E-WASTE GENERATION IN CHILE

SITUATION ANALYSIS AND AN ESTIMATION OF ACTUAL AND FUTURE COMPUTER WASTE QUANTITIES USING MATERIAL FLOW ANALYSIS

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MASTER'S THESIS

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ABBREVIATIONS

ACTI	Chilean Information Technology Association
CONAMA	National Commission on the Environment
COREMA	Regional Commission on the Environment
CRT	Cathode ray tube
DA	Digital Agenda
EMPA	Swiss Federal Laboratories for Materials Testing and Research
EOL	End-of-life
EPFL	Swiss Federal Institute of Technology at Lausanne
EPR	Extended producer responsibility
ESTACOMEX	Foreign Trade Statistics (Estadística de Comercio Exterior), Interactive foreign trade data base provided by the Chilean customs
GAD	Digital Action Group
GTZ	Gesellschaft für Technische Zusammenarbeit
ICT	Information and Communications Technology
IDC	International Data Corporation
LAC	Latin America and the Caribbean
LCD	Liquid crystal display
MFA	Material flow analysis
MSW	Municipal solid waste
PYMES	Small and medium size companies (pequeñas y medianas empresas)
RM	Metropolitan region of Santiago (Region Metropolitana)
SEIA	Environmental Impact Assessment System
SINA	National System for Environmental Information
SUR	Corporación Estudios Sociales y Educación
SWICO	Swiss Association for Information, Communication and Organization Technology
WEEE	Waste of Electrical and Electronic Equipment

EXECUTIVE SUMMARY

Objective of the study

Whereas the Chilean economy and its Information and Communications Technology (ICT) industry is booming, action will soon be required to manage the increasing streams of waste from electrical and electronic equipment (WEEE). To help develop appropriate recycling infrastructure this study intends to:

1) analyze the generation and management of electronic waste and
2) estimate actual and future quantities of computer waste in Chile.

Method

Material flow analysis (MFA) has been used as a method for the estimation of computer waste quantities in Chile from 1994 – 2020. Computer waste has been chosen as tracer equipment for WEEE and is defined in this study as desktops, laptops, CRTs and LCDs. An MFA model has been developed to simulate the flow of computer equipment from its production to recycling / disposal. The model is based upon computer sales numbers, usage times and flows connecting the principal actors in the market – data that has been collected by means of a questionnaire, interviews and a literature review.

Results

The Chilean computer market

The Chilean computer market is characterized by the dominance of a small group of international ICT producers with a market share of around 75% and a large number of small local assemblers with a market share of 25%. The three principal consumer groups, businesses, households and government institutions purchase 55%, 35% and 10% of the computer equipment (see Figure 1). However, not all equipment is purchased new as re-use is a phenomenon of major importance and more than half of all computer equipment experiences a second use. As a consequence, refurbishment plays an essential role. Re-use of computer equipment occurs mainly in households as well as in small companies and institutions, which eventually dispose of almost 90% of all computers. The average computer lifespan is about eight years.

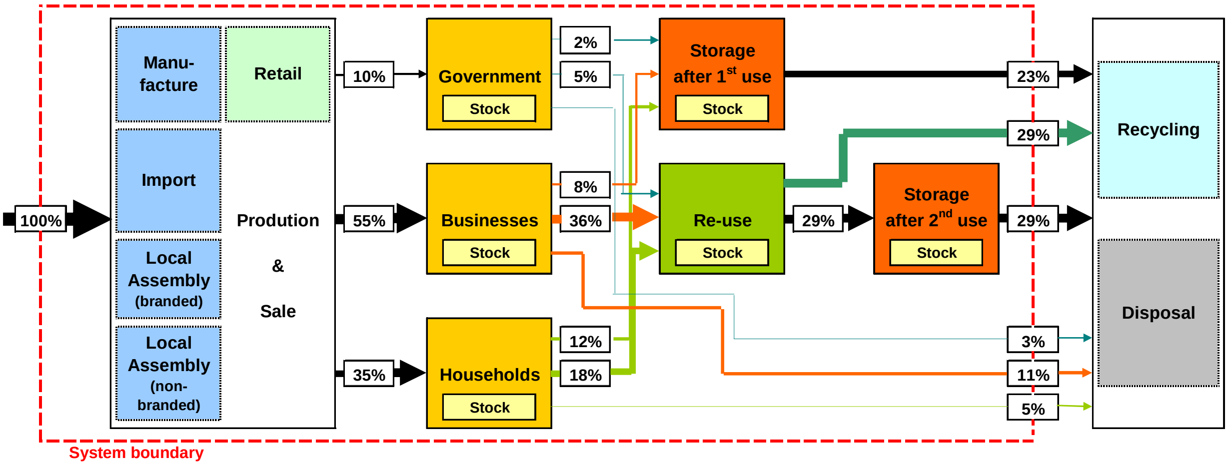

Figure 1 The MFA model illustrating the importance of the flows in the market

Computer waste generation

Computer waste streams will grow rapidly at a rate of 10% during the next decade – twice as fast as municipal waste streams. As the model predictions show, over 300.000 desktops and laptops will become e-waste in 2007. Yet, this will increase considerably and reach 1.7 million obsolete computers per year in 2020. In terms of weight – due to a change in technology towards lighter equipment – the amount of computer waste will merely triple from 7.000 tons in 2007 to 20.000 tons in 2020 (see Figure 2). From the total amount of computer waste that will have been produced during the simulation period (1994-2020), only around 10% of the waste has already been produced in the first half of the period (until 2006), whereas 90% will be generated in the second half (2007-2020).

This corresponds to around 215.000 tons of computer waste which contain 2 tons of arsenic (enough to contaminate 225 million litres of drinking water[1]), 3 tons of mercury and almost 10.000 tons of lead. Needless to say, these pollutants pose a threat to public and environmental health if not treated appropriately. At the same time aluminium, zinc, copper and precious metals worth several hundred million US dollars will be lost if not recovered.

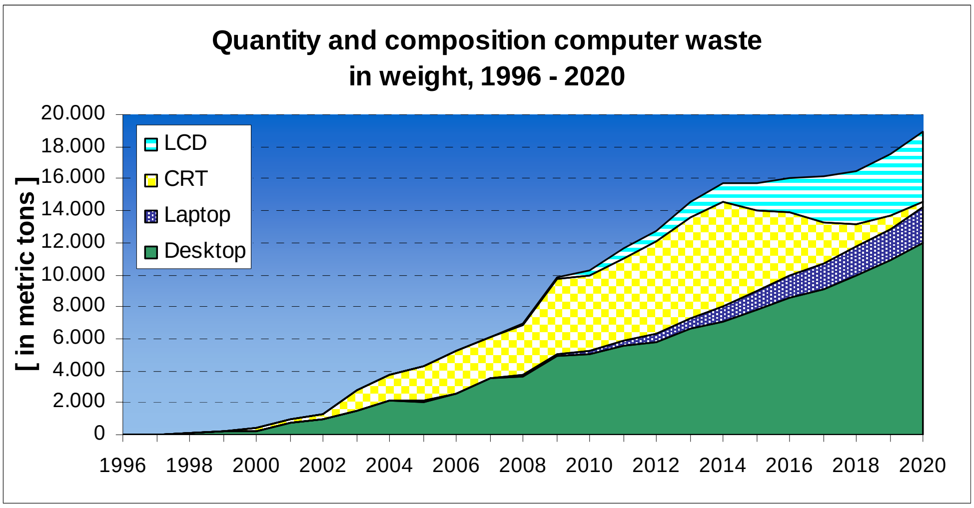

Figure 2 Computer waste generation in weight, 1996-2020

Waste management

Even though waste management in general has improved during the last decade, the e-waste problem has not yet been addressed by the responsible authorities. In fact, the fate of the vast majority of e-waste remains unknown. Due to the value of the materials contained in computer waste, it is likely that an important fraction is already being recovered. At the same time it may be assumed that hazardous substances are not treated appropriately. Currently, a major yet diffuse pathway for WEEE from households is the municipal solid waste (MSW) stream.

Good news is thus the recent establishment of the first formal recycling companies with environmental standards and authorizations – although a closer look reveals that the difference between informal and formal recycling remains small. Meanwhile, the striking difference in recycling costs between the formal and the informal sectors calls for a detailed cost analysis in order to determine a price that ensures proper recycling, but remains competitive and thus attractive for the disposer. In 2007, between 1.5 and 3 percent of the generated computer waste will be recycled with these recyclers.

[1] WHO Guidelines for Drinking-water Quality (WHO 1993)

A socially and environmentally responsible alternative to recycling of still re-usable computer equipment provides the non-profit organization Todo Chilenter which refurbishes donated computers from public and private institutions.

Conclusions and recommendations

First of all, further research is necessary to shed light onto issues such as the actual fate of WEEE and its potential environmental effects.

Solutions will have to be found to deal with the important flow of WEEE from households into municipal solid waste. Environmental education and the establishment of a convenient recycling infrastructure will play a key role for the achievement of better recycling quotas.

Nevertheless, the most essential measure required for the adequate management of WEEE in Chile is the introduction of a legislative framework dealing specifically with e-waste. This framework must define the appropriate treatment of WEEE and introduce the concept of Extended Producer Responsibility (EPR). The ICT industry and Producer Responsibility Organizations (PROs) – such as the Chilean Association of Information Technology Companies (ACTI) – will have to assume their share of responsibility and actively participate in this process.

However, due to the structure of the Chilean ICT market this is not an easy task. Innovative ideas will be needed to implement EPR in a market with a high share of non-branded local assemblers and with a significant flow of computers going to re-use and refurbishment.

In addition to the business-driven players, other social and public actors – such as the Chilean Subsecretariat of Telecommunications and the institutions involved in the Digital Agenda – will also have to become active in order to solve the e-waste problem. After all, sustainable development in the information age is only possible if obsolete ICT products are managed responsibly.

1 INTRODUCTION

According to the OECD list of ODA recipients, Chile is still a developing country, however its economy has been growing rapidly during the last decades (OECD 2007). Chile is also among the countries with the fastest development of Information and Communication Technologies (ICT) in Latin America. As the industry is booming and more people get access to these technologies, the amounts of e-waste[2] will also increase significantly. In order to ensure a sustainable development of ICT, Chile will thus soon have to develop a suitable infrastructure to deal appropriately with the increasing streams of e-waste.

In order to determine future strategies for e-waste management it is crucial to get a closer insight into the amount of e-waste generated in Chile nowadays and in the future. In the present master's thesis, a material flow model has been developed in order to increase the understanding of the material flows and make quantitative predictions. Due to its broad and intensified use computer equipment will be taken as tracer equipment to determine an important fraction of e-waste.

1.1 Objectives of this study

This study is based upon two major objectives:

1) *to provide a situation analysis with respect to the generation and management of electronic waste in Chile*

The principal actors that share some responsibility for the fate of obsolete computer equipment shall be described. The knowledge about how the different actors are involved in the life cycle of a computer shall bring some light into the question of how to tackle the e-waste problem in Chile.

2) *to estimate actual and future quantities of computer waste in Chile*

An estimation of future computer waste quantities based on a material flow analysis shall raise awareness of the e-waste problem. Moreover, it shall generate a basis for discussion, since there is currently no data available. It may be used in the future to think about the infrastructure necessary to face the e-waste problem appropriately.

1.2 Definition of computer waste

Computer waste represents an important fraction of the total amount of e-waste and its contribution is increasing rapidly as the computer market in Chile is growing fast. For this reason, it will be taken as tracer equipment for e-waste in the material flow analysis.

Computer equipment in this study includes the following:

- Desktop computers
- Laptop computers
- Cathode ray tube monitors (CRTs)
- Liquid crystal displays (LCDs) or flat screens

[2] E-waste is *"any appliance using an electric power supply that has reached its end-of-life"* as defined by the Organisation for Economic Co-operation and Development (OECD 2001).

It has been chosen to investigate these four products separately (instead of simply talking of “computers”) because of two principal reasons:

1) The *weight* and the *composition* of desktops, laptops, CRTs and LCDs differ significantly (i.e. a desktop with a CRT monitor weighs 27 kg; a laptop 3 kg; a CRT monitor contains lead, but no lead is present in LCDs)

2) The *share* of sold equipment is *not constant* (i.e. CRTs are now being replaced by LCDs and the penetration of laptops is increasing)

As a consequence of the separate analysis more precise predictions can be made in terms of *weight* and *composition* of future amounts of waste from computer equipment.

Additional computer equipment as for example mouse and keyboard are excluded from this analysis.

1.3 Institutions involved in this study

The institutions involved in this study are:

- **EPFL**: The study has been elaborated as a master’s thesis in Environmental Sciences and Engineering at the Swiss Federal Institute of Technology in Lausanne.

- **EMPA**: The Swiss Federal Laboratories for Materials Testing and Research (EMPA) is the official control body of the SWICO e-waste recycling system in Switzerland. EMPA maintains a non-profit program that aims at advancing e-waste recycling in several countries worldwide and has developed an online “e-waste guide”.[3] EMPA’s international activities are financed by SECO, the Swiss State Secretariat for Economic Affairs.

- **SUR Corporación / IDRC**: SUR Corporación Estudios Sociales y Educación in Santiago de Chile is the cooperating institution of EMPA in Latin America. SUR is investigating the situation regarding PC-waste on the Chilean and the Latin American level with the support of the Canadian International Development Research Center (IDRC).[4] Parts of the research and data collection for this study has been done in Chile with the support of SUR Corporación.

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[3] For more information see: http://ewasteguide.info/
[4] See: www.rrrtic.net

2 SITUATION ANALYSIS

2.1 ICT usage in Chile

Chile has had a constant economic growth since the 1980s, which has averaged around 6% after 2000. Since the economic crisis in Argentine, Chile has the highest GDP per capita in Latin America with over 9,000 US$. For this reason, Chile is among the countries with the highest development in usage of information technology in Latin America and the Caribbean (LAC).

According to the Indicator of the Information Society (ISI 2006), the computer penetration rate was 201 computers per 1000 Chileans at the end of 2006, which is the highest on a regional scale. It is estimated to grow 26% in 2007 and reach around 250 computers for every 1000 Chileans. The Latin American average in 2006 161 computers per 1000 people. Equally high was the rate of internet users: 29.4 % of the population is using the internet on a regular basis, which is also the highest rate in a regional comparison. In terms of broadband connections (DSL, cable, etc) Chile is even further ahead of its neighbours. More than one million broadband connections existed in 2006 which equals 6.8 connections for every 100 Chileans. Nevertheless, there remains a big gap in the usage of information technology compared to Europe and the United States. Only in terms of mobile telephones, Chile has reached the level of usage of the United States: 78 out of 100 persons currently use mobile phones. See Table 2-1 for a comparison of the ICT usage in Chile with other parts of the world.

Table 2-1: Indicators of the ICT development of Chile and other countries in 2006

	Chile	LAC	Switzerland	United States	World
Computers per 100 habitants	20.1	16.1	86*	76.2*	19.8
Broadband connections per 100 habitants	6.8	3.0	26.2*	19.2	5.7
Mobile phones per 100 habitants	77.7	53	92*	77.22	45.3

Sources: (Worldbank 2007); * 2005

2.1.1 The Digital Agenda

Chile's Digital Agenda is the result of the Digital Action Group (GAD[5]), which is led and supported by the ICT coordinator of the Chilean government as well as by various private, public and academic institutions. In 2004 it has presented a plan to the presidency of the republic consisting of 34 actions with the goal to promote the development of Chile through progress in Internet and Communication Technologies. Concrete actions involve i.e. measures to increase the internet access of the Chilean people through so-called Infocenters, education and capacitating programmes and the digital development of the Chilean companies.

Even though e-waste is not mentioned explicitly in its agenda, it is obvious that a sustainable ICT development in Chile can not ignore the issue of responsible management of obsolete ICT products.

[5] Grupo Acción Digital

2.2 The computer industry

2.2.1 General characterization

A comprehensive computer manufacturing does not take place in Chile apart from the manufacturing of some minor components (i.e. power supplies), thus the term “producers” used here refers to companies that import computer equipment. Computers are either imported in parts and then assembled or imported as whole computers (ready to sell). The market shares of the principal importers and assemblers of computer equipment are shown in the following table:

Table 2-2 Producers of computer equipment in Chile and market shares, 2006

Company	*Approximate market share*
Olidata	25%
Hewlett Packard	15%
Packard Bell NEC	10%
Dell	5%
Lenovo	5%
Acer	5%
Toshiba	5%
Sony	3%
Apple	2%
Local assemblers	25%

Source: Information provided by one producer

It can be observed that international companies dominate the Chilean computer market with more than 75% market share. The three most important producers in Chile are Olidata, Hewlett Packard and Packard Bell NEC. Together they have a market share of about 50%.

Table 2-2 also illustrates the importance of the non-branded local assembly or so-called clones (“others local”). Around one quarter of the computers sold (new) in 2006 were clones, assembled locally from imported parts. The types of shops that sell non-branded locally assembled computers range from small corner shops to Chile-wide chains and they often sell new as well as refurbished computers at the same time.

Table 2-3 shows a rough estimation of the percentages for the import of whole computers (ready to sell), branded local assembly and non-branded local assembly.

Table 2-3 Import, branded local assembly and non-branded local assembly, 2006

Computer types	*Market share*
Import of whole computers (ready to sell): *HP, Dell, Lenovo, Acer, Toshiba, Sony, Apple*	42%
Branded local assembly: *Olidata, Packard Bell NEC*	35%
Non-branded local assembly: *Other local assemblers*	23%

Source: IDC data sorted into categories through information found on the homepages of the companies

2.2.2 Computer sales

Chile’s computer market has boomed in recent years, showing growth rates of 23% for 2005 and 35% for 2006. In 2006, over 800.000 computers have been sold and in 2007 sales of more than 900.000 computers are expected. Sales and import data on the amounts of computer equipment (desktops, laptops, CRTs and LCDs) has been obtained from publications that are based on IDC data (CNC 2004), internet articles (Chiletech 2007) and the Chilean customs office online database ESTACOMEX (Aduana 2007). See Figure 2-1 for detailed information on the number and type of computer equipment sold from the years 1996 to 2006.

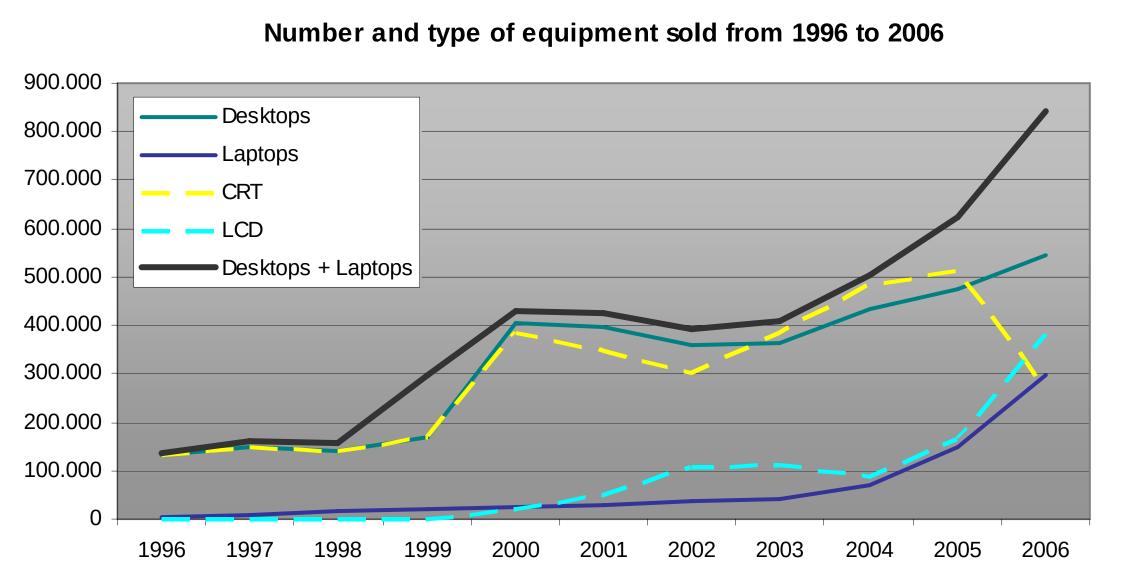

Figure 2-1 Computer sales in Chile from 1996 to 2007
Sources: Desktops and laptops from IDC data (CNC 2004)
CRTs and LCDs from IDC and Chilean customs data (Aduana 2007)

Figure 2-1 illustrates clearly that two important changes in technology are currently happening in the computer market:

1) a shift from the usage of CRT monitors to LCD flatscreens
2) a strong increase in the market share of laptops (35% of all computers sold in Chile in 2006 were laptops)

As a consequence, the composition and weight of computer waste will also change in the coming years.

2.2.3 Extended producer responsibility

The OECD defines EPR as *"an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle"* (OECD 2001).

The two related features of EPR policy are:

1) a shift of responsibility upstream toward the producer and away from municipalities and

2) the creation of incentives to producers to incorporate environmental considerations in the design of their products

The benefits of introducing extended producer responsibility may thus be that the manufacturers:

- Use environmentally safer materials in the production process
- Consume fewer materials in the production process

- Design the product to last longer and be more useful
- Create safer recycling systems
- Keep waste costs down
- No longer pass the cost of disposal to the government and the taxpayer

In Chile, the computer producers have not yet implemented extended producer responsibility, despite the fact that the important producers already have experience with EPR it other parts of the world (i.e. in Europe). Personal interviews with leading computer producers[6] revealed the principal reasons for the missing industrial initiative:

- Lack of consciousness of the problem in general
- Missing acknowledgement of responsibility by the industry itself
- Absence of true recycling alternatives in Chile (disassembly only)
- Difficulty to convince all producers to participate in EPR (due to informal market and local non-branded assembly)
- Fear of loss if risking initiatives on their own, i.e. the introduction of an advanced recycling fee
- Heterogeneity of the international policies of the big producers
- Lack of legislation that obliges (all) producers to introduce EPR

2.2.4 The potential role of ACTI

When producer responsibility is introduced, umbrella organizations so called Producer Responsibility Organizations (PRO) of the most relevant producers and importers have proved to be the most suitable body for the implementation and coordination of the process. As the Chilean Association of Information Technology Companies (ACTI)[7] regroups the most important producers and importers of ICT infrastructure, it is an ideal actor for the coordination of initiatives of the producers of electronic equipment. It could thus play an active part in the creation of an e-waste recycling system in Chile.

2.3 ICT Consumers: Government, businesses, households

The consumers have been divided into three mayor groups in this study: government institutions, businesses and households.

Due to their nature, their consumer behaviour – meaning how they purchase, manage and dispose of computer equipment – differs significantly. It is fundamental to understand the consumer behaviour of these actors in order to find good solutions for the e-waste problem.

2.3.1 Computer consumption

To provide a general idea of the relative importance of the consumers in terms of computer consumption, IDC data from 1999 – 2004 reveals the following: at an average, 55% percent of all computers were sold to businesses, 35% to households and 10% to the government[8] (CNC 2004) (see Figure 2-2).

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[6] Personal interviews have been conducted with Chilean representatives of Hewlett Packard, IBM and Olidata
[7] Asociación Chilena de Empresas de Tecnologías de Información A.G., see: www.acti.cl
[8] The assessment included government and schools, which are included in the share for the government in this study

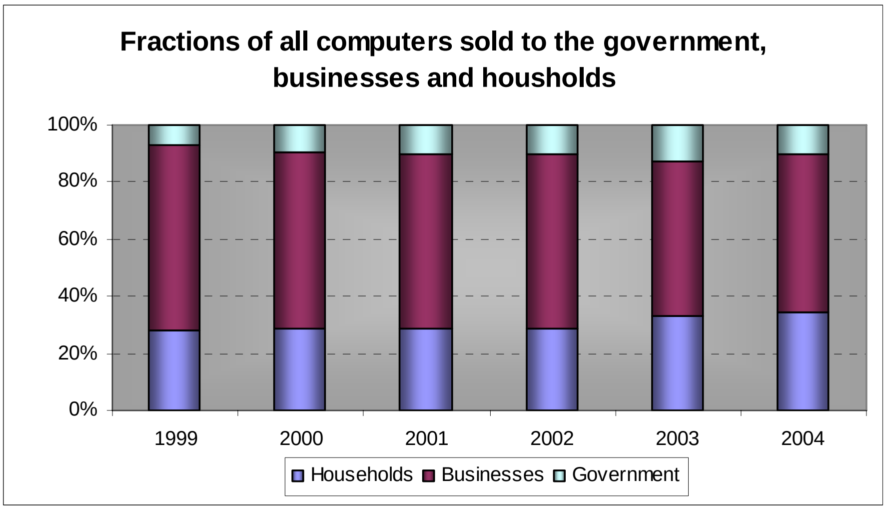

Figure 2-2 Fractions of all computers sold to the government, businesses and households
Source: IDC

According to the same study, one third of the computers sold to businesses were sold to big and two thirds to small companies.

