E-waste Generation in Chile: Analysis of the Generation of Computer Waste using Material Flow Analysis

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Abstract

Chile will soon have to find solutions for dealing with rapidly growing quantities of Waste Electrical and Electronic Equipment (WEEE) due to its strong economy and fast increase of internet and communications technology usage. To support this process, the state of the Chilean recycling infrastructure as well as government, industry and consumer efforts to deal with e-waste were analyzed. Current e-waste quantities were assessed and future flows were predicted using a material flow analysis model. In this model computer hardware was used as tracer equipment for WEEE. Best available numbers indicate that today's formal recycling infrastructure receives less than 3% of the annual quantities of computer waste. This study represents the most comprehensive analysis regarding e-waste in Chile, identifying relevant streams of e-waste and providing a basis for authorities and producers of electronic goods in order to take the necessary actions to establish an adequate recycling system.

Introduction

Since 1991, Chile has experienced a period of strong economic growth. It is amongst the countries with the fastest development in the sector of Information and Communication Technologies (ICT) in Latin America and the number of people with access to ICT has been growing rapidly. The high growth rates of the computer market over the last years are representative for the ICT sector with the consequence that the generated quantities of electronic waste are increasing rapidly [1, 2].

Waste Electrical and Electronic Equipment (WEEE) or e-waste is *"any appliance using an electric power supply that has reached its end-of-life"* as defined by the OECD [3]. Even though the overall waste management in Chile has improved much over the last decade, the issue of e-waste was hardly addressed. Due to the value of the materials contained in computer waste - such as precious metals, basic metals as copper or plastics - it may be assumed that an important quantity is already being recovered. This usually takes place on the informal market under questionable conditions for human health and the environment [1, 2, 4].

To foster the development of an e-waste recycling scheme and to improve the available data quality, this study's goal is to provide more insight on how e-waste is currently managed and which quantities are generated.

Material and Methods

A material flow analysis model has been developed to investigate the flows of electronic waste from cradle to grave. Due to its important role within the ICT sector, personal computers (desktop computers and laptops) were chosen as tracer equipment for e-waste. The European Environmental Agency suggests several methods for the investigation of WEEE potentials, such as the *time step method*, the *market supply method*, the *Carnegie Mellon method* and some *other approximation methods* [5]. The Carnegie Mellon method has been applied in this study. It is based on historical sales data and assumptions on typical lifetimes of the electronic equipment and takes into account consumer behaviour such as re-use and storage. Similar approaches to estimate specific e-waste quantities have been used in some other studies too [6-8]. The material flow analysis model is integrated into the “e-Waste Assessment Methodology”, which was developed by the Swiss Federal Laboratories for Materials Testing and Research (Empa) for the global “Knowledge Partnerships in e-Waste Recycling” programme [9] and was applied in several country assessments [10-15]. To acquire the data for the material flow analysis, a field survey has been conducted.

Material Flow Analysis

The goal of a material flow analysis is to increase the understanding of a studied system, which may lead to a better system control and management [16]. Material flow analysis is based on the principle of material conservation. The basic equation is:

$$\Delta M = \Sigma F_{in} - \Sigma F_{out}$$

ΔM represents the variation of the material stock in a process, ΣF_{in} is the sum of flows entering a process and ΣF_{out} is the sum of flows leaving a process. The technical terms used in the material flow analysis shall be defined in accordance with the Practical Handbook of Material Flow Analysis [17]: The *materials* considered in the model are desktops, laptops, liquid crystal displays (LCDs) and cathode ray tubes (CRTs). In the following, they shall be referred to as computer equipment. A *process* is defined as the transport or storage of materials. A process of storage includes a stock, where material is stored for a defined time. A *flow* is defined as a transfer of material from one process to another. It can be converted into a mass flow by multiplying the material units by their mass. See Table 1 for the average weight of computer equipment [18]. *Transfer coefficients* describe the partitioning of the flows after a process.

Table 1. Average weight of computer equipment [18]

	Desktops	Laptops	CRTs	LCDs
[in kg]	13,39	3,51	15,87	5,72

Model Description

The geographical system boundary is the territory of the State of Chile. The time period over which the computer market is modelled is from 1994, due to available records of sales data, to 2020. The processes defined in the model cover the *phases of production, sale, consumption and use* (Figure 1).

