University of Southern Queensland

Faculty of Engineering and Surveying

Life Cycle Assessment of a Mobile Phone

A dissertation submitted by

Kevin Chin Ning TAN

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Abstract

The environment has been under constant stress from human activities. An energy crisis in the 1970s and the publication of Limits to Growth eventually contributed to heightened awareness of environmental impacts contributed by human activities. This eventually led to the formulation of the Life Cycle Assessment. The Life Cycle Assessment is a 'cradle-to-grave' approach of carrying out the evaluation of effects that a product has on the environment over the entire product life. The product analyzed in this project is a mobile phone.

There are currently 1.5 billion mobile phone subscribers in the world and this number is fast increasing. This means that the rate of disposal is great as general consumer behavior suggests frequent replacement of mobile phones.

This project aims at coming up with a result for the environmental impacts of a mobile phone. This is done by carrying out the necessary steps suggested by the International Standards Organization.

The mobile phone was first categorized, and then striped to get its individual components to form the inventory list. These items were then entered into an LCA software. SimaPro V.6 was used to carry out the LCA impact assessment. The results obtained were analysed. This later allowed recommendations and suggestions on decreasing negative environmental impacts.

Different types of results were obtained through a Sensitivity Analysis. Changes in the inventory list and Methods of carrying out the impact assessment were done. This was to test whether data is critical to the impact assessment. Choices of Methods used, the inventory list, among other information can be justified as well.

Finally, this project also involves the evaluation of SimaPro. This project is going to be used as a basis for an electronics database for SimaPro. An evaluation is required

to determine the problem areas in the software, and then fix them. Ideas for future work involving this project is also discussed in the final chapter of the dissertation.

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I further certify that the work is original and has not be previously submitted for assessment in any other course or institution, except where specifically stated.

Kevin Chin Ning TAN

Student Number: d1233098

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Signature

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Date

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Chapter 1 – Introduction

Alexander Graham Bell invented the telephone in 1876 (The Great Idea Finder, 2005). Guglielmo Marconi invented the radio in 1896 (The Great Idea Finder, 2005). Little did both inventors know that both technologies would merge and become a mobile phone. Mobile phones adapt the simple concept of a wire-based electrical system in which sound was transmitted electrically would evolve to a worldwide wireless telecommunication system. Generally, mobile phones generally use radio frequencies to transmit and receive signals. Over the last century, telephones have evolved from the very first dial version to what is portable and cordless which can be carried about at just about anyway at home. During the beginning of the 1990s, the world saw a new step in telecommunications technology; the introduction of mobile phones. This meant that users would not have to move to specific locations, be it their homes or public booths, to make calls.

Over the years, the mobile telecommunications industry has changed drastically. So much so that there are a large variety of different services network (CDMA, GSM, and 3G) and a lot more functionality in our mobile phones. In fact we have become so dependent on our mobiles that we eventually forget the main essential function of a mobile phone; which is to make and receive calls.

The very first phones that entered the market were bulky and awkward in their mould. It was extremely inconvenient to carry one around as it was big. On top of that, it was extremely expensive to own one. The only function of the phone then, was just to make calls. Today's mobile phones however, boasts an array of functions, small in size and fits comfortably onto the palm of one's hand or pocket. Drastic improvements come out to the market every now and then. Mobile phones have become not only a mode of communication, but also a fashion statement and it is known to be outdated for one not to own one. Due to the major improvements in technology, affordability has now become a problem of the past. These factors provide additional incentives to own a mobile phone.

1.1 Project Background

The sale of mobile phones has been one of the fastest growing markets in the world today. It started being mass-produced in 1984. The mobile phones back then were bulky with limited functions, but the fact that it was portable drew the attention of millions and by 1994, 15 million Americans owned a mobile phone. I could recall my dad's very first mobile phone was only used to make and receive calls and now, my phone is equipped with an array of functions and it is not considered the top of the range phone. The question then arises; where do the old phones go? Out of the 15 million phones acquired by 1994 in America, most or all of them have either been thrown away or left sitting around in the house. (Global Source Marketing, 2005)

The number of phones used at present is very large and all that is associated with a mobile phone can't be taken for granted. As of December 2004, there are more than 1.5 billion mobile phone users in this world (Mobile Phone Discuss, 2005) and in ten years time, there will essentially be 1.5 billion mobile phones thrown away. This means that the disposal of the packaging, the charging of a phone, the disposal of a phone may have a significant impact on the environment as the numbers involved are big.

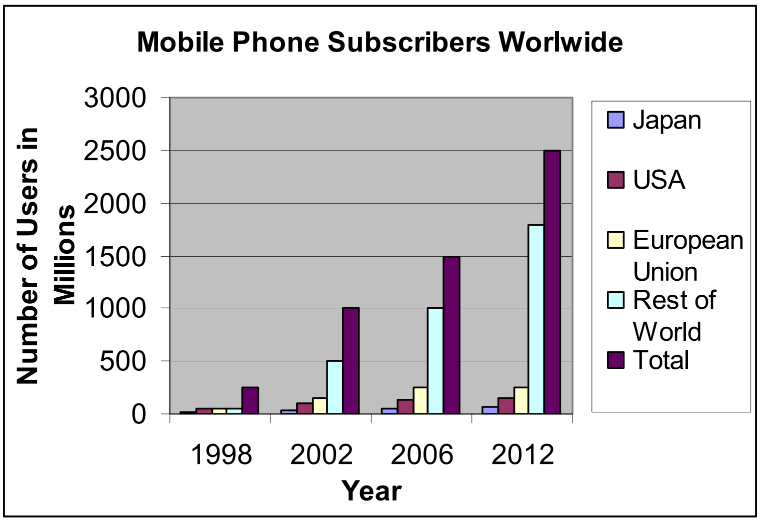

Figure 1.1 Current figures and predictions of mobile phone subscribers worldwide (Source: Mueller J., Griese H., Hageluken M., X-Free Mobile Electronics – Strategy for Sustainable Development, Germany, 2003, p13)

Figure 1.1 above shows the current and future number of mobile phone users. This prediction was made in 2003. Predictions made were underestimated and contradicts current figures. The 1.5 billion user mark is already reached but the graph indicates that it is reached in 2006. This means that by 2012, there will be more than 2.5 billion mobile phone subscribers world wide.

Something has to be done, and soon. It would be fit to carry out a life cycle assessment of a mobile phone. This is to assess the impacts of a mobile phone and anything that is associated with it on the environment. If one phone can already do so much damage to the environment, imagine what a billion phones could potentially do! The life cycle assessment will inform everybody of the consequences of owning a mobile phone. Manufacturers might get a data that is unbiased and independent of any ideology, which allows them to be aware of environmental issues. This study is done with hopes that mobile phone users are aware of these problems, that they recognize the serious issues of the manufacture of mobile phones.

1.2 Further background: Why carry out LCA of a Mobile Phone

According to a report posted by the Institute of Electrical and Electronics Engineers, (Stutz et al, 2003) it was found out that mobile phones handsets are the dominant cause of environmental problem in the whole mobile communication system. From an environmental perspective, the production and use of the mobile phone account for most of the impacts. In total, they contribute to approximately 90% of the total environmental impacts (Stutz et al, 2003). This mainly due to the fact that the life of a mobile phone is very short, while the infrastructure (e.g. mobile phone base stations) used lasts anywhere from 4 to 10 times longer. This paper stresses repeatedly that the production of the mobile phone itself already contributes to almost half of the total environmental impacts posed by a mobile phone system. This is mainly from the production of the electronic chips found in a mobile phone.

The article, LCA of the Mobile Communication System (Stutz et al, 2003), provides incentive to carry out this project. Results found have been astonishing and the figures cannot be taken for granted. This project can be used as an additional tool for a more sustainable environmental future in the electronics world.

1.2.1 Sustainability in the Electronics World

The construction of any electronic product requires significant input of energy and subsequent use of the product will also involve energy. All these add up to cause significant physical damage to the environment. According to WorldChanging (2005), electronics make up 70 percent of all hazardous waste. This comes as no surprise as it takes large amounts of chemicals to produce electronic products. There are so many new gadgets appearing at of late as we enter the technology age one has to wonder how much the environment can take.

As of late, numerous companies have contributed to lessen environmental impacts. Products are recyclable and are made with more simplicity so that it requires less energy to produce and dispose. Nokia has been encouraging such mentality and have even adopted a system called Design for Environment (DfE). The key principles to ensure more sustainable products (according to Nokia) are as follows:

- Use of recycled materials
- Standardise all components
- Avoid using contaminants
- Simple fastening to compile products
- Allow for easy decommissioning

1.2.2 Effects of Batteries on the Environment

Mobile phones, being portable electronic devices, are powered by batteries of several different technologies. There are two types of batteries generally used by mobile phones; nickel-cadmium and lithium ion batteries. When mobile phones first came out, they were powered by nickel cadmium batteries, and in the present scene, all mobile phones use lithium ion batteries. According to the Australian Mobile Telecommunication Association (2005), since 1999, they have collected about 94 tonnes of batteries, about half of it being Nickel-cadmium batteries.

Unlike the phone, the battery has a more limited life. This is subject to how well it was taken care of. A battery is normally replaced once it does not work efficiently or does not charge anymore. In the case of mobile phones, once a battery is worn out, people would usually change their phones as it would cost a fair bit to replace the battery. This is why batteries play a large role in determining the life of a mobile phone.

1.2.2.1 Nickel-Cadmium Batteries

Different batteries have different mAh ratings. This stands for milli-ampere-hours and means that current can be drawn for a set amount of time on a fully charged battery. In order to recharge them, a certain amount of current should be put in for a set amount of time. For example, a battery of 100 mAh produces 10mA for 10 hours. In an ideal world, these times should be identical. On the contrary, the charging process is far less efficient when compared to taking power out of the battery. This is due to the memory effect it possesses. It means that each time a mobile phone battery is to be recharged; it needs to be discharged before charging the battery again. This was very inconvenient in more ways than one. If such measures were not taken, the battery would lose its ability to discharge.

Nickel-Cadmium or Ni-Cd batteries have been slowly being phased out by lithium ion batteries as they are far more superior technology of batteries. This is discussed in the following section.

1.2.2.2 Lithium-Ion Batteries

Mobile phones that have been recently produced are all powered by lithium-ion batteries. These batteries have been slowly replacing nickel-cadmium batteries since the mid-1990s.

Lithium-ion batteries are made out of lithium ions dissolved in carbon or graphite as anodes and a cathode made up of lithium cobalt-oxide in a liquid electrolyte of lithium salt. The advantages of using lithium-ion batteries over nickel-cadmium batteries are size, weight and energy density. Lithium-ion batteries are lighter, smaller and dissipate larger amounts of energy. They have more appeal because of convenience; they are designed to be charged when still plugged into the equipment while charging.

1.2.2.3 Deterioration of a battery

A typical battery, independent of type, loses a certain amount of charge with time. A lithium ion battery loses about 0.1% of its total charge per month and a nickel-cadmium battery loses about 1% of its charge per day in storage. This provides enough evidence that a battery life is limited. Past observation often shows that after about one and a half years, the efficiency of the battery decreases and eventually another few months would see the battery losing its ability to be charged.

These batteries which can no longer be used anymore can be recycled, rather than throwing them away or leaving them in the shelf. Throwing these unusable batteries can cause unnecessary environmental damage. The materials can be processed and reused again, including new battery production.

1.2.3 Recycling

Companies have recently been emphasizing a lot on recycling and been working around the notion of ‘thinking green’. This can be applied in the case of Nokia, as they are paving the way to mobile phones that are more recyclable. Nokia has been slowly developing mobile phones that require less material and energy consumption, and at the same time, maximizing reusability and recyclability. A good example would be the Nokia 6650 is the first Nokia 3G phone. It is also Nokia’s first phone that is designed for recyclability.

1.3 The Life Cycle of a Mobile Phone

The world has moved into the technological age and mobile phones have made a firm establishment in that era. The decision to undertake this project was inspired by the question of where things end up after being disposed. With more than six billion people in the world today, there is more waste production than ever before.

The next step in the project was the research of the background methodology for the project. This included various types of information which proved to be a challenge in its own way.

Chapter 2 – Life Cycle Assessment

2.1 Life Cycle Assessment: How It Came About

The 1970s energy crisis and the publication of Limits to Growth heavily influenced awareness on the environment and led to the introduction of a detailed system that covers energy use in the manufacture of a product. The Life Cycle Assessment methodology was developed in parallel with this process. Throughout the years, the LCA expanded to include a variety of information, including depletion of energy sources and other resources, impacts of emissions and waste generation. Since the 1980s, methods have been developed to quantify product impacts on different categories of environmental problems.

Present day LCA reports have been improved since it first began with the introduction of standards. Only LCA reports that follow the guidelines listed in the current standard; ISO 14140, can be considered reliable and worthy to be compared with another LCA report. Since then, LCA has been used to design environmental policies as well as a very reliable form of environmental decision support tool.

2.2 Introduction to Life Cycle Assessment

A life cycle assessment (LCA) is a process where an evaluation of the effects that a product has on the environment over the entire period of its life cycle is done. It is carried out in a systematic way and it adapts the ‘cradle-to-grave’ approach. An LCA provides objective data which is not dependent on any ideology and is much more complex when compared to other environmental tools. It also provides a goal for any related parties to reduce adverse effects throughout the product life cycle. While a life cycle assessment doesn’t necessarily certify a product as “environmentally friendly”, it can aid in the identification of problem areas to be improved. (Standards Australia/ Standards New Zealand, 1998).

A typical Life Cycle Assessment is made up of four components. They are the goal and scope definition, life cycle inventory, impact assessment and improvement assessment (Standards Australia/ Standards New Zealand, 1998). All components are essential when conducting a Life Cycle Assessment but there is no one universal way of tackling all four components. The only limitations to this are general guidelines that may help in the performance of any particular LCA. *Figure 2.1* below graphically shows a Life Cycle Assessment and all its components.

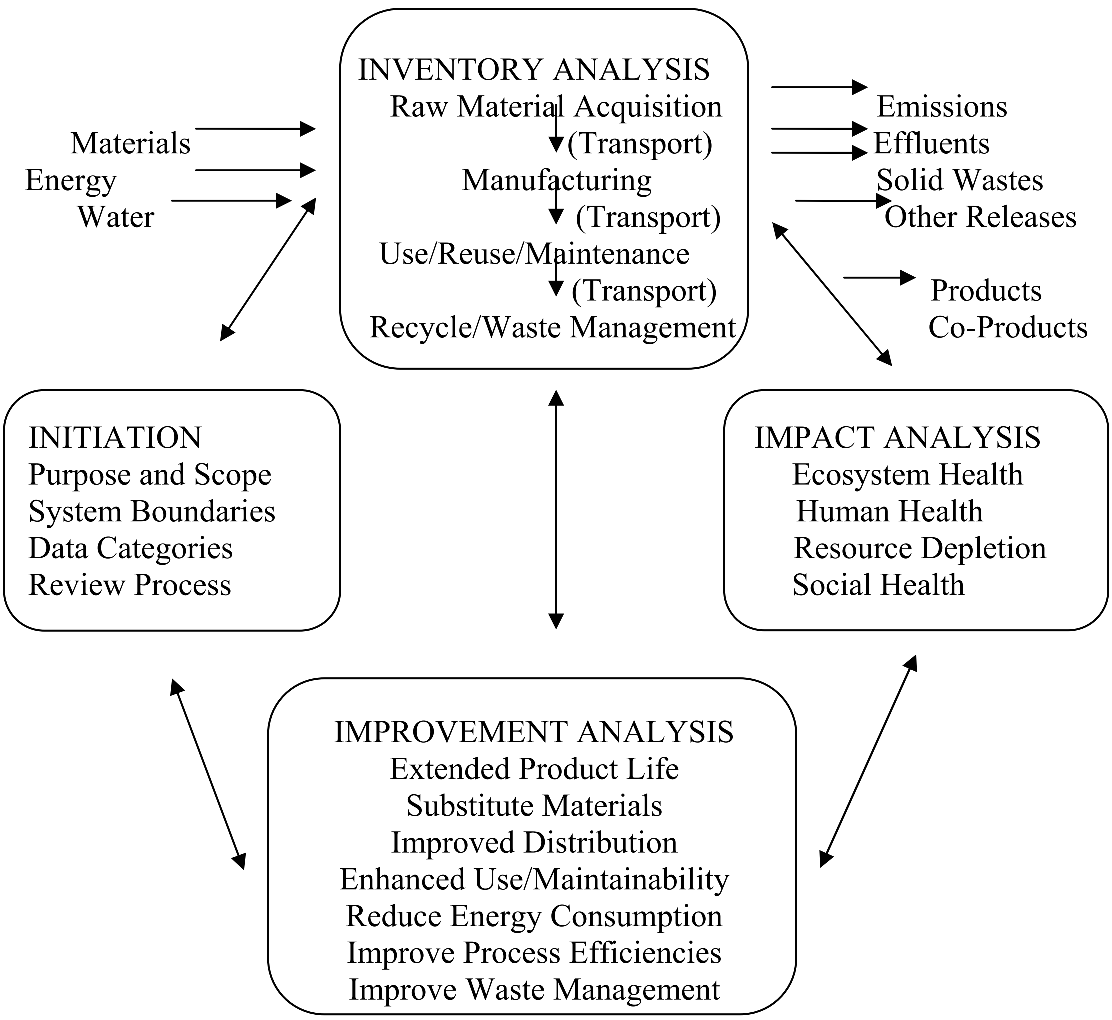

Figure 2.1 – Generic Life Cycle Assessment Model

(Source: Generic Life Cycle Assessment Model, Husseini. A, Canadian Standards Association, Febuary 1994)

Each of the above components will be described in relevant chapters of this dissertation.

Goal and Scope	-	Chapter 3
Inventory Analysis	-	Chapter 3
Impact Assessment	-	Chapter 4
Improvement Assessment	-	Chapter 7

2.2.1 International Standards of LCA

The ISO standards set by the International Organization for Standardization for carrying out the LCA are the ISO14140 series. The three most important documents are listed in the following table. The Australian equivalent of these standards are also listed.

International Standard	**Australian Equivalent Standard**	**Description**
ISO 14140:1997	AS/NZS 14140:1998	Environmental management -- Life cycle assessment -- Principles and framework
ISO 14141:1998		Environmental management -- Life cycle assessment -- Goal and scope definition and inventory analysis
ISO 14142:2000	AS/NZS 14142:2001	Environmental management -- Life cycle assessment -- Life cycle impact assessment
ISO 14143:2000	AS/NZS 14143:2001	Environmental management -- Life cycle assessment -- Life cycle interpretation

Table 2.1: List of ISO standards for LCA

It is mentioned in numerous journals and articles that there is no set way of carrying out a Life Cycle Assessment. Due to this reason, these standards are set in place to act as a guide for people keen in carrying out project as this one. They are also used as a standard to be compared to when reviewing or comparing one LCA with another. If a Life Cycle Assessment was not conducted according to the guidelines of the ISO standards, it is not worthy of being compared with one that complies with the standards.

2.3 Product Life Cycle

The life cycle of a product begins with the extraction of raw materials. These extracted materials then go through several processes to be fit for use in production. They are then put through a number of manufacturing steps to produce individual components. All individual components are then assembled, packaged and ready to be distributed for retail. The sold products then go through the stage where it is used. After the end of its life, it is then disposed. Disposed products are either decommissioned, recycled or end up in the landfills. Recovered products go through several processes and are used again in the manufacturing process. It is, at this stage, important to make mention of the use of transportation throughout this life cycle as it plays a significant role the usage of energy. It also acts as a link for the stages of the life cycle. This can all be summarised in *Figure 2.2* below which shows the life cycle of a mobile phone.

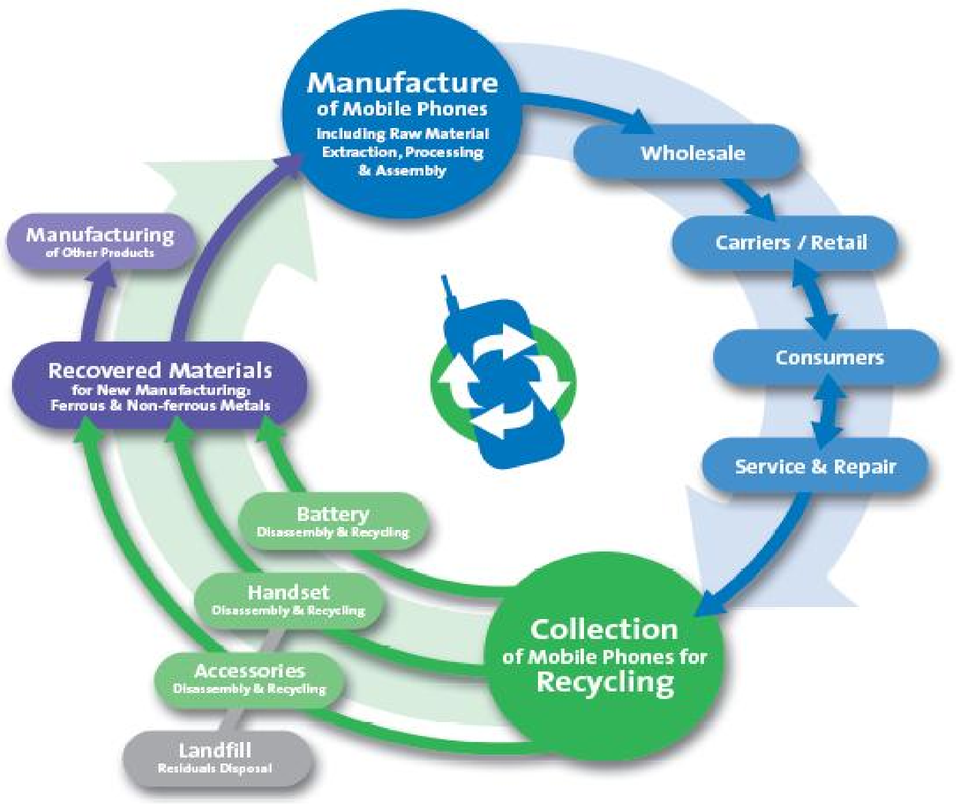

Figure 2.2 – Life Cycle of a Mobile Phone

(Source: *Life Cycle of a Mobile Phone*, 2005, AMTA, viewed: 7th May 2005, <http://www.amta.org.au>)

With the above in mind, the following flowchart summarises the stages of a typical mobile phone. This is similar to the above but is elaborated in different sections of life of the mobile phone.