2.3.2 Type of computer equipment in use

The questionnaire used in this study revealed that governments, businesses and households had the following shares of computer equipment in use:

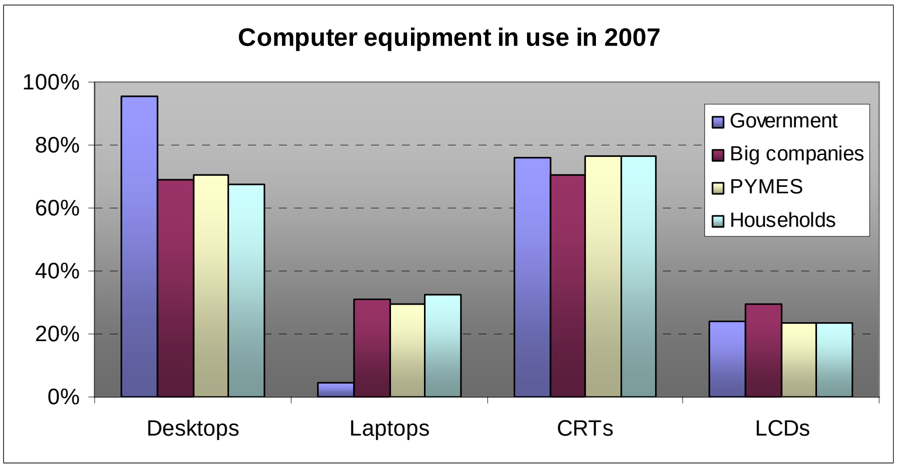

Figure 2-3 Type of computer equipment in use in 2007
Source: Questionnaire

It can be seen that in general, around 70% of the computers are desktops and 30% laptops, while about 80% of the monitors are CRTs and 20% LCDs. The percentages for government institutions and households appear to be little representative due to the small sample size of the questionnaire.

2.3.3 Purchase of new equipment

New computer equipment was purchased via import (meaning directly with the company that imports the equipment, i.e. HP or Dell), retail or branded / non-branded local assembly.

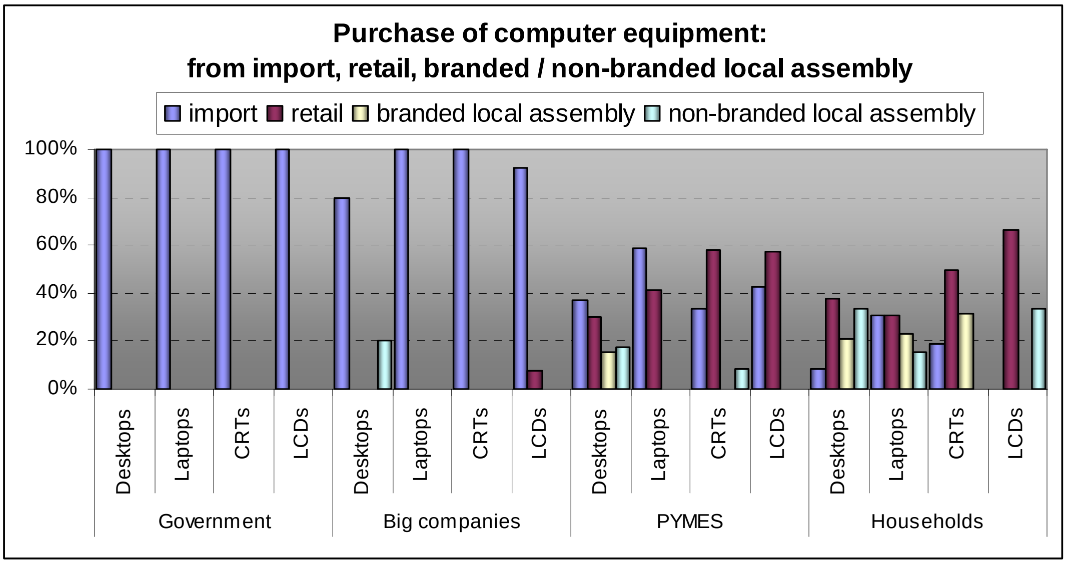

Figure 2-4 Purchase of computer equipment
Source: Questionnaire

As might be assumed, the government and big companies mainly buy directly from the importers. Due to the quantities purchased, big companies often have special contracts with certain computer producers. Government institutions acquire computers through solicitations via an intermediary called ChileCompra.[9]

Small companies buy from importers as well as via retail. Expert interviews revealed furthermore that a high percentage is bought from non-branded local assemblers as they offer better service and a better choice of the individual components of computer equipment.

Households purchase computers mainly through retail, however, the other options play an important role as well.

2.3.4 Acquisition of equipment: new, used (2nd use) or leased

It can be observed in Figure 2-5 that government institutions and big companies bought mainly new equipment. Leasing also played a major role. Personal interviews revealed that the fraction of leased equipment is likely to increase in the coming years. One of the two government institutions interviewed stated that they will in the future acquire their equipment entirely through leasing.

For small companies and households, equipment was also predominantly bought new. However, the purchase of used equipment was also important (up to 40% for households).

[9] See: https://www.chilecompra.cl/Portal/InicioPortal.aspx

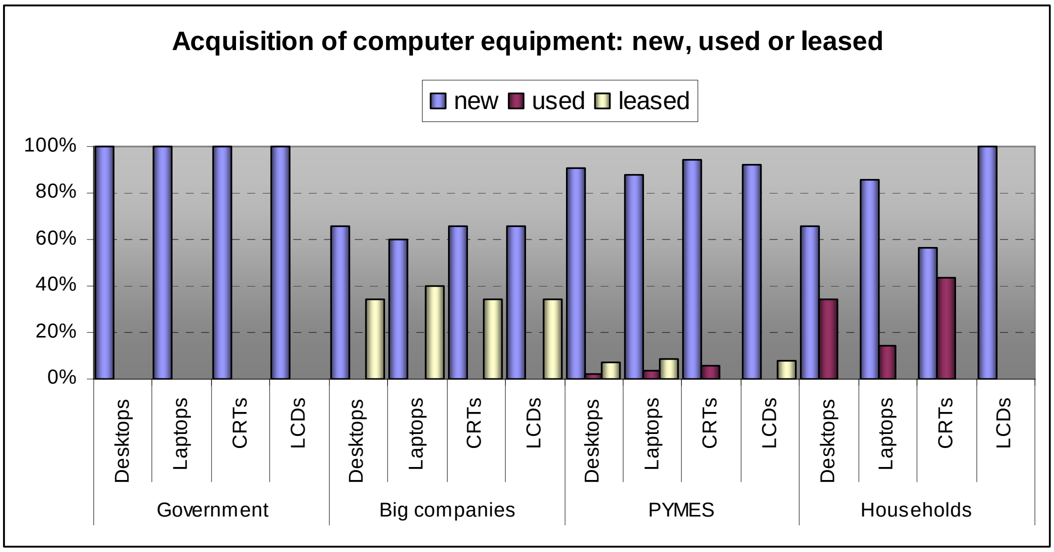

Figure 2-5 Acquisition of computer equipment (new, used or leased) in 2007
Source: Questionnaire

2.3.5 Usage times

The average usage time of computer equipment in government institutions, businesses and households for new, leased or used computer equipment was indicated as the following:

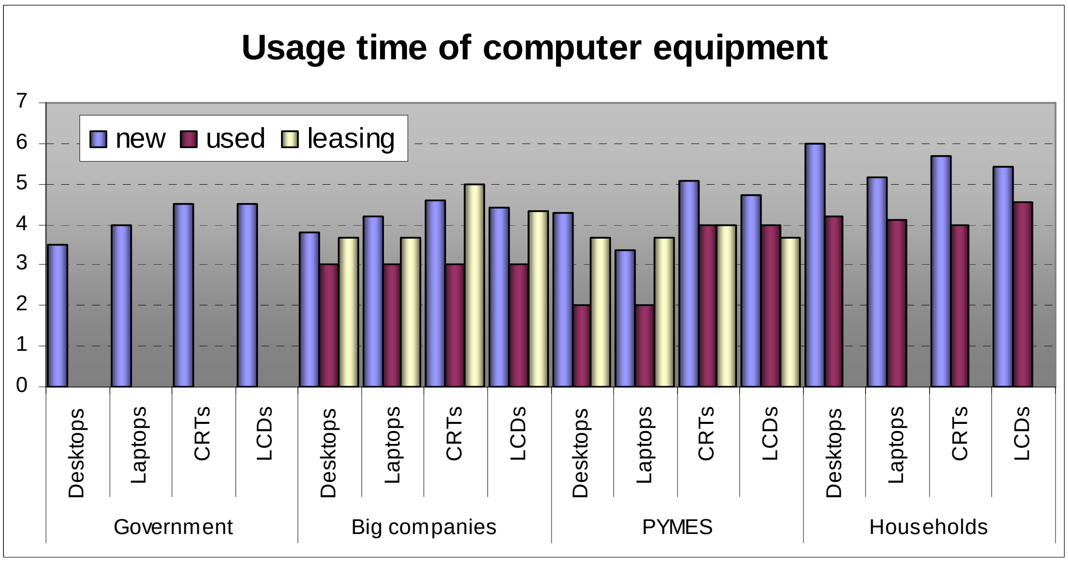

Figure 2-6 Usage time of computer equipment
Source: Questionnaire

New computers are thus used for around 4 years in government institutions and businesses and about 5-6 years in households. Monitors tend to be used up to a year longer. Leasing contracts for computer equipment varied between 3-4 years.

In addition to that, the results indicate, that the usage time of re-used (and refurbished) equipment is principally between 3-4 years.

2.3.6 Fate of obsolete computer equipment

The results for the fate of obsolete computer equipment have been consolidated in the following for government institutions, businesses and households[10]:

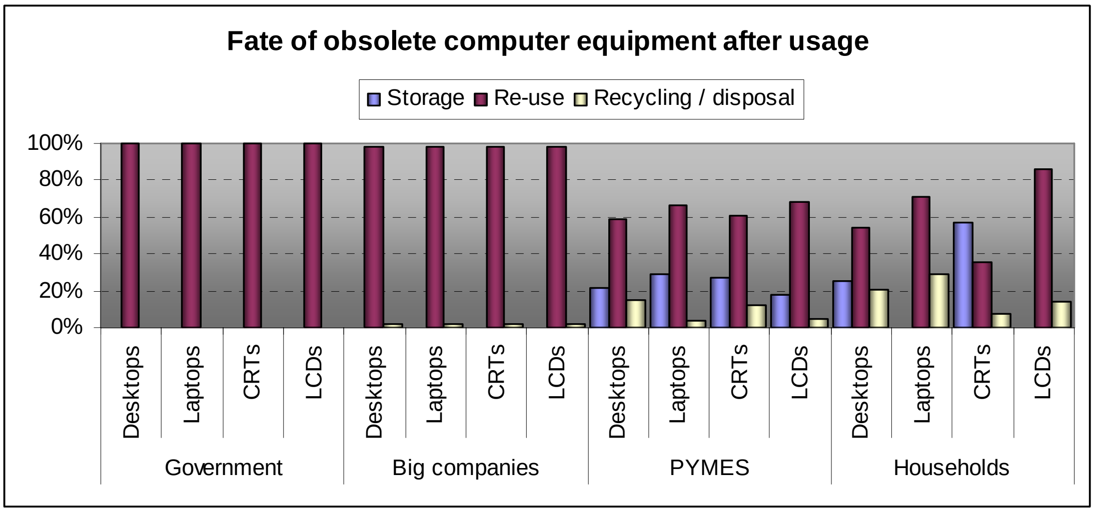

Figure 2-7 Fate of obsolete computer equipment
Source: Questionnaire

It can be observed that re-use is by far the dominant option for obsolete computer equipment. In the case of the government much of the equipment was donated to the government supported program Todo Chilenter or to schools. In the case of big companies, equipment was usually sold through auctions. Neither government institutions nor big companies stored significant amounts of computers. However, storage was an important option in small companies and households. Disposal (and recycling) played a role mainly for small companies and households.

2.4 Computer re-use and refurbishment

2.4.1 In general

As Chile is part of the developing world and has a strong gradient of income within the society, used and obsolete computational equipment is generally not considered waste. For instance, an obsolete computer may be perceived as waste by a person with a relatively

[10] The options in the questionnaire comprised: Storage, sale, donation, disposal, recycling and other. “Sale”, “donation” and “other” were consolidated to “re-use”. “Recycling” and “disposal” were consolidated to “recycling / disposal”. The principal reason for this consolidation was that when indicated “other”, it referred in most cases to “re-use”. “Recycling” had to be integrated into “Recycling / disposal” since when indicated “recycling”, it often referred in fact to disposal. See Annex C for the detailed results.

good salary, but remains an item of value for someone with a low income. As a consequence, there exists a well developed (formal and informal) market for obsolete computer equipment and an important fraction of the computers in Chile have a second usage time (2nd use).

The second usage time may involve a process of refurbishment, where certain computer parts are replaced by more modern ones, i.e. memory is added, faster processors are installed or the hard disk is exchanged through a bigger one. Refurbishment may also include the upgrade of the operating system and the exchange of peripheral hardware such as keyboard and mouse. Only a minor flow of computers enters the waste stream after its first use.

Common examples of how a computer may be re-used (directly or after a refurbishment step) are:

- Companies sell their used computers to their employees
- Companies sell their computers to businesses that refurbish computers, usually through auctions
- Companies or public institutions donate their computers (for example to schools or non-profit refurbishers)
- Computers are passed on within families
- Computers are given to a third person, a friend, etc.

The most important user groups that add to the flow of computers to re-use are government institutions and big companies as can be observed in Figure 2-7. Nevertheless, small companies and households also contribute a relevant fraction.

Figure 2-8 summarizes the typical pathways by which computers are transferred from their 1st to their 2nd use:

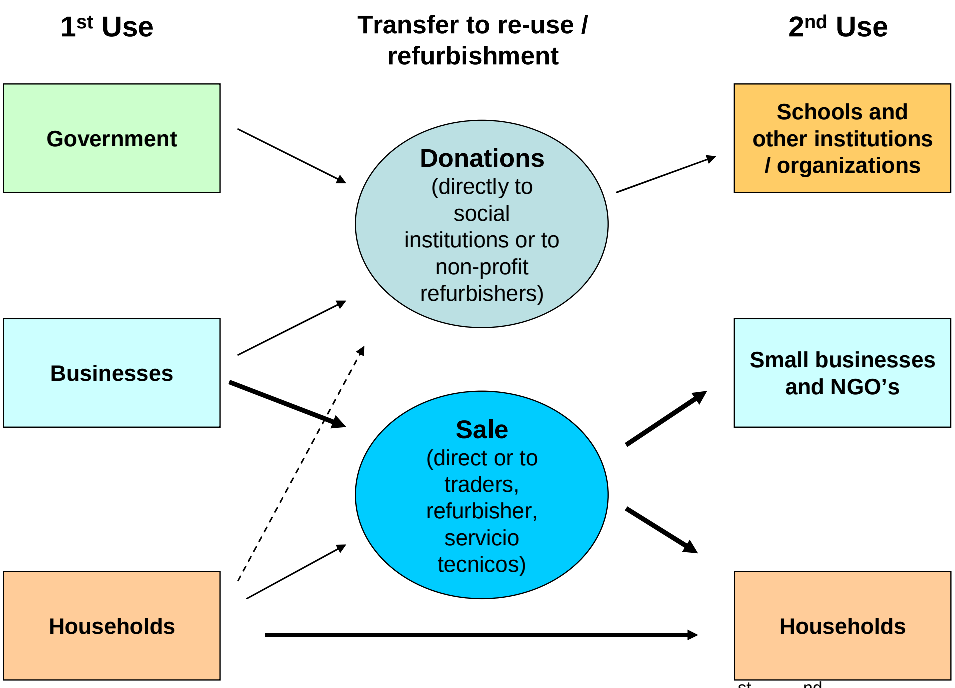

Figure 2-8 Principal flows of computer equipment from 1st to 2nd use

It would involve extended research in order to quantify accurately how much is re-used by which user group, however, and Figure 2-5 is able to give a first impression. Nevertheless, the most important stream of computers from 1st to 2nd use constitutes the sale of obsolete hardware from big companies to traders and refurbishers that in turn sell to small businesses and households for re-use.

Besides that, 1st and 2nd use may also happen by the same user, i.e. when he gets his computer refurbished.

The usage time of obsolete computer equipment is normally in between 2-4 years, see also Figure 2-6.

2.4.2 Commercial re-use and refurbishment

Selling prices for refurbished computers are in the range of 30 to 240 US$. The cheaper equipment usually stems from auctions, whereas the better refurbished equipment is often imported (i.e. from the United States)[11]. The most modern computer at *Refly* at the time of research was a computer with monitor (CRT, 17'') with a 2.5 GHZ processor, 512 RAM and 20GB hard disk. Monitors are available from 20 US$ (CRT) to 140 US$ (LCD).

The two most important locations in Santiago for commercially refurbished computers are:

- a concentration of computer shops in a street called *San Diego* and
- a weekend market known as *Biobio*.

These two locations have been investigated in order to get a more realistic picture of commercial re-use and refurbishment in the Chilean context.

2.4.2.1 San Diego

General description

San Diego is an important ICT and electronics cluster in a street called San Diego in Santiago. An estimated 60 shops sell new and used computers, computer parts and offer repair services ("servicio tecnico"). Prices are generally lower than in retail stores and international brands are generally not sold. Among the reasons of its popularity is the fact that people have the possibility to order a computer assembled from components of their choice. The San Diego area has a reputation for more modern and higher quality equipment than the Biobio neighbourhood, which usually attracts clients with a smaller budget.

Figure 2-9 Computer shops in the San Diego area of Santiago

Computer sources and types

[11] Prices stem from Latin Computer Chile Ltda and Refly (www.latincomputer.cl and www.refly.cl)

Interviews with several shop owners revealed that around 60% of the computers sold are new and 40% used. New means that the computer has been assembled from new parts, whereas used means that the computer has been assembled at least partly from components that have had a previous use.

New equipment is bought through wholesalers. Used equipment is acquired through various channels, for instance from customers or from auctions. It seems that there is a market for every part of the computer with a dynamic network of dealers specialized on certain components. A high percentage of computers, especially monitors, sold in San Diego are obsolete equipment from the United States that has been imported. The biggest dealer in San Diego, Refly, which is well know in Santiago even uses this fact as an advertisement of its store.

Refurbishment and repair

Most of the San Diego computer dealers also offer repair and refurbishment services for people with broken equipment or for people who wish to upgrade their computer. This equipment is between 2 and 5 years old and refurbishment equipment is said to have a further usage time of at around 3 years more.

Waste management

Several of the shop owners confirmed that hardly anything is thrown away and most components can be re-used, repaired or sold for the materials they contain. However, a certain waste stream is produced by the shops and piled up in a parking lot. One shop owner indicated that waste is sold to the recycling company Recycla. Another shop owner indicated that a truck is paid from time to time to pick up the waste. Where that truck disposed of the waste was unknown. A third shop owner estimated that much of the waste ends up in the municipal solid waste. Some of the waste is simply thrown into the garbage bins in the shops.

Figure 2-10 A repair shop and a heap of computer waste in a parking lot in San Diego

2.4.2.2 Biobio

General description

Biobio is a neighbourhood of Santiago around a street called Biobio. It is famous for its weekend markets, where anything is sold from clothes to furniture including computers. Small computer shops mark the area and recently Chile-wide operating chains opened up as well. The small shops only sell a few computers a day whereas the chain's sales numbers are up into the hundreds. Since the business is on weekends only, many of the owners have a second computer shop somewhere in the city. One can buy computer parts and accessories as well as complete refurbished computers, sometimes with a guarantee and pre-installed software.

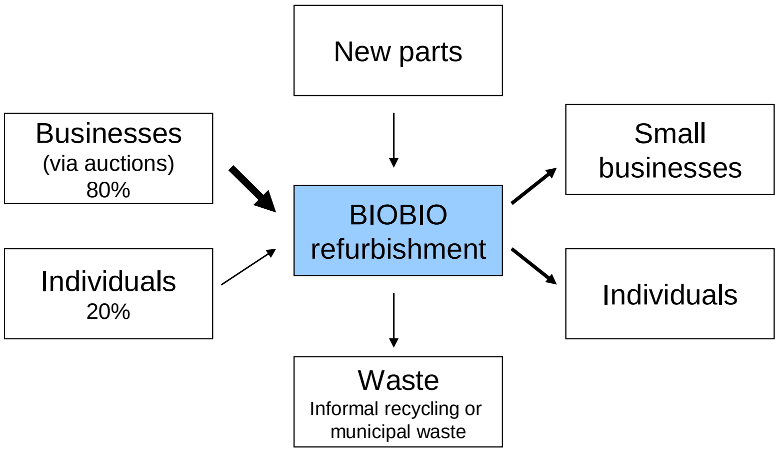

Figure 2-11 Scheme of the computer flows in Biobio

Computer sources and types

Interviews with several vendors revealed that almost all the computers stem from companies that sell their computers at auctions. However, computers are also bought from individuals. The computers are usually between 2 and 7 years old, with an average of around four. An interview with a bigger store belonging to a chain revealed that the computers were imported from the United States. Direct contacts exist with dealers in the United States who ship containers with desktop PCs and CRT monitors.

Figure 2-12 Computer shops in the Biobio area of Santiago

Refurbishment

The refurbishing includes the selection, testing, repair and assembly of equipment. The chain indicated that the computer flow at their site was high enough to work in serial production. New parts are also incorporated in the refurbished computers, especially hard disks. Computer parts such as motherboards and broken printed wire boards are equally being repaired.

Waste management

The question: “what do you do with your waste?” was usually answered with “there is no waste, everything has a value”. Broken parts from the small shops are put into the streets, where people pick it up to recycle parts and materials that can be sold (such as metals: copper, iron and parts: capacitors, transistors). The chain store indicated that they give their waste to a private person who does informal recycling.

2.4.3 Donations

Donations are mainly made by public institutions and (big) companies. However, households also contribute equipment, for example to a Christian organization called "*Hogar de Cristo*[12]" or the "*Traperos de Emaus*[13]".

The two most important non-profit refurbishers that receive considerable amounts of computers are:

- the *Todo Chilenter Foundation*[14] and
- the *Committee for the Democratization of Informatics (CDI)*[15].

The Todo Chilenter foundation has been visited and the principal facts shall be presented in the following.

2.4.3.1 Todo Chilenter Foundation

Todo Chilenter is the biggest refurbisher in Chile and its target is to refurbish more than 7000 computers in 2007. This is equal to about 190 tons of equipment or about 2.9% of the predicted amount of computer waste for 2007 (see page 56). These computers go to schools and social organizations throughout the whole country. In 2006, over 200 projects were accepted to receive equipment, about twice the number postulated. An interview with Rubén Martínez Muñoz, the executive director of Todo Chilenter revealed the following information:

Computer sources and types

Todo Chilenter receives about half of its equipment from overseas (Computeraid in England and Interconnection in the US). The other half is contributed by public institutions and big companies of the private sector. The objective for the future is to decrease the fraction of imported computers.

The main incentives for public institutions and companies to donate to Todo Chilenter are:

- public institutions perceive donations as part of their contribution to society and the development of the country
- private companies make donations in the context of their social responsibility and for image reasons

Financial aspects

Todo Chilenter is financed by the Ministry of Education, which supports the foundation with a fixed sum once per year. The cost per refurbished computer is estimated to be about US$ 130. Institutions that receive computers from Todo Chilenter do not pay anything.

