Meeting Environmental Certification in Design: A Toolkit Facilitating the Process of Eco-Labelling through LCA for Electronic Products

by

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ABSTRACT

Personal computers (PCs) significantly contribute to e-waste. The design of eco-environmentally friendly PCs may be enhanced through a wider and better awareness among the designers of the life cycle assessment (LCA) tool options. This study clarifies how LCA tools can be used to meet eco-label criteria. The research finds that designers need to become more aware of their role in meeting eco-label criteria.

Four telephone interviews, nine critical reviews, one online survey, and an interactive workshop were conducted to better understand how to help designers select an LCA tool. The interviews and critical reviews were used to gather the information to be used in the toolkit that would explain the differences among eco-labels for PCs and the differences among six LCA tools. The survey and workshop verified the effectiveness, importance, and value of this toolkit.

Keywords: E-waste, Eco-labels, LCA, Materials Phase, New Consumer, PCs, Sustainability

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CHAPTER 1

INTRODUCTION

Sustainable development is one of the most important issues of our time, and its importance has brought more attention to the current habits that need to be modified to become more environmentally friendly. It is defined by the Brundtland report (WCED 1987, 8) as meeting "the needs of the present without compromising the ability of future generations to meet their own needs." Governments, organizations, and consumers around the world have become more aware of the environmental issues arising from the hazardous emissions caused by the harmful manufacturing processes and materials, and the large amounts of waste being sent to the landfill each year. E-waste is composed of many different types of electronic products, such consumer electronics and household appliances. "The global volume of e-waste generated is expected to reach 93.5 million tons in 2016 from 41.5 million tons in 2011" (TransWorldNews 2011). Consumer electronics in particular have been sent to the landfills at an alarming rate over the past few years, which is a result of their shortened lifespan. For example, "in some products such as personal computers, the life cycle can be as short as 9 to 18 months" (Landers et al. 1994, 19). This issue has become more prominent as electronics are being developed more quickly and causing slightly older electronics to become obsolete in a short period of time. "Consumer electronic products include televisions and monitors, computers, computer peripherals, audio and stereo equipment, VCRs, DVD players, video cameras, telephones, fax and copying machines, cellular phones, wireless devices, and video game consoles" (Ecycling 2011).

Personal computers (PCs), such as laptop and desktop computers, are the most popular consumer electronic products to be purchased and they are also the largest percentage of consumer electronics to be sent to landfills (Harrison Group 2010). As a result of the growing consumer awareness and more government environmental legislations that have been coming into place, businesses have noticed this new consumer market and are trying to modify their traditional business methods to suit their customer needs. The business market of developing environmentally friendly products is increasing; however, businesses continue to develop products at a fast pace and would sometimes make false claims as to how environmentally friendly their products actually are. These false claims have become known as greenwashing, which is defined in the David Report (2007, 4), as "the phenomenon that describes companies and persons that in a false way exploits the green trend." The solution to greenwashing by governments and organizations was to develop eco-labels, also known as green labels, which are used to communicate to consumers that the product is indeed environmentally friendly based on a list of proven required criteria.

The consumers that are interested in purchasing more environmentally friendly products are known as the 'new consumers.' Canada and the United States are two of the countries with some of the highest growing percentages of new consumers; however, "the way many humans, particularly in North America, are currently living is unsustainable" (Nicolasco Da Silva et al. 2008). It has been shown that consumers within Canada and the United States are interested to purchase more environmentally friendly products, but not on the account of the product's quality or price. "If everyone on Earth lived like the average Canadian or American, we would need at least three such planets to live sustainably" (Wackernagel and Rees 1996, 13). It is important for designers to develop environmentally friendly products, have them certified by eco-labels so that consumers can easily differentiate them from others, and still be able to maintain their high quality at a reasonable price.