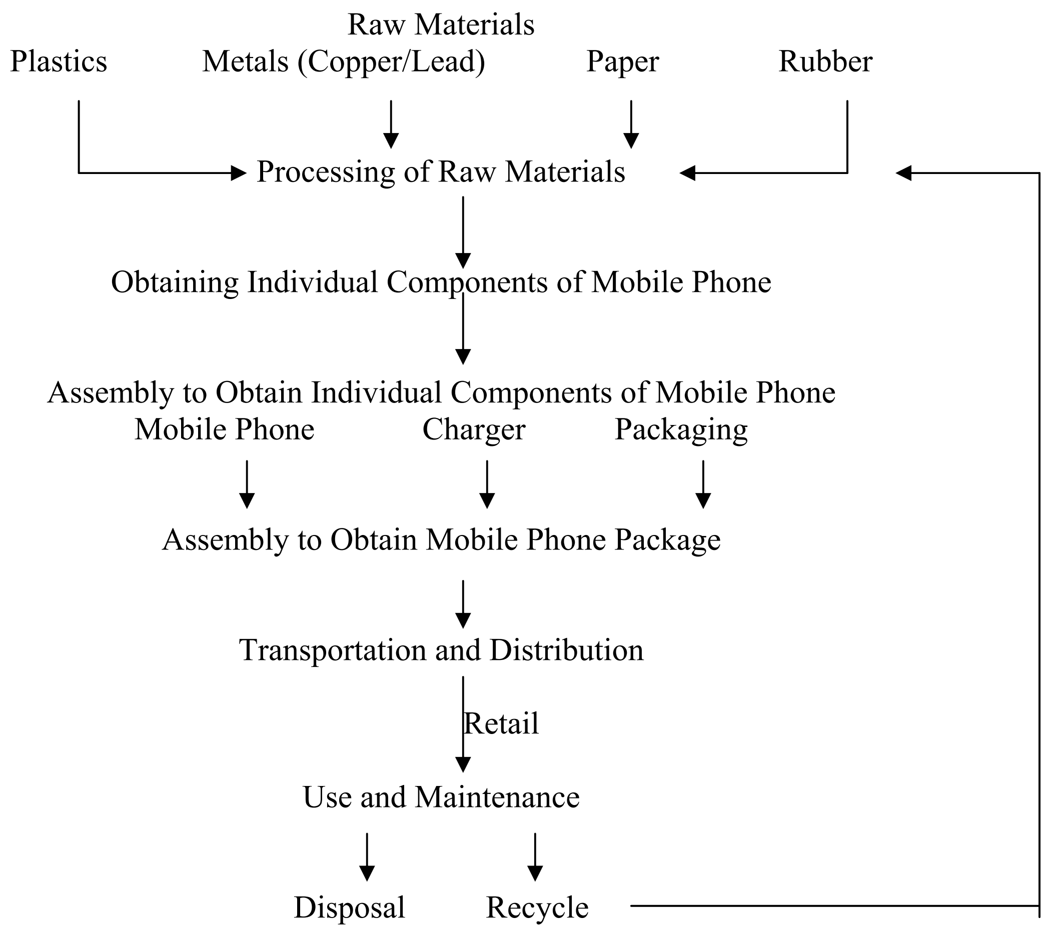

Figure 2.3 Life Cycle of a Mobile Phone – A Different Perspective

2.4 Overview of Each Process

The production of a mobile phone goes through numerous steps before it is ready for use. First, minerals are extracted, refined and processed so that it can be made into the individual components of the mobile phone. These components are then assembled to become the mobile phone and various accessories. They are then packed, transported then sold. After usage, the phone is thrown away or recycled. Compiling the inventory list for analysis can be considered as the reverse engineering of the above process.

2.4.1 Raw materials to manufacturing

In the most defining moment in the life and destiny of a mobile phone, the life of the mobile phone begins with the extraction of raw materials. This process itself already possesses implications not only for the performance, safety and cost of the production, but also its impact on the environment in terms of scarcity and its value. Raw materials are extracted through various mining activities and processed for pre-production and specification in the production of individual components of the mobile phone.

Each mobile phone company may adopt different strategies in the manufacture of mobile phones but most share the common goal of reducing environmental impacts. The design, innovation and manufacturing technology involved determines the mobile phone's life cycle environmental impacts. It is mentioned in Chapter 1 that Nokia has adopted the DfE principle and these measures can improve environmental attributes from the outset while filtering out negative aspects.

2.4.2 Distribution, Storage and Retail

There are numerous types of transportation involved in the distribution of mobile phones. This includes air and sea transportation to diesel trucks.

A study done in Norris et al (2003) showed that wholesaling and retailing often play an essential role from an energy standpoint in the total pre-consumer phase of product life cycle. Results showed that wholesaling and retailing contributes to 10% and 30% respectively of total pre-usage energy use (Norris 2003). This is very significant and should be included in a Life Cycle Assessment. As for this particular project, energy used in retail and wholesale was not researched on due to the time limitations. Despite this, energy used during this phase was not neglected in the project.

2.4.3 Usage and Disposal

This phase of the life of the product is mostly determined by the consumer. Different people have different behaviours and this ultimately determines the life of the phone. They also have different mentality as to what to do with mobile phones that are replaced with newer ones. This is presented with a unique and environmentally sensitive option for disposing of their obsolete mobile phones. These factors were taken into account when carrying out this project and will be further discussed in later sections of this paper.

2.5 The Inventory Analysis

This chapter discussed what the product life and how it came about. One of the next steps in the project was the compilation of the inventory list. This was basically the dismantling, or as others would describe as reverse engineering of the mobile phone. The real beginning of the project was considered to be after the literature review as hands on work was done to the mobile phone. There were numerous struggles involved in the next few steps of the project but non the less, very interesting parts of the project too.

Chapter 3 – The Analysis of a Mobile Phone

3.1 Mobile Phones Used

For this project, three different phones were used, and are as follows:

Figure 3.1 – Samsung SGH-600

- Samsung SGH-600
  Description:
  Age: Approx. 7 years
  Not working
  Charger: desktop charger

Manufacturer's Specifications:

Phone	
Networks	GSM 900
Physical design	
Dimensions (W x D x H)	108 x 44 x 21 mm
Weight w/battery	95 g
General	
LCD display size	4 lines of text
Performance	
Battery type(s) supported	Li-ion
Max. talktime (in hours)	3.5 hours
Max. standby time (in hours)	65 hours
Included accessories	Travel charger
Other Features	
Additional functions	Voice dialing; one-touch vibration

Table 3.1 – Specifications of the Samsung SGH-600

(Source: Samsung SGH-600 Specifications, CNET Asia Reviews, viewed: 20th May 2005, < http://www.asia.cnet.com>)

The Samsung SGH-600 was used to build up a list to make up the inventory analysis. This phone was donated to the research by Mr. Danny Tan. It was no longer used and was considered a backup phone, if his current phone was ever out of order. After sitting in the dark for a few years, dust and corrosion started attacking the phone. This resulted in the failure of the battery. The decision was made that this phone was to be given away in the name of research when it was decided that this phone was impractical to use. More superior technologies eventually phased the phone out.

- Nokia 7260

  Description:

  Age: Approx. 2 weeks

  Working condition

  Charger: travel charger

Figure 3.2 Nokia 7260

Manufacturer's Specifications:

Phone	
Networks	GSM 900
Physical design	
Dimensions (W x D x H)	105 x 45 x 18 mm
Weight w/battery	92 grams
General	
LCD display size	65K TFT, 128 x 128 pixels
Performance	
Battery type(s) supported	Li-ion
Max. talktime (in hours)	3 hours
Max. standby time (in hours)	up to 350 hours
Included accessories	Travel charger
Other Features	
Additional functions	Java, HSCSD, Stereo FM radio, WAP 2.0, xHTML browser, Voice memo/dial, T9, Calculator, Calendar, Pop-Port, Presence enhanced contacts

Table 3.2 Specifications of the Nokia 7260

(Source: Specifications of Nokia 7260, Incomms, viewed 20th May 2005, <http://www.incomms.com>)

The Nokia 7260 was used to measure energy used when the phone was charged. This phone was chosen as it was a fairly new phone when undergoing tests. When it was tested, it was only 1 month old. Measurements started with a totally flat battery and stopped once it is fully charged.

Figure 3.3 Samsung SGH-R220

- Samsung SGH-R220

Description:

Age: Approx. 2 years

Working condition

Charger: travel charger

Phone	
Networks	GSM 900
Physical design	
Dimensions (W x D x H)	100 x 46 x 23.5 mm
Weight w/battery	99 g (With standard battery)
General	
LCD display size	128 x 64 pixel
Performance	
Battery type(s) supported	Li-ion
Max. talktime (in hours)	Up to 3.5 hours
Max. standby time (in hours)	up to 120 hours
Included accessories	Travel charger
Other Features	
Additional functions	Voice dialing; one-touch vibration

Table 3.3 Specifications of the Samsung-R220

(Source: Specifications of the Samsung-R220, SamsungMobile, viewed: 20th May 2005, <http://www.samsung.com.my>)

The purpose of the Samsung SGH-R220 is similar to that of the Nokia 7260. It was also used to measure energy usage while charging. The only difference is that the phone has been used for about a year. This allowed for the results obtained from both phones to be compared.

3.2 Goal and Scope Analysis

The initiation stage sees the goal and scope of the project being defined. Other reports may call this stage the goal and scope analysis. The reason for this stage is due to the fact that it is too time consuming to attempt all sub-sections of the above model. This phase is important as it determines why an LCA is being conducted and describes the system to be studied and the data categories to be studied (International Standards, 1998). This section of the LCA is usually done in compliance with the ISO standard, ISO14141:1998.

First, a set of goals will be set out before starting the project. Together with the goals, limitations should also be set out. These limitations will play a significant role in the project. These factors will influence the direction and depth of the project. The limitations also determine the quality of the data that is collected and used in the project.

3.2.1 Goals of Project

The goals of the project were set mostly during the reviewing of background information. Some were too adventurous while others seemed like good ideas. These were then further reviewed until the following list was obtained.

- Evaluate software that had been chosen to carry out the LCA impact assessment.
- Get an accurate result for the impact a mobile phone has on the environment.
- Point out harmful parts in a mobile phone
- Upon analysing results from the LCA impact assessment, make recommendations to minimise these impacts.

3.2.2 Scope of Project

The boundaries of the project should be determined at the start as it would give an indication of how detailed the project should be. The scope can also be used as a safeguard for the prevention of going into too much detail in one particular section and neglecting another one. With that in mind, the boundaries set for this project were as follows:

- Time limitations

It should be made known that the time available for this project was very limited. It was carried out in the duration of two semesters, which was approximately 32 weeks.

In relation to time limitations, there were other assignments and commitments that had to be tended to. Proper organisation of time would still see the time limitations imposed on this project

- Standardisation of report

As time was the main bottleneck of the project, the proper guidelines set in the ISO standards could not be complied. Despite that, the project was structured with the effort to try complying with the standards.

- Mobile phone used

The limitations that the mobile phone had on the mobile phone should be made aware of. These limitations were also boundaries to this project. Finalising all components of the mobile phone would eliminate most uncertainties in compiling the inventory list. This is further elaborated in the report. This phone is also 6 years of age and this does not represent current mobile phone technologies.

- Mobile phone is of second generation

The only mobile phone available to the project is a Samsung SGH-600. It is a second generation GSM phone. A second generation mobile phone was chosen because it is the most common type of phone used. Due to time constraints, phones of other technologies will not be included in the project.

- Only one mobile phone is used

As mentioned above, due to time constraints, only one mobile phone is used. The whole project will hence be based on that particular mobile phone; Samsung SGH-600.

- Use of phone only consists of making calls and SMSes (Phone made in 1999)

Mobile phones have been getting more advanced as cameras and MP3 players have been integrated into the mobile phone. As of late, the cameras have evolved to become video cameras with capability to produce mini clips as well as pictures of high quality. Sharing capabilities such as Bluetooth and infrared technologies have also made its mark in the mobile phone industry. These features are only a few out of what seems like the thousands of features available in the modern day mobile phones. These technologies vary from phone to phone and are secondary features when compared to calls and SMSes made in a day. Hence, an assumption is made that a mobile phone is mainly used for making calls and SMSes. All additional features incorporated into a phone are neglected.

- Mobile phone only, not mobile phone telecommunication system

Only the mobile phone was taken into consideration. As mentioned above, mobile phones account for 90% of total environmental impacts. Lack of information about mobile phone base stations also accounted for this boundary.

3.3 Inventory Analysis

This stage saw a list of individual components made up from the product. In the case of this project, a mobile phone was taken apart and categorised according to what each component is made of.

3.3.1 Collection of Data

Numerous ways of collection of data was used for this project. This included:

- Mobile phone usage behaviour via survey
- Collection of statistics via research from numerous sources
- Research papers to support ideologies

All of the above will be discussed further in the following sub-sections.

3.3.2 Statistics

Various statistics was retrieved from numerous sources for a few reasons. They are used as a rough estimate of how many mobile phones that are ultimately involved. If one mobile phone can already do so much damage to the environment, imagine what a billion phones can do. The sheer number alone will also serve as awareness to the environmental effects of mobile phones.

These statistics were not easily obtained as manufacturers do not publicly release these numbers. Reports released by these manufacturers might also be biased to maintain a good image of the company.

These statistics were useful in determining other information. For example, there are no exact figures for the amount of mobile phones being recycled. In the project, the number of mobile phones recycled in 2004 was compared to the number of mobile phones imported in the same year. The result was an estimate of the percentage of mobile phones recycled in Australia.

3.3.2.1 Statistics Retrieved

There were a few statistics mentioned in this paper. Some were more obvious than others. A few useful statistics were recovered and some of them are in the list below.

- 1.5 billion mobile phone subscribers currently. (Cellular Online, 2005)
- 15 million American own mobile phones by 1994. (Global Source Marketing, 2005)
- the production of the phone and its components contribute approximately 90% of the total impacts (Stutz et al, 2003).
- 17 million phones imported into Australia in 2004 (ABS, 2005)

3.3.3 Energy Measurement When Charging of Mobile Phone

The Nokia 7260 and Samsung SGH-R220 was used to carry out tests on energy usage while the battery was being charged. This was done by using a power quality analyzer (Shown in Figure 2.3).

Figure 3.4 Power Quality Analyser

This phone was part of the research for a couple of reasons. A new phone means a new battery. It is very common to hear mobile phone users complain about their phone after a year or so of usage. The usual problems usually pointed to the battery. The batteries do not operate with full efficiency. Since the Nokia 7260 was just recently acquired, it was used as a control in this research. Test results were then compared to the SGH-R220.

3.3.3.1 Energy Use Analysis – Charging of Mobile Phone Battery

Samsung Phone		**SGH - R220**				
V	A (milli)	W	VA	VAR	PF	Time
235.1	33.43	4.841	7.842	6.15	0.617	11.00 PM
234.5	32.51	4.671	7.618	5.969	0.617	10mins
234.4	32.22	4.638	7.54	5.963	0.615	10mins
236.2	32.05	4.632	7.587	6.015	0.611	10mins
236.4	32.08	4.639	7.569	5.958	0.614	10mins
235.1	32.25	4.627	7.594	6.013	0.61	10mins
235.6	32.03	4.626	7.566	5.996	0.612	10mins
237	32.76	4.369	7.758	6.177	0.6	10mins
237	32.44	2.634	7.67	6.14	0.604	15mins
234.4	23.65	3.187	5.505	4.492	0.577	15mins
234.7	16.325	2	3.822	3.25	0.523	15mins
234.6	11.532	1.2852	2.698	2.356	0.476	
Nokia		**Nokia 7260**				
V	A Milli	W	VA	VAR	PF	Time
235.7	39.12	5.51	9.15	7.31	0.603	11.45 AM
235.3	39.25	5.603	9.258	7.359	0.607	15mins
236.4	39.57	5.619	9.3	7.402	0.605	15mins
232	40.26	5.673	9.362	7.468	0.604	15mins
231.7	39.4	5.8	9.4	7.465	0.6	15mins
235.1	41.42	5.88	9.74	7.74	0.608	15mins

Table 3.4 – Energy Use Analysis When Charging A Mobile Phone Battery

The above table enables the calculation of the total energy expenditure in Watt-Hour used through out the total product life. It was assumed that the average age of the battery was two years before it was thrown away. The survey showed that at average, a mobile phone was charged every two days. It should also be noted that it took different amounts of times to fully charge a flat mobile phone battery. The calculations are as follows:

3.3.3.2Samsung SGH-R220

Average Wattage:

$$AvgW = \frac{4.814 + 4.671 + 4.638 + 4.632 + 4.639 + 4.627 + 4.626 + 4.369 + 2.634 + 3.187 + 2 + 1.2852}{12} = 3.8458W$$

Total charge time:

$Tot.Time = 145\min = 2.42hrs$

Energy used in Watt-Hour (per charge)

$Wh = 3.8458 \times 2.42 = 9.2939Wh$

Energy used in Watt-Hour (2 years)

$TotalkWh = 9.2939 \times 182.5hrs = 1696.144Whrs$

3.3.3.3 Nokia 7260

Average Wattage:

$AvgW = \frac{5.51 + 5.603 + 5.619 + 5.673 + 5.8 + 5.88}{6} = 5.6808W$ Total charge time:

$Tot.Time = 70\min = 1.1hrs$

Energy used in Watt-Hour (per charge)

$Wh = 5.6808 \times 1.1 = 6.2489Wh$

Energy used in Watt-Hour (2 years)

$TotalkWh = 6.2489 \times 182.5hrs = 1140.427Whrs$

The average value of energy expenditure is calculated by taking the average of both the values, thus arriving at the value $\frac{1696.144 + 1140.427}{2} = 1418.285Wh$.

3.3.3.4 Poor Power Factor

It should be noted that the average power factor measured is only 0.6, which is unacceptable. The definition of power factor is the ratio of true power (watts) to apparent power (VA). This means that the current flowing into the equipment is larger than required, which would cause various problems. One very significant problem is transmission losses. In simple words, the charger only uses 60% of the total energy transmitted by the power station.

3.3.4 Survey

The purpose of a survey was to get information about the general usage pattern of mobile phone users. This was done with the help of a survey. Appendix B shows a sample of the questionnaire used to carry out this survey.

The questions present vital information that can be used in various parts in the calculation of energy used through the average life of a mobile phone. These would include the following:

- The make of the phone and age of the phone.

Reason for inclusion: It is assumed that the battery of the phone is of the same age as the mobile phone. The longer the battery is in use, the less efficient it becomes. Low efficiency of the battery means the need for more frequent charging, hence more energy use.

- The daily average use of a mobile phone. This will only include phone calls and sending SMS (Short Message Services).

Reason for inclusion: Longer calls and more SMS sent each day would mean more energy used as battery charges will be more frequent. This would lead to the question of the frequency of phone charging and habits associated with it.

- Personal information

Reason for inclusion: People of different genders, age, and occupation usually have very different mobile phone usage patterns. This section is closely linked to the average use of a mobile phone section. People from different countries tend to have different usage patterns too because of different rates of calls and SMS. Different levels of dependency of mobile phones also exist in different countries.

3.3.4.1 Results obtained from the survey

Different people have different habits and patterns of use of their mobile phones. Some believe in myths circulated while others ignore them to suit their life styles. The survey feedback was from a wide range of people; from students to managers, ages 16 to 60, from Singapore to Sweden. Mobile phone usage often differs from different groups.
A total of about 80 survey forms were returned; 23 surveys from Australia, 28 from Malaysia, 18 from Brunei and 5 from Singapore. Others includes New Zealand, Sweden, Canada and USA but were not used because too few were collected from those countries.