Refurbishment

The refurbishment process involves the following steps: selection, configuration and maintenance, control and packaging. The critical and cost-intensive steps are selection, control and the logistics (transport of the equipment to the foundation). Computers are principally refurbished from the equipments that are received through donations, however some parts are also bought new: these are typically hard discs, mice and keyboards. The computer equipment is delivered with Windows installed, since Microsoft supports the

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[12] www.hogardecristo.com/navegacion/index.html
[13] www.traperosemaus.cl/
[14] www.chilenter.cl/
[15] www.cdichile.org/

foundation with 5 US$ Microsoft Authorized Refurbisher (MAR) licenses. The equipment also comes with a guarantee.

E-waste

About 10% of the equipment Todo Chilenter receives from big companies and 35% of that from small companies is unsuitable for refurbishment and thus e-waste. Approximately 36 tons of e-waste per year are currently sent to the recycling company Degraf. However, in order to save costs (and since the recycling industry in Chile does dismantling only), Todo Chilenter plans to do the dismantling by itself in the future. The hazardous components will be sent directly to the company Hidronor.

To date it is unclear to Todo Chilenter what happens to their computers, when they reach the end of their use. A takeback system has not been installed yet and would probably be difficult due to the current cost of recycling in Chile.

2.5 Waste management

2.5.1 Solid waste management in general

According to the Chilean national environmental authority CONAMA[16], 11-12 million tons of waste are currently produced in Chile per year. More than 50% of the waste is generated in the Metropolitan Area of Santiago (RM), equivalent to 5.752.100 tons annually (CONAMA 2007). A 2005 analysis in the RM estimated that the most important waste fractions in size are MSW with 46%, construction material with 37% and industrial waste with 16% (see Figure 2-13).

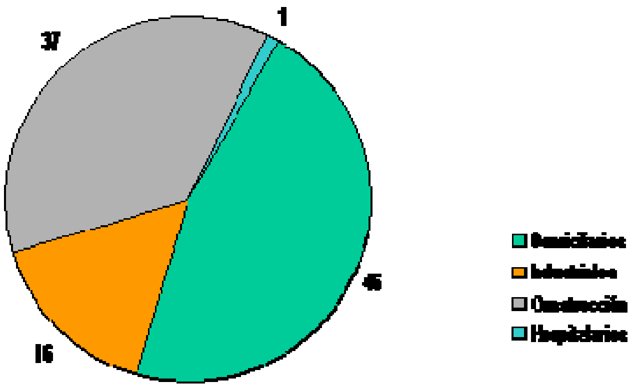

Figure 2-13 Different types of wastes generated in Chile
Source: Ministry of Health (www.seremisaludrm.cl)

The first systematic efforts to improve waste management have started in 1997 with a policy for the management of MSW. Since 2005, Chile has a National Policy for Integrated Solid Waste Management[17].

2.5.1.1 Municipal solid waste

An OECD study estimates that MSW has experienced an average 5% annual growth from 1990 to 2004. About 380 kg of MSW were produced per person in Chile in 2004, which is

[16] Comisión Nacional del Medio Ambiente
[17] Free translation of: Política de Gestión Integral de Residuos Sólidos

equal to roughly 1kg per person per day (OECD 2005). In the Metropolitan Area it is estimated to be 1.63 kg. Fractions of other wastes can also be found within the MSW, such as batteries, varnish, paint, used oils, medication and electronic waste (GTZ 2006).

The organization of municipal waste management is within the responsibility of the community. Since recently communities can charge waste disposal fees. Yet, only 35% of all households contribute financially since only households below a certain property value are exempted from the payments. At average, 15% of the real costs are covered through the waste disposal fee. Thus, often the necessary resources for an appropriate waste treatment do not exist (GTZ 2006).

Another problem is that neither the types of wastes nor the corresponding disposal methods are specified clearly in the legislation. As a consequence, most municipalities do not offer alternatives for the disposal of certain wastes, such as furniture, garden rubbish or e-waste(GTZ 2006).

About 80% of the communities have franchised the management of MSW to private companies (GTZ 2006).

As a result of the efforts of the last decade, today, only about 40% of the municipal waste ends up in unauthorized dumps called “vertedores” or “basurales”. The majority, about 60% is disposed in authorized landfills with sanitary and environmental standards named “rellenos sanitarios” (CONAMA 2007).

2.5.1.2 Industrial waste

In Chile more than 2.5 million tons of industrial waste is produced each year. In spite of the progress made during the last decade, it is estimated that the final disposal of around 60% of the industrial waste is still uncontrolled (OECD 2005). One of the remaining problems is that Chilean companies often subcontract to transport companies to dispose of their waste without knowing its final destination. At the same time – due to insufficient control by the authorities – illegal and clandestine dumps persist. Nevertheless, the number of companies with an authorization to dispose industrial waste has increased from only 8 in 1994 to over 2500 in 2001 (CONAMA 2007).

2.5.1.3 Hazardous waste

Approximately 125.000 tons of hazardous waste is generated each year in Chile. The most important treatment facilities for hazardous waste are operated by the companies Hidronor Chile S.A. and Bravo Energy Chile S.A. in the Metropolitan Area. In 2004 they processed 40.000 tons and 6.000 tons respectively of material with a high proportion of hazardous waste. Additionally, there are around 40 disposal sites with the authorization of the Ministry of Health.

Although none of these facilities uses its full capacity yet, the capacity of authorized facilities has almost doubled from 277.000 tons in 2003 to 484.000 tons in 2006. These major investments indicate that Chilean increasing amounts of hazardous waste are expected in the near future. A reason for that may be the introduction of legislation such as the Regulation on the Management of Hazardous Waste (GTZ 2006).

2.5.1.4 Waste separation and recycling

Informal waste recycling is common and exists in Chile at least since the 1970s. Several thousand waste collectors – also known as “cartoneros” (cardboard collectors) – collect wastes from the streets and households such as paper, cardboard, plastics and aluminium.

Nowadays, with increasing environmental awareness, containers for the collection of materials such as glass, metals, plastic and paper have been installed in a growing number of communities.

The total amount of materials recycled from MSW reaches roughly 5% in Chile and 9% for the Santiago area. Estimates reveal that in Chile about 40% of the paper, 10% of the glass and 3% of the plastic waste is recycled. As a comparison: in Switzerland about 70% of paper 90% of glass and over 70% of plastics (PET) are recycled (see Table 2-4).

Table 2-4 Recycling quotas in Chile and Switzerland for certain materials

	Chile	Switzerland
Paper	40%	70%
Glass	10%	95%
Plastic	3%	75% (PET)

Sources: Bundesamt für Umwelt (www.bafu.admin.ch) for Switzerland and (GTZ 2006) for Chile

2.5.1.5 Recycling of hazardous waste from households

Hazardous wastes from households are for example batteries, paints, oils, medication or e-waste. Since there is no regulation obliging a special collection of this kind of hazardous waste from households, it often ends up in the municipal solid waste. There are currently no statistics available of how much of these products are generated. In some communities, mainly in the Metropolitan Area, campaigns have been launched to collect batteries and other special wastes. Collected batteries were sent to the hazardous waste recycling company Hidronor. A public collecting point for different wastes has also been installed in the community of Vitacura (Punto Limpio)[18].

In 2007, an initiative of Nokia and Movistar called for the recycling of mobile phones. Regardless of the brand, used mobile phones can be deposited at sales points of Movistar free of charge. 15.000 phones have been collected in the first two months of the initiative and will be sent to a company in the United States for recycling (Chiletech 2007).

2.5.1.6 Recycling of industrial waste

Even if recycling is not as developed as for instance in Europe, certain materials have been recycled in Chile for a long time. A look at the Chilean market reveals a certain development for recycling of the following materials:

- Used industrial oils
- Solvents
- Scrap metals
- Silver from fixers in photography
- Paper and cardboard
- Certain batteries
- Aluminium
- Plastic

In 2004, more than 85% of the metallic wastes have been recycled. They were either melted in the central region of Chile or exported to Peru (GTZ 2006). This impressive percentage is interesting with respect to e-waste recycling since electronic products contain high levels of metals. E-waste recycling may thus constitute an attractive business. Unfortunately it can be assumed that environmental standards are not always respected in these processes.

[18] See Punto Limpio: www.vitacura.cl/vitaservicios/medio_ambiente.php#

2.5.1.7 Costs

It is difficult to generalize on the costs of the solid waste management in Chile, but the numbers indicated here may serve for a first orientation. Costly stages in waste management are usually storage, transport and treatment. Table 2-5 summarizes the indications of costs of the GTZ study:

Table 2-5 Costs of certain waste disposal options

Type of cost	Cost
Transport of 5 tons of industrial waste for 2 hours	90 US$
Cost per ton and hour	9 US$
Cost for the disposal of 1 ton MSW in Santiago	32 US$
Transport	20 US$
Landfilling	12 US$
Disposal in an unauthorized dump (without transport)	4 US$
Treatment of 1 ton hazardous waste at Hidronor	190 US$

Source: (GTZ 2006)

2.5.2 Legal framework

2.5.2.1 International legislation

The most important international legislation concerning electronic waste is the Basel Convention which entered into force in 1992. The Basel Convention is an international treaty (a UN convention) that was designed to reduce the transboundary flows of hazardous wastes, especially from developed to less developed countries. Its principal concepts are:

- The minimization of hazardous wastes
- The treatment and disposal of hazardous wastes as close as possible to their source
- The minimization of transboundary movements of hazardous wastes

In order to make it easier to define which wastes are considered hazardous under the Basel Convention, the member states established two lists (A and B) in 1994. Electronic equipment – as long as it contains substances such as lead, alloys of copper and beryllium – and circuit boards are thus to be considered hazardous wastes (UN 1992).

Chile has ratified the Basel Convention.

2.5.2.2 National legislation

With increasing waste quantities, the pressure on the state grew to develop new legislation and regulations for waste management. CONAMA has drafted a National Strategy for the Prevention and Minimization of Solid waste, which includes the concept of extended producer responsibility, calling for product stewardship. Even though the strategy is too general to address specific wastes, e-waste has been mentioned in its Annex[19].

In 2005, the Regulation on the Management of Hazardous Waste has entered into force.

Table 2-6 provides an overview on the most important legislation with respect to waste management in Chile:

[19] http://www.eiatrack.org/r/1067

Table 2-6 Legislation applicable for solid waste management

Legislation	Description
Law on the General Bases of the Environment (Ley General de Bases del Medio Ambiente)	First legal framework dealing explicitly with the environment.
DS 95/01 Regulation for the Environmental Impact Assessment (Reglamento del Sistema de Evaluación de Impacto Ambiental, SEIA)	This regulation became operative in 1997 and applies for public and private projects in the areas: infrastructure, urban development, agriculture, forestry and industry. It enables the participation of the public and includes regulation on environmental compensation.
DFL 725/68 and DS 553/90 of the Sanitary Code (Código Sanitario)	This regulation of the Ministry of Health defines the sanitary and safety guidelines that apply to the accumulation, classification, industrial usage, trade and disposal of waste.
DS 594/99 Regulation on the Basic Sanitary and Environmental Conditions at the Workplace (Reglamento sobre Condiciones Sanitarias y Ambientales Básicas en los Lugares de Trabajo)	Regulation of the Ministry of Health that describes the environmental conditions at the workplace. It specifies also that industrial waste has to be transported by authorized companies.
DS 148/04 Regulation on the Management of Hazardous Waste (Reglamento Sanitario sobre Manejo de Residuos Peligrosos)	Regulation of the Ministry of Health that defines the sanitary and safety minimum conditions for the generation, possession, storage, transport, treatment, re-use, recycling and final disposal of hazardous waste.
DS 298/94 Regulation on the Transport of Hazardous Goods on Roads (Reglamento Transporte de Cargas Peligrosas por Callesy Caminos)	Regulation of the Ministry of Transport and Telecommunication that regulates the transport of hazardous goods.

Source: adopted with modifications from (GTZ 2006)

The Law on the General Bases of the Environment

This law became effective in March of 1994 and it is the first law in Chile dealing specifically with the environment. It also initiated the creation of the National Commission of the Environment, CONAMA, as a technical, coordinating body. This law provides the basis for a more elaborate normative and institutional framework with the aim of the protection of the environment. Its most important contributions in the area of solid waste management are (Seremisalud 2007):

- The integration of measures to protect the environment with the aim of preventing a worsening of the environmental situation in Chile and to support a sustainable development of the Chilean industry
- The preference of market oriented instruments for environmental protection
- The introduction of a system for environmental impact assessment (SEIA)
- Standards for environmental quality and emissions
- Waste management plans

Recently however, criticism has been voiced with regards to its scope. The main arguments are that the regulating authorities have too little possibilities to take action and that it falls short of international environmental standards. A reform is currently discussed by the parliament.

Regulation on the Management of Hazardous Waste

The Regulation on the Management of Hazardous Waste (DS N° 148)[20], that is operative since 2005, established procedures for the management of hazardous waste as well as for the operation of collection points and treatment facilities (Salud 2004).

Article 10 of the regulation states that "*a waste or mixture of wastes is hazardous if it presents a public health risk and/or adverse effects to the environment being this in a direct manner or due to actual or established management, as a consequence of presenting any of the characteristics defined in article 11*".

Article 11 states that waste is to be classified as hazardous, if it shows one of the following 6 characteristics:

- Acute toxicity
- Chronic toxicity
- Extrinsic toxicity
- Flammability
- Reactivity
- Corrosiveness

These characteristics are defined in articles 12 to 17.

Article 25 prescribes that "*facilities, establishments or activities that annually generate more than 12 kg of waste with the property of acute toxicity or more than 12 tons of waste with any other characteristic of hazardous waste have to develop a Hazardous Waste Management Plan and submit it to the Sanitary Authority*".

The regulation also specifies conditions for the storage and transport of hazardous waste.

2.5.2.3 Is computer waste hazardous waste?

In addition to the articles 10 and 11, the regulation states the following with respect to computer waste:

Article 18, list I of the Regulation on the Management of Hazardous Waste defines *"substances or parts of waste that contain or are contaminated with the following elements"* as hazardous waste (Salud 2004):

- polychlorinated biphenyls (PCB)
- polychlorinated triphenyls (PCT)
- polybromated biphenyls (PBB)

Article 18, list II states that waste that contains the following elements is also considered hazardous:

- berilium and compounds with berilium
- compounds with hexavalent chrome
- copper compounds
- arsenic and compounds with arsenic

[20] The regulation can be downloaded (in Spanish): www.sinia.cl/1292/articles-38293_pdf_respel.pdf

- cadmium and compounds with cadmium
- mercury and compounds with mercury
- lead and compounds with lead

Article 19, states that wastes listed in article 90, list A are hazardous unless proved otherwise to the Sanitary Authority: *"Waste from electronic devices and its scrap that contain components such as*

- *batteries […]*
- *mercury switches*
- *glass of cathode ray tubes (CRTs) and other activated glass […]*
- *capacitors contaminated with i.e. cadmium, mercury, lead, PCB*

in concentrations such that the waste represents a potential hazard".

According to this analysis, it can be concluded that computer waste can be considered hazardous waste. The main evidence is summarized in the following:

- computer waste may show characteristics of article 11 (i.e. chronic toxicity), which may put a risk to public or environmental health (i.e. through inadequate management) and it is thus hazardous waste according to article 10
- computer waste contains materials that are mentioned in article 18, list I and II and should thus be considered hazardous waste
- computer waste contains components that are mentioned in article 19 and should thus be considered hazardous waste

2.5.3 Computer recycling industry

2.5.3.1 General description

In the same way that the generation of waste in Chile has increased during the last decades, electronic waste quantities have grown rapidly. For this reason the Chilean recycling industry has developed much in recent years with the result that first formal e-waste recycling activities exist today.

In order to characterize the Chilean recycling industry it has to be distinguished between the formal and the informal market[21].

Informal e-waste recycling plays an important role in Chile, but due to the high complexity of the informal market, it has not been investigated in this study. It is difficult to estimate, whether it is quantitatively more or less important than formal recycling market. However,

[21] Note by the author: The definition of *formality* refers to the degree of legality of the activities of a company, which is based on the permissions it possesses. Some of these permissions are issued by CONAMA or the Ministry of Health (such as the permission to treat, store or transport hazardous wastes). Technically, none of the investigated recyclers was in possession of all of the required permissions at the time of research. Moreover, the responsible authorities apparently had not requested the same authorizations for all of the recyclers. These legal uncertainties, have led to a situation where each recycler is in possession of different authorizations, claiming to be the only fully accredited recycler. The term *formal* shall thus refer in this context to the fact that a company has at least some kind of environmental permission or is currently applying for it. Nevertheless, for the moment, it seems more important to help those companies without authorizations to improve their environmental, health and safety standards than to putting too much emphasis on these legal issues.

various experts[22] estimate that a large quantity of computers is recycled in the informal market, obviously without the necessary environmental precautions.

Formal e-waste recycling activities in Chile are currently in a dynamic developing stage. Nevertheless, the number of recyclers is still small and all of them are located in Santiago. It remains unclear, whether further recycling companies exist, especially outside of the Metropolitan Area. However, electronic waste from other regions is also recycled in Santiago.

So far, recycling companies operate on a business to business model for the reason that the industry has the means to pay for adequate recycling. The majority of the costumers are big Chilean and international companies. The principal incentives for the industry to send their equipment to recycling are environmental responsibility and the image of the company. Balance and tax benefits seem to be another reason. Household computers are not yet recycled in the formal e-waste recycling industry.

2.5.3.2 Steps of the recycling process

Recycling activities in Chile remain basic (compared to European standards) and recycling is principally done by hand without the use of machinery. Figure 2-14 illustrates the flow of computer equipment through the recycling process.

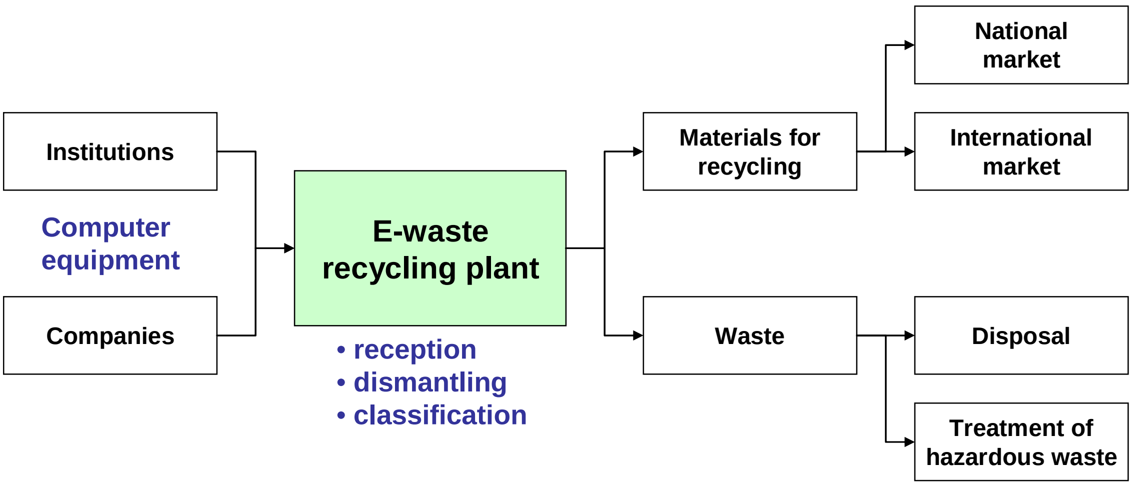

Figure 2-14 Principal scheme for the flow of materials during e-waste recycling in Chile

The principal steps that are involved in e-waste recycling in Chile are described in the following:

Collection and transport

The recycling companies usually provide the transport and collect electronic waste from the generators. As computer waste is considered hazardous, at least one company has been obliged by the authorities to have an authorization to transport hazardous waste.

Dismantling and classification

At arrival, electronic equipment is first sorted and then manually dismantled for the recovery of different materials, which are then classified. The most important recovered materials are:

- Plastics
- Metals: ferrous, zinc, aluminium, copper
- Printed wire boards (precious metals)

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[22] Personal interviews with CONAMA, recyclers and refurbishers

Commercialization of re-usable / recyclable materials

Materials for re-use or further recycling (i.e. smelting of metals) are commercialized. Plastics and metals are principally recycled in Chile (mostly in the Metropolitan Area), however, some are also commercialized internationally (Europe, North America or Asia). Printed wire boards are commercialized in Europe or Asia. The economically most important materials are copper and circuit boards.

Disposal of hazardous materials

Materials that are not recycled are classified into solid and hazardous waste. Hazardous waste, such as cathode ray tubes from monitors, are sent to the hazardous waste recycling company Hidronor.

2.5.3.3 Description of some recycling companies

The formal recycling companies that have been analyzed in the context of this study are *Carrascal, Grupo Comec, Degraf Ltda* and *Recycla*. As they seem to constitute the most important recycling companies in Chile, they shall be briefly described in the following:

Recycla

Recycla[23] is presently the biggest and most important e-waste recycler in Chile. According to information provided by the company it receives approximately 600 tons annually, 10% of that being computer waste. Since the company has only become operative a few years ago, its success is also due to good marketing strategies. Recycla has clients in many regions in Chile and e-waste is transported over distances of up to 2500 km by truck to reach the company.

Recycla charges around 300 US$ per ton of e-waste, but assures adequate recycling and disposal of hazardous materials through a contract with Hidronor. Recycla has obtained environmental authorization by the Ministry of Health. The recycling activities involve manual dismantling and the recovery of materials for national and international sale. Printed wire boards are sent to Europe for smelting and recovery of precious metals.

Carrascal

Carrascal is the oldest recycler of electronic equipment in Chile with a history dating back to the 1980s. Its origins are in the scrap metal dealing, but nowadays its core business is with office equipment such as computers, monitors, printers, etc. It is also known as the “computer cemetery” in Santiago. It is the only recycler investigated that does not charge its customers for the recycling of e-waste, but instead buys it from them. It is thus well known and receives the highest amount of computer equipment of all the recyclers.

Its business model consists of a mixture of re-use and recycling. Computers and monitors can be bought at a low price and are re-used i.e. by private persons or refurbishers. On the other hand, materials are recovered by manual dismantling and sold to the Chilean or international market.

It should be mentioned though, that its environmental standards are also among the lowest of the investigated recyclers. Even though according to the owner, Carrascal is authorized by SESMA[24], computer equipment is stored on the company ground without a roof protecting it from rain and the ground is unpaved. The owner indicated that the hazardous waste (such as

[23] See: www.recycla.cl
[24] SEREMI de Salud, formerly SESMA is the Regional Office of the Ministry of Health, see: www.seremisaludrm.cl

monitors) is being recycled with the municipality, however, it seemed unlikely that they experience an environmentally sound treatment (such as in Hidronor). Carrascal is thus sort of in the grey area with respect to the distinction made earlier between formal and informal recyclers. However, the actual differences between Carrascal and the more formal recyclers appear to be only small.

Degraf Ltda

Degraf[25] is a small, family based company, although recently the plant location was shifted and a bigger and roofed plant exists today. The company is currently in the process of applying for the necessary environmental permissions for its new site. Once approved by the authorities, it will by the only company with an environmental impact assessment. An authorization for the transport of hazardous waste has been obtained in 2007. An ISO 9001 certification may follow in the near future.

Degraf charges approximately 200 US$ per ton for its recycling service. Its recycling activities involve manual dismantling and the sale of recovered materials. Hazardous waste is send to Hidronor. As the company is new in the market, some technical questions on appropriate recycling or the commercialization of materials remain open.

Grupo Comec

Grupo Comec[26] is a company with various branches in Chile. Its main facility is located in Santiago and its core business is metal recycling. Computer equipment is just a marginal part of its business and Comec does not receive monitors for the reason of them being hazardous waste. Computer recycling is offered to its costumers as an additional service and computers are picked up free of charge if other cargo is to be collected. It is mentioned here also because of the assumption that Comec is a typical case for the metal dealing industry. If more metal dealers receive marginal amounts of computers the total amount may become important.

The recycling process in Comec involves manual dismantling of the electronic equipment and commercialization of recovered materials. Printed wire boards and other materials are compacted and sent to China.