There are a number of tools that have been developed to help design more environmentally friendly products, which may be either software or web-based tools. Most of these tools are developed to facilitate the process of calculating the life cycle assessment (LCA) of the product. This study has discussed the importance of facilitating the process of meeting eco-label requirements for PC designers from the growing amount of e-waste, and would analyse consumer purchasing decisions, current software and web-based tools for designing environmentally friendly products, and how designers may benefit by using these LCA tools during the product's design and production stage. Basically, the scope of the research was to analyse the current LCA tools and to develop a toolkit that would facilitate the process for PC designers to decide on an LCA tool that would help meet certain eco-label criteria and to validate the importance and value of the toolkit for designers. The methods used in order to develop the toolkit were with four interviews, the use of nine critical reviews of three eco-labels and six LCA tools, a survey that received a total of twenty respondents and eight of those respondents are from designers, and a workshop that had a total of six participants. The interviews and critical reviews were used to analyse the relationship between the eco-label criteria and what the LCA tools specifically calculate, the survey was used to analyse the value and importance of a toolkit being developed to facilitate the process for PC designers in choosing an LCA tool to meet eco-label criteria, and the workshop was conducted with a professional and five Master of industrial design students in order to understand how effective, understandable, and easy to use the toolkit is for designers.

1.1 Importance of Eco-Labels

"Certification or eco-labelling refers to the provision of information to consumers that a product is environmentally friendlier than other products in the same category" (Nunes and Riyanto 2005, 145). However, they were originally developed in order to communicate to consumers that a product is indeed as environmentally friendly as the company claims. Eco-labels can be found globally, but they are mainly widespread in developed countries such as North America and Europe. Many companies have changed certain aspects of their products to meet environmental requirements, such as using different materials, altering their production process, or using renewable energy. "Like other forms of environmental regulation, labels could encourage manufacturers to improve the 'environmental quality' of their products or production processes" (Clark and Russell 2005, 114). It would also help consumers understand which products are better for the environment at the point of purchase. They provide a competitive advantage for the company, because consumers are more likely to believe the environmental claims that an organization which certifies products with eco-labels has reviewed. The first eco-label was developed only 33 years ago, and now there are already over 400 labels found on a wide variety of products. Each eco-label contains its own set of required criteria that differ from one another, because some of the eco-labels may specifically consider one aspect during the life cycle of the product while others may look at all the aspects within the product's life cycle.

"Demand for products with eco-labels are growing" (Ecolabel Index 2010), and there is a considerable difference between national and international PC companies based on whether or not they have made changes to develop certified products. The differences between these companies have lead to an understanding that it is easier for international companies to develop certified products than for national companies who sometimes have none of their PCs certified by any eco-label. Some of the reasons for this can be from the fact that analysing the environmental impacts of products is costly, time consuming, requires training, and difficult to do with complex tools. There is also "no statistical data providing quantitative evidence of the actual market penetration of eco-labels, nor the average market power that an eco-label is likely to confer on a product or services" (CEC 1999). However, it is believed to improve the businesses reputation and sales because many companies are still aiming to meet eco-label criteria for their future products.

1.2 Tools for Designing Environmentally Friendly Products

"Designing and manufacturing green products requires appropriate knowledge, tools, production methods, and incentives" (Dorf 2001, 122). There are a large number of tools developed in order to help produce environmentally friendly products by either helping to calculate one aspect of the product and its effects on the environment, or by considering the full life cycle of the product from the time it is in its production and planning stages to the time it is disposed. There are several limitations; however, that are found with most LCA tools "such as the expensive purchase price of LCA commercial software, the complexity of assumptions, the involvement of uncertainties in each evaluation process, the dependence on extensive databases, and the failure to satisfy the special requirements and priorities of individual companies" (Zhou and Schoenung 2009). An example of a tool used to develop environmentally friendly products is the Eco Materials Advisor, which is located within the Autodesk Inventor Software. The tool was developed by both Autodesk and Granta Design, and it "enables engineers to make more sustainable design decisions by exposing information on environmental impact, cost, and performance to guide materials selection" (Granta 2011). The program has a specific tab called Environments where the user could browse a list of materials and assign materials to the product, generate PDF reports, and it also provides alternative analysis of how the impact of the product may change if a different material were used. The Eco Materials Advisor, compared to other tools, mainly focuses on the materials aspect of the product. A further analysis of the tools and what they help calculate is provided within the Results and Discussion chapter.