The general observation from these surveys is that users from different countries have very different usage patterns. Generally, people from Australia use their mobile phones the least, with an average of 3 SMS sent and about 10 minutes calls made per day. In Brunei and Malaysia, the average use is slightly higher, with an average of 10 SMS sent and about 30 minutes calls made per day. Singaporean mobile phone users showed the highest average mobile phone use with an average of 50 SMS sent and about one hour of calls made per day. This pattern is mainly due to the rates of calls and SMS. It was observed that the call and SMS rates for one country differ from one service provider to another but still remain similar. Rates differ significantly from different countries; Singapore being the cheapest (5cents SMS, 0.1cents/min calls) and Australia offering the most expensive rates (25cents SMS, $1/min calls).

Age seem to be another factor that determines mobile phone usage patterns. Independent of where the user is from, there are occasions where usage is below average. These usually people who are after their 40s.

The pattern of mobile phone battery charging can be characterized into two categories; overnight charging and limited time charging. More than half of mobile phone users charge their mobile phones overnight daily. According to PowerStream (2005), a lithium-ion battery is not capable of accepting any trickle charge (overcharge). Over charging the battery would cause damage to the cell and could potentially cause it to be hazardous. This is one of the main reasons why batteries do not last as long as they should. The recommended way of charging the battery is to wait for it to become fully discharged, and charging them until they are fully charged.

It should also be noted that the mobile phone age rarely exceeds two years. This justifies the hypothesis that the average life of a mobile phone is two years.

3.4 Steps Taken to Compile Inventory List

This stage of the LCA was quite simple when compared to other tasks. Upon getting as much information about the phone as possible, it was then opened up. The tamper proof screws were easily unscrewed with the right tools. After that, everything inside just fell apart and they were divided into sub-groups. These included the following:

1. Mobile phone housing *(Figure 3.1)*
2. Mobile phone electronics *(Figure 3.2)*
3. Mobile phone battery *(Figure 3.3)*
4. Mobile phone desktop charger *(Figure 3.4)*
5. Mobile phone charger adapter *(Figure 3.5)*
6. Mobile phone packaging

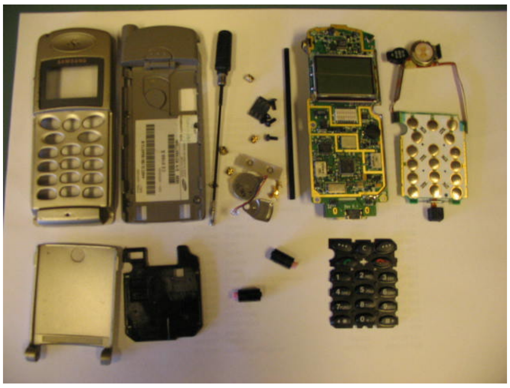

Figure 3.5 Mobile Phone Housing (L)
Mobile Phone Electronics (R)

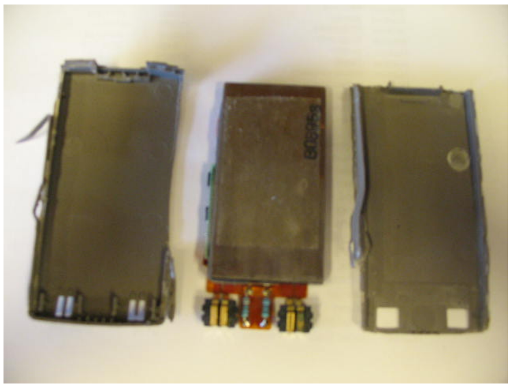

Figure 3.6 Mobile Phone Battery

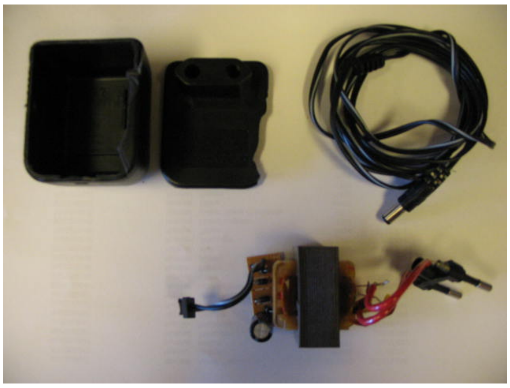

Figure 3.7 Charger Adapter

Figure 3.8 Desktop Charger

Due to the unavailability of the mobile phone packaging, a picture is not available. After sub-division, each item was further broken down into individual components. All these later make up the inventory list.

Of all the sub-groups, it was first assumed that the printed circuit board was to be considered as just a printed circuit board in the analysis. This was due to the components being too small to be taken out using a conventional soldering iron. After several trials in vain, a heat gun was used.

Figure 3.9 –Heat Gun

The heat gun operates by blowing hot air out of a tube of about 5mm diameter. This allows the hot air to be concentrated. This heat will thus accumulate and after a few seconds, the solder would melt and, with the help of a pair of thin-nose pliers, everything that was held to the printed circuit board was removed. Upon removing as much as possible from the printed circuit board, similar components were grouped together and assumed to be made out of similar material. This stage also included the identification of certain materials. This part was vital, as wrong identification would result in undesirable and possible errors in the final results.

Data about mobile phones are rarely posted by manufacturers for various reasons. This made it difficult to determine what each component was. It was particularly difficult when it came to the identification of metals. The identification of metals involved a lot of assumptions. Despite this fact, the metals were identified according to its characteristics observed. For example, copper was identified in various places. Such a conclusion was made when some corrosion was found to be greenish in appearance (Corrosion Source, 2005). It also had a brownish appearance to it. This indicated that it was copper. As this is the best way to identify metals, all metals with similar characteristics are thus identified as copper.

3.5 Results for Inventory Analysis

3.5.1 Break down of individual components of a mobile phone

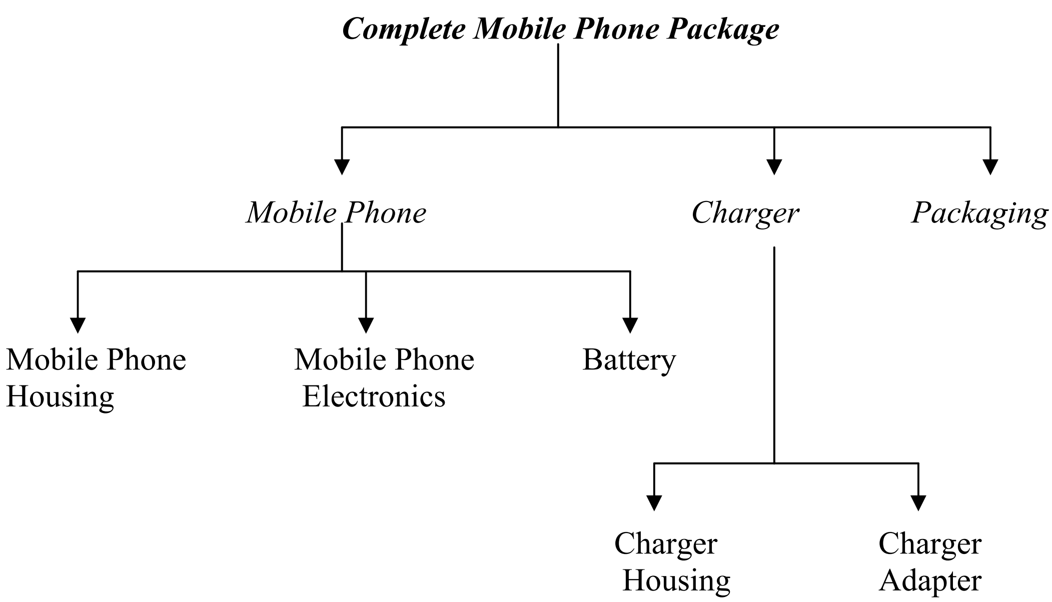

Figure 3.10 Break down of individual components of a mobile phone

3.5.2 Mobile Phone Inventory List

Material	Weight (Grams)	Comments
Mobile Phone Casing		
Plastic	27.53	Acrylonitrile Butadiene Styrene - Polycarbonate
Rubber	0.62	
Metal 1	1.43	Used for screws
Metal 2	0.08	Gold plating
Metal 3	1.28	Copper
TOTAL WEIGHT	**30.94**	
Charger		
Printed Circuit Board	17.79	
Inductors	8.87	
Liquid Crytal Display	2.55	
Metal	3.87	Copper from inductors
Capacitors	1.42	Assumed to be ICs in SimaPro
Transistors	2.04	Assumed to be ICs in SimaPro
Diodes	0.77	Assumed to be ICs in SimaPro
Resistors	1.09	Assumed to be ICs in SimaPro
Metal	0.14	Tin
Integrated Circuit	0.74	
TOTAL WEIGHT	**39.28**	
Charger Casing		
Plastic housing	42.35	Acrylonitrile Butadiene Styrene - Polycarbonate
Metal	2.10	Material used for screws
Metal	0.33	Copper
Glue	0.18	
Copper wire	0.25	Material found in wire
Insulator (PVC)	0.25	Material found in wire
Metal	0.85	Stainless Steel
TOTAL WEIGHT	**46.31**	

Battery		
Plastic	10.31	Acrylonitrile Butadiene Styrene - Polycarbonate
Metal	0.37	Tin
Printed Circuit Board	0.41	
Battery Pack	39.83	
TOTAL WEIGHT	**50.92**	
Charger Adapter		
Copper Wire	15.28	Contents of wire
Insulator (PVC)	15.28	Contents of wire
Printed Circuit Board	2.00	
Capacitor	2.19	
Diode	1.00	
Transformer	167.68	Laminated Iron Core
Plastic	40.73	Acrylonitrile Butadiene Styrene - Polycarbonate
Metal	27.68	Copper from transformer
TOTAL WEIGHT	**271.84**	
Mobile Phone Electronics		
Printed Circuit Board	11.22	
Integrated Circuit	6.66	
Liquid Crystal Display	2.53	
Plastic	1.54	Acrylonitrile Butadiene Styrene - Polycarbonate
Metal	3.03	Tin
Metal	0.41	Copper
Metal	0.56	Steel
TOTAL WEIGHT	**25.95**	
TOTAL WEIGHT OF MOBILE PHONE	**465.24**	

Table 3.5 – LCA Inventory List of a Mobile Phone

3.5.2.1 Integrated Circuit (IC)

At the time of compiling the inventory list in SimaPro, electronic components like capacitors, resistors, transistors, etc, were entered as ICs. This was due to lack of electronic data both in SimaPro and other resources. There were also no appropriate substitutes available in the SimaPro database. This led to the amplified environmental impacts in the results obtained.

3.6 The Inventory List

Obtaining the list marked the start of the project. These figures were then entered into SimaPro, which then marked the shifting of attention to the next component of the Life Cycle Analysis; the Life Cycle Impact Analysis.

Chapter 4 – SimaPro

The current market serves a range of software for use when conducting a LCA; LCAit, EcoQuantum, Gabi and PEMA just to name a few (RMIT, 2005). SimaPro was chosen to carry out this Life Cycle Assessment project.

SimaPro stands for System for Integrated Environmental Assessment of Products. It is developed by PRé Consultants, a company based in the Netherlands. It follows the ISO 14040 series recommendations that consist of environmental management; principles and framework of life cycle assessment. First released in 1990, it has sold about a thousand licences all over the world and has proven itself to be a reliable and flexible tool.

This program is designed with the mindset of simplicity and user friendliness. Most features of the program are easily accessible via a tool-bar on the left hand side of the screen. The existing database found in the program can be easily changed. If desired, it is possible to add new data to be used in the inventory list.

Included in SimaPro is a set of methods of carrying out the impact analysis of the inputs. Each method is different but similar; there are different situations such as European, Australian or USA conditions. For the same process, different regions of the world might experience the same amount of environmental damage, but it might affect each region differently. A good example would be the extraction of non-renewable resources.

Basically, a user just has to enter all data from the inventory list, and then a simple click of a button will show all results.

4.1 Impact Analysis

ISO 14042:2001 makes the third part of the International Standards of carrying out an LCA (2000). A Life Cycle Assessment Impact Assessment is to assess the individual components in the inventory analysis and determine any environmental impacts that each possess. The ultimate goal of this section is to convert results from the inventory analysis to a set of impacts with a form of measure. This section is closely tied with the improvement assessment as the understanding of the environmental significance of each component will allow room for evaluation of each component of the product.

Since this project revolves around the use of software, in this case, SimaPro, it is important to use the different methods of analysis. Controversy always arises due to this confusion. No one choice is correct but it is important to state and define the method of analysis.

An LCA Impact Analysis consists of three stages; classification and characterisation, normalisation and evaluation (Searcy C, 2000). In the classification stage, all substances are sorted out into categories according to their environmental effect. Characterisation sees the categories being modelled in terms of indicators so a basis for comparison within individual categories. Normalisation is done next so that the various impacts can be compared numerically. These results are then evaluated and weigh the impacts categories against each other in terms of relative importance. This is all done within SimaPro to achieve results relevant to the project.

4.2 Validation of Methods for Conducting LCA

There are numerous types of methods found in SimaPro, as well as other life cycle assessment programs. Luo et al (2001) compares several methods of evaluating the environmental impact of electronic products; Eco-Indicator 95, Eco-Indicator 99, Ecological footprint and EcoPro. Each method is based on different methodologies and weighting systems and the absolute magnitude of the output cannot be compared. Despite that, the final results can be examined on a relative basis.

Luo et al (2001) analysed the relative single-scores of two examples of three products; a laptop computer, a telephone and a mechanical part. Their results indicate that all four methods give consistent results charts which of the two examples, is environmentally better. The single scores from each method vary with all scores. The laptops had similar results but mechanical parts have results ranging up to three times in difference. The results from the above tests suggest that the method used in the present study is credible in the context of other similar methods and hence results devised from using it can be considered to be reasonably valid.

4.3 Impact Assessment Method: Eco – Indicator 99 (E) V2.1 Australian Substances

The method of evaluation chosen to carry out the impact assessment in SimaPro is the 'Eco-indicator 99 (E) V2.1 Australian substances'. According to http://www.pre.nl, the Eco-indicator is considered to be a state of the art impact assessment method for carrying out an LCA. This particular method was the preferred one because it has a more sophisticated weighting method where damage models instead measures the seriousness associated with the environmental effect.

The Australian version of the Eco-indicator is constantly being developed by the Centre for Design at the RMIT University in Melbourne. This is done as there are currently very limited methods for quantifying environmental impacts and a standard to compare it with (RMIT, 2005).

The Eco-indicator 99 is basically an extension and update of the Eco-indicator 95. It is based on a damage-oriented methodology; human health, ecosystem quality and resource depletion. The categories of impact analyzed by this Method are as follows:

- Carcinogens (emissions into the environment)
- Respiratory Organics (emissions to air resulting from summer smog)
- Respiratory Inorganics (emissions to air resulting from winter smog)
- Climate Change (damage to human health by climate change)
- Radiation (radioactive radiation)
- Ozone Layer (damage to the depletion of the ozone layer)
- Ecotoxicity (emissions of ecotoxic substances into the environment)
- Acidification/ Eutrophication (measure of acidity in the environment)
- Land Use (Damage resulting from conversion or occupation of land)
- Minerals (decreasing mineral grades resulting from mining)
- Fossil fuels (measures lower quality of resources)

The above are then categorized into the three main areas as mentioned above and have been expressed as follows:

- DALY – Disability Adjusted Life Years
- PAF – Potentially Affection Fraction
- MJ/kg extracted materials

The 'E' in the name of the method stands for the egalitarian perspective (Pre Consultant, 1999). This means that the environmental impact is measured in terms of time. Using crude oil as an example, what is the worth of a particular mineral in 100 years time when it is very rare? Would it cause more damage extracting it in a hundred years when compared to present times? Other factors that contribute to the egalitarian perspective are the economic, social and technological factors. There might be a substitute for petrol in the future which may cause less pollution. Petrol may be very expensive and frown on by society. These are the possibilities that may ultimately contribute to level of environmental impact in the future.

4.3 Impact Assessment

Armed with the knowledge of SimaPro, one can begin the retrieval and analysis of results. There is only one clear cut way of compiling the inventory list but there is no one way of carrying out the impact analysis. The following chapter will comprise of several single score results to get things started. Single score results can also be considered as summaries of the numerous graphs of breakdown results. This will then lead on to more detailed analysis in future chapters.

Chapter 5 – Life Cycle Assessment Results

After entering all available data from the inventory analysis, the results can be obtained with just a click of a button. This was of course done after specifying the method of assessment. As mentioned in the previous chapter, the method of choice for this project is the Indicator 99 (E) V2.1 Australian Substances.

The graphs in this chapter show aggregate of results. This is otherwise known as the single score results. These single score results are usually used to give the general results without having to go too much into the specifics. There are various methods of impact assessment but all these impacts are converted to normalized figures, and then added to form these single scores. It does well in letting the user know what is going on. It is often used as comparisons with other methods of impact analysis as single score results are often regarded as a standardised unit. Comparisons with other methods of impact analysis will be discussed in a later chapter.

Another graph that is very important in this analysis is the comparison of the individual major components of the mobile phone. This will point out specifically which component is the main problem area in the whole mobile phone package.

5.1 Results Obtained from SimaPro

In order to grasp the idea of what was to be expected, the single score and summaries of results were first analysed. Figures 5.1 to 5.3 shows single score results while figures 5.4 and 5.5 show the comparisons of the impacts from individual components of the mobile phone. The list below shows the figures in their respective subsections for analysis. They are as follows:

- Figure 5.1 - Analysis Flow Chart for the Whole Mobile Phone Package.
- Figure 5.2 - Comparison of the environmental impacts for each process from the inventory list.
- Figure 5.3 - Comparison of types of impacts.
- Figure 5.4 - Comparison of levels of environmental impacts for each component of mobile phone.
- Figure 5.5 - Comparison of types of environmental impacts for each component of mobile phone.

5.1.1 Analysis Flow Chart for the Whole Mobile Phone Package

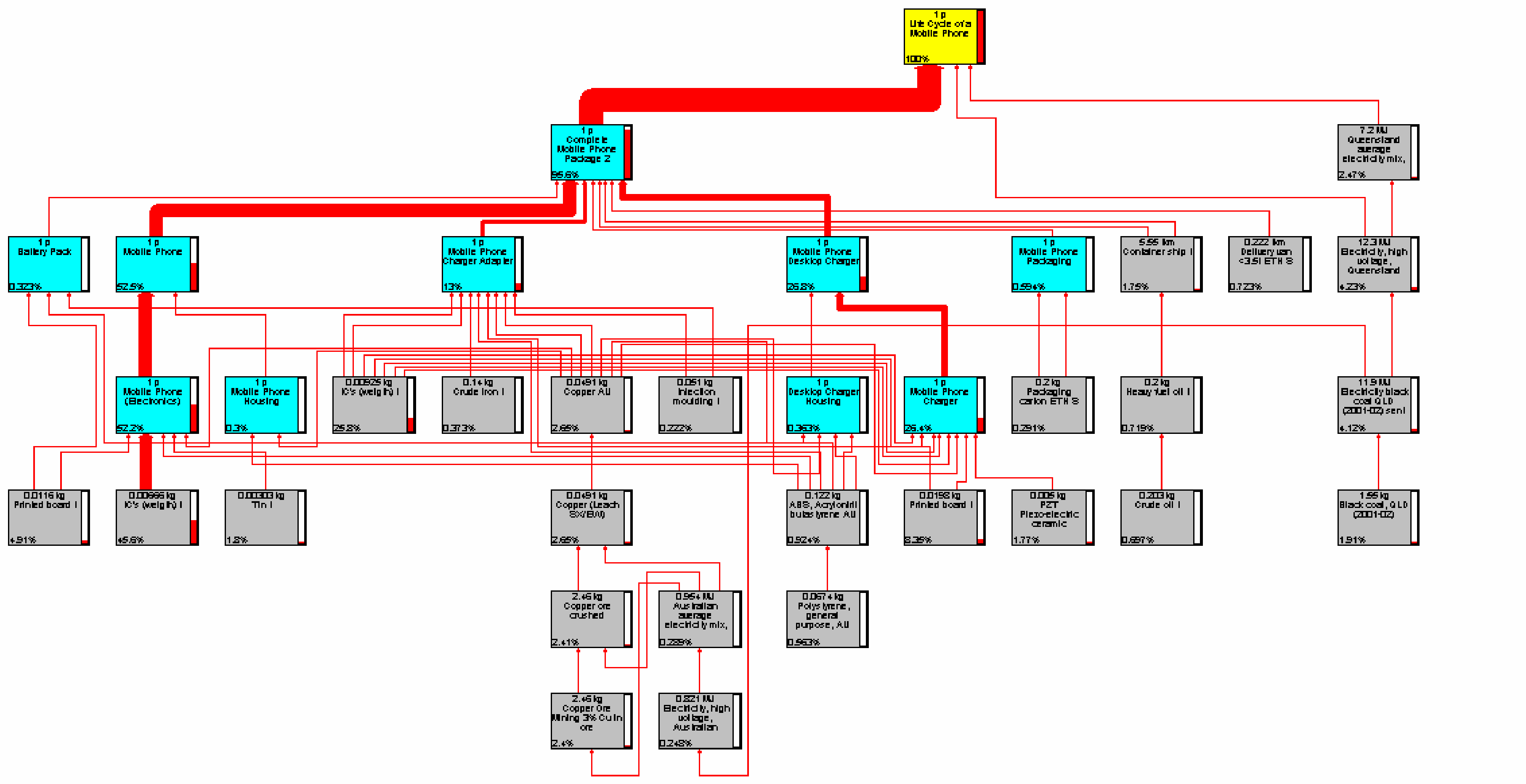

Figure 5.1 Analysis Flow Chart for the Whole Mobile Phone Package

The yellow box indicates the product life cycle of a mobile phone, and the blue boxes are the major individual components of the mobile phone. The red box indicates the disposal scenario of the mobile phone. The grey boxes that follow are the items from the database which make up the processes in the software.