2.5.3.4 Recycled quantities and costs

Table summarizes the quantities of computer waste received and the financial flow involved for the investigated recyclers:

Table 2-7 Amount of computational equipment recycled annually by recycling companies

Recycling company	*Computer waste in [tons/year]*	*Financial flow*
Recycla	60	Charges 300 US$ / ton
Carrascal	(80)	Buys at 70 US$ / ton
Degraf	48	Charges 200 US$ / ton
Comec	5	No financial flow
in total	*113 / 193**	

* It shall be left open in this study, whether the activities of Carrascal may be considered recycling
Source: Information provided by the recycling companies

A total of 193 tons is thus recycled by these companies in Chile annually (or 113 tons if one were to consider Carrascal as an informal recycler). The differences in financial flow are

[25] See: www.degraf.cl
[26] See: www.comec.cl

striking and suggest that a financial analysis should be conducted in order to find a recycling price that insures proper standards and remains attractive for waste generators at the same time.

A major problem for some of the interviewed companies is the competition by the informal sector. Companies of the informal sector may offer significantly better prices for obsolete computer equipment, but sell the valuable parts without a responsible management of the hazardous components.

2.5.4 Disposal

2.5.4.1 General situation

Significant changes occurred during the last decade. Before 1995, MSW was generally filled in unofficial dumps. Since then there have been major investments by private companies in the construction of disposal sites with certain environmental standards. Since 1997, all projects for the final disposal of MSW have to do an environmental impact evaluation in order to be authorized by the Ministry of Health. Thus, the environmental and sanitary standards are much higher in the installations built after the year 1997.

A 2004 investigation revealed that out of 257 disposal sites, 128 corresponded to criteria of an authorized disposal site with international environmental standards. Fortunately, about 80% of Chile's waste is produced the central zone, where the climatic and geological conditions are suitable for the maintenance of cost-efficient and safe landfills[27] (GTZ 2006).

In the Santiago Metropolitan Area, the picture is somewhat different from the rest of the country most of the MSW is disposed in three large landfills owned by private companies.[28] Together they receive around 2.3 million tons of MSW per year.

These landfills had to do an environmental impact assessment meet the requirements of a regulation called "Minimum Requirements for the Operation of a Disposal Site in the Greater Santiago Area"[29]. The most important standards include:

- A waterproof sealing of the bottom of the landfill in order to prevent the dispersal of the contaminants, i.e. into the ground water
- A drainage system and a treatment facility for the leachate
- A facility to treat the produced gases

Nevertheless, a recent assessment in the Metropolitan Area by CONAMA showed that clandestine dumps and so called "microdumps[30]" continued to exist. Most of the waste deposited in these dumps is construction material, but worse cases with used tires or barrels containing hazardous wastes had also been found.

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[27] A detailed description of individual landfills in Chile can be found in the following Spanish publication: "Sitios de disposición final, gestión y tratamiento de residuos sólidos domiciliarios e industriales", published by the journal ECOAMERICA in March 2006.
[28] *Santa Marta* (operated by a Chilean group of companies), *Santiago Poniente* (operated by PROACTIVA, a consortium of a Spanish and a French company, FCC and Veolia Environnement) *and Loma Los Colorados* (operated by Urbaser-Kiasa)
[29] Free translation of: Normas Mínimas de Operación de Basurales Ubicados en el Gran Santiago
[30] Free translation of: microbasurales

2.5.4.2 Disposal of computer equipment

Due to the scope of the study, the situation regarding the disposal of computer equipment could not be investigated in depth. Thus, many questions on the fate of computer equipment remain unanswered. In fact, the final destiny of the vast majority of e-waste can not be explained with certainty.

Nevertheless, it is assumed that an important fraction of computer equipment ends up in the municipal waste stream and thus in landfills or dumps. Due to the contents of electronic waste, it is obvious that this constitutes an environmental problem.

2.6 Environmental authorities

The environmental authorities in Chile are the National Commission on the Environment (CONAMA, Comisión Nacional del Medio Ambiente) and the Regional Commission on the Environment (COREMA, Comisión Regional del Medio Ambiente). As suggested by the names, CONAMA's responsibilities are on the national level and COREMA's responsibilities on the regional level. Both have been created in 1994 with the introduction of the first comprehensive legislation for the environment, the Law on the General Bases for the Environment. CONAMA reports to the Ministry of the Office of the Presidency[31] whose principal task is to consult and help the government in the coordination and development of policies and legislation. A ministry of the environment does not exist in Chile yet, but a minister for the environment (Ana Lía Uriarte Rodriguez) has been appointed by the current government with the mission to create a ministry of the environment in the near future.

2.6.1 Role, responsibility and instruments

The Law on the General Bases for the Environment defines the role and the key responsibilities of CONAMA as the following:

- to assure for the Chilean people a living in an environment free of contamination, the protection of the environment and the preservation of nature and environmental heritage,
- to act as an organism that can consult, analyze, communicate and coordinate in matters that are related to the environment,
- to propose environmental policies to the presidency and to inform it about compliancy with environmental legislation.

It is thus clear that it is within the responsibility of CONAMA to take action to solve the e-waste problem in Chile and prevent environmental damage resulting from it. To assure the implementation of the responsibilities defined above, CONAMA has been provided with a number of functions and instruments, of which the most important concerning e-waste are listed here:

- the administration of the Environmental Impact Assessment System (SEIA)[32] (waste treatment facilities are obliged to do an environmental impact assessment)
- the promotion of environmental education, i.e. in schools
- the financing of certain projects and activities with the objective of environmental protection through a Fund for Environmental Protection[33]

[31] free translation of: Ministerio Secretaría General de la Presidencia (http://www.minsegpres.gob.cl/portal/menu/inicio.html)
[32] for more information see: www.e-seia.cl/

- the elaboration of environmental regulations and prevention and decontamination plans
- to be the Chilean counterpart for internationally financed development aid programmes that are related to environmental issues
- the establishment and upkeep of a National System for Environmental Information (SINA), where citizens are provided with free information about different environmental topics

2.6.2 Progress with respect to the e-waste problem

Unfortunately, little progress has been made so far concerning the e-waste problem in Chile. Personal interviews with CONAMA and COREMA officials have shown that they were aware that the issue of e-waste remained unresolved. However, only basic knowledge was available on the topic and little was known on the fate of obsolete electronic equipment. Nevertheless, CONAMA is actively working on introducing the concept of extended producer responsibility for some areas of solid waste treatment and officials have stated that they would like to introduce EPR for e-waste.

The principal reasons for the missing of action to resolve the e-waste problem were indicated as the following:

1) *Lack of knowledge:*
Information on the situation regarding e-waste remains basic due to a lack of investigation; this is valid for the general situation, such as the question of the fate of electronic equipment and its environmental consequences as well as for the actors involved in it (often in the informal market).

2) *Lack of capacity and priority of other issues:*
The current lack of action may be explained considering the financial resources, the personal capacity and the short history of CONAMA. Considering that the environmental authority exists only since 1994 and that not much had been done to protect the environment before, it is comprehensible that many problems remain unresolved and that more urgent problems keep the authority busy for the moment, such as the disposal of used industrial oils, batteries, plastics and tyres.

3) *Lack of power to control and sanction:*
CONAMA's power to control and sanction the recycling and disposal industry remains limited – both, in theory as well as in practical application. This is due to various reasons, such as the lack of an appropriate legislative framework providing CONAMA with the necessary powers and general limitations due to institutional context in which CONAMA has been created.

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[33] free translation of: Fondo de Protección Ambiental

3 METHODS

3.1 Material flow analysis

3.1.1 In general

Material flow analysis is a method to describe, investigate and evaluate the metabolism of anthropogenic (or geogenic) systems. It can be used to quantify the flow of materials in a system defined through a spatial and temporal boundary. The goal of a material flow analysis is to increase the understanding of a studied system, which is a prerequisite for a better control and management (Baccini and Bader 1996).

A material flow analysis involves the following four steps:

- An analysis of the system and the involved processes and materials
- Measurements of the material or mass flows
- Calculation of the material or mass flows
- Interpretation of the results

3.1.2 Choice of the method

Material flow analysis has been chosen for this study since it has been previously used in similar studies, i.e. in a study on the estimation of future outflows of personal computer systems in California (Kang and Schoenung 2006) or in a study on computer waste generation in the United States (Matthews et al. 1997). The study of the Kang and Schoenung has also had some influence on the choice of processes that are included in the model.

3.1.3 Definitions

The most important terms used for the material flow analysis in the context of this study shall be defined according to the Practical Handbook of Material Flow Analysis (Brunner and Rechberger 2003):

- *Material*
  The term of material includes substances and goods. Substances are defined as chemical elements, whereas goods are real life items, such as wood or a computer. In this study, the term product and good refer to the same.

- *Process*
  A process is defined as the transformation, transport, or storage of materials. The processes used in the material flow analysis in this study involve only transport and storage. A process of storage includes a stock, where material is stored for a defined time.

- *Flow*
  A flow is defined as a mass flow rate. This is the ratio of mass per time that flows through i.e. a water pipe or the amount of obsolete computer material that flows to recycling and disposal in one year. The physical unit of a flow may thus be given in units of tons/year. In this study, a flow may also refer to a flow of goods. The flow is

then given in units/year (which can easily be converted into a mass flow, multiplying the units by their mass).

- *Transfer coefficient*
  Transfer coefficients describe the partitioning of a material in a process.

- *System and system boundary*
  A system is the actual object of the study and may be considered to be the sum of the interacting elements in the system (i.e. the actors described in this study). A system may be open or closed, depending on whether interactions with elements outside of the system boundaries exist. The system boundary defines the limits of the study in space and time.

Figure 3-1 illustrates the above:

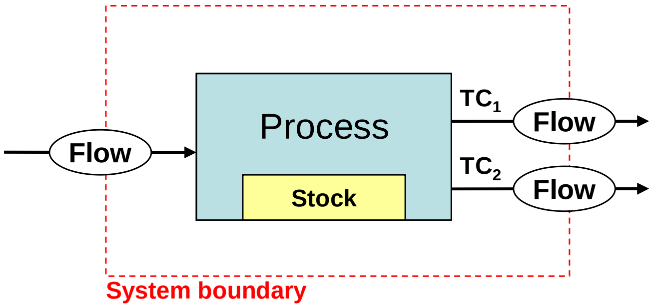

Figure 3-1 Illustration of the principal elements used in MFA
TC stands for transfer coefficient

3.1.4 Mathematical description

In order to describe a system mathematically, a set of variables has to be found that describes the system. The goal of the material balance is to be able to calculate the material flows and the material in storage at any time and any point of the system.

The basis of a mathematical description of the system in space and time is the principle of mass conservation. Since the computer market described in this study is an open system, the amount of material that has entered will eventually leave the system again.

The principal equation of the material balance is the following:

$$\frac{dM^{(j)}}{dt} = \sum_r A_{rj} - \sum_s A_{js}$$

$M^{(j)}(t)$: amount of material in $V^{(j)}$ (stock)
$A_{rj}(t)$: material flow from V_r to V_j
V_r : selected balance volume (process)

The partitioning of material flows (after a process) is described by transfer coefficients (k). These transfer coefficients indicate the fraction of material that is transferred from the selected balance volumes V_r to V_s. The following equation gives the mathematical definition:

$$k_{rs} = \frac{A_{rs}}{\sum_j A_{jr}}$$

The principal steps involved in developing a mathematical model are:

- A complete description of the system and the involved variables (i.e. computer sales, usage times and transfer coefficients)
- The determination of the mass balance equations, which describe the interactions in the system
- The implementation of these in a model

3.1.5 System description

3.1.5.1 Material

The materials or goods described are:

- Desktop computers
- Laptop computers
- Cathode ray tube monitors (CRTs)
- Liquid crystal displays (LCDs)

The average weight for these goods has been assumed as:

Table 3-1 Average weight of computer equipment

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

Source: (SWICO 2006)

3.1.5.2 System boundaries

The geographical system boundary chosen for the study is the Chilean state. The principal reason of choosing the entire country (i.e. instead of the Metropolitan Region) is that import and sales statistics are only available for the country as a whole.

The time interval considered is between 1994 and 2020. This is due to historical sales data which are available starting in 1994. Computer waste quantities will be predicted until the year 2020.

The processes included in the model cover the phases of production, sale, consumption and use (see Figure 3-2). Due to its complexity, the individual processes in the phase of production and sale are combined and reduced to a single process, the distribution of computer equipment to the government, businesses and households. The processes of recycling and disposal are left outside of the system boundary as the principal interest of the model is to estimate future e-waste quantities. Nevertheless, the recycling and disposal quotas are assessed separately.

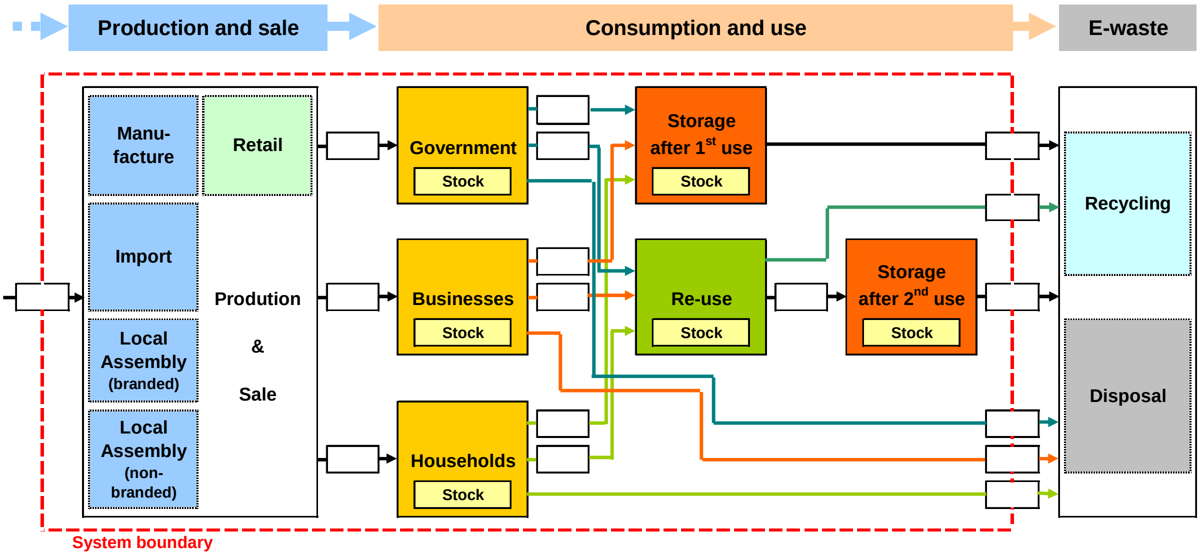

Figure 3-2 MFA model scheme

3.1.5.3 System data and variables

The principal data and variables that are necessary to describe all flows in the model are:

1) **Production and sales data**: the inflow or the total amount of computer equipment entering the model.

2) **Usage time**: computer equipment remains for a considerable time in all the processes except for the production and sale. In order to estimate the generation of e-waste correctly, good approximations for the usage times in the different stages are needed.

3) **Transfer coefficients**: Determine which pathway computer equipment follows in the model. Different pathways take different times.

See Figure 3-3 for the practical implementation of the above in the model:

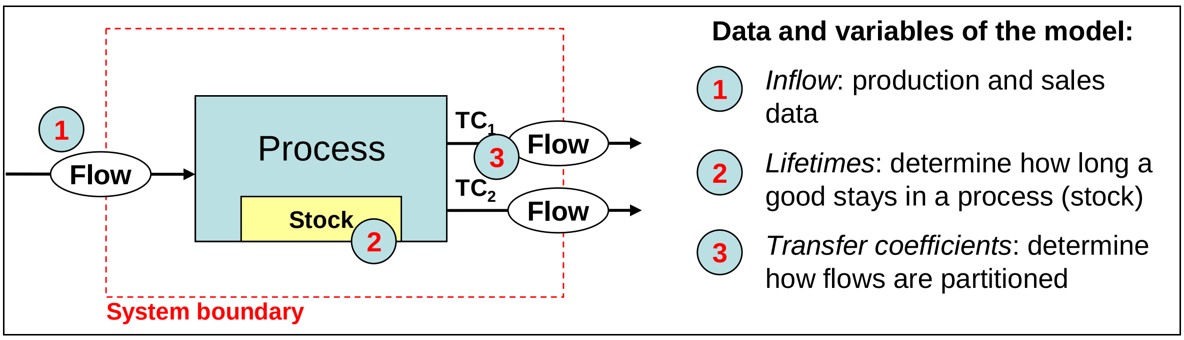

Figure 3-3 Description of the model input data

3.1.5.4 Processes

The processes used to describe the computer market in Chile are described in the following.

Production and sale

Production and sale consists of the sub-processes manufacturing, import, branded assembly and non-branded assembly as well as retail. Due to the complexity that it would involve investigating these sub-processes, a process production and sale has been used instead.

This was helpful for the simulation, as good data was available on computer sales in Chile. Since the time it takes to sell computer equipment is negligible compared to the time it is used afterwards, this process does not have a stock (it serves just for the partitioning of the production data).

1st Use: Government, business and household

Computers are used by the three principal groups in the market, the government, businesses and households. Each process contains a stock, since computer equipment stays for some time in these processes. When the computer equipment becomes obsolete, 1st users have three principal choices for their equipment: to dispose it, to store it or to pass it on to a 2nd user.

Storage 1

This process refers to the storage of computer equipment for a certain time after its first use.

Re-use

Re-use or second use occurs, when a computer is passed on from a first to a second user.

Storage 2

This process refers to the storage of computer equipment for a certain time after its second use.

3.2 Data collection

Data has been collected by literature and online research, through the help of a questionnaire and in personal interviews.

3.2.1 Literature

Even though hardly any literature was available on the specific situation regarding e-waste in Chile, literature research was one of the principal sources of information for this study. It has been used for:

- the preparation of the study, i.e. the choice of method and other general information (mostly articles)
- the introductory chapter on waste management and legislation in Chile (internet research and a publication by GTZ)
- information on various actors of the computer market (mostly internet research)
- model data (internet research of production and sales data from IDC sources)

3.2.2 Questionnaire

Questionnaires have been sent to government institutions, businesses and households in order to obtain data for the model. The main objective was to get some statistical data with respect to consumer behaviour (see Annex B and C for the questionnaire and the results).

The questions were designed to find out the following:

- Where do consumers buy their computational equipment?
- How do consumer acquire their equipment (new, used or leased)
- What kind of products do they purchase?
- How long do they use it?

- What is the fate of obsolete equipment?
- How long is computer equipment stored for?
- Which quantities are recycled / disposed?

For businesses, the questionnaires were evaluated in two categories[34]:

- small companies or PYMES (< 200 employees)
- big companies (> 200 employees)

This was done for the reason that the management of computer equipment differed significantly between small and big companies. In order to calculate transfer coefficients and usage times for businesses (as one process) the questionnaire results were weighted by the fraction of computer equipment sold to small and big companies (approximately two thirds and one third).

A total of 43 replies has been received. Table 3-2 shows in more detail how many questionnaires were sent to government institutions, businesses and households and how many replies were received.

Table 3-2 Number of questionnaires sent and replies received, sorted by recipient

Recipient	*Number contacted*	*Number of replies*
Government institutions	5	2
Businesses	160*	19
Households	90*	22
Total	255	43

* numbers are estimated, since third persons helped with the distribution of questionnaires

3.2.3 Interviews

Personal interview have been conducted with various experts in order to obtain or complement information. Annex A provides a résumé of the personal interviews conducted in the course of this study.

[34] Definition by a major Chilean industrial association (SOFOFA), see also: http://es.wikipedia.org/wiki/PYME

4 MATERIAL FLOW ANALYSIS

4.1 The model

In order to estimate actual and future computer waste quantities, a model for the material flow analysis of the computer market in Chile has been developed. Microsoft Excel has been chosen as the modelling software mainly for the reason that it is relatively simple to use and commonly available. It may thus even be used for further research.

The development of the model involved the following stages:

- Development of the model in order to represent the Chilean computer market through processes, flows and stocks
- Simplification of the model to be able to model it with available data
- Development of scenarios

As the historical data was available from the year 1994 on and it's direct influence is noticeable until the year 2015 (or later), it has been chosen to model until the year 2020.

The model flows are calculated on the basis of the absolute number of computer equipment and not in weight. However, the conversion is straightforward to make, one simply has to multiply the number of equipment by its specific weight.

4.1.1 Simplification

The original model considered the processes in the production and sale phases separately (import, local assembly, retail, etc). As it proved to be too complex to quantify the flows in between these processes, the model was simplified to consider them as part of one process, production and sale. Another reason was that potentially reliable data is available on the overall computer sales and their distribution to the subsequent processes (government, businesses and households). Figure 4-1 shows the model used for the simulation of the computer market.

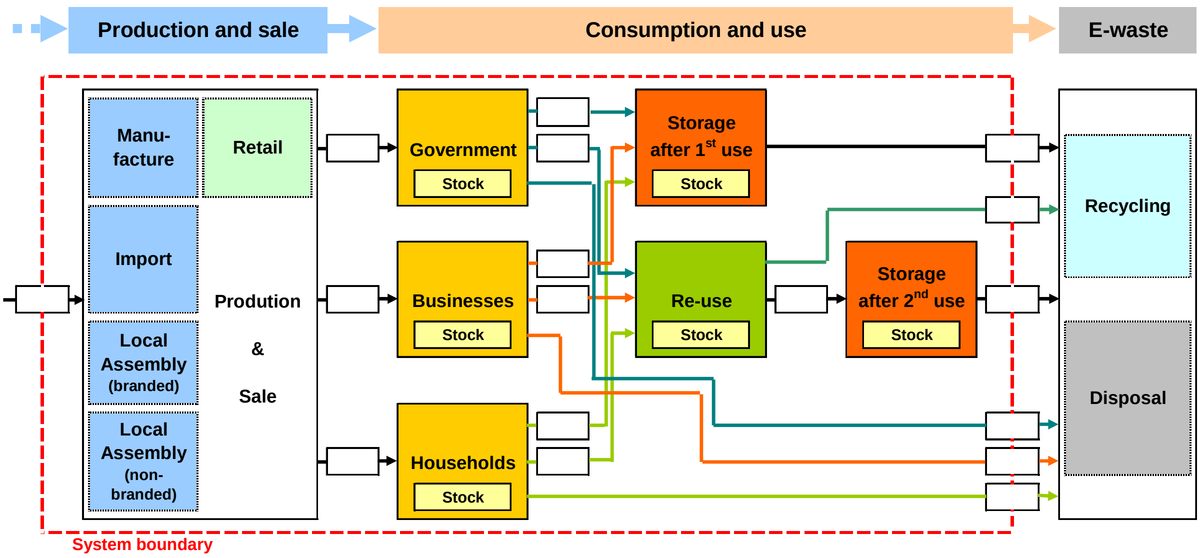

Figure 4-1 Flow scheme of the model used in this study

4.2 Model input

As already described to some extent previously, the model uses three kinds of data to determine all the flows of computer equipment:

- **Production and sales data** for the goods considered in the model (desktops, laptops, CRTs and LCDs) constitute the inflow of the model.
- **Usage times** per process determine the time a good remains in one process.
- **Transfer coefficients** determine how a good is partitioned when more than one flow exists after a process.

See Figure 4-2 for an illustration on how this data is used in the model:

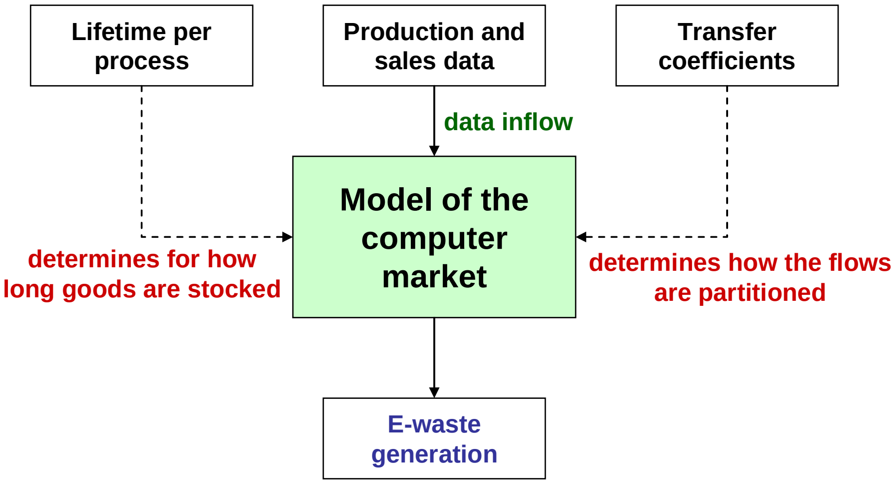

Figure 4-2 Principal data flow through the model

4.2.1 Production and sales data

The following figure presents the quantities of computer equipment that have been used as inflow to the model for the years 1994 to 2020.

