of disused electronic equipment

4. Generation and electronic waste management

The interest in the problems associated with the generation and management of electronic waste has led authorities to conduct studies to go dimensioning the problem, SEMARNAT, in the field of environmental research through the National Institute of Ecology (INE, by its

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acronym in Spanish) currently National Institute of Ecology and Climate Change (INECC, by its acronym in Spanish) has conducted diagnoses of electronic waste generation to estimate the generation of these wastes by region and propose strategies for handling.

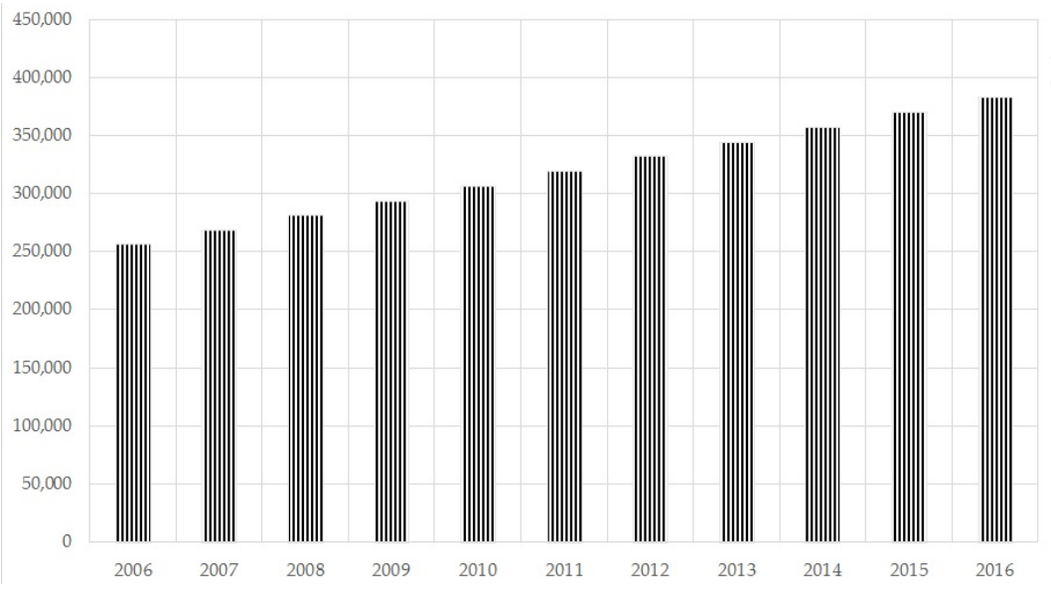
The first national study on the generation of electronic waste was made by the INE in 2006, in which the potential of televisions, personal computers (desktop and portable), recording devices or sound reproducing equipment, fixed and mobile phones generation was estimated. The estimated generation of these wastes in 2006 was 257,000 tons amount to be discarded, generating an indicator of 1.5 to 1.6 kg / year per capita [39]. The inventory made provided the elements for an approach to the magnitude of the problem; however, there are still gaps regarding more precise information on consumption patterns and particularly storage alternatives and end of life electronic waste. Roman [40] notes that despite the lack of formal infrastructure to manage these wastes in its various stages, the informal market is a reality in the management of WEEE in Mexico.

The next step that followed the authorities was to develop a guidance document for the development of management plans for it were classified into three sources generating electronic waste: postconsumer waste of society, post-consumer waste companies and organizations and waste production electronic equipment (obsolete and waste). They conducted a material balance for the amount of electronic waste from the three critical currents, desktop computers, mobile phones and televisions and representing more than 65 percent of the estimated in the first study of overall generation. The result of this document was integrated into a Model Program for Electronic Waste Management in Mexico, oriented to support decision makers involved in the management of WEEE, primarily the SEMARNAT and the private sector. It focused on these players because they are the ones who could develop a management plan nationwide. From this work we would be prepared to specify the responsibilities, activities, functions and interactions of the various actors involved [40].

Subsequently updated WEEE generation data through regional studies, the first of these was held in 2007 in the northeast region of the country, the aim of this study was to characterize the generation of WEEE 's (computers, mobile phones, TVs, fixed phones, audio and video) in border cities in the northeast region of Mexico through a flow analysis coupled materials with an economic study to develop proposals for proper handling that can be implemented as public policy, in this study it was estimated to be generated annually in the region 48,331toneladas [27]; for 2009 a study was conducted in the area of the northern border, including the border cities of Tijuana and Ciudad Juarez ; the WEEE's generation for this region was between 32,000 and 40,000 tons per year [41]; in 2010 the study of generation Metropolitan Area of Mexico was performed in this study WEEE 's generation was 94.203 tons / year,[42]. Studies in Mexico to evaluate the generation and management of electronic waste at the end of its useful life, seeking to propose a policy option according to national conditions and existing infrastructure for future recovery of WEEE's present a policy according to national conditions and existing infrastructure in the country.