1.3 Rationale: Need for a Toolkit for Meeting Eco-Label Criteria through LCA Tools

There are "over 2,000 currently marketed" tools developed in order to facilitate the process of developing environmentally friendly products (Bank 2000, 106); however, "people who wish to use an LCA software tool often face the dilemma of which tool is best for their purposes" (Unger et al. 2004, 2). Meeting eco-label criteria for a product would cause an interdisciplinary collaboration between the people working in the company, because the criteria involve a range of techniques and methods in order to be achieved. Eco-labels are becoming increasingly more important in the perspective of companies and their rapid development over the past three decade's show that they will continue to be an important communication medium from companies to consumers. Companies are facing an increasing consumer demand for products that are friendlier towards the environment. Designers are now pressured into integrating a more environmentally conscious approach in their product development during the early stages of the design and development process. The aim of this research project was to have the toolkit developed so that it was easy to use, effective, and understandable even to designers who do not have previous knowledge or experience in using LCA tools or meeting eco-label criteria. It is explained further in the research that the toolkit is meant to be sold to PC designers to use during the design and development stage of their products, which emphasizes the value of a workshop being conducted to ensure that the toolkit is effective and easy to use. The workshops caused changes to be made to the original design of the toolkit. However, all the participants seemed to understand how to use the toolkit and make the connection between the offering map and the issue cards in minutes. The survey that was conducted with professionals in the field and research into the current methods used to develop PCs proved the value of a toolkit developed to facilitate the process of meeting eco-label criteria through the use of LCA tools.

1.3.1 Interdisciplinary Contribution to Professionals

The LCA tools that help meet eco-label criteria would be particularly valuable for designers, manufacturing engineers, mechanical engineers, and business managers. Business managers would benefit by having a more environmentally friendly company, earning more respect from consumers, and appeal to a new consumer market. In addition eco-labels provide several benefits for the company, such as promoting sales since consumers value corporate social responsibility methods, as well as having the company reduce their negative impacts on the environment, an opportunity for them to save on their energy bills, have an enhanced reputation, have reduced regulatory pressures, and it is also regarded as a long-term method for success (Charter and Tischner 2001, 264; Yoshimura 2010). LCA tools would facilitate the process for industrial designers, manufacturers, and engineers to meet the various requirements of the eco-labels for their products, which could have significant savings on time and cost. "Electronic manufacturers that can compress the time for getting a product to market gain a strong competitive advantage" (Landers et al. 1994, 19), which further emphasizes the importance of using LCA tools during the product's development stage. A toolkit that would help professionals understand the different options they have among the LCA tools and the differences between the eco-labels may allow companies to increase their development of certified PCs and decrease the amount of energy emissions and percentage of e-waste sent to landfills. Basically, this research would provide a method to help designers develop a larger number of certified products, in hopes of reducing the amount of e-waste caused by PCs and meet their rising consumer demand.

1.3.2 Contribution to the Public

Natural resources are being used at an alarming rate, and "many of these resources are unable to be naturally replenished by the Earth at anything like the rate at which humans are currently consuming them" (Crawford 2011, 8). This creates "the need to shift to a more sustainable level of consumption and way of living even more urgent if we are to have any hope of maintain the planet in a state that is liveable for future generations (Crawford 2011, 9). The public would benefit from companies meeting eco-label criteria for their products, because it affects the amount of hazardous chemicals emitted into the atmosphere and it would reduce the amount of e-waste. "Computers contain heavy metals as mercury, lead, chromium VI, and cadmium, rare metals as gold, palladium, or tantalum, and hazardous chemicals as flame retardants" (Ciroth & Franze 2011, 21). The demand for products with eco-labels is increasing and consumers value the company's efforts towards developing more environmentally friendly PCs (Ecolabel Index 2010). Considering the large amount of PCs that are annually sent to the landfills, their variation in design for an easier disassembly process, for example, would have great environmental benefits. Much of the e-waste is shipped to developing countries where the "chemicals [of PCs] are known to cause cancer, respiratory illness and reproductive problems" (Silicon Valley Toxics

Coalition 2010). Reducing the amount of e-waste would not only have environmental benefits, but it would also contribute to a healthier living environment for the people living near the area where the PCs are disposed.