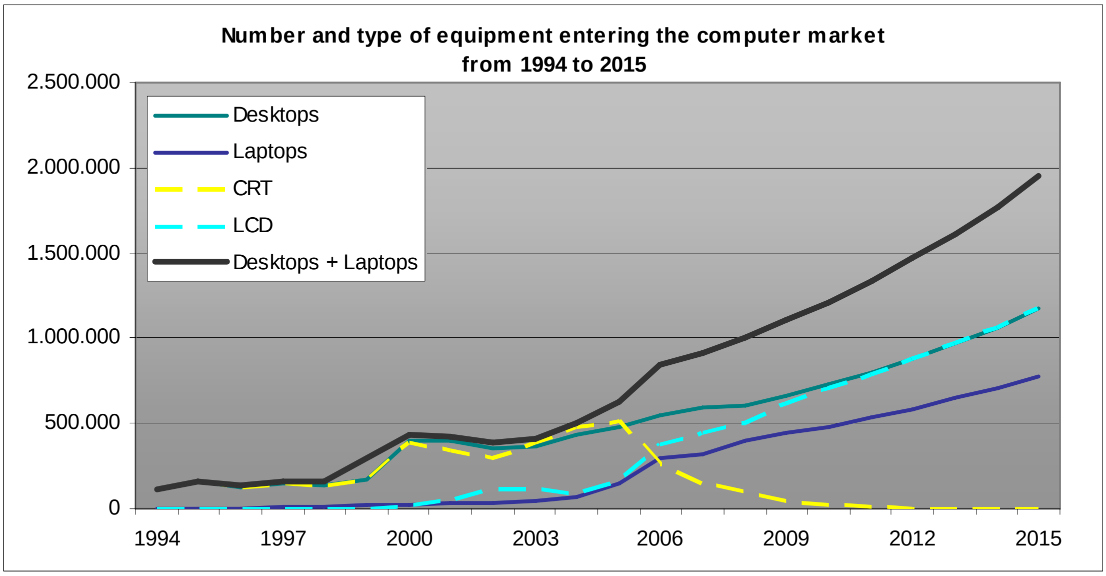

Figure 4-3 Graphical presentation of the model input: desktops, laptops, CTRs, LCDs

The principal sources for the production and sales data have been:

- Data from the International Data Corporation (IDC)[35], which has been collected from various publications available on the internet
- Data from the Chilean Customs Office (import statistics from the online data base ESTACOMEX[36])

Table 4-1 presents the production and sales data in absolute numbers:

Table 4-1 Computer equipment sold in Chile from 1994 to 2007 and projection until 2020

Number of desktop, laptops, CRTs and LCDs sold in Chile

Year	Computers total	Desktops	Laptops	CRTs	LCDs
1994	**110.000**	**110.000**	*0*[a]	*110.000*[b]	*0*[c]
1995	**160.000**	**160.000**	*0*[a]	*160.000*[b]	*0*[c]
1996	**136.035**	*131.035*[a]	*5.000*[a]	*131.035*[b]	*0*[c]
1997	**159.601**	*149.601*[a]	*10.000*[a]	*149.601*[b]	*0*[c]
1998	**157.072**	**141.813**	**15.259**	*141.813*[b]	*0*[c]
1999	**299.094**	**167.325**	**20.078**	*167.325*[b]	*0*[c]
2000	**429.177**	*404.177*[a]	*25.000*[a]	*384.177*[c]	*20000*[c]
2001	**425.865**	*395.865*[a]	*30.000*[a]	*345.865*[c]	*50000*[c]
2002	**393.724**	**357.509**	**36.216**	**301.459**	**108.505**
2003	**407.744**	**365.219**	**42.524**	**382.688**	**110.594**
2004	**504.560**	**434.593**	**69.966**	**482.566**	**85.968**
2005	**622.709**	**474.571**	**148.138**	**512.109**	**164.608**
2006	**843.117**	**545.088**	**298.029**	**267.668**	**380.851**
2007	*910.828*[d]	*592.038*[d]	*318.790*[d]	*150.000*[g]	*442.038*[g]
2008	*1.001.911*[e]	*601.146*[f]	*400.764*[f]	*100.000*[g]	*501.146*[g]
2009	*1.102.102*[e]	*661.261*[f]	*440.841*[f]	*50.000*[g]	*611.261*[g]
2010	*1.212.312*[e]	*727.387*[f]	*484.925*[f]	*25.000*[g]	*702.387*[g]
2011	*1.333.543*[e]	*800.126*[f]	*533.417*[f]	*10.000*[g]	*790.126*[g]
2012	*1.466.898*[e]	*880.139*[f]	*586.759*[f]	*0*[g]	*880.139*[g]
2013	*1.613.587*[e]	*968.152*[f]	*645.435*[f]	*0*[g]	*968.152*[g]
2014	*1.774.946*[e]	*1.064.968*[f]	*709.978*[f]	*0*[g]	*1.064.968*[g]
2015	*1.952.441*[e]	*1.171.464*[f]	*780.976*[f]	*0*[g]	*1.171.464*[g]
2016	*2.147.685*[e]	*1.288.611*[f]	*859.074*[f]	*0*[g]	*1.288.611*[g]
2017	*2.362.453*[e]	*1.417.472*[f]	*944.981*[f]	*0*[g]	*1.417.472*[g]
2018	*2.598.699*[e]	*1.559.219*[f]	*1.039.479*[f]	*0*[g]	*1.559.219*[g]
2019	*2.858.568*[e]	*1.715.141*[f]	*1.143.427*[f]	*0*[g]	*1.715.141*[g]
2020	*3.144.425*[e]	*1.886.655*[f]	*1.257.770*[f]	*0*[g]	*1.886.655*[g]
Source	IDC	IDC	IDC	Customs	Customs

The numbers in black is data obtained from one of the indicated sources.
The numbers in italic are estimations.
The following assumptions were made:
a: The number of laptops was approximated; the number of desktops is equal to the difference of computers total and laptops
b: The assumption is that 1 CRT monitor is sold for every desktop computer
c: The number of LCDs was approximated; the number of CRTs is equal to the difference of desktops and LCDs
d: The number of computers sold in the first quarter of 2007 (IDC) was multiplied by four; The ratio of laptops to desktops is assumed as 35% to 65%, as in 2006
e: A 10% annual increase of the computer sales.
f: The numbers are based on the assumption that of the total amount of computsr sold, 60% are desktops and 40% laptops
g: The numbers are based on the assumption of a complete disappearance of CRTs until 2012; the number of LCDs is calculated from the difference of CRTs and desktops

[35] See: www.idc.cl
[36] See: www.aduana.cl

4.2.1.1 Assumptions made to complete the data set

As the set of historic data is not complete and future data had to be estimated, some assumptions were made. These shall be briefly discussed in the Table 4-2:

Table 4-2 Analysis of the assumptions used to complete the model input data

	Assumption	*Comments*	*Magnitude of the error*
a	The number of desktops is equal to the difference of computers in total and laptops.	Laptop have only been started to be used.	Very small
b	The assumption is that 1 CRT monitor is sold for every desktop computer.	This is an assumption made in various articles related to the estimation of computer waste. It should be relatively correct.	Small
c	The number of LCDs was approximated; the number of CRTs is equal to the difference of desktops and LCDs (thus: one monitor per desktop).	This should be fairly correct (The ratio of monitors to desktop computers changed however when LCDs prices lowered and a change in technology occurred.)	Very small
d	The number of computers sold in the first quarter of 2007 (IDC) was multiplied by four; The ratio of laptops to desktops is assumed as 35% to 65%, as in 2006.	This is also based on IDC predictions that computer sales will be higher than 900.000 in 2007.	Small
e	A 10% annual increase of the computer sales.	The IDC prediction for the year 2007 indicates that the extremely strong growth phase of the years 2004-2006 is temporarily at an end. However, the assumption is that the computer market will keep growing rapidly (around 10%) during until 2020. As a comparison: the average growth from 1994 to 2006 has been 21%.	Medium
f	The numbers are based on the assumption that of the total amount of computers sold, 60% are desktops and 40% laptops.	In 2006, the ratio of laptops to desktops was 35 to 65. This will probably reach the level of western states with a ratio of around 40 to 60 soon.	Small
g	The numbers are based on the assumption of a complete disappearance of CRTs until 2012; the number of LCDs is calculated from the difference of CRTs and desktops.	It is probable that CRT technology will be replaced by LCDs in the future, thus, the assumption is that in 5 years from now no more new CRT equipment is sold.	Medium

4.2.2 Usage times

The usage time of computer equipment in the individual processes of the model has been assessed through the questionnaire. For businesses, the weighted average of the results for small companies and big companies has been taken. Only insufficient data could be collected on the time computer equipment is stored after re-use (businesses and the government hardly dealt with used equipment and data from household questionnaires was insufficient). It was thus estimated that computer equipment is stored for two years if stored after re-use. Table 4-3 summarizes the usage times used in the model. More detailed results of the questionnaire may be found in Annex C.

Table 4-3 Usage times of computer equipment used in the processes of the model

Lifetime of computer equipment per process				
	Desktops	**Laptops**	**CRTs**	**LCDs**
Government	4	4	5	5
Business	4	4	5	5
Households	6	5	6	5
Re-use	3	3	4	4
Storage after 1st use	3	2	3	2
Storage after 2nd use	2	2	2	2

4.2.3 Transfer coefficients

In analogy to the usage times, the transfer coefficients were assessed through information gathered via compilation of the questionnaires and weighted averages for the process business were calculated. The transfer coefficients from production and sale stem from IDC sales data (CNC 2004). Only insufficient data could be collected on the fate of computer equipment after re-use. It was thus estimated, that half of the computer equipment is stored, while the other half is disposed of or recycled. See Table 4-4 for a summary of the transfer coefficients used in the model. The detailed results of the questionnaire can be found in Annex C.

Table 4-4 Summary of the transfer coefficients used in the model

Transfer coefficients for computer equipment in the model					
from	*to*	**Desktops**	**Laptops**	**CRTs**	**LCDs**
Production and sale	**Government**	10%	10%	10%	10%
	Business	55%	55%	55%	55%
	Households	35%	35%	35%	35%
Government	**Storage after 1st use**	0%	0%	0%	0%
	Re-use	100%	100%	100%	100%
	Disposal / Recycling	0%	0%	0%	0%
Business	**Storage after 1st use**	14%	19%	18%	12%
	Re-use	72%	77%	73%	78%
	Disposal / Recycling	14%	3%	9%	10%
Households	**Storage 1**	25%	0%	57%	0%
	Re-use	54%	71%	36%	86%
	Disposal / Recycling	21%	29%	7%	14%
Reuse	**Storage after 2nd use**	50%	50%	50%	50%
	Disposal / Recycling	50%	50%	50%	50%

4.3 Model validation

The concept of validating a model is to see in how far the predicted results reflect the reality. In order to do so, one has to find a set of data from another reliable investigation and compare it with calculated data of the model. In the case of this study, such data could be:

- Measurements of the flows in between processes (i.e. how much is flowing from governments to re-use or how much e-waste is generated)
- Measurements of the stocks of computer equipment in a process
- Measurement of the total life span of computer equipment (which is a function of the individual usage times and the transfer coefficients in the model)

Due to the general lack of data concerning the computer market and e-waste quantities it has been found difficult to validate the model.

The only data suitable to perform a validation that has been found is IDC data on the installed quantity of computers in households, businesses and the government for the years 1998 – 2003 (CNC and IDC 2002). This data has been compared with the quantities of computers (desktops and laptops) stocked in the respective model processes. See the following figure for the comparison of the two datasets:

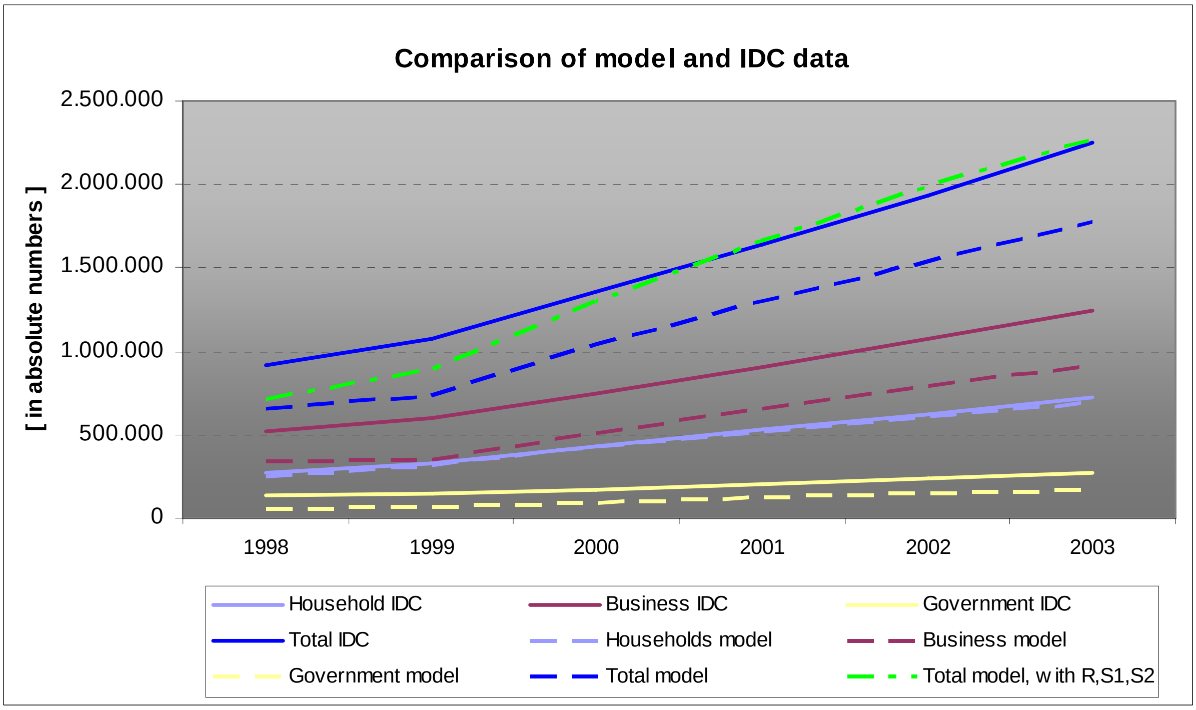

Figure 4-4 Comparison of model and IDC data for validation
(R = re-use, S1/S2 = Storage after 1st /2nd use)

The comparison shows a significant difference between model and IDC data with respect to the installed quantities of computers. The average difference was 3% for households, 31% for businesses and 46% for the government (see Table 4-5). The average difference in the total installed base of computers was 24% (blue lines).

These differences may be partly explained by the fact that in theory the installed base of computers may also include computers that are *re-used* or *stored* (which are accounted for separately in the model). The green line in Figure 2-1 represents the model data including re-use and storage. It can be observed that from the year 2000 on it fits well with the IDC data (with a maximum deviation from the IDC data is 4%). For the previous years, the stocks of re-use and storage have not been filled completely, as the model starts in 1994.

Since the model does not include separate re-use and storage processes, no data is available on how much is re-used and stored by households, businesses and the government. However, knowing that an important fraction of computers is stored and re-used by households, it appears that the model is overestimating the amount of computers installed in households. Following this line of thought, it seems obvious, that the model is underestimating the computer base installed in businesses and the government.

Table 4-5 Underestimation of the model relative to IDC data

	1998	1999	2000	2001	2002	2003	Average
Households	5%	4%	0%	1%	2%	4%	3%
Business	35%	42%	32%	27%	27%	27%	31%
Government	54%	56%	45%	40%	39%	38%	46%
Average difference (blue line)	29%	32%	23%	21%	20%	21%	24%
Average difference, with R,S1,S2* (green line)	22%	18%	4%	-2%	-3%	-1%	6%

*R = re-use, S1/S2 = Storage after 1st /2nd use

The conclusions may be summarized to the following:

- The model is underestimating the stocks of computers in businesses and government institutions.
- The model apparently provides a good estimation for the quantity of computers in households. However, considering that an important fraction of the computers in re-use are installed in households, the model is in fact overestimating the number of computers in households (for 1998-2003). This is probably due to the fact that a constant market share of households is assumed for the whole period of simulation (constant transfer coefficients). In reality the fraction of computers sold to households was lower in the 1990s than afterwards.
- The model makes precise predictions for the total installed base of computers in the market (including re-use and storage)

As a final word of caution, it shall be reminded, that both, part of the model data and the data for comparison are based on IDC data. No information is available on the quality of the IDC data.

4.4 Model scenarios

Four scenarios have been designed for the prediction of e-waste from computer equipment in Chile for the years 2007- 2020. The scenarios are described in the following. All parameters can be seen in detail in Annex D.

4.4.1 Scenario 1: from collected data

This scenario is based on the data sources presented previously in this study. The model inflow data is based on IDC data and the usage times and transfer coefficients are based on the questionnaire.

4.4.2 Scenario 2: from collected data with adjustments

Since the sample size of the questionnaires remains relatively small, the principal idea of this scenario is to make some adjustments that seem reasonable based on expert interviews and the experience gained while conducting the study.

One principal change has been i.e. the fraction of computer equipment that flows from government institutions to re-use, storage and recycling / disposal. The questionnaire data indicated that 100% of the equipment was given to re-use. However, other government sources estimated that this was not correct.

4.4.3 Scenario 3: best case

The best and the worst case scenarios are designed to find out what could be the maximum and the minimum e-waste generation from computer equipment in Chile during the next years.

The best case thus assumes a higher life span for computers (higher usage times) and flows of computer equipment to storage and re-use are favoured over flows to direct recycling / disposal. In addition to that, the growth of the computer market from 2008 – 2020 has been assumed to be 5% only.

4.4.4 Scenario 4: worst case

The worst case scenario assumes the opposite of the best case scenario, thus, shorter life span for computer equipment (shorter usage times in the processes), a preference of the flows to recycling / disposal and a growth of the computer market of 15%.

4.4.5 Summary of model scenarios

Table 4-6 summarizes the scenarios described previously:

Table 4-6 Summary of the model scenarios

Scenario	*Characterization*
1: from collected data	• data from literature review and questionnaire • 10% annual growth of computer sales
2: from collected data with adjustments	• data from literature review and questionnaire and some adjustments in the transfer coefficients and the useful lives based on expert opinion • 10% annual growth of computer sales
3: best case	• long useful lives • re-use and storage are preferred over direct disposal • 5% annual growth of computer sales
4: worst case	• short useful lives • direct disposal is preferred over re-use and storage • 15% annual growth of computer sales

5 RESULTS

5.1 E-waste generation

5.1.1 Scenario comparison

The results from the scenario analysis for the generation for e-waste in Chile from 1996 to 2020 are presented in Figure 5-1 (in weight) and Figure 5-2 (in numbers). The dashed lines represent computer sales for the same period of time.

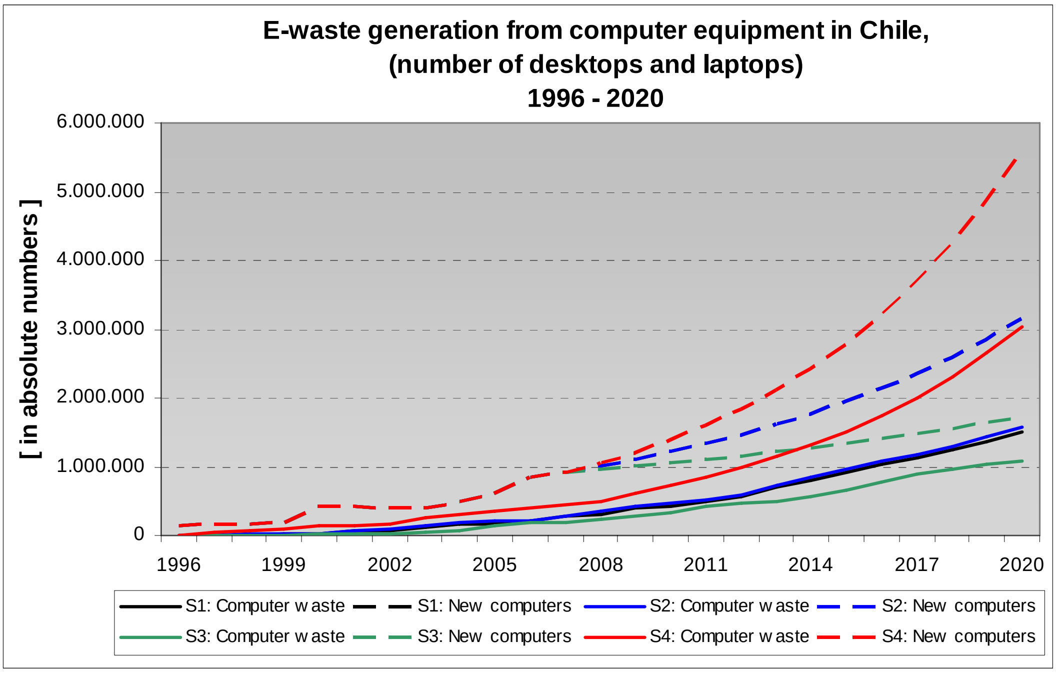

Figure 5-1 Computer waste generation in Chile, in numbers from 1996 – 2020

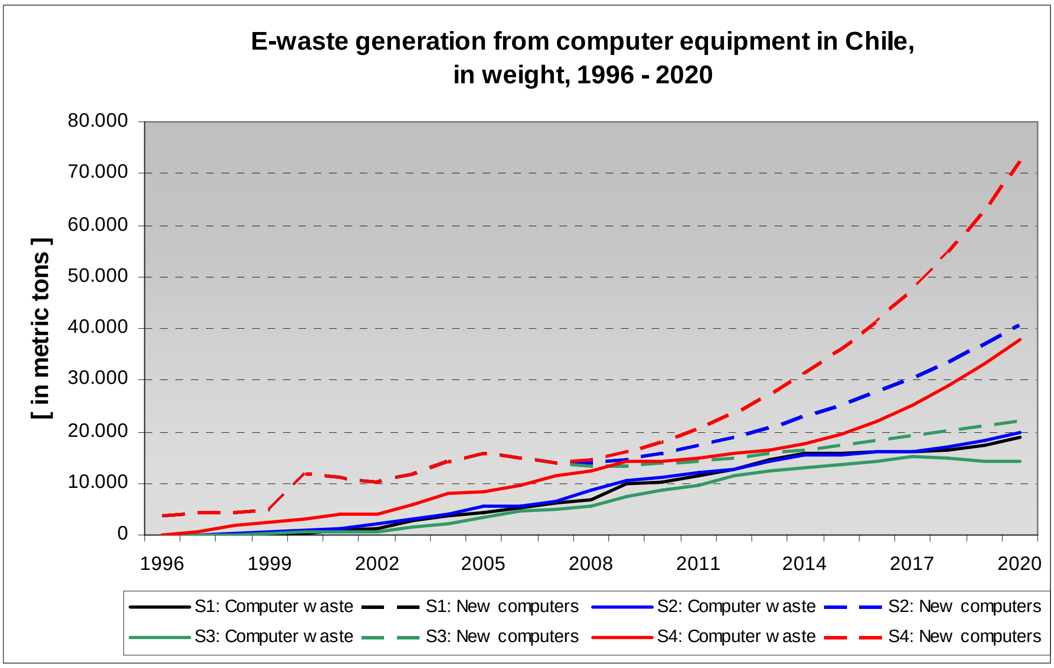

Figure 5-2 Computer waste generation in Chile, in tons from 1996 – 2020

The principal observations are the following:

- Scenario 1 and 2 are very similar to each other, thus the adjustments made in scenario 2 had only minor influence on the model predictions.
- The best case scenario (3) is quite similar to scenario 1 and 2. Only after 2018 the difference becomes more noticeable.
- The worst case scenario (4) shows significantly higher values for the whole time period.
- The life span of a computer is of critical importance: the smaller the life span, the faster e-waste is generated (this may be seen in the worst case scenario)
- The assumption on the growth of the computer market made for the years 2008 – 2020 is notable at the earliest during the year 2013 (when the first equipment sold in 2008 becomes waste). Until then, the prediction relies on historical data and the assumptions for the usage times and transfer coefficients.