Figure 9 generation WEEE's a national level is presented without considering technological change to digital television, according to the study of Roman [39], in 2006 257 000 tons per year were generated from this study estimated that by 2016 the generation will be 383, 424 tons in

the year, these data generations are conservative, mainly because it has not included the volume of analog televisions discarded by the analog switch, which ended on December 31 2015. In this regard Roman [43], indicates that generate 400,000 Ton by changing television between 2015 and 2016.



Source: [44]

Figure 9. Generation of electronic waste in Mexico.

The method used to estimate the generation also influences to determine the tonnage in Figure 10 estimated between 2013 and 2016 by two methods, employed by National Institute of Statistic and Geography (INEGI) generation occurs, the first results from the national survey, which shows the EEE data in use, the other method used is based on production data and foreign trade [43].

From the experience of INECC in recent years on the issue of electronic waste, is to strengthen the technical capacity for actors to generate information on the subject and industry can access best management of these wastes. Among the actions was the need to develop management tools and implementation of management plans at all levels, in this case, states and municipalities set a target.

The valorization of WEEE's, is critical to the use of raw materials, which also avoids the high environmental and energy impact by obtaining them through traditional methods. That is why recycling of WEEE is an important issue not only from the point of view of waste treatment, but also from the perspective of material recovery.

Decisions on strategies in the management of WEEE should be designed to maximize the welfare of the population. The waste management affects people in three areas; economic through tax management concept, due to environmental emissions and derivatives and psychological effects due to the location of facilities management. In the search for better

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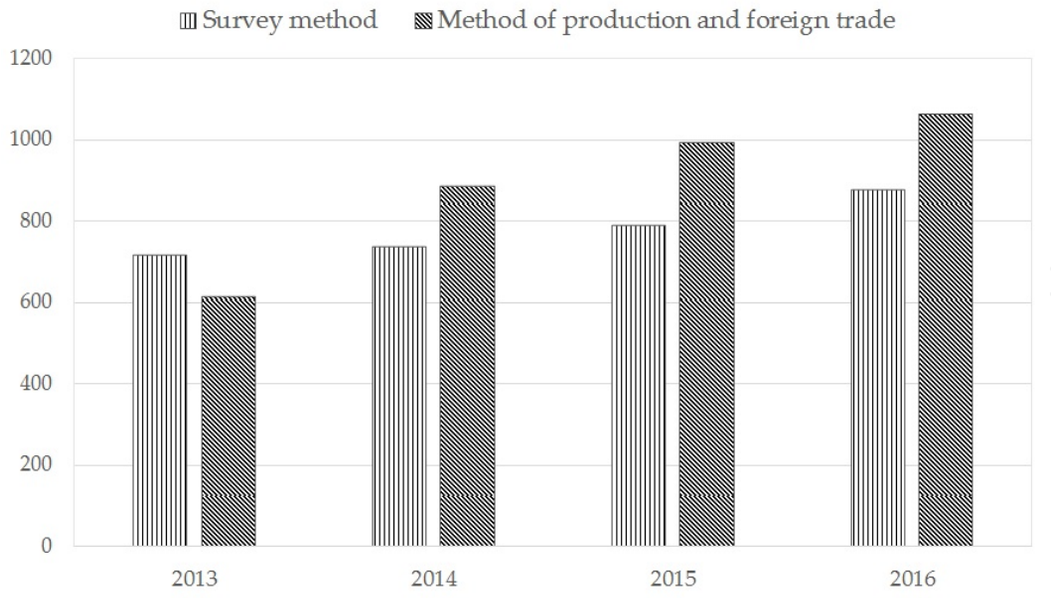

Source: [43]

Figure 10. Estimed annual generation of electronic waste in Mexico.

strategies for managing WEEE's and determination of impacts associated with it is important to consider a whole range of factors related to both the product and the consumer and post-consumer keeper's management. In the case, electronics can be analyzed and evaluated environmentally in each stage of the life cycle. From a consumer perspective we might consider aspects such as the level of environmental awareness, consumption habits, socioeconomic status, disposal practices, etc. Also important to consider that a management model will be influenced by population issues such as: economic status, geographic location, cultural level, etc.

In Figure 11, a universal model for the recovery of electronic waste is presented to formalize the process of recovery of components WEEE's has value and market to subsequently implement more complex and comprehensive models. The rate shown represents the practices currently being carried out, which have not been systematized or have been ordered. This scheme can be adopted by municipalities and assemblers who perform recovery informality.

It is important that those involved in the recovery chain, at different levels work on responsibility for WEEE's management models are developed, taking advantage of the wills of the actors who are already recovering some components and materials for recycling and reuse and evolve to management models that are applicable to the locale. The model presented takes up two of the functions proposed by the Swiss model, which is the recovery of materials and functions.