1.4 Hypothesis and Limitations

The study did not focus on a particular country, because the same LCA tools are used around the world, with alterations in language or information regarding certain legislations. Eco-labels for electronics from around the world were discussed in this study and the connection between the LCA tools and eco-labels were also analysed. Eco-labels are important in providing messages to consumers to understand certain environmental claims of a product or service. They are increasing in popularity and there is a raising consumer demand for certified products. Businesses have attempted to meet the raising consumer demand of environmentally friendly products by using the LCA tools that are currently developed. It was hypothesized that designers need a method developed in order to facilitate the process of choosing the correct LCA tool to meet their needs, and they need further understanding as to how they may use these tools in order to meet eco-label criteria. It was also hypothesized that the use of this toolkit among PC designers in the industry would facilitate the process of choosing the correct LCA tool for meeting certain eco-label criteria, and would increase their awareness of the eco-labels and LCA tools available. Based on the hypothesis, this research aimed to answer the following four questions:

How do the LCA tools chosen for this study help with meeting eco-label criteria for PCs?

How are the eco-label criteria not being met with the LCA tools for calculating the environmental impact of PCs?

How much are PC designers involved in the process of meeting eco-label criteria?

How would a toolkit developed for PC designers facilitate the process in choosing the suitable LCA tool for meeting eco-label criteria?

The limitations to this chapter include the fact that it was focused on designers, the PC industry, and on six of the most popular LCA tools in the industry. The following chapters analysed the differences among the types of criteria that eco-labels require, and an analysis of certain LCA tools would also be discussed. The eco-label criteria were compared to the tools functions in order to answer the first and second research questions. The findings and discussion chapter would discuss in detail about the toolkit that was developed for this research and the impact it would have for PC designers in developing more environmentally friendly products that are certified with an eco-label.

CHAPTER 2

LITERATURE REVIEW

Chapter 2 is organized into eight sections. Sections 2.1 and 2.2 provide background information on sustainability and e-waste. Sections 2.3 and 2.4 describe the government efforts from each region around the world, and their percentage of new consumers. Sections 2.5 and 2.6 describe the efforts of PC companies to develop more environmentally friendly products, and the importance of certifying those products with an eco-label. Sections 2.7 and 2.8 provide background information on life cycle analysis and describe the interdisciplinarity of the research.

2.1 Sustainability

Sustainability is a growing global issue (Bridges and Wilhelm 2008; Jones, et al. 2008). The Brundtland report was the most influential piece of literature on sustainable development (Worster 1993), and "in 1972, the UN Stockholm Conference on the Human Environment marked the first great international meeting on how human activities were harming the environment and putting humans at risk" (Sustainability Reporting Program 2000). In 1992, during the Earth Summit in Rio de Jeneiro, "over 120 nations endorsed 'sustainable development' as the most important economic and environmental policy for the 21st century" (Basiago 1995). The seriousness of global warming is also rising, and it is expected that "within the next half-century, that 40% of the world's people may well face a very serious drinking water shortage, unless the world acts boldly and quickly to mitigate global warming" (Gore 2006, 58). "In 1962 Rachel Carson's Silent Spring awakened the world to the grave environmental threat of the massive production and the use of hazardous chemicals" (Peterson 2008, 31), and since that time people became more aware of the importance of sustainability. The new awareness that people have for the environment has motivated companies from a wide range of fields into making changes to their traditional methods of doing business in order to portray themselves as companies that consider the environment.

2.1.1 Companies and Sustainability

Businesses are increasingly realizing the importance of producing environmentally friendly products as a result of the growing green consumer market in order to increase their profits and improve their reputation (Bridges and Wilhelm 2008; Ottman 2011; Dorf 2001; Min and Galle 1997; Schaefer 2005). In addition, businesses are finding many positive factors and improvements towards developing sustainable production methods, such as an increase in innovation, product quality, employee motivation and improved morale, and cost reductions from the fewer materials and lower energy input (Newton and Besley 2006, 70). These are considered to be internal motivations, but there are also many external motivations for sustainable production, which include the pressures from government policies, organizations, design competitions, market pressures, and waste disposal charges (Newton and Besley 2006, 72). Survey results from My Sustainable Canada (2008), describe that "64% of business decision makers agree that being perceived as green helps their brand." This increased consumer interest in purchasing environmentally friendly products has been characterised as the "new consumer" (BBMG 2011). New consumers "are looking at the companies behind the products that they buy and they believe it's important to purchase from companies acting ethically and responsibly" (BBMG 2011).