As can be seen in Figure 5-3 below, according to the 4 scenarios, the total amount of e-waste generated from computer equipment for the years 1996 – 2020 varies between 173.000 and 332.000 tons. Of these amounts, only between 9-15% has been generated until the year 2006. Hence, 85-91% of the amount of e-waste will be produced during the years 2007 – 2020. The average prediction of the scenarios for generated quantity of computer waste for the years 2007 – 2020 is 206.744 tons. The average prediction for the amount of e-waste produced in 2007 is 7.291 tons.

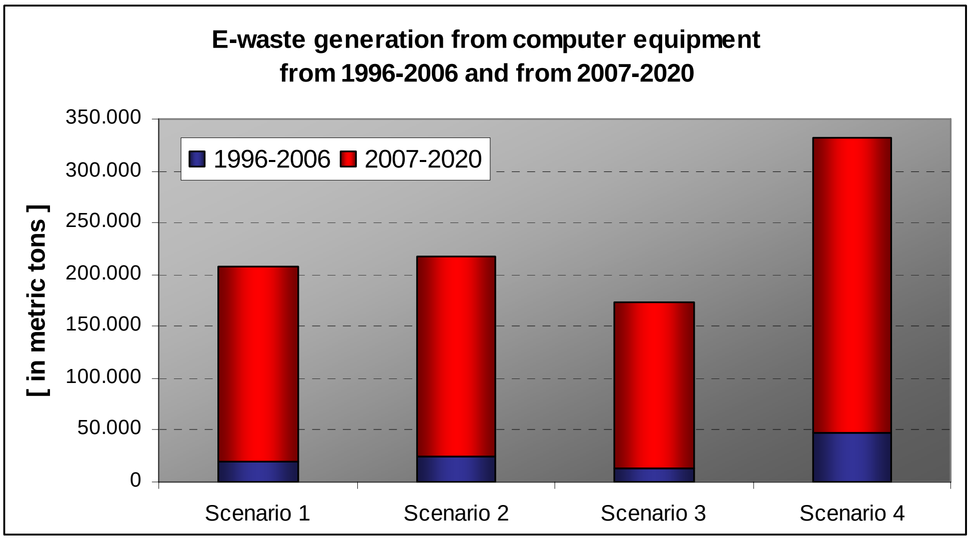

Figure 5-3 Computer waste generation, in tons, 1996 – 2006 and 2007 - 2020

5.1.2 Computer waste generation according to collected data

The following figures show the quantity of new computers entering the market and the generation of computer waste in absolute numbers and weight as a result of the data collected in this study (scenario 1). The most important observations are:

- In the figure illustrating the absolute numbers it can clearly be seen that computer waste is generated with a time-lag of approximately 7-8 years, which corresponds to the average life span of the equipment
- In the figure illustrating the quantities in weight this behaviour is not observable. The reason for that is the change in technology previously mentioned (from desktops to laptops and from CRTs to LCDs). As a consequence, the amount of computer waste does not increase significantly in terms of weight during the years 2014 – 2018.
- Yet, computer waste streams are growing fast, especially in the coming years. From 2008-2010 the average growth rate will be 20%. From 2007-2020 the mean growth rate will be an annual 10% for weight and 16% in absolute number.

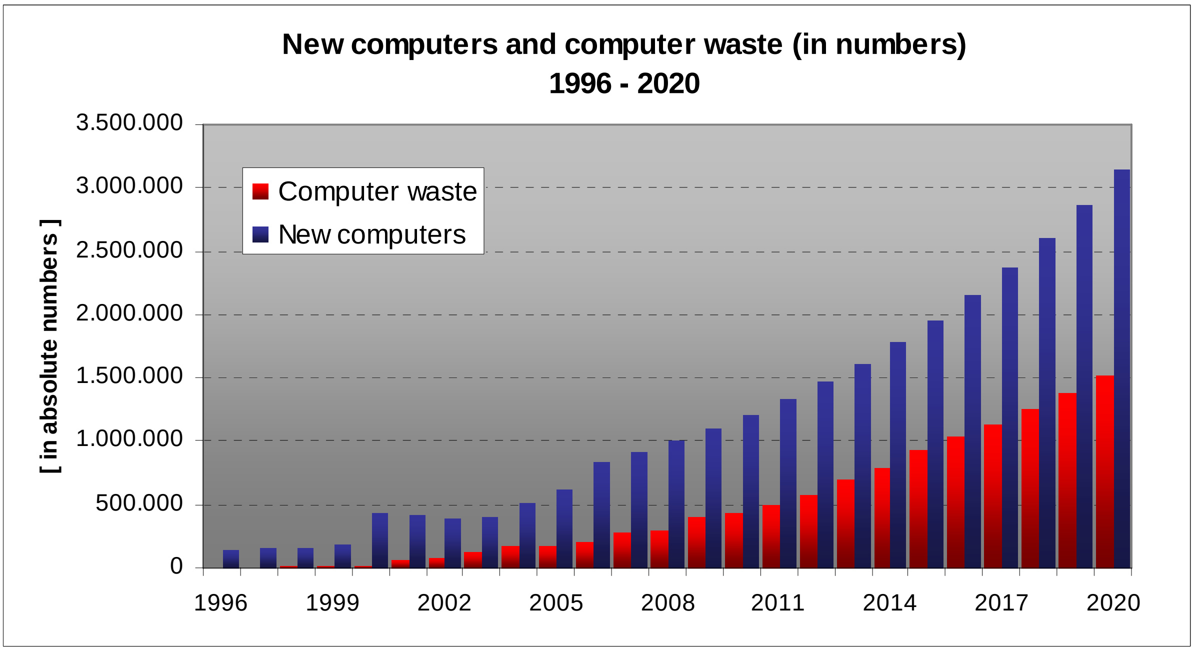

Figure 5-4 Computer waste generation in absolute numbers, from 1996 – 2020

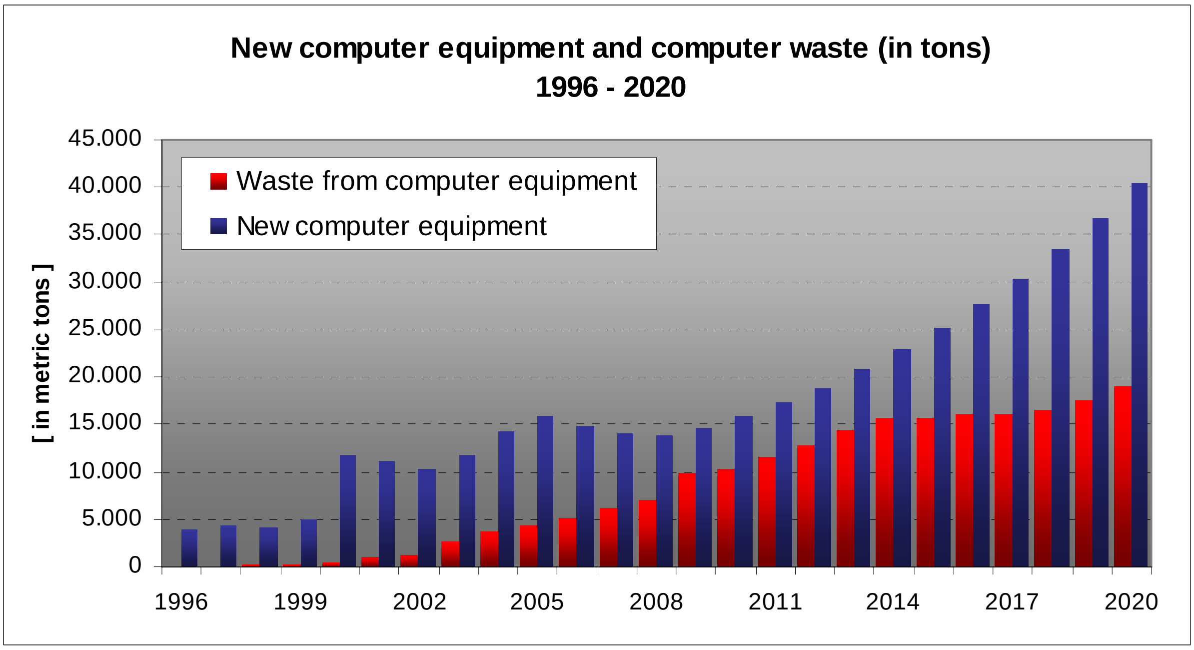

Figure 5-5 Computer waste generation in weight, from 1996 – 2020

5.1.3 Waste from desktops, laptops, CRTs and LCDs

Figure 5-6 and Figure 5-7 show the scenario 1 results for the composition of computer waste in Chile in quantities and weight. It can be seen how the change of technology in the computer market is reflected in the composition of computer waste. It may be observed, that laptops and LCDs are still negligible fractions of computer waste. However, from 2010 on, they will constitute increasingly important streams of waste. Today, both desktops and CRTs make up about half of the waste stream.

Another observation is that the importance of desktop computers for the waste streams (in weight) will continue to increase. In 2020, desktop computers comprise around two thirds of computer waste in terms of weight.

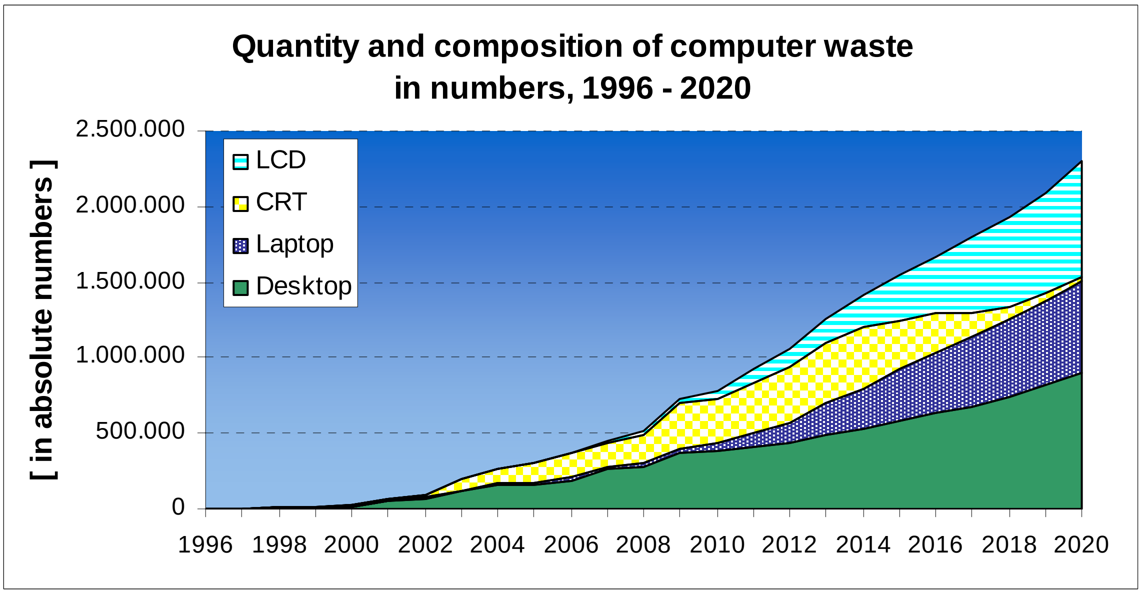

Figure 5-6 Quantities and type of computer waste, in numbers from 1996 – 2020

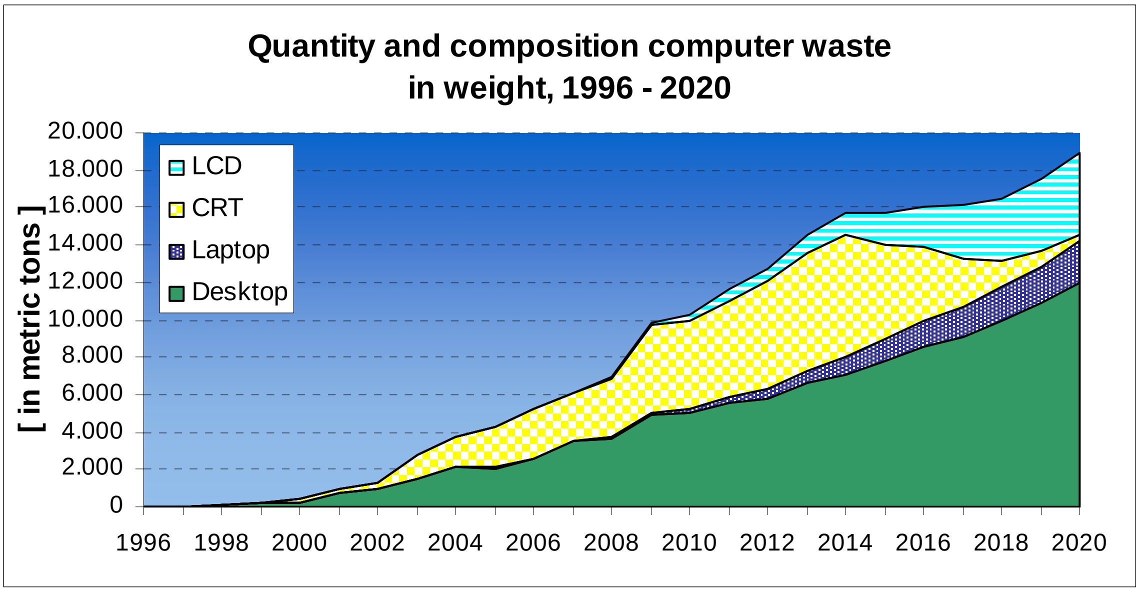

Figure 5-7 Quantities and type of computer waste, in weight from 1996 – 2020

5.1.4 Importance of the individual flows

The importance of the individual flows of computers in the Chilean market has been analyzed and is presented in the following (for scenario 2)[37]:

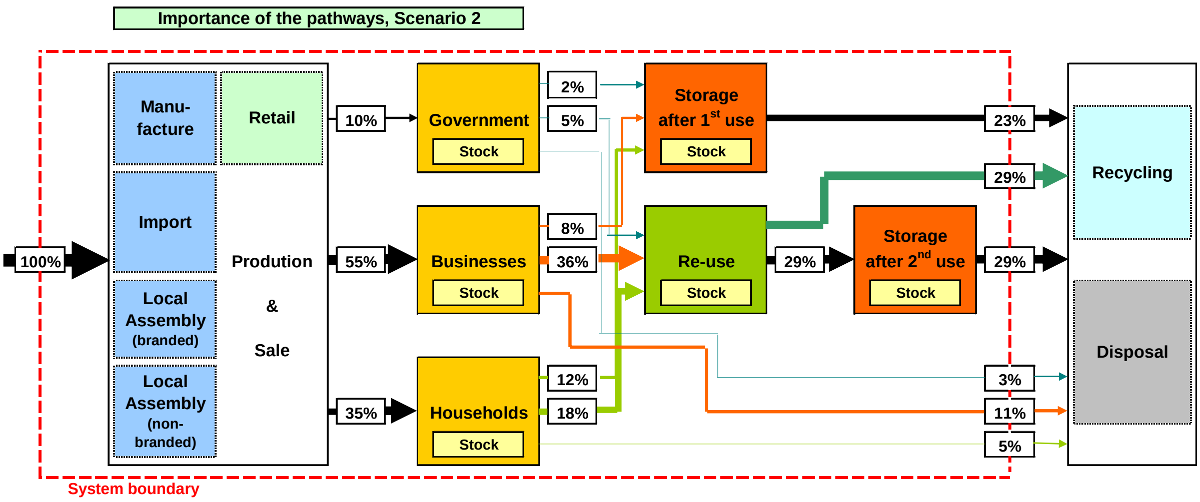

Figure 5-8 Importance of the individual flows in the model for scenario 2

It can be observed that the most important flows of computer equipment in the consumption phase are to re-use (36% from businesses and 18% from households). Together, 58% of the computers are being re-used, 23% are being stored and only 19% are being disposed of directly (see Table 5-1).

Table 5-1 Fate of obsolete computer equipment after 1st use

Fate of computer equipment after 1st use	*in %*
Storage	23%
Re-use	58%
Recycling / disposal	19%

[37] scenario 2 has been chosen due to the "zero flows" to storage and recycling / disposal from the government in scenario 1, see the assumptions for scenario 2

Total	100%

This implies at the same time that only 42% of the computers are disposed by the same person that has purchased the new computer.

5.1.5 Computer waste flows in Chile in 2007

A “snapshot” of the computer flows in tons is presented for the year 2007 in Figure 5-9 (for scenario 2). In total, 13.955 tons flow into the market, 4360 are being stored (including storage after 2nd use), 6092 tons go into re-use and 6566 to recycling and disposal.

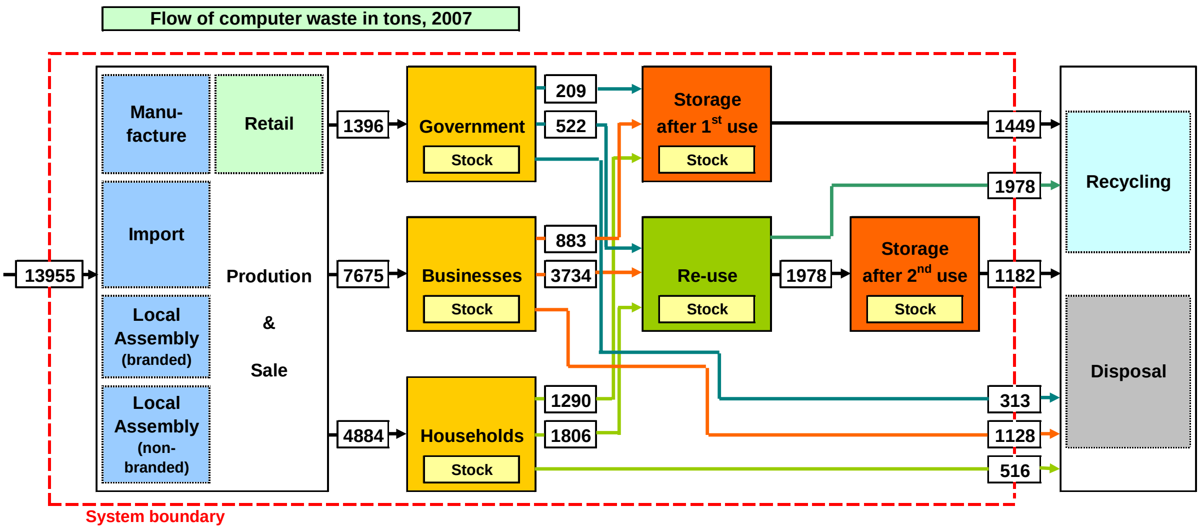

Figure 5-9 Flows of computer waste during the year 2007 in tons according to scenario 2

5.2 Comparison of the MFA model with a simple model

A simple model has been taken and results have been compared with the MFA results in order to see the quality of predictions that can be made with simpler methods.

In the simple model, *only* a life span for computer equipment is assumed. The hypothesis is that computer equipment becomes waste after this life span. Since it is the only variable of the model, production and sales data are simply shifted for the period of the life span.

See Figure 5-10 and Figure 5-11 for the comparison in terms of number and weight between scenario 1 and the simple model results for life spans of 5 and 7 years:

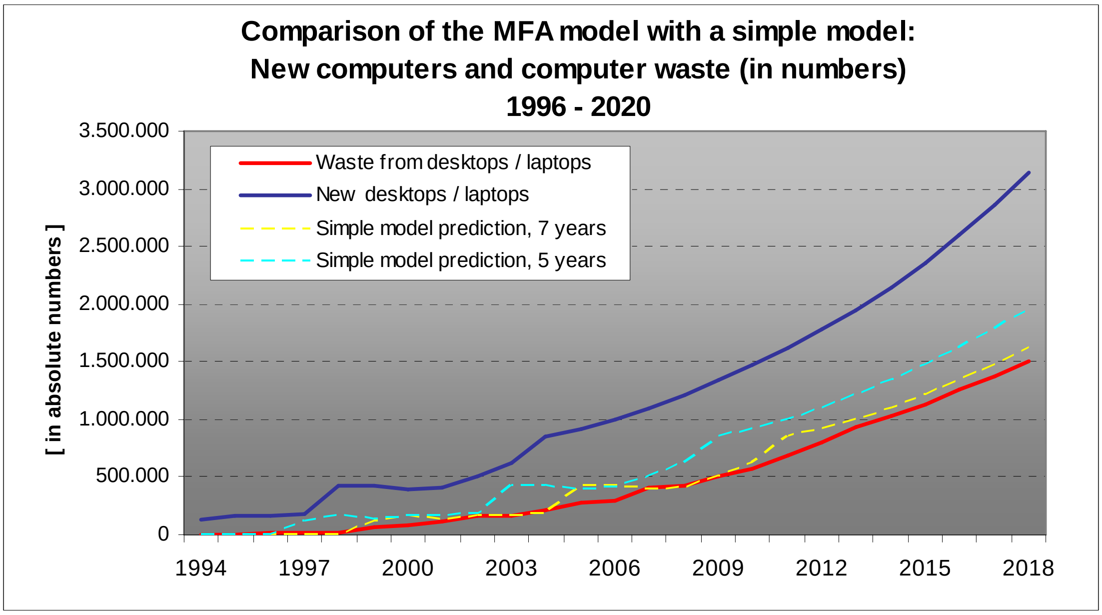

Figure 5-10 Comparison of simple model and MFA data, absolute numbers

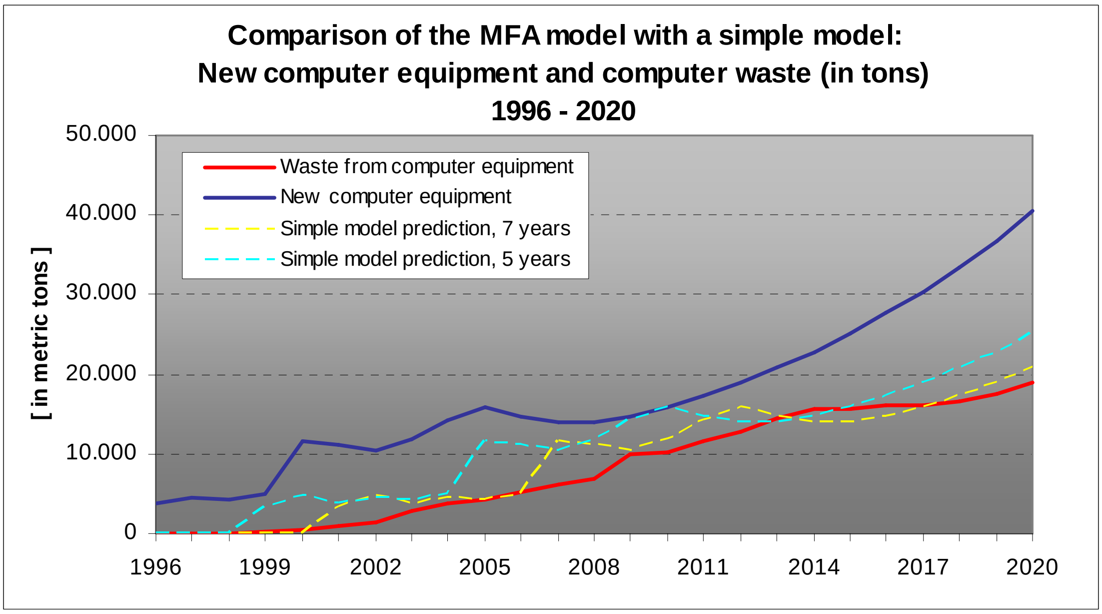

Figure 5-11 Comparison of simple model and MFA data, weight

Some observations can be made with respect to the simple model prediction:

1) **In the 7 year case** the simple model produced similar predictions as the MFA model in terms of the absolute numbers, but less precise predictions with respect to the quantities in weight (the general trend remains the same, but individual data points differ significantly)
2) **In the 5 year case**, the estimation differed drastically from the scenario 1 prediction, in both numbers and weight

It may be concluded from the above, that the simple estimation method is – at least for a quick estimation – an interesting tool to make estimations about the number of obsolete computer equipment. At the same time it is less useful to estimate computer waste quantities in terms of weight. This is due to the fact that the model incorporates less information about the consumers (i.e. specific usage times for desktops, laptops, CRTs and LCDs in each process).