Figure 5.1 shows the flow chart used in the whole life cycle of the mobile phone. It is in terms of single score. Upon closer observation, one can see that the mobile phone itself causes the most impact out of all the other individual components. This is noted by the thick red line. This is mostly caused by the presence of electronic components; especially PCBs and ICs. Later on in the following chapter, there will be discussions on why these components cause so such significant environmental impacts. Observations in this chart will be used together with other graphs in order to carry out more detailed investigations for main problem areas and source of environmental impacts in the following chapter.

5.1.2 Comparison of the environmental impacts for each process from the inventory list

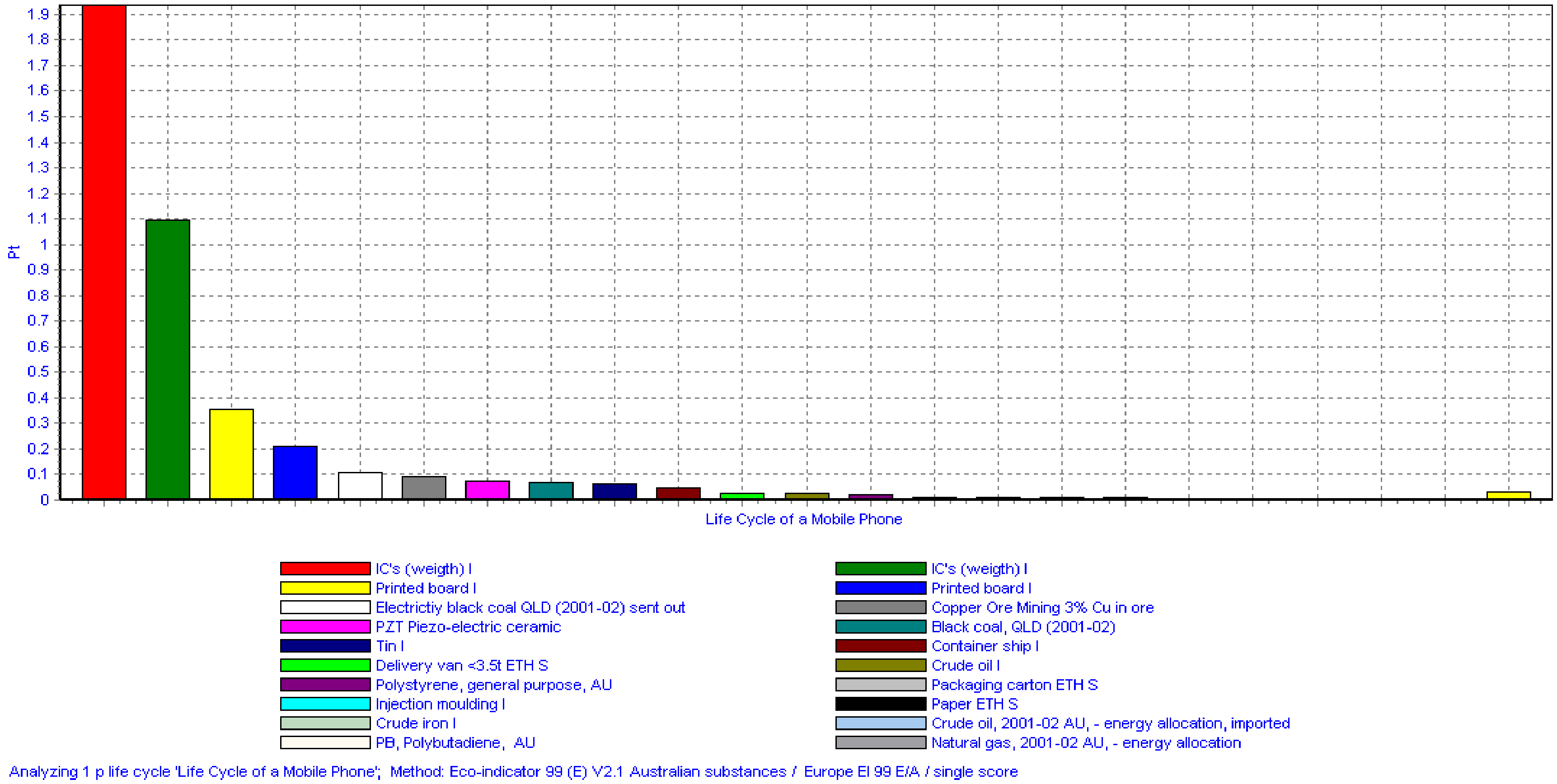

Figure 5.2 Comparison of the environmental impacts for each process from the inventory list

Figure 5.2 shows the single score environmental impacts caused by each process entry into SimaPro. As mentioned in chapter 4, the normalisation process is to allow the various impacts to be numerically compared. Again, this graph is in terms of single scores.

This graph does not show the complete list as impacts from a lot of the items can be considered as negligible. It should be noted that the impacts from ICs (Integrated Circuits) and PCBs (Printed Circuit Boards) are very significant. This is due to the fact that there are a lot of energy and materials required to produce a PCB. Some of these materials are chemicals that can harm human health and the environment. Good examples would include arsenic and acids. This will be discussed in the following chapter.

It should also be noted that there are two categories of integrated circuits and printed boards in figure 5.2. This is because these two items are present in both the mobile phone electronics and the desktop charger of the mobile phone. Instead of adding both as one in the impact assessment, SimaPro has conducted the assessment of these products as two separate items. This similar pattern is also observed in similar graphs throughout the dissertation.

5.1.3 Comparison of types of impacts

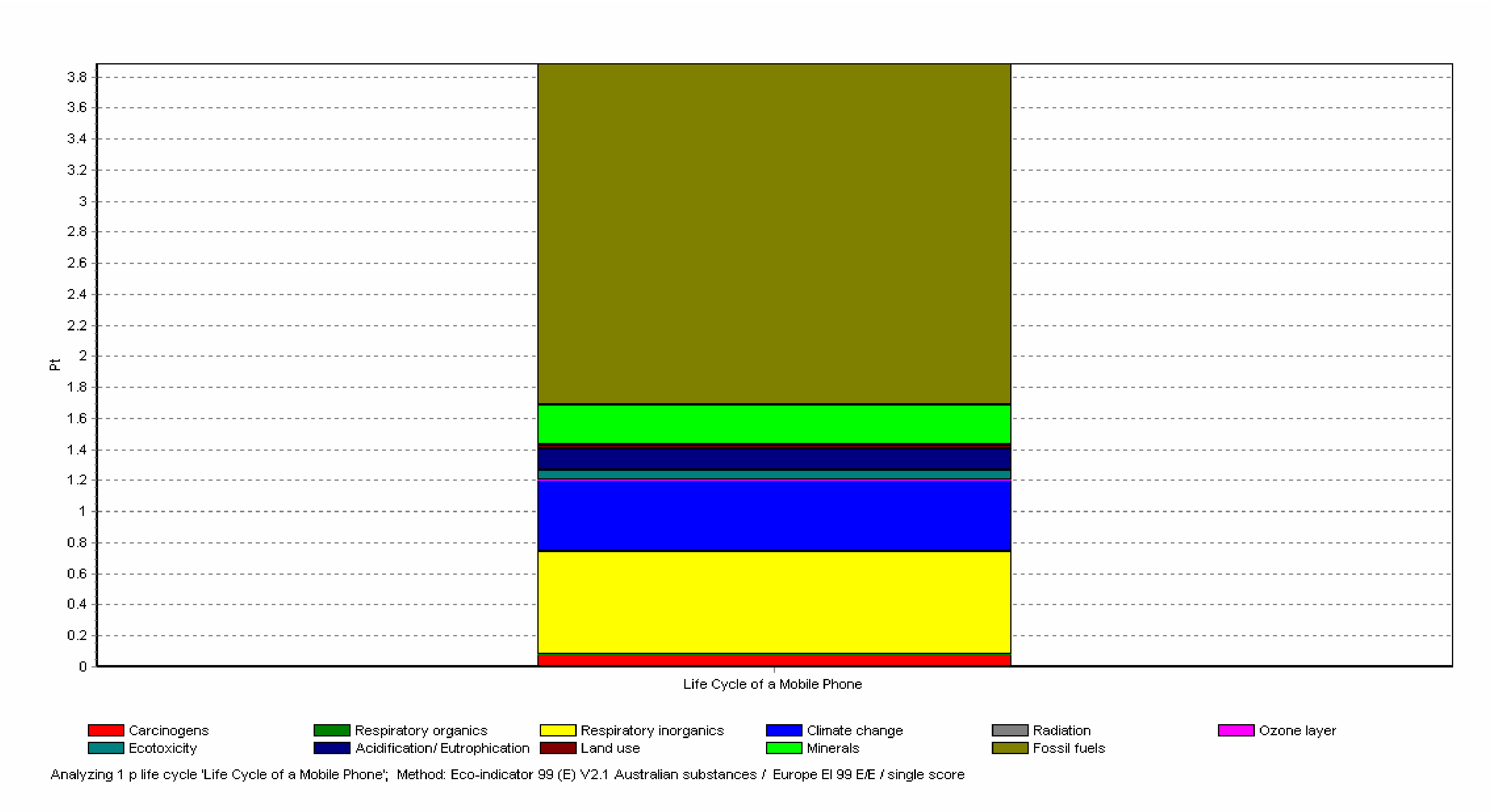

Figure 5.3 Comparison of types of impacts

Figure 5.3 is a summary of the types of impacts from the whole mobile phone package. As seen in the graph, there are many types of impacts taken into account by the Eco-Indicator; carcinogens, respiratory organics and respiratory inorganics, climate change, radiation, ozone layer, ecotoxicity, acidification, land use, minerals and fossil fuels. As mentioned before, these figures are all single score results. This is why the graph above is able to illustrate all the impacts in one bar chart. The ability for such comparisons is because in the above graph; all the impacts are normalised.

Upon closer inspection of the graph, it can be noted that fossil fuels cause most of the environmental damage when compared to the other types of impacts. There are several reasons for that. The method used for this particular analysis emphasises on the egalitarian perspective. Fossil fuels are one of the few non-renewable resources used in the making of the mobile phone. It comes from many sources throughout its life. Usage of fossil fuels my come from Queensland power plants, the making of plastics and printed circuit boards. The fact that this mineral is not renewable means that each time it is used, there is a certain amount of environmental impact caused.

Figure 5.3 gives the user a rough idea of the types of impacts involved, as well as the amounts relative to one another.

5.1.4 Comparison of levels of environmental impacts for each component of the mobile phone

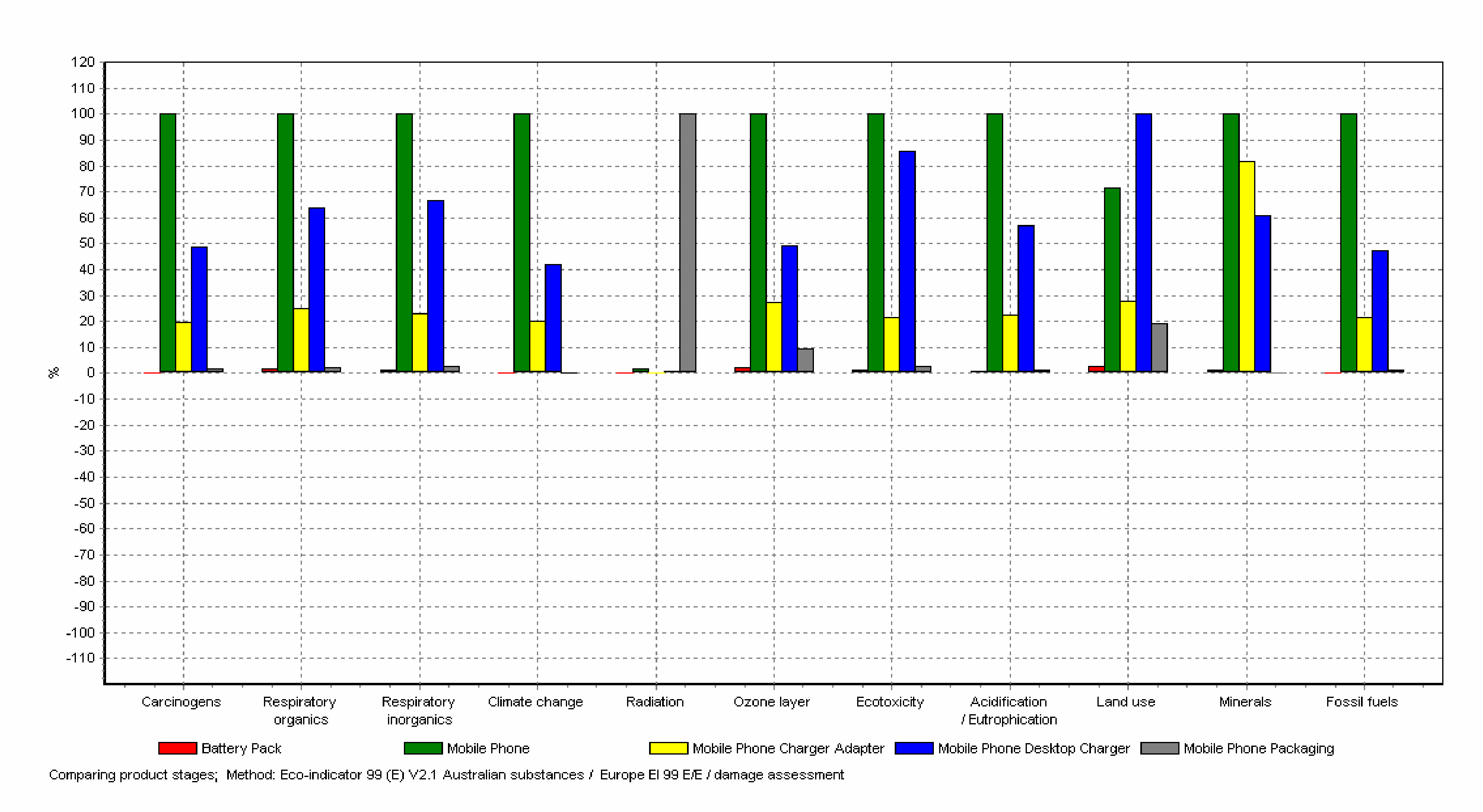

Figure 5.4 Comparison of levels of environmental impacts for each component of mobile phone

Figure 5.4 shows the impacts of each individual component of the mobile phone. It also acts as a compliment to *figure 5.1* as well as *figure 5.3*. Positive percentages indicate environmental impacts where as negative percentages means environmental improvement.

It should be noted that in most cases, the mobile phone addresses the most damage, when compared to the other components of the mobile phone. Next in line is the desktop charger. Both these components possess such impacts when compared to the others is because of the electronic components found in them. It was suggested previously in figure 5.2 that PCB and IC cause the most impact environmentally. This is another reflection of that argument.

On the opposite end of the scale, battery packs seem to have little or even positive environmental impacts. This might be due to the batteries being something that is constantly being reused. What this means is that the batteries are recharged rather than disposed off when it is out of energy. Each battery can be recharged up to 1000 times throughout its life. This means that 1 rechargeable battery can take the place of 1000 non-rechargeable battery. By the end of its life, it would have done more good than damage to the environment. Its benefits would cancel out the negative impacts caused during the production of the battery.

5.1.5 - Comparison of types of environmental impacts for each component of mobile phone

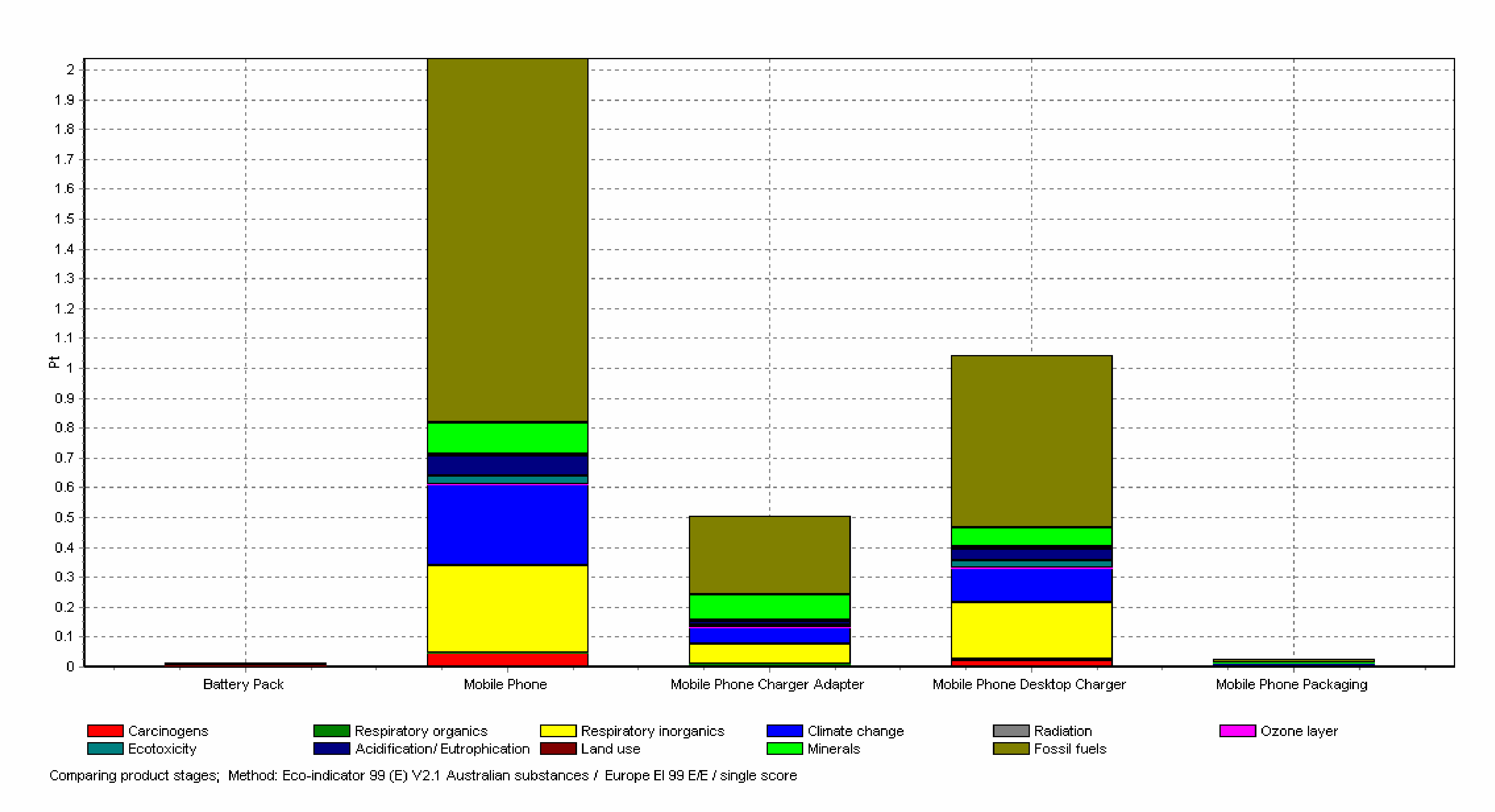

Figure 5.5 Comparison of types of environmental impacts for each component of mobile phone

Figure 5.5 is like the breakdown of *figure 5.3* and *figure 5.4* so that the impacts of each component of the mobile phone are broken down. The types of impacts covered in this graph are the same as in figure 5.3.

The results from this graph are consistent with the graph in figure 5.4. Once again, the use of fossil fuels seems to be the main cause of environmental impact. As for the battery pack and the packaging seem to have very little impact on the environment when compared to the other components. The graphs are so small that it is impossible to investigate the different impacts. It was discussed previously that the battery causes so little impact because it is a reusable item. The repeated use of it almost cancels out the negative impacts caused during the other parts of its product life. As for the relatively low environmental impact of the mobile phone packaging, the impacts are just insignificant when compared to processes such as fabrication of PCB. It does not require much energy to produce paper, when compared to other components of the mobile phone.