2.1.2 Design and Sustainability

"Design, in one form or another, has always played a key role in the environmental and social conditions that affect our human well-being" (Thorpe 2007, 8). In order for products to become more environmentally friendly, it is necessary for companies to reconsider their product's overall design and manufacturing method. "The past few decades have seen a growing interest in researching and developing green products" (Figueiredo et al. 2011). The "initial research and design phase is the first and best time to start a product down the path of reduced environmental impact" (GreenBiz Group 2011). For example, designers could make changes to the traditional materials used and have them replaced with more recyclable choices, and the products were also being designed for easy disassembly. "Re-evaluating the way we do things and designing new processes is extremely important to sustainable design" (Olthof et al. 2008). A process that is particularly popular in companies is with Design for Environment (DfE) or eco-design practices, which include "design for dismantling, use of fewer components, use of fewer plastics, use of recycled materials, use of smart, greener materials, removal of hazardous substances, increased functionality, increased energy efficiency, and dematerialisation" (Seeba Global Resource 2006). The benefits of designing for dismantling at the end of a products useful life "has the ability to significantly enhance its long-term environmental performance by encouraging reuse and recycling, minimising waste production and providing greater opportunities for adaptive reuse (Crawford 2011, 28).

2.2 E-Waste

"The production of electrical and electronic devices is the fastest-growing sector of the manufacturing industry in industrialised countries" (Schwarzer et al. 2005). There are still many electronics that are not considered sustainable and becoming "one of the fastest growing waste streams in the world" and expected "to grow to 12.3 million metric tons by 2020" (Nimpuno et al. 2009). Technology is already involved with solving certain environmental issues (Giudice et al. 2006, 16; Grubler et al. 2002); however electronics themselves are contributing to the problems of the environment causing researchers to blame environmental issues on constant electronic innovations (Dorf 2001; Pamlin 2002). Every year or two new electronic products are developed by companies, which is causing the previously designed products to become obsolete in a short amount of time. E-waste is composed of several types of hazardous electronic products, which include personal computers (PCs), televisions, and printers.

"Just one computer can contain hundreds of chemicals, including lead, mercury, cadmium, brominated flame retardants (BFRs) and polyvinyl chloride (PVC). Many of these chemicals are known to cause cancer, respiratory illness and reproductive problems" (Silicon Valley Toxics Coalition 2010). Many companies and organizations are providing consumers with the options of recycling their electronic devices, with either take-back systems developed by the company or by organizations that would attempt to refurbish or fix the product. Some examples of these organizations located in Canada are Computers for Schools and ReBOOT Canada, which has locations in almost every province. Several provinces throughout Canada have been developing their own green initiatives, such as Saskatchewan, which developed its own electronics stewardship system known as the Saskatchewan Waste Electronics Equipment Program (SWEEP). In addition, "Ontario has a program in the works, as does B.C. and Alberta is at the

front of the pack, having recycled 142,429 computer monitors, 70,487 printers, and 63,711 TVs between the time the program started in October 2004 and July 2006" (Vasil 2007).
Canada and the United States are similar in their number of e-waste exports to developing countries, in fact, "it is estimated by industry insiders that about 50-80% of the electronic waste that is currently sent to recyclers in Canada and the United States are not recycled domestically at all, but are very quickly placed on container ships bound for destinations like China" (Basel Action Network 2002).

2.3 Government Efforts

Both small and large businesses have been considering how they may develop more environmentally friendly products; however, environmental efforts differ from country to country. For example, the government in both Canada and the United States have considered the growing issue of the environment, and have developed several acts in order to regulate this issue. It is a pressing issue for those countries in particular since "over fifty percent of North American homes have at least one PC" (Randall Conrad & Assoc. Ltd. 2000). "We live in a disposable society driven by electronic technology, resulting in huge amounts of obsolete and discarded products which may find themselves in landfills, affecting regional water supplies. Recently initiated by government environmental directives, efforts are underway to change the way we design, manufacture, and discard these items" (Shina 2008, 151). The study by the GlobeScan Ethical Consumerism Funnel (2011) conveys that "as many as three-in-ten Canadians, and more than one-quarter of Americans and Australians, profess high expectations on companies to act responsibly in the areas of product safety, environmental integrity, and employee treatment, while claiming to be aware of what companies do to be responsible, and in addition also say they reward and punish companies for being socially responsible or irresponsible in their purchasing choices."