Nevertheless, the simple model makes useful predictions only if a good estimation for the life span of computer equipment is available, as can be seen by the 5 year case. In this study, such information was not available in the beginning and expert opinion varied significantly (somewhere between 4 and 12 years). One of the mayor achievements of the MFA model is thus the prediction of an overall life span for computer equipment due to a detailed analysis of the market.

5.3 Life span of computer equipment

The average life span of computer equipment in the model can be calculated as a function of the transfer coefficients and the usage time.

Table 5-2 presents the average life span of computer equipment for scenario 1 and 2:

Table 5-2 Average life span of computer equipment in years according to scenario 1 and 2

Average life span	*Desktops*	*Laptops*	*CRTs*	*LCDs*
Scenario 1	8,1	7,5	9,0	9,2
Scenario 2	7,7	7,7	8,7	9,0

Desktops and laptops are thus currently used for approximately 8 years and CRTs and LCDs for 9 years.

5.4 Computer recycling quota in 2007

In order to estimate the fraction of computer waste that is currently recycled in Chile, the following calculation has been made:

The total amount of recycled computer equipment (as estimated in section 2.5.3.4) is 193 tons (or 113 tons if one were to exclude Carrascal for its recycling practices). The total amounts of computer waste generated in 2007 are calculated through the MFA model. The computer recycling quota of computer waste in Chile in 2007 is thus between 1.7 and 3.1% (see Table 5-3).

Table 5-3 Recycling quota for computer waste in 2007

[in tons]	Computer waste generation	Recycled computer waste	Recycled without Carrascal	Recycling quota	Recycling quota without Carrascal
Scenario 1	6.131	193	113	3.1%	1.8%
Scenario 2	6.566	193	113	2.9%	1.7%

5.5 Who buys is not who disposes

It is fundamental to know *who is disposing how much* in order to find appropriate solutions for the e-waste problem in Chile. As it has been shown previously, a high amount of computer equipment is re-used. At the same time, government institutions and big companies hardly install used equipment. Most of the equipment is thus re-used – and finally disposed of – by small companies and households.

In order to quantify who is disposing how much, an assumption had to be made regarding the re-use of computer equipment. Based on expert opinion, it was assumed that 40% of the computer equipment is re-used by small companies and 60% by households[38]. A calculation for the relative shares at the time of purchase and at the time of disposal of computer equipment is presented in the following figure:

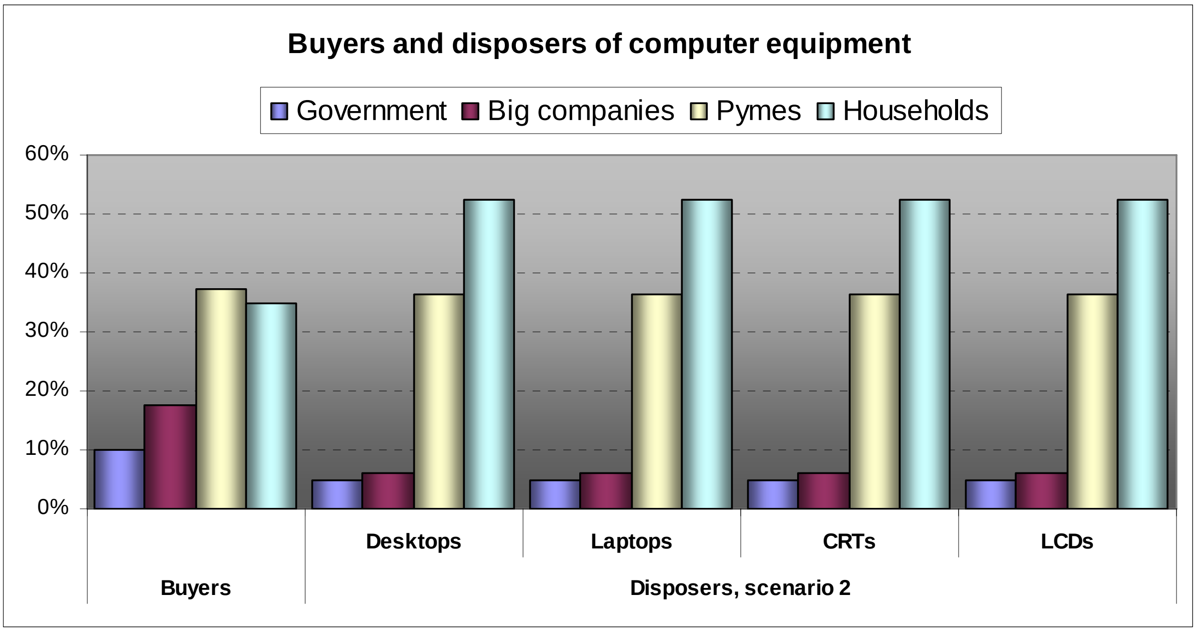

Figure 5-12 Buyers and disposer of computer equipment (in numbers)

It can clearly be observed that the buyers of computer equipment are not necessarily the same as the disposers. Instead, there is a net flow from government institutions and companies to households. As a result, households dispose with approximately 50% the biggest fraction of computer equipment. Households and small companies together dispose almost 90% percent of all computers. This observation is of high importance when it comes to the question of how to tackle the e-waste problem in Chile.

[38] Various expert estimations (i.e. from Biobio and San Diego)

5.6 Material recovery from computer waste

The following table provides an idea of how much material could be recovered from computer waste from 2007 to 2020. The calculation is based on the cumulative amounts of computer waste according to scenario 2 and the relative contents of computer equipment according to a SWICO analysis (SWICO 2006)[39].

Table 5-4 Possible material recovery from computer waste, 2007-2020

[in tons]	*Desktop*	*Laptop*	*CRTs*	*LCDs*	*Total*
Metals	85.061	5.325	4.514	8.871	*103.770*
Plastics	6.380	3.062	18.055	8.131	*35.628*
Metal-plastic mixtures	1.063	1.730	1.003	0	*3.797*
Cables	2.127	133	0	0	*2.260*
Circuit boards	10.633	1.464	0	1.971	*14.068*
Pollutants	1.063	1.065	0	0	*2.128*
Glas	0	532	26.581	5.667	*32.781*

Source: Analysis of computer composition (SWICO 2006)

The following table shows a more detailed analysis of some selected metals and pollutants contained in waste from desktops and CRTs in Chile from 2007 – 2020.[40]

Table 5-5 Selected metals and pollutants contained in desktop and CRT waste, 2007-2020

Substances	*Percentage contained in an average desktop computer with a CRT monitor*	*in tons*	*in US$ / ton**	*Value in million US$*
Metals				
Iron	*20,47%*	*32031*	*?*	*?*
Aluminum	*14,17%*	*22173*	*2.849*	*63*
Zinc	*2,20%*	*3443*	*3.772*	*13*
Copper	*6,93%*	*10842*	*8.050*	*87*
Gold	*0,0016%*	*2,5*	*21.801*	*55*
Pollutants				
Lead	*6,30%*	*9856*		
Mercury	*0,0022%*	*3,4*		
Cadmium	*0,0094%*	*14,7*		
Arsenic	*0,0013%*	*2,0*		
			Total:	*241*

Source: (Microelectronics and Computer Technology Corporation 1996),
see also : http://ewasteguide.info/valuable_materials_in_e_waste
* based on metal prices as of July 2007, see http://www.n-tv.de/rohstoffe and http://www.metalprices.com/

It is thus obvious that advancing the recycling infrastructure does not only represent a step towards more sound environmental practices, but also a step towards material efficiency. Depending on the costs for the appropriate treatment of the pollutants, e-waste recycling may even be a business opportunity.

[39] see Annex F for the average composition of computer equipment
[40] These numbers should be seen as an approximation for two reasons: first it is unclear how the composition of computer equipment will change in the future; second, metal prices may vary significantly.

6 DISCUSSION

6.1 Data collection and quality

6.1.1 Literature

Data that has been collected by literature research appears to be quite reliable, especially the qualitative information on various actors, i.e. on the environmental authorities.

The principal sources for quantitative data were the International Data Corporation and the Chilean Customs Office. It appears thus to be reliable data, although it is unknown how carefully these institutions have been collecting their data.

6.1.2 Questionnaire

With respect to working with the *questionnaire* it may be concluded that it is an interesting method as it reveals detailed results for many aspects concerning the computer market. It is thus a good way to come up with *new* data, which may not be available otherwise.

The principal disadvantages were found to be:

- **It is labour intensive**: an important fraction of the time of research has been used to develop, test and send the questionnaires to the various actors. Additional time was necessary for follow up and evaluating if the questionnaires were filled out correctly
- **It requires a representative sample size**: In order to obtain results that are representative, the sample has to include all relevant social classes (households) or all relevant sectors (industry). Moreover, the sample size should be higher than in this study. However, this involves a significant investment in time
- **The responders may not understand**: Another difficulty encountered was that the questions were not understood by all the interviewed persons. As questionnaire was generally felt to be easy to fill by the responsible persons in the institutions, private persons often had difficulties in understanding some of the questions (i.e. non-branded local assembly). A questionnaire assessing consumer behaviour of households may thus not be able to include the same technical questions.
- **The responder may not like admit certain aspects**: This has been true i.e. with respect to the question of how institutions disposed of their equipment. Even though the questionnaire was treated anonymously, it may be supposed that some actors did not want to admit their practices regarding e-waste disposal.

The data collected with the help of the questionnaire in this study should thus be considered of rather indicative value. Nevertheless, it is believed, that the combined assessment of questionnaire data and expert interviews yielded fairly reliable and useful information for a preliminary investigation.

6.1.3 Interviews

The interviews were found extremely useful for this study for the following reasons:

- Interviews were an efficient way to gather information from experts that had considerable experience in their area

- Questionnaire data validation could be done with the help of expert opinion
- Interview persons often opened up new contacts and contributed to this study with their ideas

A side effect of the interview was furthermore, that awareness was raised to some degree for the issue of e-waste recycling (i.e. with the environmental authorities).

However, not all data from personal interviews appeared to be very precise. Some data was simply not available or not available with a high precision and the interviewed persons were estimating or guessing (i.e. the quantities of recycled computer waste rely on estimations by the recycling companies).

6.2 Model

Material flow analysis has previously been used in similar studies to estimate e-waste quantities and is therefore an established method. As shown in the results, powerful insight may be gained into the functioning of the computer market and detailed analysis of the individual components can be performed. At the same time, the reliability of the model results depends on the quality of the model assumptions and the available data.

6.2.1 Quality of the assumptions and weaknesses of the model

Even though the model provides a powerful tool for the analysis of the computer market it relies on certain assumptions that may not reflect reality.

The principal assumptions are:

- *The model itself*:
  The most fundamental assumption is the design of the model itself – the processes and the connecting flows. A comparison of several models would have to be made and data for appropriate validation would be necessary in order to evaluate if the model represents the market correctly. As very similar models have been used in previous studies, it has not been investigated how a different model would affect the results (apart from the simple model).
  .
- *Constant usage times*:
  Computer life spans have generally decreased in recent years[41], nevertheless it remained unclear whether this was true for Chile as well, as it is still a developing country. The usage times for the whole simulation period were thus kept constant.

- *Constant transfer coefficients*:
  The same applies for the transfer coefficient, although it is even less probable that they remained constant. A good example is the fraction of computers that is bought by households. The computer producers stated that in the early 1990s computers were mainly sold to institutions, whereas today private individuals play a much more important role.

As to the influence of usage times and transfer coefficients, model tests showed that the general influence of the usage times was significantly greater than of the transfer coefficients.

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[41] See i.e. (Kang and Schoenung 2006)

One obvious weakness of the model is that it does not clearly show the quantities of computers installed in government institutions, businesses and households. This is due to the fact that some of the equipment installed in these is in the process of re-use, which does not distinguish between the actors.

However, if the model was designed in a way that the process re-use did not stock equipment but instead returned it to the actors, information on how much equipment is in re-use at a given point in time would be lost. It remains thus a trade-off unless a more complex model was to be developed (i.e. with 3 separate processes for re-use).

6.2.2 Comparison with the simple model

The comparison with the simple model showed that, to a certain degree, similar results may potentially be obtained with less sophisticated models. Since there was no data available for a true validation, no information is available on how far either of the models differs from reality. Nevertheless, it might be worth to do some further research in order to see how far the model used in this study could be simplified without a significant loss of precision.

6.2.3 Quality of the predictions

As to the certainty of the predictions made in this study it appears that the MFA model makes fairly reliable predictions. While it is true that data validation could only be done to a limited extent, the scenarios provide an idea of how a best and a worst case may look like. With respect to the worst case it should be considered that the life spans were assumed to be quite short. It is thus likely that in reality the actual and future computer waste streams are closer to scenario 1-3.

Furthermore, even if the quantitative data is not absolutely precise, the accuracy should largely satisfy the purpose of the study, which is to understand the magnitude of the e-waste problem in Chile.

7 CONCLUSIONS AND RECOMMENDATIONS

What is the actual and future e-waste generation?

At the same time that the ICT market is booming in Chile, computer waste streams will grow at an alarming rate of 10% during the next decade – twice as fast as municipal waste streams. As the model predictions show, over 300.000 desktops and laptops become e-waste in 2007. This is yet to increase considerably to 1.7 million computers per year in 2020.

In terms of weight – due to a change in technology towards lighter equipment – the amount of computer waste will merely triple from 7.000 tons in 2007 to 20.000 tons in 2020. The cumulative computer waste generation up to 2006 has been about 25.000 tons. This appears to be almost negligible compared to with the approximately 215.000 tons that will be generated from now to the year 2020. Furthermore, as computer equipment only represents a fraction of e-waste, the real problems still lay ahead.

What happens to computer waste?

Although the overall management of e-waste is still under-developed, some important changes have recently taken place in Chile. First of all, non-profit refurbishing, such as done by Todo Chilenter, has provided a socially and environmentally responsible alternative for obsolete computers from public and private institutions.

Secondly, formal recycling companies with environmental standards and authorizations have been established. While this represents an important step in the right direction, the actual difference between formal and informal recyclers still remains small. Meanwhile, there is a striking difference of cost between formal and informal recycling. This suggests that a cost analysis should be conducted in order to make proper recycling more competitive and thus more attractive. In 2007, only 1.5 to 3 percent of the generated computer waste will be recycled appropriately.

At the same time, 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, the final destination of the hazardous substances contained in computer equipment has not been revealed with certainty. It is assumed that in the best case it ends up in the municipal waste stream as does an important fraction of obsolete household computers. Needless to say this presents an unsustainable situation with respect to public and environmental health.

How can the e-waste problem be solved?

First of all, further research has to be done in order to shed light onto the actual fate of WEEE and its associated environmental damage. Solutions will have to be found to deal with computer waste from households, which currently represents the biggest e-waste stream or about 60% of the total quantity. Thus, environmental education and the establishment of a convenient recycling infrastructure will play a key role in the achievement of better recycling quotas.

Most importantly, 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 their share of responsibility and participate actively in this process, especially due to their international experience with EPR. Furthermore, other related public and social actors, such as the Sub-secretariat for Telecommunications and the Digital Agenda will have to become active. After all, sustainable development in the information age can only be achieved if obsolete ICT products are managed responsibly.

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ANNEXES

A INTERVIEWS

Table A1 Interviews conducted during this study

Person	*Institution*	*Purpose*
COMPUTER PRODUCERS		
Axel Heilenkotter	Hewlett Packard	Gather information on the computer market and corporate environmental responsibility
Christian Alvarez	IBM	
Sandra Olguin	Olidata	
GOVERNMENT		
Eduardo Carter	Comisión Nacional de Energía	Collect questionare data and other information
Pablo Quintana	Comisión Nacional del Medio Ambiente	
COMPANIES		
César Maldonado	AES Gener S.A.	Collect questionare data and other information
Roberto Giadach	Consorcio Nacional de Seguros	
Gregorio Guerrero	Nestlé	
REFURBISHERS		
Rubén Martínez Muñoz	Todo Chilenter	Learn about non-profit refurbishing
Anonymos	Latin Computer Chile Ltda	Collect information about refurbishing and local non-branded assembly
Anonymos	CSByte	
Hector Herrera	Servicio Tecnico	
Oscar Torres	Servicio Tecnico	
Anonymos	Other servicio tecnicos	
Anonymos	Refly Chile Ltda	
RECYCLERS		
Sr. Gastón Herrera	Carrascal	Collect information about the situation regarding e-waste recycling
Mitzy Lagos	Comec	
Gabriele Perez Juan Carlos Perez	Degraf	
Juan Sequel	Punto limpio Vitacura	
Fernando Nilo	Recycla	
OTHER INSTITUTIONS		
Raúl Ciudad Verena Fuhrmann	ACTI	Gather information on ACTI / establish contact to companies for questionnaires
Joost Meijer Claudia Guerrero	Comisión Nacional del Medio Ambiente	Collect information on CONAMA and the e-waste situation
Paola Angel	Comisión Regional del Medio Ambiente	Collect information on COREMA and the e-waste situation
Wilfred Adelsdorfer Velasco	Aduana	Collect data on the import of computer equipment
Elke Hüttner Alvaro Zurita	GTZ	Gather information on recycling in general

B QUESTIONNAIRE

Figure B.1 The questionnaire used in this study

Questionnaire

General questions	check	Definitions and notes
		Please check the boxes with an X.
1 Did you know, that computers are toxic waste in the environment?		Computers contain lead, mercury, cadmium and other heavy metals, as well as toxic flame retardands such as PCB Their import/export is controlled in many countries du to this reason, according to the Basel Convention
a YES	☐	
b NO	☐	
2 Did you know, that some computer parts can be profitably recycled?		
a YES	☐	Computers contain valuable materials, such as gold, silver, copper and some plastics.
b NO	☐	
3 Does your institution/department have a procedure to deal with electronic waste?		*Please answer for your institution if you can, otherwise for your department*
a YES	☐	
b NO	☐	
4 If not, does your company have the intention of introducing a policy for electronic waste?		
a YES	☐	
b NO	☐	

Computer stock	Number	Definitions and notes
5 How many personal computers does your institution/department possess? (desktop and laptop computers)	☐	*Please answer for your institution if you can, otherwise for your department*
6 How many of them are *not* in use?	☐	Amount of computers stored or waiting for disposal/recycling
7 How many of the computers in use are	or %	
a desktop computers?	☐	It is important information since the weight and (toxic) materials differ much between the type of equipment, *i.e. PC vs notebook*
b notebooks?	☐	
8 How many monitors are	or %	
a traditional monitors? (CRT)	☐	CRT means *cathode ray tube* (the same as in a television)
b flatscreen monitors? (LCD)	☐	LCD means *liquid cristal display*

1st, 2nd use or leasing	Please indicate names	in %	Definitions and notes
9 How much of the equipment was purchased *new*?			1st use of the equipment
a desktop computers?		☐ %	
b notebooks?		☐ %	

c traditional monitors? (CRT) %
d flatscreen monitors? (LCD) %

10 **How much of the equipment was purchased *used* ?**
a desktop computers? %
b notebooks? %
c traditional monitors? (CRT) %
d flatscreen monitors? (LCD) %

2nd use or re-use

11 **Where is *used equipment* mainly purchased?**
(Please indicate type and name of the principal sources)

Please help us to understand the market better and indicate, where you purchase equipment
i.e. Refly

12 **How much of the equipment is *leased* ?**
a desktop computers? %
b notebooks? %
c traditional monitors? (CRT) %
d flatscreen monitors? (LCD) %

Definition = computers belong to an external provider that does maintenance and renewal of equipment as a service

13 **Where is equipment mainly *leased* ?**
(Please indicate type and name of the principal sources)

Please help us to identify who are important actors in the market, that may be included in future recycling initiatives.

Origin of *new* equipment	**Please indicate brand**	**in %**	***Definitions and notes***

14 **Origin of desktop computers?**
a Direct import of international brand %
b Via retail, international brand %
c Local assembler *with own brand* %
d Local assembler *without own brand* %

15 **Origin of notebooks? ***
a Direct import of international brand %
b Via retail, international brand %
c Local assembler *with own brand* %
d Local assembler *without own brand* %

16 **Origin of traditional monitors? (CRT) ***
a Direct import of international brand %
b Via retail, international brand %
c Local assembler *with own brand* %
d Local assembler *without own brand* %

Importer: International companies produce abroad and sell their imported computers directly to their costumers
i.e. IBM, Dell, HP

Retailer: A shop or store that buys from manufacturers or importers and sells to the consumer
i.e. Olidata, Falabella, Ripley

Local Assembler: Computers are assembled (from imported parts) in Chile, the assembler has its own brand
i.e. Cibertec

Local assembler, non branded: Assembly of imported parts, but small scale, without brand; garage store

* if the origin is the same as for other equipment, just fill in "*see ...*" (i.e. "*see desktop computers*")

17 **Origin of <u>flatscreen monitors</u>? (LCD) ***
- a Direct import of international brand — %
- b Via retail, international brand — %
- c Local assembler *with own brand* — %
- d Local assembler *without own brand* — %

Life time	in years	Definitions and notes
		refreshment cycle = vida útil
18 **What is the average refreshment of *new* equipment?**		1st use of the equipment
a desktop computers?		
b notebooks?		
c traditional monitors? (CRT)		
d flatscreen monitors? (LCD)		
19 **What is the average life time of *used* equipment?**		2nd use or re-use
a desktop computers?		
b notebooks?		
c traditional monitors? (CRT)		
d flatscreen monitors? (LCD)		
20 **What is the average refreshment cycle of *leased* equipment?**		Leasing
a desktop computers?		
b notebooks?		
c traditional monitors? (CRT)		
d flatscreen monitors? (LCD)		

Obsolete equipment	Please indicate who receives the equipment	in %	Definitions and notes
21 **What happenes with obsolete <u>desktop computers</u>?**			
a We *guard/store* them		%	i.e. the IT department stores them and uses computer parts
b We *sell* them		%	i.e. sold to another company or to employees
c We *throw them out*		%	i.e. landfilled
d We give them to a *recycler*		%	i.e. to a company that wipes out data and recycles properly
e We *donate* them to schools and other non-profits		%	i.e. to schools and other non-profits
f Olther		%	
22 **What happenes with obsolete <u>notebooks</u>? ***			* *if the destination of the equipment is the same, just fill in "see ..." (i.e. "see desktop computers")*
a We *guard/store* them		%	
b We *sell* them		%	

c We *throw them out* %
d We give them to a *recycler* %
e We *donate* them to schools and other non-profits %
f Olther %

23 **What happenes with obsolete <u>CRT monitors</u>? ***
a We *guard/store* them %
b We *sell* them %
c We *throw them out* %
d We give them to a *recycler* %
e We *donate* them to schools and other non-profits %
f Olther %

24 **What happenes with obsolete <u>LCD monitors</u>? ***
a We *guard/store* them %
b We *sell* them %
c We *throw them out* %
d We give them to a *recycler* %
e We *donate* them to schools and other non-profits %
f Olther %

25 **If equipment is *stored* after its use, please indicate for *how long* at average** in years
a desktop computers?
b notebooks?
c traditional monitors? (CRT)
d flatscreen monitors? (LCD)

It is quite common that computers are stored for some years, before they are re-used or become waste. This delay is an important element in the prediction of future amounts of e-waste.

Information about the Institution	check	*Definitions and notes*

26 **Name and address of the institution**

27 **Please indicate a contact person**
Name:
Phone:
Email:

28 **Type of Institution**
a Government
b NGO
c Company

29 **Principal activity of the institution**

30 **Number of employees of the institution/department**

31 **Is your institution ISO 14001 certified?**
- a YES
- b NO

In you opinion	check	*Definitions and notes*

32 **Would your institution be ready to pay to ensure proper recycling?**
- a YES
- b NO

33 **What is the most important obstacle to proper recycling of computers?**
- a Costs
- b Lacking procedures within the institution
- c Absence of recycling possibilities
- d Lacking legislation
- f Olther

34 **What should be done to foster e-waste recycling in Chile?**
- a Don't know
- b Please indicate

Your ideas are very important to us!