5.2 Analysis of Results

From the readings obtained above, the user can grasp the general trend of the environmental impact of a mobile phone. Obtaining the graphs was very straight forward and constitutes the inventory analysis part of the normal life cycle assessment. The final part of the Life Cycle Assessment is the interpretation which is left to Chapter 8 after further breakdown of the results for analysis. This was done in Chapter 7. The ability to analyse and break the results down is very vital in this project as wrong diagnosis would cost the user a lot; especially if future development of a product is solely based on the analysis of these graphs. Wrong diagnosis would lead the user to focus on less important parts of the product.

The next chapter will focus more on the breakdown of the graphs obtained in this chapter. There will also be further discussions on the problem areas found in graphs in both chapters.

Chapter 6 – Analysis of Results

The results obtained in Chapter 5 are summaries of the various impacts of a mobile phone and its individual components. This is otherwise known as the single score analysis of the impact assessment. In this chapter, a more detailed analysis of results is presented. They are broken down into several categories and are illustrated in the following sections of this chapter.

6.1 Description of Type and Category of Results

There were different types of results for analysis; network, impact assessment, inventory, process contribution and checks. This is further discussed below. Various types of charts were obtained from the first 4 types of analysis, while the last option was used to check whether a substance is included.

Within the types of results are the different types of impacts, classified under different categories; inventory, characterization, damage assessment, normalization, weighting and single score. All the different types of results will be discussed in the following section. The characterization and single score results are the more important graphs while the other results are usually optional and are not available in some methods of analysis.

6.1.1 Type of Results

Network simply shows flow charts of the different types of impacts. It basically shows the amount of each type of impact. This was illustrated in figure 5.1 where the thicker lines indicated that the particular component of the mobile phone caused more environmental impacts. The *impact assessment* shows the summaries of impacts caused by the product throughout its whole life. Different Methods usually concentrate on different types of impacts and this will vary accordingly. The *inventory* shows the impacts caused by the raw materials used to make the different components in the mobile phone. Last but not least, the *process contribution* shows the impact caused by each of the process involved in producing and using the mobile phone.

6.1.2 Categories of Results

The *inventory* results only show a list of substances used in the analysis in each type of results. *Characterization* shows the different types of impacts for the particular method of assessment. These substances contribute to an impact category that is multiplied by a characterization factor that expresses the relative contribution of the substance. This may vary with the different types of methods of assessment as each method focuses on different types of impacts. The units used for quantifying the damages are different and usually are not used as comparisons of one another. The *damage assessment* can be used as the summary of results obtained in the characterized graphs. After summarizing the graphs, they are then converted into the same units so that comparisons can be made. This is otherwise known as *normalization. Weighting* allows for the impact category results to be multiplied by weighting factors and then added forming a total score. *Single scores,* as discussed in chapter 5, is the summary of results.

6.2 Analysis of and Discussion of Results

Mentioned previously in chapter 4, the 'Eco – Indicator 99 (E) V2.1 Australian Substances' Method was used to achieve initial results. These results can be found in the appendix section of this dissertation. Each type of the results will be discussed in the following subsections of this chapter.

6.2.1 Network

The networks of various flow charts are provided in Appendix C of the dissertation. Figures C.1 to C.8 shows the different categories of environmental impacts; fossil fuels, carcinogens, land use, acidification, exotoxicity, etc. Figures C.9 to C.11 shows the three types of damage assessment charts; human health, ecosystem quality and resources. Most categories of damage assessment are included while the others were left out because of similarities between them and other included charts. As mentioned in chapter 5, the yellow box indicates the life cycle of the mobile phone, the blue box indicates the separate components of the mobile phone, while the grey box indicates the processes from the inventory list.

The single score indicated that most of the environmental impact is contributed by the mobile phone package itself, rather than the other components of the mobile phone; charger, packing, etc. The break-down of the single score flow chart indicates shows that in each category, the mobile phone package contributes to about 90% to 100% of the environmental impact. The mobile phone handset contributes to about half the environmental impact of the mobile phone package. The reason for these impacts is due to the presence of integrated circuits (IC) and printed circuit boards (PCB). The damage assessment flow charts also show similar results. The PCB and IC contribute to most of the environmental impacts in each case. This is indicated by the thick red lines that flow into the 'mobile phone' box and then to 'Integrated Circuits' or 'Printed Circuit Boards'.

6.2.2 Impact Assessment

The graphs showing the summaries of impact assessments are in Appendix D. The first graph shows the damage assessment of each type of components in the mobile phone. The components were compiled as one item when entering data in SimaPro. Hence, this shows the obvious; each category of impact is contributed by 100% of the mobile phone package. Figure D.2 shows that all the categories of impact have normalized units so that they can be compared with one another. All these impacts are very small but the one that stands out is caused by fossil fuels. The use of fossil fuels occurs in various stages in the life of a mobile phone. Most of it is used in transportation. It is also used in the production stage to carry out various tasks; lubrication for production machinery, raw material used in producing plastic, etc. The next highest impacts are respiratory inorganics, climate change and minerals. Respiratory inorganics defines the gases produced in the various stages in the life cycle of the mobile phone. Most of these gases lead to the change in climate, which then leads to impacts in human health.

Figure D.3 also shows similar results to that of figure D.2. Figure D.3 is a graph but with different units of measurement, hence the similarities.

6.2.3 Inventory

The graphs obtained showing the categories of environmental impact contributed by the individual substance of the mobile phone components are in Appendix E. These graphs show the more minute details of the entries into SimaPro. These can be considered to be the environmental impacts caused by the raw materials used to assemble the mobile phone.

Due to the lack of expertise in the chemicals involved in each of the processes, further investigations and analysis could not be carried out.

6.2.4 Process Contribution

The graphs that show the categories of environmental impact contributed by each of the processes are in Appendix F. Figures F.1 to F.8 shows the different categories of impact by each process. Figures F.9 to F.11 shows the three types of impact assessment while figures F.12 to F.17 shows the normalized and weighted results. The processes referred in this section mean the inputs entered into SimaPro from the database. These inputs make up the components in the inventory list.

Most of the graphs give strong indications that ICs and PCBs are the main contributors of the various types of environmental impact. There are several graphs that indicate that energy use is the next major environmental impact; despite being very low when compared to ICs. This will be discussed in the following section of this chapter.

Figure F.5, which shows environmental impacts due to land use, indicates PCBs and container ships give highest readings in the graph. This might be due to the PCBs causing land pollution when disposed. A container ship is quite a big vehicle and it takes up a lot of space when in operation. Figure F.6 shows that the use of copper has produced the highest reading in the graph. It is then obvious that the use of a non-renewable resource damages the environment as it deteriorates the amount of reserves.

There is no contest that ICs and PCBs are the main contributors to the damage assessment, normalization and weighting graphs. This further compliments the single score analysis in chapter 5. These factors will be discussed in the following section of this chapter.

6.3 Integrated Circuits and Printed Circuit Boards

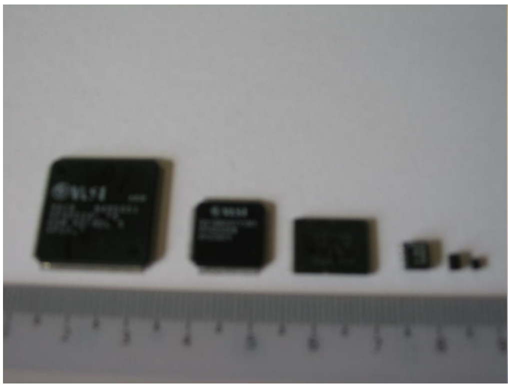

Figure 6.1 Integrated Circuit

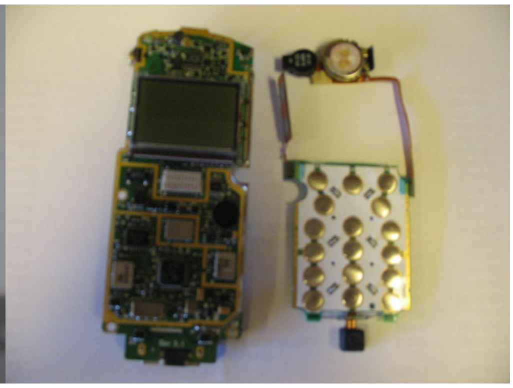

Figure 6.2 Printed Circuit Boards

In 2002, the American Chemical Society published an article containing certain information about the manufacture of a microchip. In The 1.7 Kg Microchip: Energy and Material Use in the Production of Semiconductor Devices' (Williams et al 2002), evidence is given that about 1.7 kg of material is used in producing a 2 g integrated circuit chip.

It seems fit therefore to use the ratio of 1672 to 2 for the estimation of how much raw material is used to produce the microchips found in the mobile phone. In the case of the mobile phone used in this project, a total of 31.42 grams of printed circuit board and 7.14 grams of integrated circuit are present. This means that a rough estimate of 26267 grams of materials is used to produce only the microchip in the mobile phone. This figure is quite significant in the big picture as millions of mobile phones are produced, which will make the materials used for production a very large number. Most of these materials are toxic as well. Emissions produced from these chemicals also have an adverse effect on the environment.

Figure 6.1 shows the list of chemicals that adds up to about 1.7 kg in the making of a 2 gram chip.

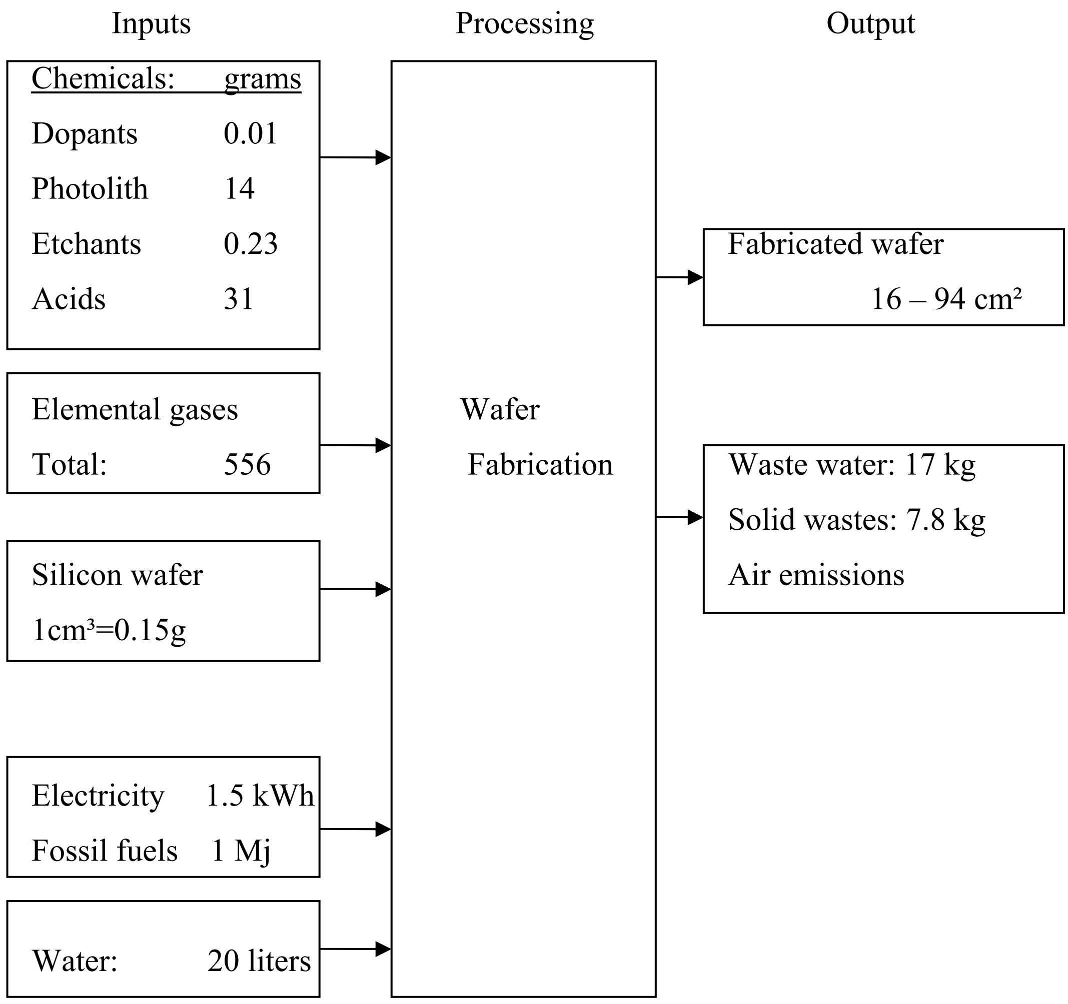

Figure 6.3 Summary of Input/Output for wafer fabrication

(Source: Williams E D, Ayres R U, "The 1.7 Kilogram Microchip: Energy and Material Use in the Production of Semiconductor Devices", USA, 2002.)

Analysis from SimaPro indicated that PCBs is the main contributor of negative environmental impacts. These readings are consistent with the analysis found in Williams et al (2003), mentioned beforehand. The production of printed circuit boards go through several processes and each process sees the introduction of various chemicals for etching away copper, cleaning, etc. It should be noted that not all the inputted chemicals end up in the final product, meaning emissions and other waste chemicals are the outputs from the manufacturing process. This may prove to be harmful to the environment even with proper disposal of these wastes.

While the above shows the processes and materials involved, the following table shows a summary of inputs and outputs involved for the production of a 6 inch silicon wafer.

Inputs	**Outputs**
3,200 cubic feet of bulk gases	25 pounds of sodium hydroxide,
22 cubic feet of hazardous gases	2,840 gallons of waste water, and
2,275 gallons of deionized water	7 pounds of miscellaneous hazardous wastes.
20 pounds of chemicals	
285 kilowatt hours of electrical power.	

Table 6.1 - Summary of inputs and outputs for production of a 6 inch silicon wafer (Source: IC Home, Environmental Impact, Canada, Viewed: 5th June 2005, <http://www.csc.uvic.ca/~mserra/Fab1/html/environmental_impact.html>)

These results are also consistent with Breitengross (1993). According to his report, there are numerous aspects of the environment that should be taken into account when it comes to the manufacturing process. The most critical are human health impact and direct environmental impacts. For example, strong mineral acids can produce fumes that are dangerous. When inhaled, these fumes could cause respiratory irritation, pulmonary edema and even death. These fumes cause metal corrosion upon contact. Big quantities of these could cause possible acid rain. Another harmful ingredient involved is arsenic (IC Home, 2005). Runoffs can pollute local streams and water bodies. It is also harmful to human health if inhaled, swallowed or absorbed through the skin. It should be noted that semiconductor workers face illness three times that of normal manufacturing workers (IC Home, 2005).

There is no doubt Printed Circuit Boards and Integrated Circuits are harmful to human health and the environment, as mentioned above. Environmental responsibility should be practiced. These issues will be further discussed in later in chapter 8.

6.4 Conclusions

It is clear now that the Integrated Circuits and Printed Circuit Boards, in which a microchip is made up of, cause the most damage to the environment. Again, this is due to the various harmful chemicals involved in the manufacturing and fabricating of the microchips. With the problem area identified, more efforts can now be focused on these particular electronic components. These will be discussed during the discussions of suggestions in chapter 8 of the dissertation.

Chapter 7 – Sensitivity Analysis

When entering data into SimaPro, several values had to be estimated. This was due to a few factors. Lack of test equipment was the main contributor to the uncertainty. For example, there were various metals extracted from the mobile phones that could not be identified. General assumptions were made based on observations. Metal plating and alloys were not taken into consideration as it was near impossible to determine the exact materials involved or their quantity. Other factors included the many choices available in the SimaPro database, and some uncertainty about, for example, which metal allow choosing for a particular component.

A useful way to assess the importance of the assumptions which were made is to carry out a sensitivity analysis. This method is to pick the most logical of the choices, then run the analysis. After that, substitute these unknown metals with the other choices and run the analysis again. Compare the results from both analysis and draw conclusions about which choice was better. For example, if the change makes little difference to final results, then the assumption made was not of great significance in the outcome. However, if the change makes significant difference, then the detail of that category is critical and may need to be given greater attention.

The sensitivity analysis was carried out in two ways; the modification of materials as well as weights within the same, original method of carrying out the impact assessment and different methods of impact assessments. It seemed like there were two completely different types of sensitivity analysis. Carrying out the first type of sensitivity analysis would allow for determining any plausible errors when initially compiling the inventory list. Results obtained from these modifications of the inventory list would be compared to the initial readings obtained in chapters 5 and 6. Using other Methods for carrying out the impact assessment would give an indication of how significant the Methods chosen are in obtaining valid results. If a different Method gave different results about environmental impact, then there would be suspicion over the validity of that Method or overs the way it was used.

7.1 Modifications of Original Inventory List

There were numerous uncertainties in the inventory list and several key items were picked out to be modified. The results were then compared to check for any changes. Drastic changes would mean that there was something wrong with the inventory list and further debugging needed to be carried out. If changes were not very big, that means that either the contribution of the process to the environmental impact can be negligible or the substitute process contribute similarly to the environmental impacts.

Several items in the inventory list were modified. These included the following:

- Various distances travelled during transportation
- Changing various electricity used

7.1.1 Increased Distances Travelled

The distances travelled were in terms of kilometres kilograms. The original values travelled were 667.715, 4881.91 and 221.905 kilometres kilograms. The first distance was the distance travelled in transporting batteries from Japan to South Korea. The next was the distance travelled from South Korea to Japan and the last distance was the average distance travelled in the distribution of the mobile phone within Australia. These values were increased to 750, 5000 and 350 kilometres kilograms respectively.

PCBs and ICs were the main problems in the results in the previous chapters, while energy use seemed to be the next problem area. Upon increasing the total distance travelled, the results are then compared to determine whether there are significant changes in results. These results were chosen to be modified as only rough estimates of distances were taken when taking measurements. The average distance travelled within Australia was not specified and a rough figure was given.

7.1.1.1 Results

Upon increasing the results, only the single score results were used as these results could be used as comparisons. The graphs obtained are as follows:

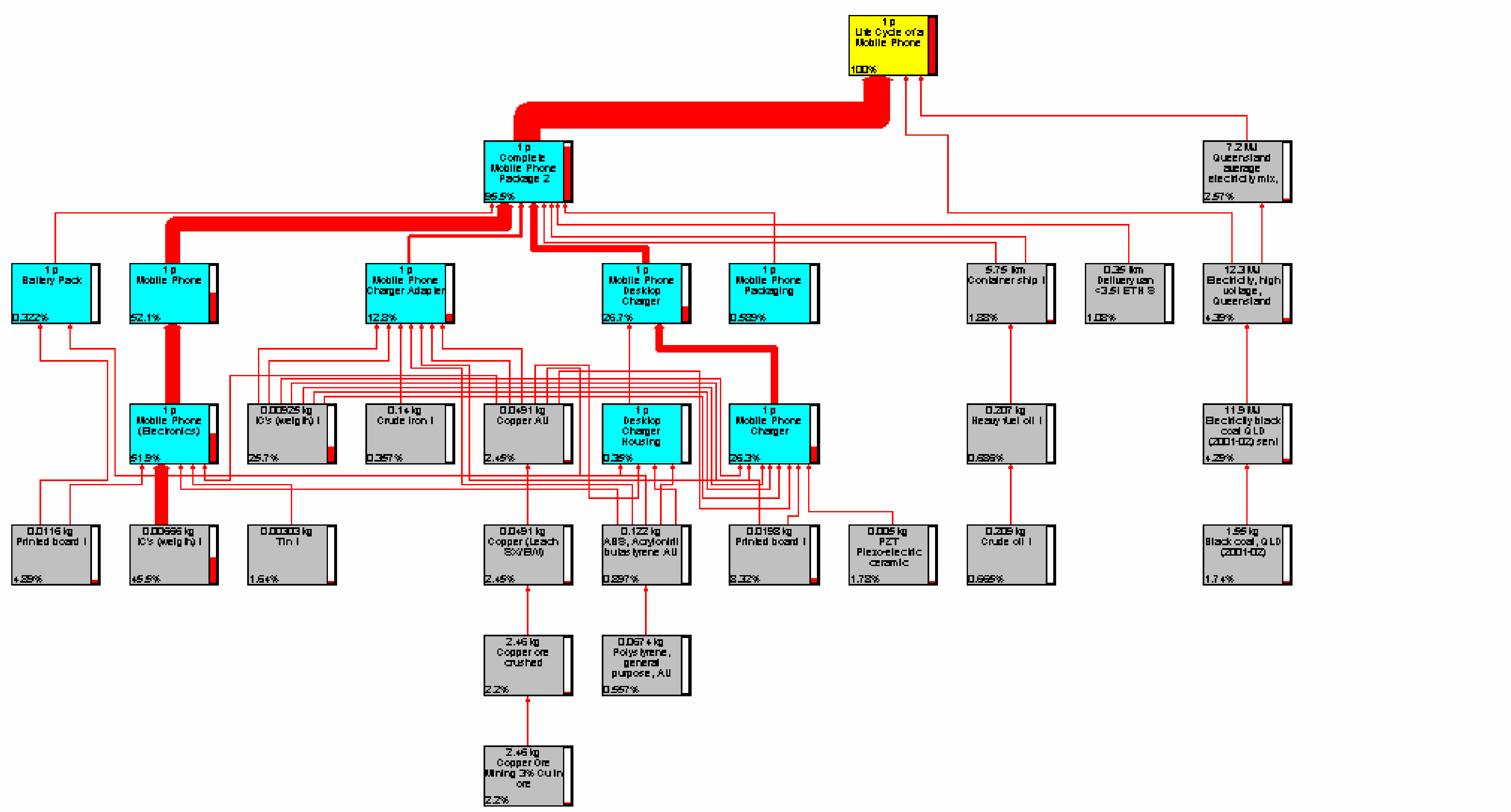

Figure 7.1 Network Analysis - Single Score Results from Increased Distances

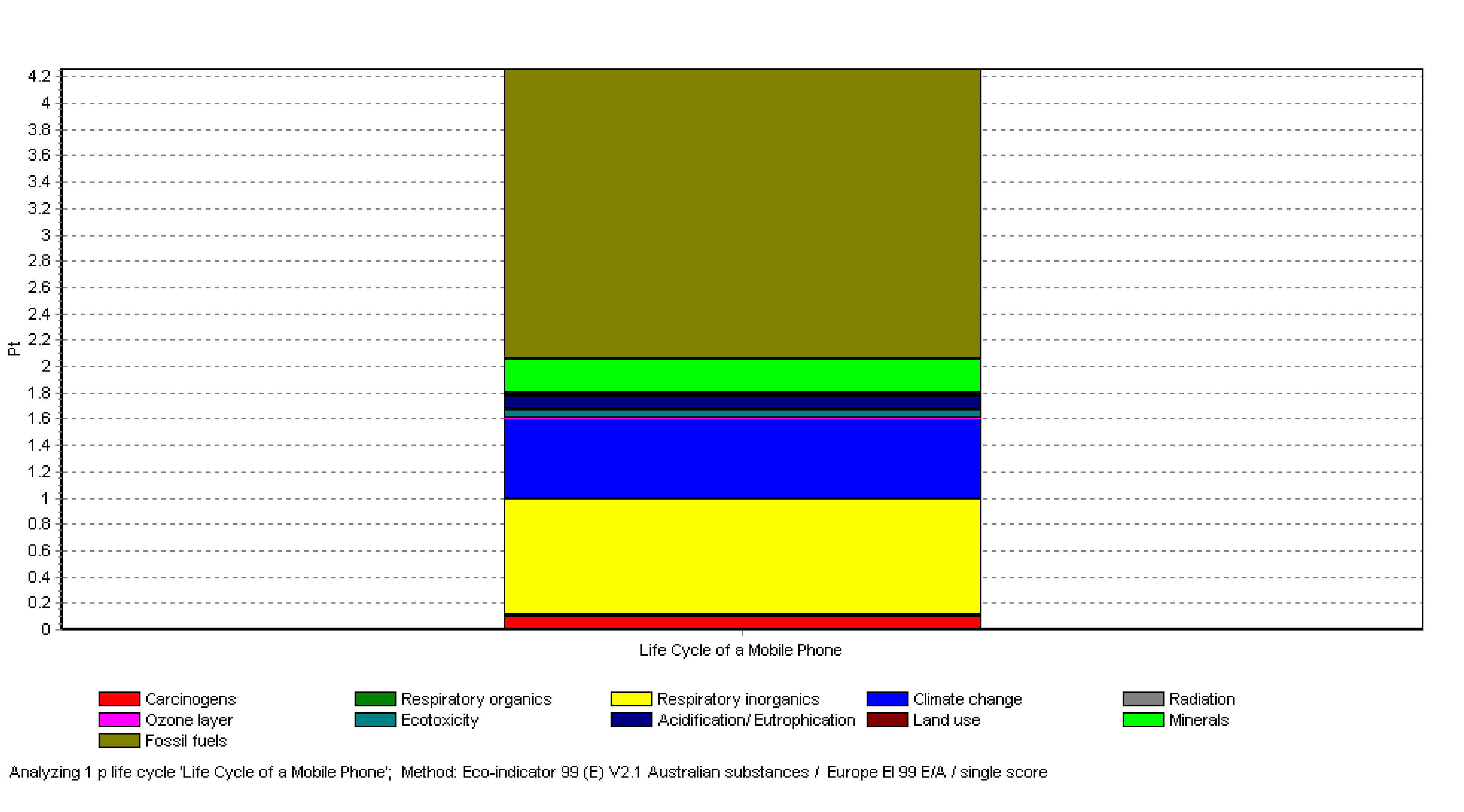

Figure 7.2 Impact Assessment – Single Score Results from Increased Distances

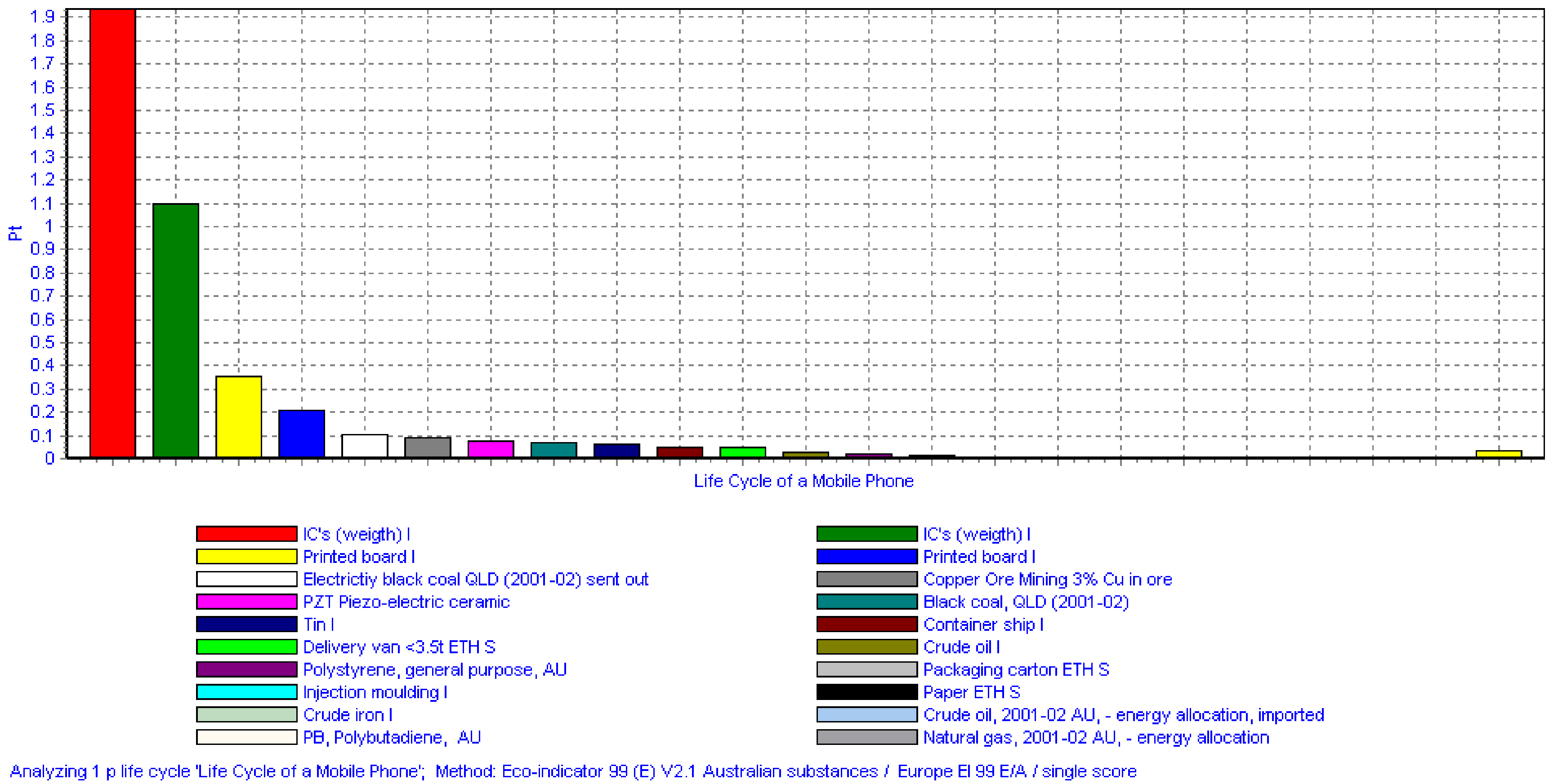

Figure 7.3 Process Contribution - Single Score Results from Increased Distances

7.1.1.2 Discussion

The comparisons of the above graphs (figure 7.1 to 7.4) with the single score results obtained in chapter 5 do not show any change. This shows that the data for transportation in the mobile phone life cycle is not the main contributor of environmental impacts and it is not a critical form of data. This also proves that the results initially obtained were accurate and not critical to the overall impact assessment.

7.1.2 Increased Energy Usage

There were two main areas of energy usage under investigation; energy used throughout its product life and energy used during wholesaling and retailing. The original readings were 1.418 and 2 kWh. Again, estimates were used in the initial impact assessment. Energy used throughout the mobile phone's life was measured as described in chapter 3 but again, there were doubts in the methods used. There were also no figures available for the energy used in the wholesaling and retailing of mobile phones. A rough figure was given upon further research of the topic.

The reason behind the increasing of these figures was similar to that of the above. It was to determine whether the increasing of the initial results would produce amplifications in the impact assessment. The mentioned numbers were increased to 3 and 10 kWh respectively. This gives an overall increase of about 4 times.

7.1.2.1 Results

Upon changing the figures, the following graphs, figures 7.4, 7.5 and 7.6, were obtained:

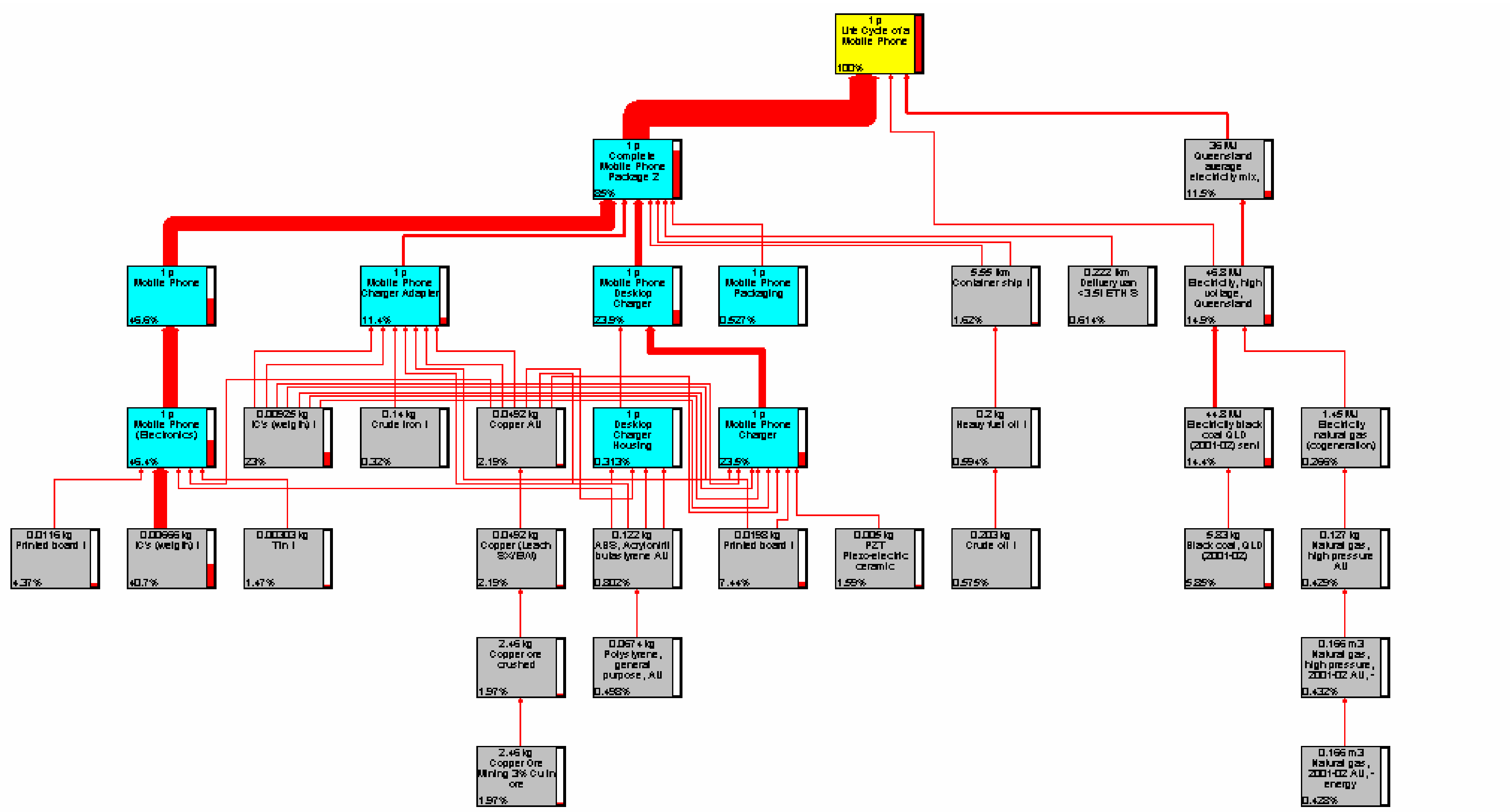

Figure 7.4 Network Analysis - Single Score Results from Increased Energy Use

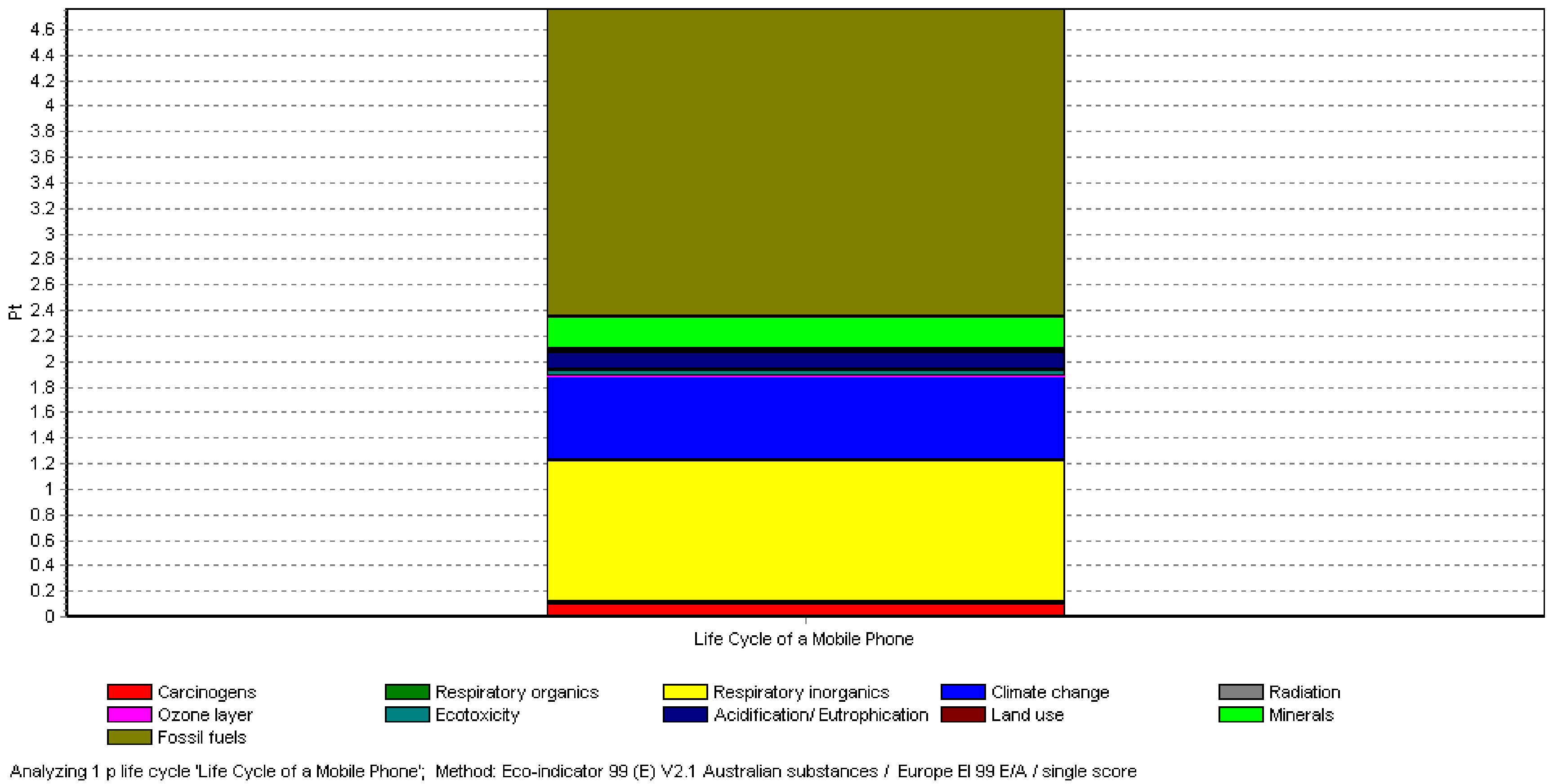

Figure 7.5 Impact Assessment - Single Score Results from Increased Energy Use

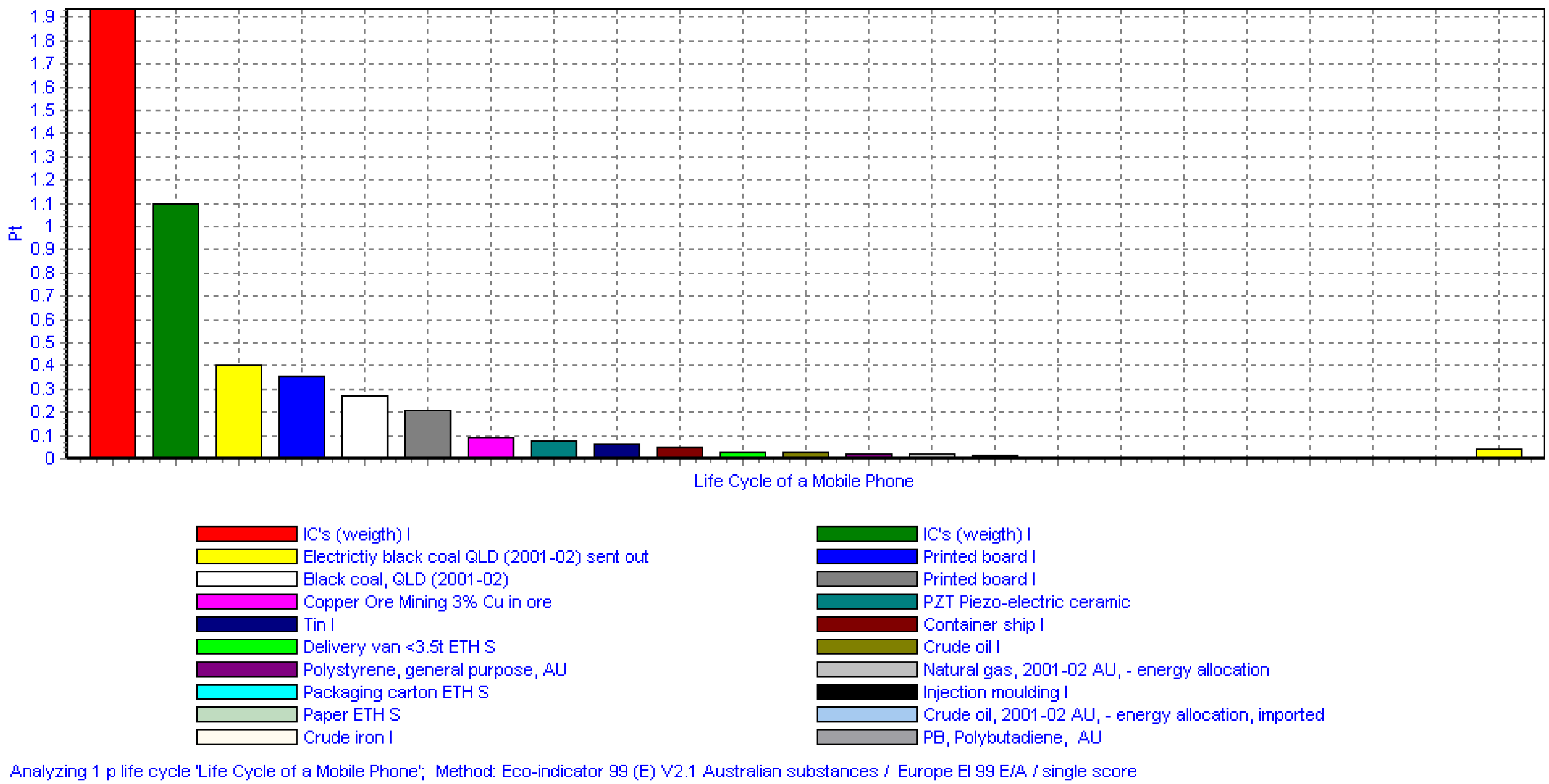

Figure 7.6 Process Contribution - Single Score Results from Increased Energy Use

7.1.2.2 Discussion

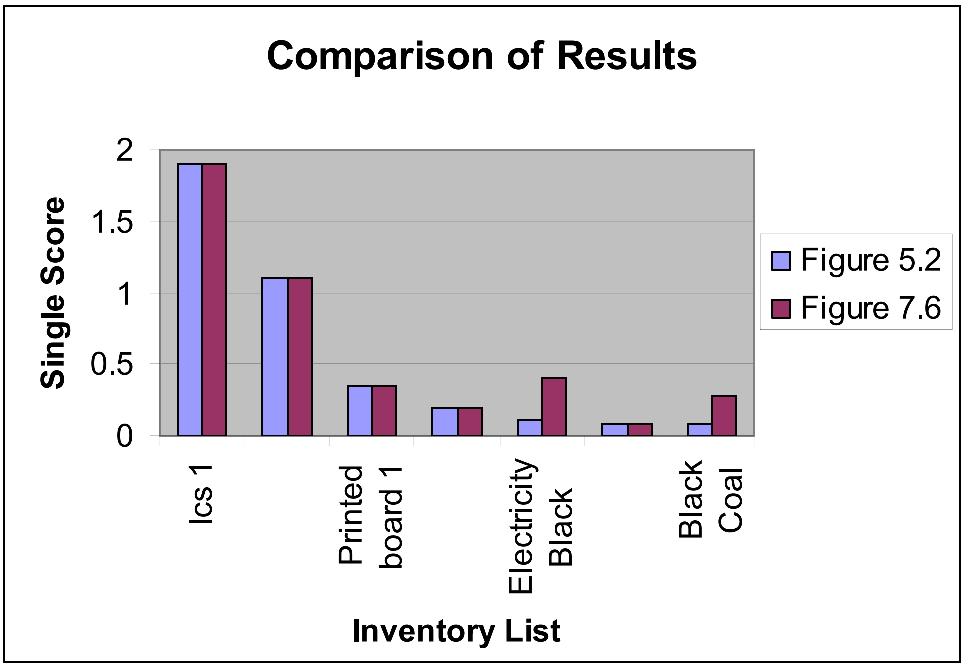

Figure 7.7 Comparison of process contribution results

The increase in energy use has increased the use of black coal to generate electricity in Queensland, Australia. It is also obvious in the network flow chart that the same increase on the environmental impact can be observed. Despite these changes, there doesn't seem to be any drastic changes observed in the impact assessment graph. This shows that data for the use of electricity is more critical to the overall assessment impact in such a way that it requires more precise readings.