The Chilean computer market is dominated by a few international brands such as Olidata, Hewlett Packard and Packard Bell NEC, which share roughly three quarters of the market and a large number of small local assemblers with a market share one quarter. In the *phase of production and sale* the producers have been aggregated into a single process. Sales data of computer equipment has been collected from studies published by the International Data Corporation (IDC) and from the Chilean Customs and some assumptions were made as to the future development of the computer market, see [2] for more details.

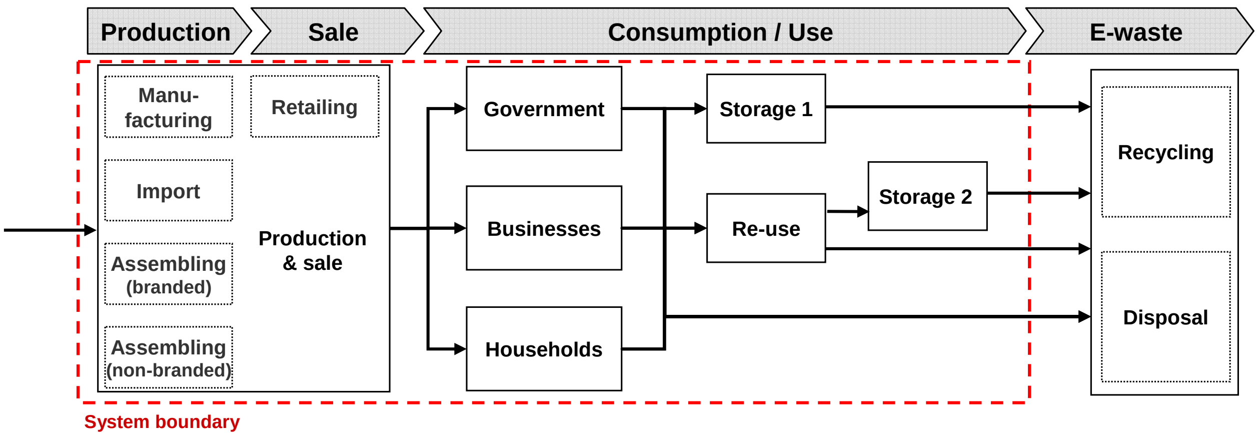

Figure 1. Material flow analysis model

In the *consumption and use phase*, three principal consumer groups, businesses, households and government institutions purchase respectively 55%, 35% and 10% of the new computer equipment [1, 2]. However, not all equipment is purchased new as refurbishment and re-use are important phenomena in the Chilean society. In fact, more than half of all computer equipment experiences a second use. Households and small and medium enterprises are the principal consumer groups that install used computer equipment. If a computer is not re-used, consumers either store it for a potential future use or disposed of it.

The processes of *recycling and disposal* are outside of the system boundary as the principal interest of the model is to understand how computer equipment reaches EOL and to estimate future computer waste quantities. Nevertheless, information on recycling and disposal was also collected.

Field Survey and Data Acquisition

Data has been collected by literature and online research, with a questionnaire sent to government institutions, businesses and households and through interviews with representatives from these groups. The main objective was to obtain data to quantify consumer behavior, average lengths of stay in the processes and transfer coefficients.

Model Scenarios

Four scenarios have been designed for the prediction of e-waste from computer equipment in Chile for the years 2007- 2020. In the *collected data* scenario, the model inflow is based on IDC data and the usage times and transfer coefficients are based on the questionnaire. In the *adjusted data* scenario, adjustments were made to the *collected data* scenario based on discussion with representatives from the computer industry. The *best case* and the *worst case* scenarios are designed to find out the maximal and the minimal e-waste generation from computer equipment in Chile from the year 2007 on, see [2] for more details.

Results

Scenario Comparison

Results from the scenario analysis for the generation of e-waste in Chile from 1996 to 2020 are presented in Table 2. It can be observed that the *collected data* and the *adjusted data* scenarios are quite similar. As the worst and best case scenarios are designed to show the extremes, it should be assumed that the real future computer waste generation will lie within the limits of these two scenarios.

The model predictions in the collected data scenario show that nearly 300.000 desktops and laptops became e-waste in 2007. This number will increase to more than 1.5 million computers per year in 2020. Computer waste streams will thus grow at a rate of 10% during the next decade, twice as fast as municipal waste streams [1].