C QUESTIONNAIRE RESULTS

Table C1 Overview of Annex C

The following is consolidated here	The following groups are analyzed	Number analyzed
Type of equipment in use	Government institutions	2
Acquisition of the equipment: new, used or leased	Big companies	5
Origin of the equipment: import, retail, local assembly	PYMES	14
Lifespan of computer equipment within the institution	PYMES (ACTI)	9
Average storage time in years, if stored	PYMES (non-ACTI)	5
Fate of obsolete computational equipment	Households	22

Table C2 Type of computer equipment in use

Type of computer equipment in use	Desktops	Laptops	CRTs	LCDs
Government	96%	4%	76%	24%
Big companies	69%	31%	71%	29%
PYMES	71%	29%	77%	23%
PYMES (ACTI)	73%	28%	80%	20%
PYMES (non-ACTI)	61%	39%	57%	43%
Households	67%	33%	77%	23%

Table C3 Acquisition of computer equipment

Acquisition of computer equipment: new, used or leased	Desktops	Laptops	CRTs	LCDs	
new	100%	100%	100%	100%	
used	0%	0%	0%	0%	**Government**
leasing	0%	0%	0%	0%	
new	66%	60%	66%	66%	
used	0%	0%	0%	0%	**Big companies**
leasing	34%	40%	34%	34%	
new	91%	88%	94%	92%	
used	2%	3%	6%	0%	**PYMES**
leasing	7%	9%	0%	8%	
new	86%	88%	90%	89%	
used	3%	0%	10%	0%	**PYMES (ACTI)**
leasing	11%	13%	0%	11%	
new	100%	89%	100%	100%	
used	0%	9%	0%	0%	**PYMES (non-ACTI)**
leasing	0%	2%	0%	0%	
new	66%	86%	57%	100%	**Households**
used	34%	14%	43%	0%	

Table C4 Origin of computer equipment

Origin of computer equipment: import, retail, local assembly	Desktops	Laptops	CRTs	LCDs	
import	100%	100%	100%	100%	Government
retail	0%	0%	0%	0%	
branded local assembly	0%	0%	0%	0%	
non-branded local assembly	0%	0%	0%	0%	
import	80%	100%	100%	92%	Big companies
retail	0%	0%	0%	8%	
branded local assembly	0%	0%	0%	0%	
non-branded local assembly	20%	0%	0%	0%	
import	37%	58%	33%	43%	PYMES
retail	30%	42%	58%	57%	
branded local assembly	16%	0%	0%	0%	
non-branded local assembly	17%	0%	8%	0%	
import	52%	75%	43%	56%	PYMES (ACTI)
retail	22%	25%	43%	44%	
branded local assembly	0%	0%	0%	0%	
non-branded local assembly	26%	0%	14%	0%	
import	10%	32%	20%	20%	PYMES (non-ACTI)
retail	44%	68%	80%	80%	
branded local assembly	44%	0%	0%	0%	
non-branded local assembly	2%	0%	0%	0%	
import	8%	31%	19%	0%	Households
retail	38%	31%	50%	67%	
branded local assembly	21%	23%	31%	0%	
non-branded local assembly	33%	15%	0%	33%	

Table C5 Lifespan of computer equipment

Lifespan of computer equipment

[in years]	Desktops	Laptops	CRTs	LCDs	
new	3,5	4	4,5	4,5	Government
leasing	N.A.	N.A.	N.A.	N.A.	
used	N.A.	N.A.	N.A.	N.A.	
new	3,8	4,2	4,6	4,4	Big companies
leasing	3,7	3,7	5,0	4,3	
used	3,0	3,0	3,0	3,0	
new	4,3	3,4	5,1	4,7	PYMES
leasing	3,7	3,7	4,0	3,7	
used	2,0	2,0	4,0	4,0	
new	3,9	3,1	4,9	4,4	PYMES (ACTI)
leasing	3,0	3,0	*3,0*	3,0	
used	2,0	2,0	4,0	4,0	
new	5,0	3,8	5,4	5,2	PYMES (non-ACTI)
leasing	4,0	4,0	4,0	4,0	
used	*2,0*	*2,0*	*4,0*	*4,0*	
new	6,0	5,2	5,7	5,4	Households
used	4,2	4,1	4,0	4,6	

Table C6 Average storage time

Average storage time in years, if stored	Desktops	Laptops	CRTs	LCDs
Government	N.A.	N.A.	N.A.	N.A.
Big companies	1,0	1,0	1,0	1,0
PYMES	2,1	1,3	2,3	1,0
PYMES (ACTI)	2,5	2,0	3,0	*3,0*
PYMES (non-ACTI)	1,7	1,0	1,7	1,0
Households	6,2	*3,0*	4,3	*3,0*

Table C7 Fate of obsolete equipment

Fate of obsolete computational equipment					
	Desktops	Laptops	CRTs	LCDs	
Storage	0%	0%	0%	0%	**Government**
Sale	0%	0%	0%	0%	
Donation	100%	100%	100%	100%	
Waste	0%	0%	0%	0%	
Recycling	0%	0%	0%	0%	
Other	0%	0%	0%	0%	
Storage	0%	0%	0%	0%	**Big companies**
Sale	47%	47%	47%	47%	
Donation	31%	31%	31%	31%	
Waste	0%	0%	0%	0%	
Recycling	2%	2%	2%	2%	
Other	20%	20%	20%	20%	
Storage	21%	29%	27%	18%	**PYMES**
Sale	33%	27%	32%	27%	
Donation	25%	21%	27%	32%	
Waste	4%	0%	0%	9%	
Recycling	15%	4%	12%	5%	
Other	2%	19%	2%	9%	
Storage	22%	36%	29%	17%	**PYMES (ACTI)**
Sale	34%	18%	42%	33%	
Donation	28%	21%	16%	25%	
Waste	1%	0%	1%	0%	
Recycling	13%	7%	8%	8%	
Other	3%	18%	4%	17%	
Storage	20%	20%	24%	20%	**PYMES (non-ACTI)**
Sale	30%	40%	20%	20%	
Donation	20%	20%	40%	40%	
Waste	10%	0%	0%	20%	
Recycling	20%	0%	16%	0%	
Other	0%	20%	0%	0%	
Storage	25%	0%	57%	0%	**Households**
Sale	13%	0%	14%	14%	
Donation	13%	43%	7%	14%	
Waste	13%	29%	0%	0%	
Recycling	8%	0%	7%	14%	
Other	29%	43%	14%	57%	

Table C8 Additional questions asked in the questionnaire

Did you know that computers contain components that are toxic for the environment?

	Government institutions	Big companies	PYMES	PYMES (ACTI)	PYMES (non-ACTI)	Households
Yes	100%	100%	80%	100%	50%	91%
No	0%	0%	20%	0%	50%	9%

Did you know that computer recycling yields components that can be sold?

	Government institutions	Big companies	PYMES	PYMES (ACTI)	PYMES (non-ACTI)	Households
Yes	100%	100%	93%	100%	80%	86%
No	0%	0%	7%	0%	20%	14%

Does your institution have a procedure for the management of e-waste?

	Government institutions	Big companies	PYMES	PYMES (ACTI)	PYMES (non-ACTI)
Yes	100%	60%	21%	33%	0%
No	0%	40%	79%	67%	100%

If not, does your institution plan to introduce a procedure for the management of e-waste?

	Government institutions	Big companies	PYMES	PYMES (ACTI)	PYMES (non-ACTI)
Yes	100%	100%	55%	50%	60%
No	0%	0%	45%	50%	40%

Would you be ready to pay to assure for adecuate recycling?

	Government institutions	Big companies	PYMES	PYMES (ACTI)	PYMES (non-ACTI)	Households
Yes	100%	100%	31%	25%	40%	41%
No	0%	0%	69%	75%	60%	59%

Is your institution ISO 14001 certified?

	Government institutions	Big companies	PYMES	PYMES (ACTI)	PYMES (non-ACTI)
Yes	0%	20%	8%	13%	0%
No	100%	80%	92%	88%	100%

What are the principal obstacles for adecuate recycling?

	Government institutions	Big companies	PYMES	PYMES (ACTI)	PYMES (non-ACTI)	Households
Cost	100%	40%	36%	44%	20%	41%
Missing policies within the institution	100%	20%	7%	11%	0%	N.A.
Lack of possibility / recycling infrastructure	50%	40%	14%	11%	20%	41%
Lack of legislation	50%	100%	36%	22%	60%	23%
Other	50%	20%	29%	33%	20%	5%

D SCENARIOS

Table D1 Summary of the model input data for scenarios 1-4

Transfer coefficients for computer equipment in the model

	SCENARIO:	Collected data (1)				Collected data and corrections (2)				Best case (3)				Worst case (4)			
from	*to*	D	L	CRT	LCD	D	L	CRT	LCD	D	L	CRT	LCD	D	L	CRT	LCD
Production and sale	Government	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
	Business	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%	55%
	Households	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%	35%
Government	Storage after 1st use	0%	0%	0%	0%	20%	20%	20%	20%	20%	20%	20%	20%	10%	10%	10%	10%
	Re-use	100%	100%	100%	100%	50%	50%	50%	50%	60%	60%	60%	60%	30%	30%	30%	30%
	Disposal / Recycling	0%	0%	0%	0%	30%	30%	30%	30%	20%	20%	20%	20%	60%	60%	60%	60%
Business	Storage after 1st use	14%	19%	18%	12%	15%	20%	15%	20%	14%	19%	18%	12%	10%	10%	10%	10%
	Re-use	72%	77%	73%	78%	65%	65%	65%	65%	72%	77%	73%	78%	30%	30%	30%	30%
	Disposal / Recycling	14%	3%	9%	10%	20%	15%	20%	15%	14%	3%	9%	10%	60%	60%	60%	60%
Households	Storage 1	25%	0%	57%	0%	35%	45%	35%	45%	35%	40%	35%	40%	35%	35%	35%	35%
	Re-use	54%	71%	36%	86%	50%	50%	50%	50%	55%	55%	55%	55%	30%	30%	30%	30%
	Disposal / Recycling	21%	29%	7%	14%	15%	5%	15%	5%	10%	5%	10%	5%	35%	35%	35%	35%
Reuse	Storage after 2nd use	50%	50%	50%	50%	50%	50%	50%	50%	70%	70%	70%	70%	30%	30%	30%	30%
	Disposal / Recycling	50%	50%	50%	50%	50%	50%	50%	50%	30%	30%	30%	30%	70%	70%	70%	70%

Lifetime of computer equipment per process [in years]

SCENARIO:	Collected data				Collected data and corrections				Best case				Worst case			
	D	L	CRT	LCD	D	L	CRT	LCD	D	L	CRT	LCD	D	L	CRT	LCD
Government	4	4	5	5	4	4	5	5	5	5	5	5	3	3	4	4
Business	4	4	5	5	4	4	5	5	5	5	5	5	3	3	4	4
Households	6	5	6	5	5	5	5	5	6	6	6	6	4	4	4	4
Re-use	3	3	4	4	3	3	4	4	3	3	4	4	2	2	3	3
Storage after 1st use	3	2	3	2	3	3	3	3	4	4	4	4	2	2	2	2
Storage after 2nd use	2	2	2	2	2	2	2	2	3	3	3	3	2	2	2	2
Average lifespan	*8,1*	*7,5*	*9,0*	*9,2*	*7,7*	*7,7*	*8,7*	*9,0*	*9,4*	*9,8*	*10,0*	*10,1*	*4,6*	*4,6*	*5,5*	*5,5*

Growth rate of computer market: 2008 - 2020

SCENARIO:	Collected data	Collected data and corrections	Best case	Worst case
Growth rate	10%	10%	5%	15%

E MODEL RESULTS (NOT PRESENTED PREVIOUSLY)

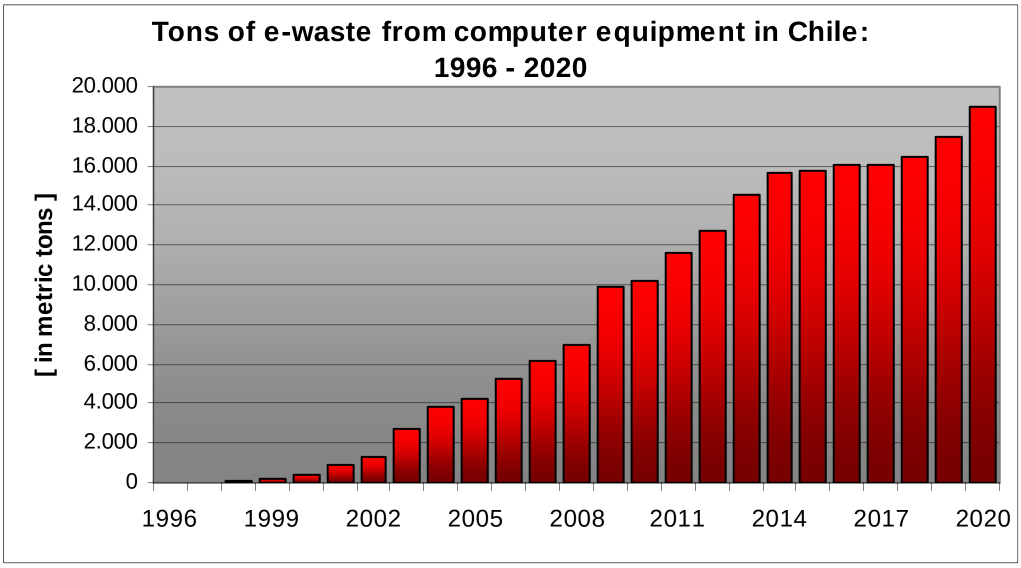

Figure E1 Quantity of ewaste from computer equipment in Chile, 1996-2020

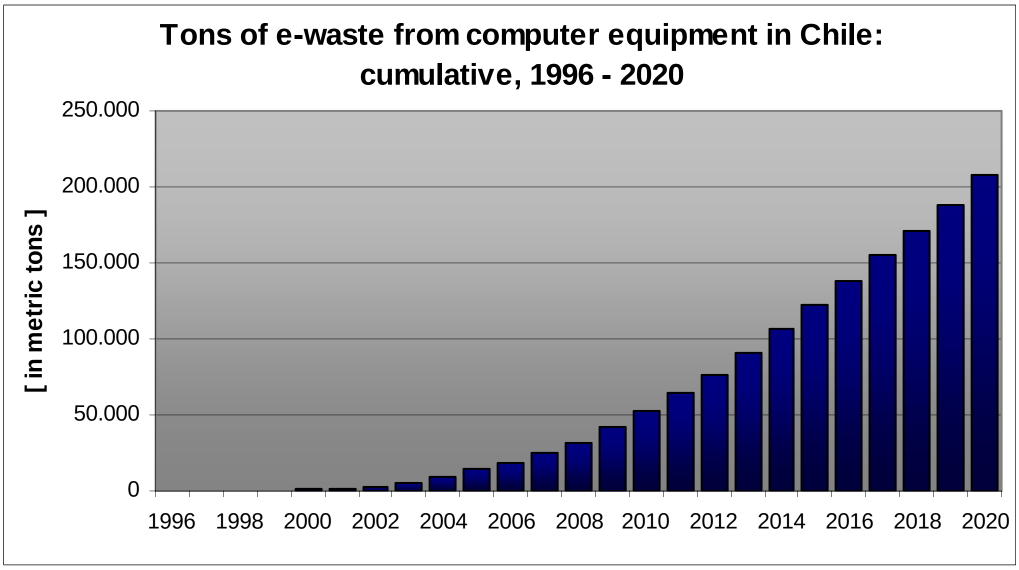

Figure E2 Cumulative quantity of ewaste from computer equipment in Chile, 1996-2020

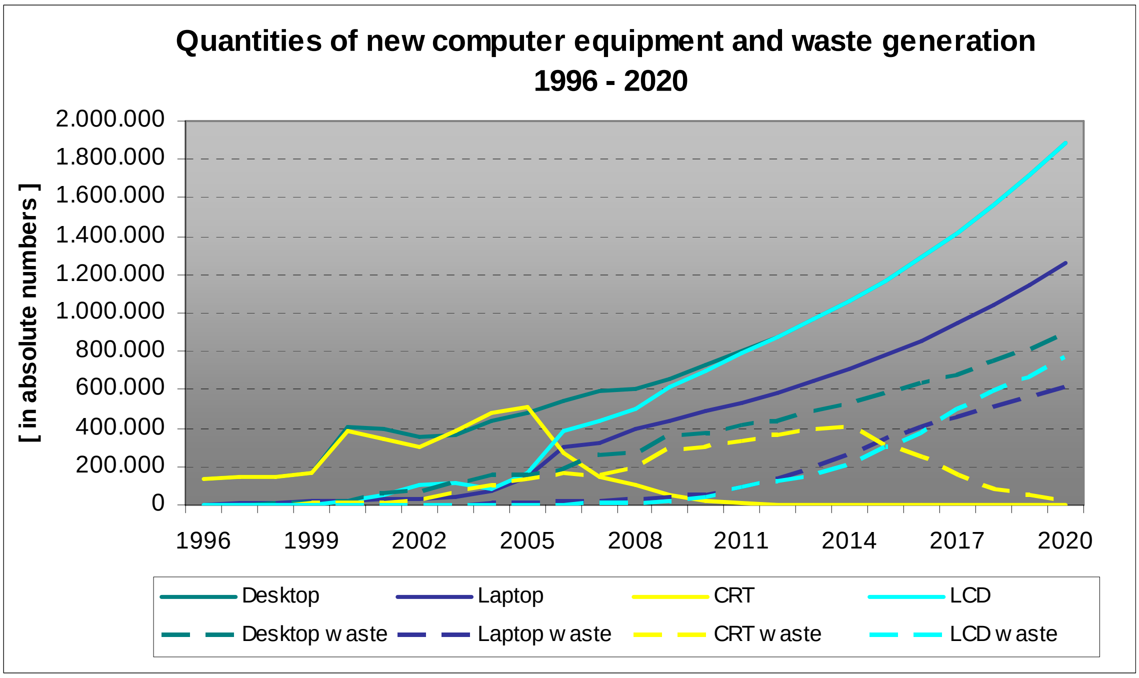

Figure E3 Quantity of new computers and computer waste in Chile (in numbers), 1996-2020

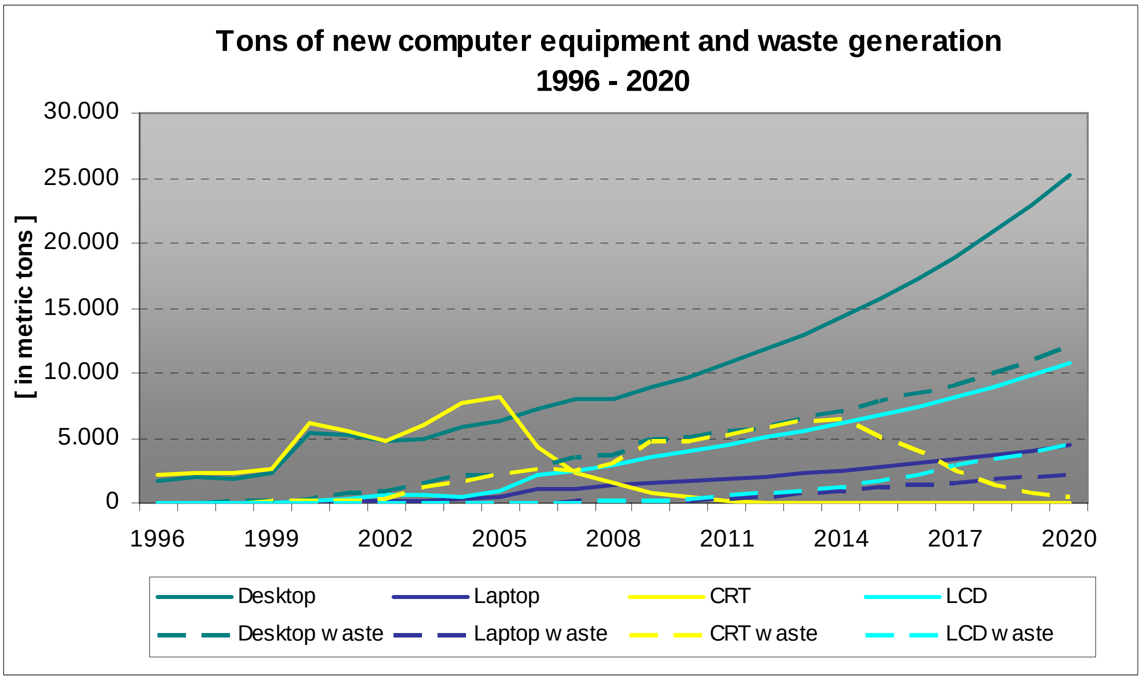

Figure E4 Quantity of new computers and computer waste in Chile (in weight), 1996-2020

ANNEX F : COMPOSITION OF COMPUTER EQUIPMENT

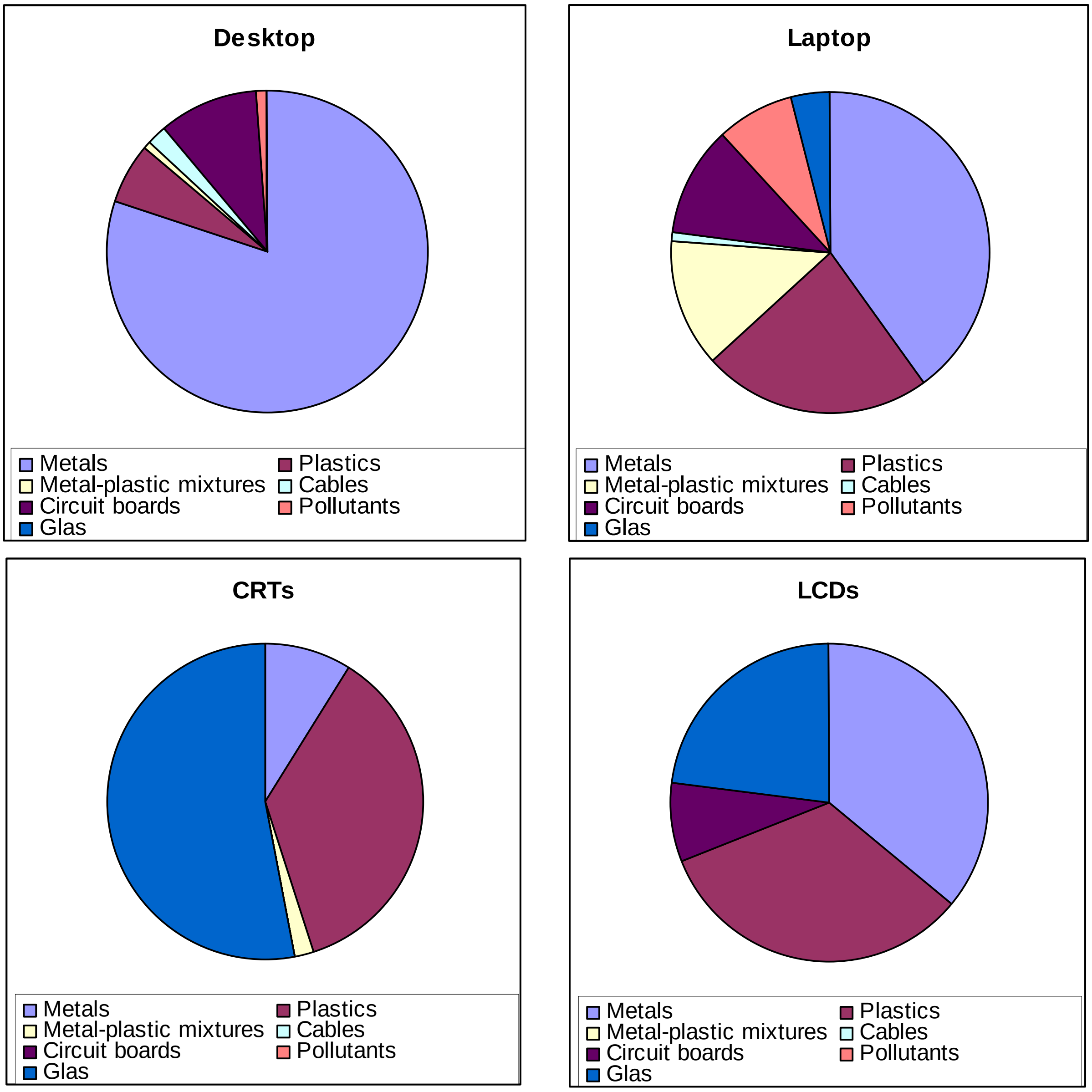

Figure F1 Average composition of desktops, laptops, CRTs and LCDs
Source: (SWICO 2006)