7.2 Different Methods Used

This was discussed in chapter 4 and was put into practice. As previously mentioned, these different methods of impact assessment would yield different single score results as different methods emphasize on different fields.

The chosen methods were mostly Australian methods, and a few methods adapted by different countries. This was so that a larger variety of data can be collected. The same thing can cause different impact in different countries. The methods chosen were as follows:

- Enviro-Economic Val. Model Nat Kerb Study (Nolan)
- Greenhouse Model - Single Point = kg CO2eq

7.2.1 Enviro-Economic Val. Model Nat Kerb Study (Nolan)

Despite a different method of analysis, the original inventory list was used. There was not enough information in the descriptions to determine what the method of analysis is based on. The only description given was that this method was based on a study by Nolan.

7.2.1.1 Results

The single score results obtained upon analysis are below. The graphs presenting the damage assessment should give a good indication as to what the analysis is based on. This Method of analysis produced figures 7.7, 7.8 and 7.9 as follows:

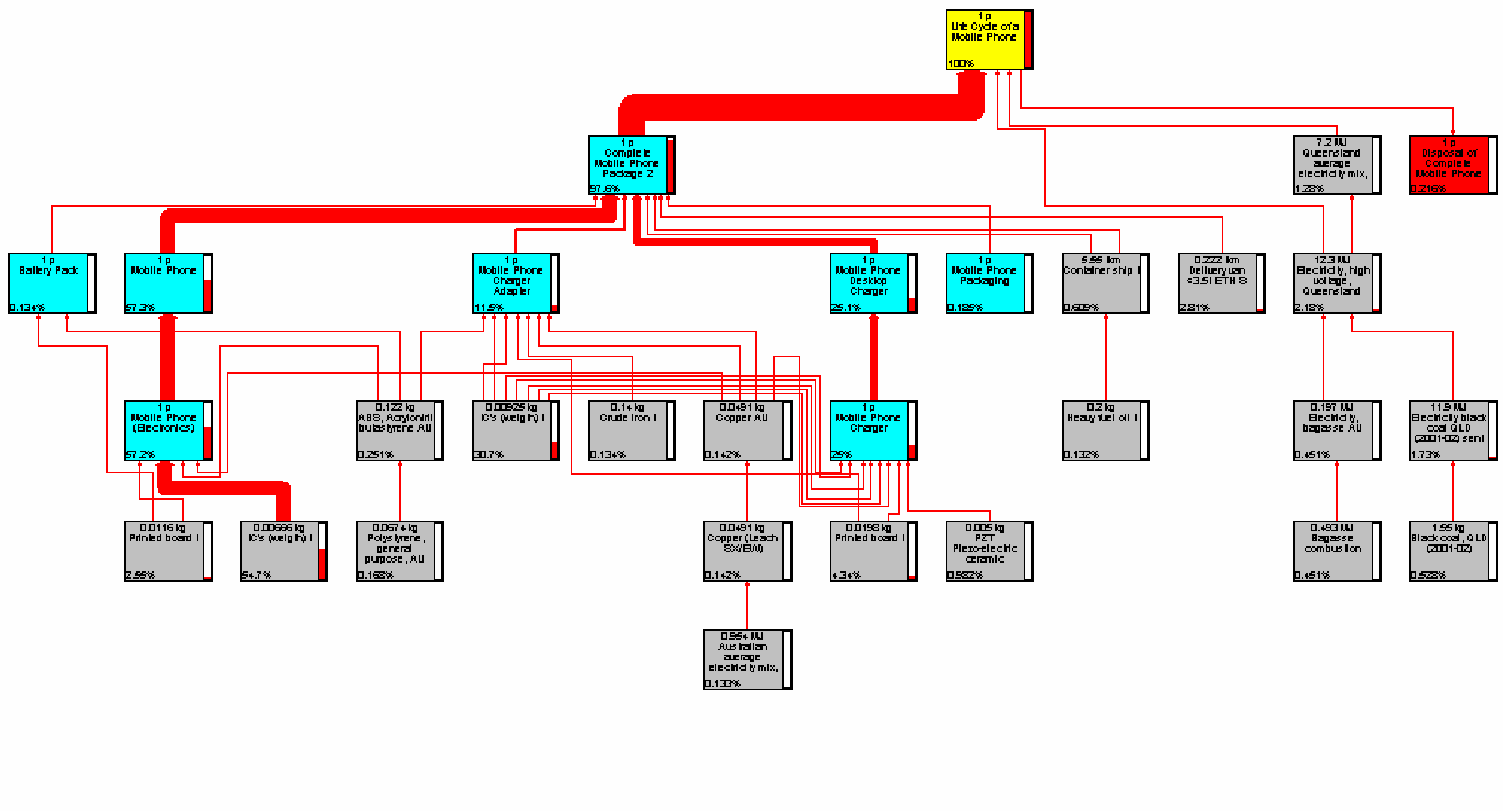

Figure 7.8 Enviro-Economic Val. Model Nat Kerb Study (Nolan) – Single Score Network

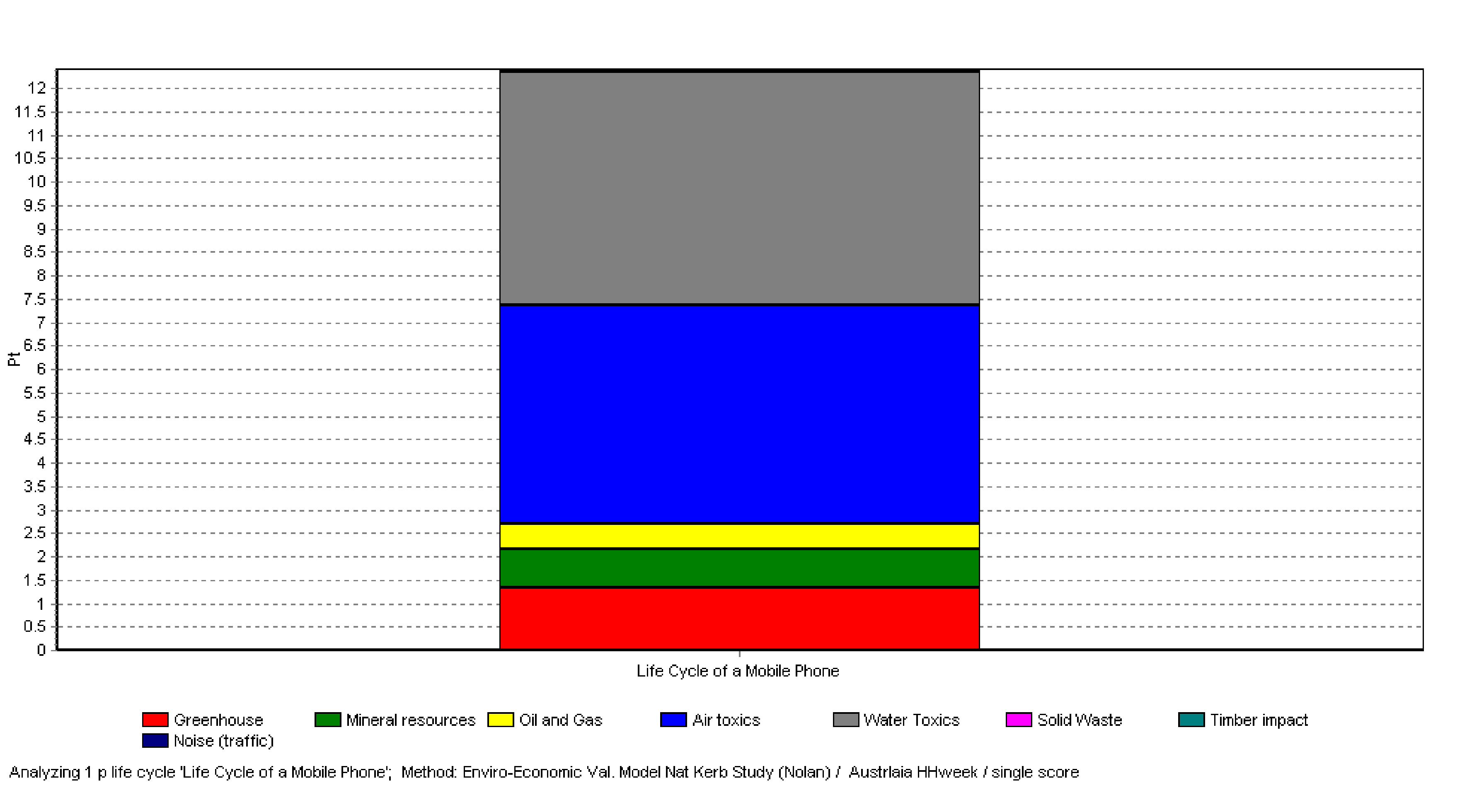

Figure 7.9 Enviro-Economic Val. Model Nat Kerb Study (Nolan) – Single Score Impact Assessment

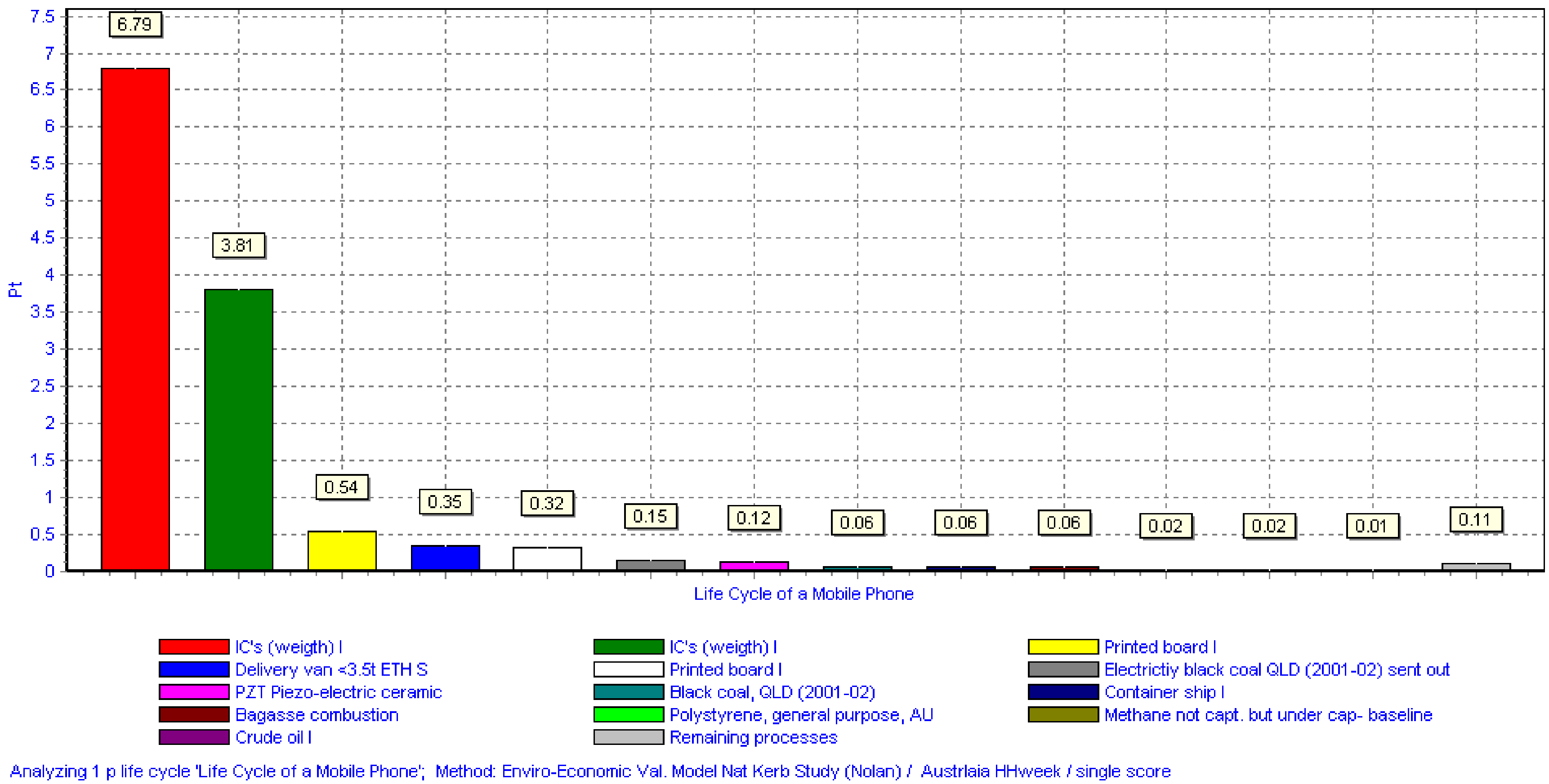

Figure 7.10 Enviro-Economic Val. Model Nat Kerb Study (Nolan) – Single Score Process Contribution

7.2.1.2 Discussion

The network analysis as well as the process contribution observed very slight but insignificant changes. Most of the impacts were still contributed by the PCBs and ICs in the mobile phones. There were similarities but the types of impacts assessed were different; greenhouse gases, mineral resources, oil and gas, air toxics, water toxics, solid waste, timber impact and noise from traffic.

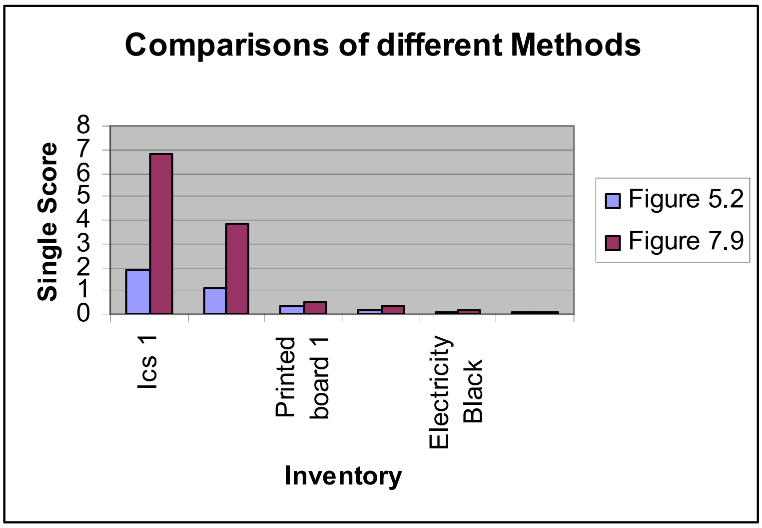

Figure 7.11 Comparison of process contribution of the Eco-Indicator Method with current Method.

The above figure shows the comparison of single score figures obtained from the process contribution graphs. It is clear that the current Method of analysis provides higher readings. This is due to the different calculations used to obtain the single score results. Despite that, the values can still be used as comparisons.

The main problem areas observed from the damage assessment graph were water toxics, air toxics and greenhouse. These factors agree with the hazards contributed by the manufacturing of microchips. As discussed in chapter 6, the manufacturing of microchips, which consists of PCBs and ICs, contributes to the environmental impacts in various forms. The main concerns discussed were water and air toxics.

The results obtained from this analysis agree with the original results obtained using the Indicator 99 (E) V2.1 Australian Substances. Both methods agreed that PCBs and ICs are the problem areas in the whole mobile phone package.

7.2.2 Greenhouse Model - Single Point = kg CO2eq

The name of the method already suggests that the analysis is based on carbon dioxide equivalents. This indicates that this method is based on greenhouse gas emissions. There was lack of information presented together with this method as well.

7.2.2.1 Results

The graphs, figures 7.10, 7.11 and 7.12 obtained upon analysis are as follows:

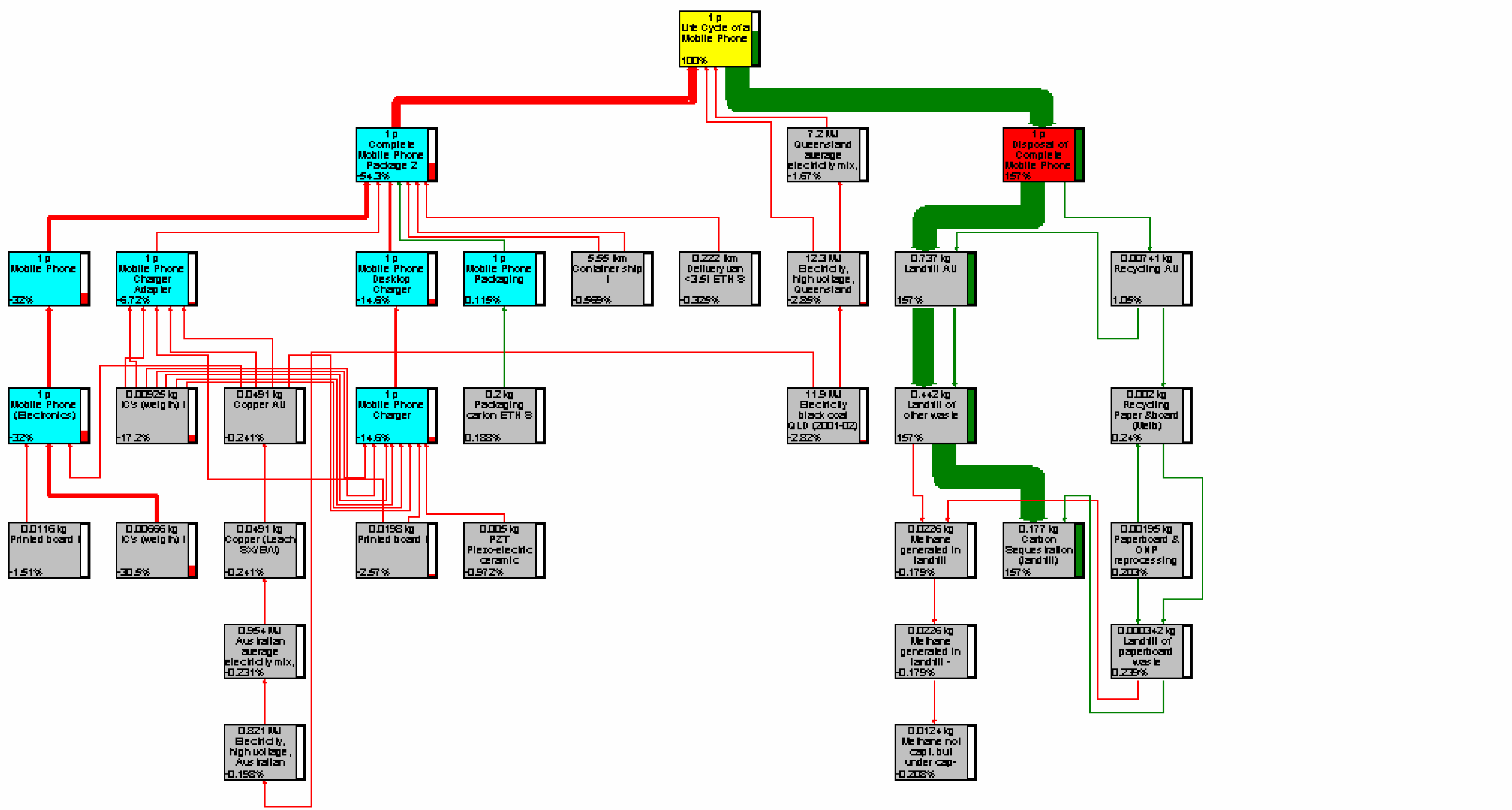

Figure 7.12 Greenhouse Model - Single Point = kg CO2eq – Single Score Network

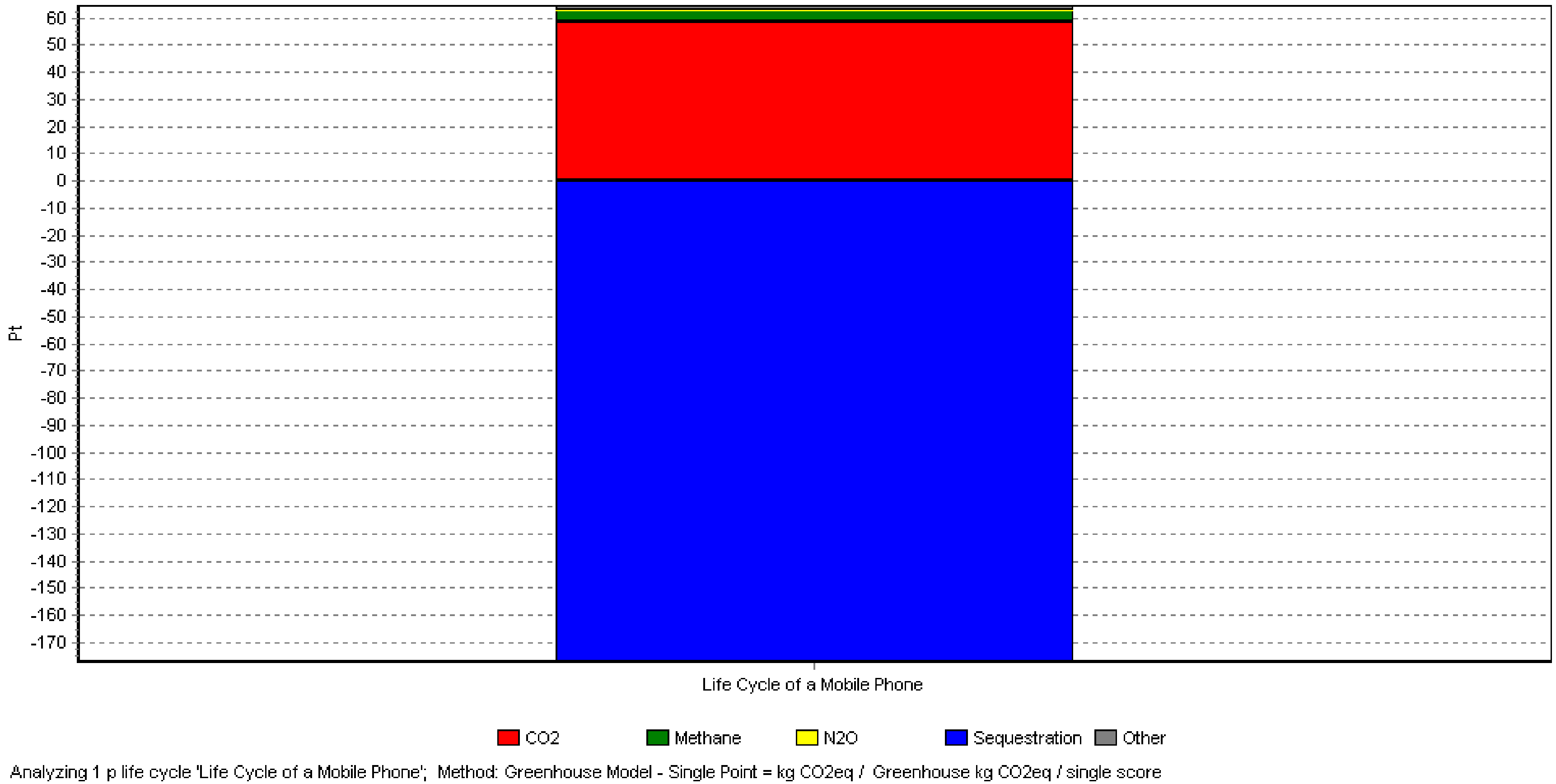

Figure 7.13 Greenhouse Model - Single Point = kg CO2eq – Single Score Damage Assessment

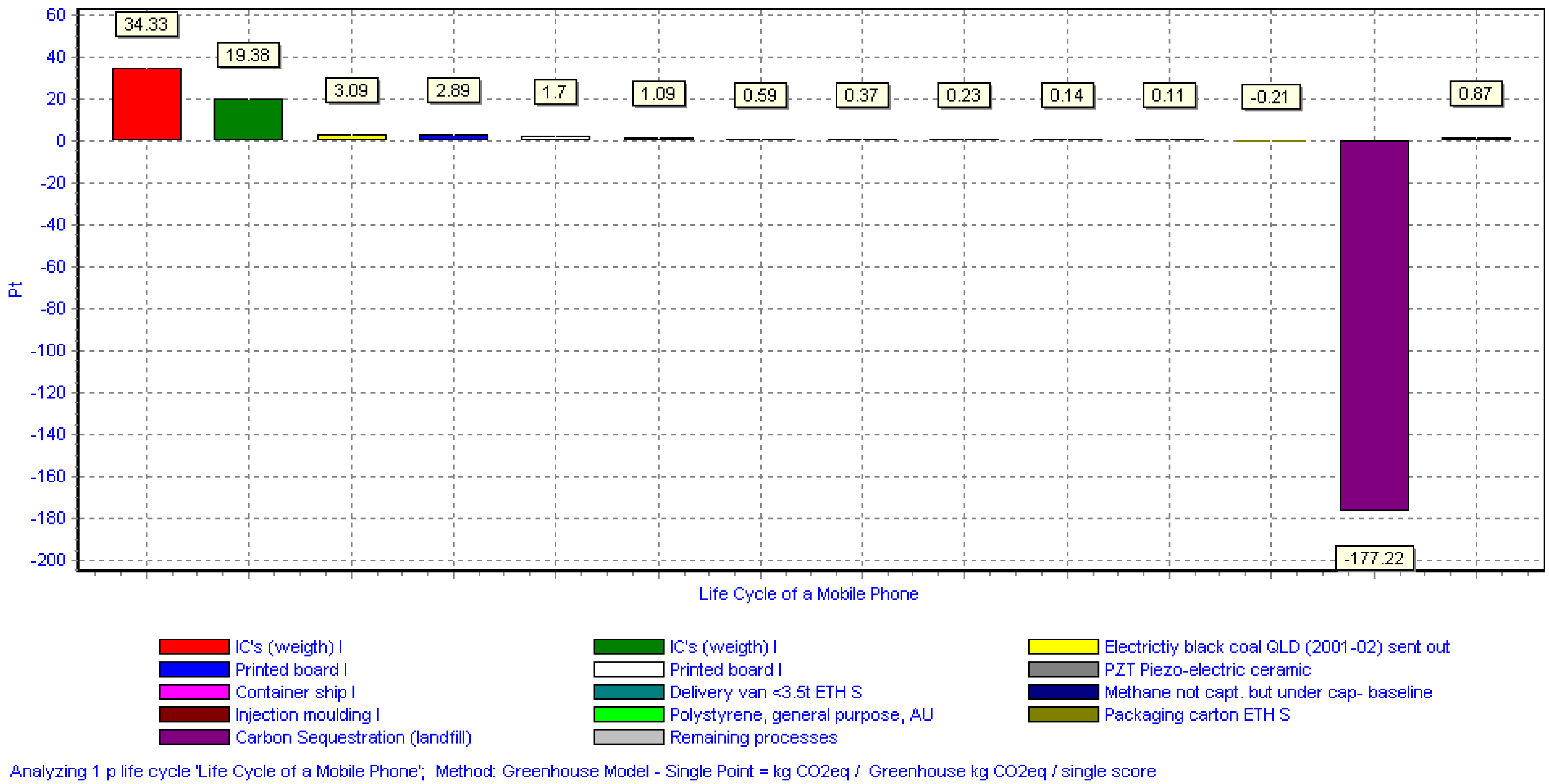

Figure 7.14 Greenhouse Model - Single Point = kg CO2eq – Single Score Process Contribution

7.2.2.2 Discussion

This method of analysis showed that the mobile phone actually contributes positively to the environment. The green bold arrow in the network indicates a positive impact in terms of the environment. This fact is further backed up by the negative result in the process contribution graph.

The positive impact is contributed by carbon sequestration during the disposal of the mobile phones. Carbon sequestration basically means that carbon is returned back into the environment. Since this method revolves around carbon dioxide equivalent emissions, the act of carbon sequestration usually cancels those emissions. When the mobile phone is disposed, the carbon from the mobile phone casing is absorbed back into the soil when it degrades. Due to the lack of expertise in this field, not much discussion is available. The negative impacts consists of the usual suspects; ICs as the main contributor.

According to the above results, there seems to be a more positive figures compared to negative figures. This contradicts with the initial diagnosis from chapters 5 and 6.

7.3 Conclusion

There were two cases from the above analysis that showed slight changes in readings despite the changes made, while another two cases were shown drastic differences after changes were made.

The increase in transportation distances showed no significant change in the impact results. This means that any assumptions made for transportation distances do not contribute to much inaccuracy in the final results. The increase in electricity, on the other hand, showed significant change in the results. This means that electrical data is more critical and more attention should be focused in getting a more accurate result in future investigations.

The two different types of Methods used also showed differences in the single score results. The Enviro-Economic Val. Model Nat Kerb Study (Nolan) resulted in graphs that were very similar to the original single score results while the Greenhouse Model - Single Point = kg CO2eq Method presented a total opposite of the original single score results. The different types of Methods of analysis are based on different factors. This does not mean that there are any problems in the method of analysis. This shows that a user must be aware of the type of impacts that the Method is focusing on.

Future projects should emphasise more on the Sensitivity Analysis results to explain why different types of Methods may lead to the various final outcomes of results.

Chapter 8 – Conclusions

The analysis gave the insights and better understanding of the results obtained in the impact assessment. If there were some hypothesis done prior to the project, the results and analysis would either prove them wrong or confirm them. For example, before the project was carried out, a hypothesis was made that batteries would cause significant impact to the environment due to the hazardous materials it is made out of. The results, on the other hand, showed that batteries actually contribute very little to the environmental impact due to its reusability.

Overall, the main problem determined from the analysis was the electronics components. Other materials used in the mobile phone did not have as significant environmental impact. The energy used throughout its life didn't impact the environment as much as the electronics. As mentioned above, the batteries provided benefits environmentally due to its reusability while packaging share the same characteristic in some Methods of analysis.

The next logical step taken was the improvement analysis. This is a set of suggestions given based on the impact assessment, as well as the sensitivity analysis.

8.1 Improvement Analysis

Improvement Analysis is the last component of the AS/NZS14040:1998 set of standards for LCA called the AS/NZS14043:2001; Environmental management – Life Cycle Assessment – Life Cycle Interpretation. The improvement analysis of the life cycle assessment summarises the results obtained from previous research and tests and from that, discusses in the form of suggestions, recommendations and decision-making which will satisfy the goals and scope set out in the beginning of the project. In the case of this project, these suggestions are made by close observation in the various tests carried out in the project, as well as by including ideas suggested by other research journals.

The improvement assessment also marks the end of the project. By this stage, it is also good practice to reflect on the whole project, scrutinizing various areas and check for ways for an improvement in the processes carried out and readings obtained from them. As discussed in chapter 7 of this dissertation, the sensitivity analysis would provide insight into improving the results and analysis of the difference in readings should be taken into account in this section. Communication present in the impact assessment adds credibility to the results obtained throughout the project.

8.2 Suggestions Towards an Environment Friendly Mobile Phone

The analysis of the results sent a very clear message that the main problem area was contributed by the electronics area of the mobile phone; made up of ICs and PCBs. Most of the focus should be on this area but this does not mean that other areas should be neglected.

- Design for energy efficiency

Prevention is better than cure. This phrase is true for a lot of cases and the electronics world makes no exception to it. If a mobile phone was better designed to perform at high energy efficiency, less energy would be consumed throughout its life. The mobile phone might even have a longer product life. During the design phase, if the manufacturing process was more efficient, less energy would be used.

- Mobile Phone made up of less components

There are several reasons less components could result in less environmental impacts. The existence of microchips cannot be substituted or left out of the manufacturing process. The product wouldn't be considered an electronic product, and changes are, it wouldn't operate as well. There should be more efforts to make an IC more integrated to allow it to carry out more than one function; compared with 5 ICs carrying out 5 tasks. Lesser components also means less energy required in the assembly and disassembly processes. This is proven by a lot of electronics companies. Panasonic has decreased the number of components in televisions (World Changing, 2005). An older model took 140 seconds to take apart while a 2000 model took only 78 seconds to disassemble.

- Improved recycling methods in Australia

Recycling of Mobile Phones in Australia hasn't been able to show its full potential yet. Most of the disassembly is done in Australia but most of the components are shipped overseas. Transportation adds to the existing burdens imposed by the mobile phone. If most or all of the recycling can take place within Australia, transportation costs as well as environmental burdens will be substantially decreased.

The disposal of microchips should also be discouraged and should be recycled. Numerous substances like lead can leak into bodies of water or land to cause pollution and health issues. Instead, there should be more awareness that such materials should be recycled. Numerous collection centres should be set up for the collection of mobile phones. There are currently establishments in Australia but very little awareness of the need to recycle among the general population.. Section 8.3 below discusses this issue in more detail.

- Elimination of hazardous materials in manufacturing

In chapter 6, there were discussions about the different types of hazardous materials used in the manufacturing of microchips. Human health is one of the main concerns.

Due to that, there should be stricter health and safety rules set in such dangerous environment. These hazardous materials should be used as little as possible while room should be made for the use of less hazardous materials. Substitutes should be used whenever possible.

8.3 Current Recycling Practices of Mobile Phones in Australia

A total of 385 tonnes worth of mobile phones, batteries and accessories has been recycled in Australia since 1999 (AMTA, 2005). This may sound like an impressive number but according to a survey conducted by AMTA, this only equates to about four percent (AMTA, 2005) of mobile phones recycled. Independent calculations conducted in the duration of this project concluded that only about one percent of mobile phones got recycled. It is obvious that despite efforts to promote environmental awareness in the telecommunication industry, it is still unnoticed.

It has been five years since mobile phones are recycled on full-scale and most of the mobile phones are shipped overseas to be recycled. Disposed mobile phones are directed to Melbourne-based MRI who is currently responsible for the collection of disposed mobile phones in Australia. Generally, MRI disassembles the collected mobile phones and sends the parts overseas. Batteries are sent to French company, Societe Nouvelle D'Affinage Des Métaux (SNAM) (AMTA, 2005), and circuit boards are sent to North America. The only component of the mobile phone that is not sent overseas is the plastic parts. They are currently stored until the processing facility is completed. All these components are recycled into products that can be re-used again. Those that cannot be reused are disposed off with minimum environmental impact.

At the moment, the Australian recycling program is still in the early stages. Almost all the components are sent overseas for recycling. In general, it requires a lot of energy to put a product together but it requires more energy to take them apart. The burden of transportation just adds to the cost and causes more environmental damage. There are signs of improvement in terms of being able to process these materials locally. A plant for the processing of used plastic is almost in its final stages of construction. As the awareness of the availability recycling mobile phones increases, there will definitely be a bigger and better response by the Australian public. There will then be the market to open up other processing plants, rather than sending them overseas. All this would lead to other factors like government funding and economical improvements.

8.4 Critique and Evaluation of SimaPro

8.4.1 SimaPro

The majority of this Life Cycle Assessment was revolved around this program and the data which was included with it. This evaluation is mostly cantered on the areas of use for this project. This project was about an electronic component so that meant that the most vital part was the electronic database.

First impressions are very important and ones on SimaPro are positive. At first glance, the program seemed very user friendly. It wasn't the easiest program to pick up and learn in a few hours but after getting used to the basic commands of the program, it was very simple to work with the program.

The sidebar made it very easy and convenient for navigation in the program. If a user followed step by step from the first option in the side bar, one can make out how the program is structured. It first allows the user to be able to enter information about the project. This includes information like goals and scope of the project, information about the user and project, and so on.

It should be considered that the entering and compiling the inventory list is one of the more difficult parts of using the program. Most of the time, it was the database that was causing the problems. Repeatedly mentioned previously was the lack of data and descriptions in the database. A general comment is that if efforts were made to include a particular item in the database, there should also be efforts to include descriptions. This can drastically eliminate the need for assumptions and uncertainties.

Despite being one of the leading software products for in carrying out Life Cycle Assessments, it is still relatively new in the electronics world. There is no doubt that there are efforts in establishing such a database. This should not be delayed for much longer as electronics is already doing significant damage to the environment. Programs of this genre are mere tools but they work as powerful aids in the combat against further environmental damage.

8.4.2 Limitations Found in SimaPro

SimaPro has been one of the leading software when it comes to LCA. Everything produced today has its own fair share of critiques and most of them are justified. This program has a number of deficiencies worth mentioning.

- SimaPro is not meant for use on electronic products; lack of data

The problem with this software from an electronics point of view is that the database for electronic components is too few when compared to other types of data. This has already been discussed in the previous section.

- Manual labour

Manual human labour is not included in the energy category in the processes section. A good example is the disassembly of mobile phones before recycling. According to the Australian Mobile Telecommunications Australia, manual labour is used to dissemble the mobile phone. These individual parts are then categorised and then recycled separately. All these involve manual labour. Despite the total accumulated figure for human labour might be small compared to the forging of a metal piece or energy used for transportation, it is vital to allow for maximum accuracy. Other sources of human labour may include activities like loading of goods onto a truck, packaging and the operation of equipment in a factory.

- Energy used during retail

According to Norris G.A et al (2003), energy used in retail and storage plays a significant role in a life cycle assessment. After a general observation of numerous mobile phone retail stores, a conclusion can be made that most of these stores are very similar. They would have air conditioning, lighting, cash register, alarm system, plasma televisions, just to name a few. This energy use can be summarised in a process that can be located in the library. Some may argue that an energy audit may be conducted to achieve this information but others may argue that an energy audit may be too time consuming. The inclusion of these data could make SimaPro results more accurate.

- Certain components are too light to be weighed

There are parts of the electronics that cannot be extracted. These include the very small resistors that are almost weightless and solder iron that cannot be collected and weighed. There is no doubt that these components impose some sort of impact, to the environment as well as human health. Instead of weight, there should be another way of measure.

8.4.3 Future of SimaPro

It is stated in previous sections of this report that there are still a lot of limitations in SimaPro. One of the biggest bottlenecks of the project is the database of electronic components. Despite the efforts of institutions like RMIT and PRe Consultants in developing as complete a database as possible, it is still lacking a lot of information required in carrying out a project such as this.

Current work involved in this project, together with ones in other projects, is used in the efforts to better improve the electronics database of SimaPro. There might also be the possibility of a new model for the evaluation of electronic products. Plans are still sketchy but research projects such as this may be the key to turning dreams into reality.

Life cycle assessment programs are constantly being updated. Extra information and updated scenarios will always be helpful to a user carrying out a life cycle assessment. Not only will be able to educate the user of the program, it can also help in achieving a more accurate result. More information will also reduce the need for assumptions.

8.5 Future of this Project

This project was done with very limited resources, as well as time. It was mentioned in a previous section of this report that there were numerous uncertainties. The numerous Methods of analysis used in the Sensitivity Analysis also resulted in different, as well as contradicting results; which are all valid. The methods chosen to overcome these problems may not be the best solutions but the end result may still be argued as valid.

With that in mind, further work can be done to this project. Efforts were taken to backup all information entered into SimaPro. These included all sub components of the mobile phone package, the inventory list, processes involved in manufacturing, transportation and use of mobile phone. Appendix B shows all entries entered into SimaPro. This can be used as references for individuals who are keen on continuing this project. Future projects involved with mobile phones can use information from this dissertation.

8.5.1 Suggestions for Continuation of Project

This project is one of the starting points in the establishment of an electronics database for carrying out a Life Cycle Assessment. This process will take a lot of effort and data so that it will be as complete as possible. A suggestion for the continuation of this project is to carry out a similar project to this, but with an electronic device that is of different nature to a mobile phone; a microwave oven, an older model television or other hand held devices. This will all provide some aid in the compilation of data to form a database that is as complete as possible.

Other suggestions for the continuation of this project are to concentrate more on the sensitivity analysis. This will allow for more detailed explanations as to why each Method of analysis is different. By doing so, there might be a wider perspective in terms of analysis of environmental impacts of the life cycle of the product.

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