Since 2006 the first national generation WEEE's diagnosis was made, it caused concern and interest in the problem of WEEE's, this process has been slow, although much work is required stakeholders, including the authority, producers, retailers, distributors and generators. Work is required in the formulation of a unique legal regime for the integrated management of

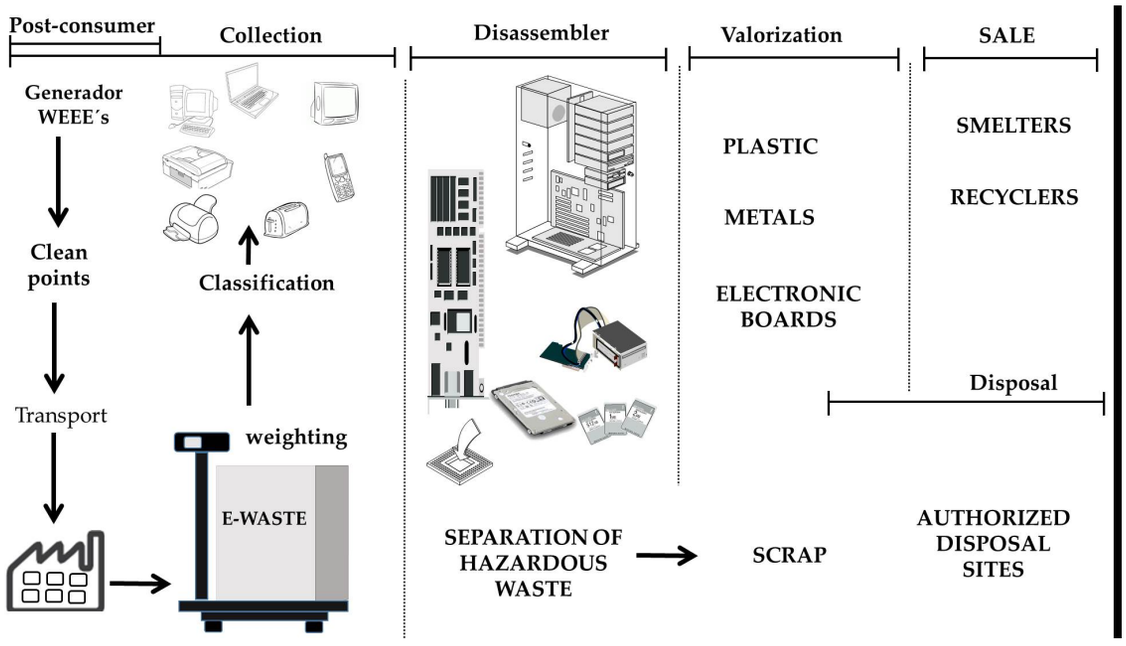

Figure 11. Flow for the recovery of electronic waste in Mexico.

WEEE's. Informal recycling is an issue that must be addressed by the environmental implications and associated health this common practice in our country.

5. Conclusions

The increase in the generation of electronic waste and insufficient formal mechanisms for handling it involves promoting schemes participation of society and decision makers involved in the value chain, giving greater opportunity to use materials, reducing environmental impacts and minimizing exposure to the informal sector in recovery WEEE's.

It is important to emphasize the topic about the management of electronic waste in rural areas it has not yet been extensively studied, it is known that there are no programs for collecting electronic waste, there are not reported generation statistics and handling practices in these communities. Therefore it is a topic of research that should be included in the agendas of experts and authorities at all three levels of government.

The existing regulations in Mexico, is not enough to develop management schemes WEEE's, so it is essential to promote a specific legal framework for the management of electrical and electronic waste equipment in which the extended producer responsibility is included, to hold manufacturers and other actors who are producers, as importers, assemblers and distributors to organize and finance the recovery and management of waste from electronic equipment put on the market. It should work on norms for WEEE's involving the three levels of government in the management process WEEE's. Also missing homogenizes the regulations of each state to avoid inefficiencies and inequities that exist in the management of this waste. It is important

to work with WEEE's large generators to assume the commitment to be socially responsible and sustainable companies.

Should be promoting among the community the recycling culture of obsolete electronic equipment to recover materials can be recycled, as well as useful components and equipment. The recycling practice of WEEE's impact the reduction in the virgin materials in the manufacturing and therefore contribute to the reduction of environmental pollution.

In the process of WEEE's managing a series of social and environmental problems arise that Mexico, like other emerging and developing economies must face. Among them are the practices of disposing of the WEEE's mixed with the municipal waste stream, without any handling for disposal. This action causes contamination in soil, air and water with toxic substances for health and environment. Another problem is the management that the waste pickers make it on this waste, which is unsafe, because the only purpose for them is to obtain plastics, metals and other materials such as printed circuit boards, facing the serious health risk to have contact with toxic substances contained in components WEEE's. The absence of extended responsibility for the producer is another problem.

Finally, it is essential that in Mexico programs integrated management of WEEE's should be established from the federal to the municipal level, where to promote private participation and are adaptable to the municipality, with the aim of implementing Integrated System Management WEEE's at a national level to promote sustainable management of WEEE's. Within these management processes as are collecting, reconditioning, repair, reuse, storage, and disposal should involve all stakeholders from the value chain, including those involved are producers, traders, consumers, carriers, collectors, repairers, and recyclers.

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