Table 2. Computer sales and waste generation from computer equipment in Chile, in numbers from 1996 – 2020

Year	S1: Collected data	S2: Adjusted data	S3: Best case	S4: Worst case
2000	18'020	27'307	19'144	132'709
2007	283'676	293'466	185'542	440'542
2010	432'914	471'661	323'341	719'129
2020	1'511'159	1'570'503	1'076'330	3'046'844

Cumulative Computer Waste Generation

The cumulative amount of e-waste generated from computer equipment for the years 1996 – 2020 varies between 173.000 and 332.000 tons in the 4 scenarios, as can be seen in Figure 2. Between 85% and 91% of the amount of e-waste will be generated in the period 2007 – 2020. This shows that action will soon be required to establish an e-waste collection and recycling infrastructure as the quantities generated will increase rapidly over the next years.

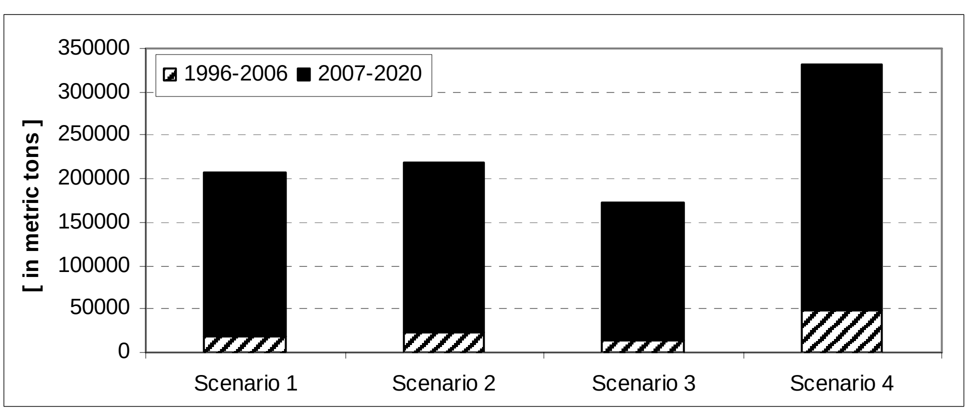

Figure 2. Computer waste generation, in tons, 1996 – 2006 and 2007 – 2020

Current Computer Recycling Quota

Formal authorized e-waste recycling in Chile is still in an early stage and the recycling techniques applied are still on a low scale. The existing formal recycling companies process e-waste mostly from international companies applying a business-to-business approach, thereby excluding households. It is dismantled, classified and separated into fractions that can be sold in the national or international markets and in fractions that can be disposed of in landfills and in fractions that need to be treated as hazardous waste. An investigation of the amounts of computer waste recycled with authorized recyclers reveals that only 1.7-3% of the total quantity of computer waste generated in 2007 was received by these companies [1, 2].

Discussion and Conclusions

Actual and future e-waste generation and management

At the same time that the ICT market is booming in Chile, computer waste streams will grow at a rate of 10% during the next decade – twice as fast as municipal waste streams. As the model predictions show, nearly 300.000 desktops and laptops became e-waste in 2007. This will increase to more than 1.5 million computers per year in 2020. Over the period from 1996 – 2020, 85-91% of the amount of computer waste will be produced during 2007 – 2020. The real challenge in dealing with computer waste is thus yet to come.

At the same time, only 1.7-3 % of the generated computer waste is currently recycled with formal recycling companies, whereas the fate of the vast majority of computer waste remains unclear. While it is evident that – due to the valuable materials contained in computers – informal recycling plays an important role, it may be assumed that the current management of e-waste is neither sustainable for the environment nor for human health.

How can the e-waste problem be solved?

A comprehensive legal framework for the management of e-waste will have to be developed that defines the appropriate treatment of WEEE and includes the concept of Extended Producer Responsibility. The ICT industry and Producer Responsibility Organizations will have to assume responsibility and participate actively in this process, especially due to their international experience with EPR. Support will also have to be given to recycling companies that have not yet acquired the necessary (environmental) authorizations. Furthermore, research needs to be undertaken in order to shed light onto the actual fate of WEEE and its associated environmental damage. Solutions will also have to be found to deal with computer waste from households which currently lack the possibility to dispose of their equipment appropriately. Finally, consumer education on how to dispose of EOL computer equipment and the establishment of convenient waste collection points will play a key role for a more sustainable management of e-waste. After all, a sustainable development of the ICT sector can only take place if electronic waste is taken care of appropriately.

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