"If everyone on Earth lived like the average Canadian or American, we would need at least three such planets to live sustainably" (Wackernagel and Rees 1996, 13). The e-waste laws in Canada and the United States are similar in that only certain provinces and states have laws towards the growing problem of e-waste. Both countries are facing the environmental setbacks of their large number of electronic products. The Canadian and American companies are responsible for ensuring that their electronic products do not go against the current provincial or state laws set in place. "An estimated 50% to 80% of American electronic waste is being dismantled without any safety protection for workers or environmental safeguards. It happens with Canadian waste, too, even though we've signed international conventions saying we would never export our toxic trash" (Vasil 2007, 171). Canada is currently trying to address this issue, but "considering the number of computers and personal electronic devices found within the average North American household, it is vital that materials are further considered in the context of their life cycles" (Lytle and Ho 2008, 157).

2.3.1 Sustainability in Canada

The environment within Canada is particularly important with its "wealth of natural resources and natural environments," and that "provides both economic prospects and leisure opportunities" (Dwivedi et al. 2001, 23). Canada's dependence on its environment makes it important for products to be designed in order to be friendlier towards the environment. In addition, "while Canada produces a great deal of energy, Canadians use more energy per capita than people in most other countries" (Dwivedi et al. 2001, 41). The "introduction of the federal Green Plan in Canada in the early 1990s marked the beginning of sustainable development policy-making" (Dwivedi et al. 2001, 224); however, the plan ended only five years later because there was a change in government and its approach towards protecting the environment failed. Canada continued to take more strides to ensure a safer environment, an example would be the development of the Canadian Environmental Assessment Act in 1995, which encourages the consideration of the environmental effects of "all projects being undertaken by the federal government" (Dwivedi et al. 2001, 159).

"Natural Resources Canada estimates that Canadians dump more than 272,000 tons of computer equipment, phones, TVs, stereos and small appliances in landfills each and every year" (Vasil 2007, 166). Canada began implementing environmental regulations since the nineteenth century; however, most of the "regulations are more recent, the product of the past thirty years" (Dwivedi et al. 2001, 124). "The Government of Canada's initial focus in tackling climate change has been on the largest source of Canadian emissions through regulation of the transportation sector, as well as actions to reduce emissions from electricity generation" (Climate Change 101 2011). In addition to the rising consumer demand for these environmentally friendly products, companies are motivated to change their traditional forms of doing business from the number of declarations and regulations that were developed towards causing companies to reduce their harmful effects on the environment. Currently Canada has developed "Environment Canada" which is a government organization that is dedicated to monitoring and reporting Canada's issues with the environment. They "coordinate environmental policies and programs for the federal government" (About Environment Canada 2011). This organization was developed in 1971 and they work with other kinds of organizations, citizens, federal departments and research facilities to develop research and collaborate in projects towards protecting the environment. Canada signed The Basel Convention, which was developed to stop the illegal transport of e-waste to developing countries such as China and Africa. "In Africa, China, India, and other places, huge quantities of e-waste are exported for inexpensive recycling that often takes place in rudimentary backyard workshops. Toxics emanating from e-waste have poisoned water and soil, created serious air pollution problems, and sickened workers, their families, and others in these communities" (Grossman 2010). There are several electronic recycling organizations in Canada and they are located in the provinces of Alberta, British Columbia, Saskatchewan, Nova Scotia, Manitoba, Prince Edward Island, and Ontario where they have also began charging an electronics recycling fee with each new electronic purchase. "The 1987 Montreal Protocol on substances causing depletion of the ozone layer (tightened in 1990 and 1992) regulates gradual reduction and actual termination by the year 2000 of production and use of chlorofluorocarbons (CFCs) and other toxic materials" (Sachs et al. 1998, 208).

2.3.2 Sustainability in the United States

"The modern U.S. environmental movement began in the early 1960s with the Clean Air Act, which was originally passed in 1963 and extended in 1970" (Shina 2008, 1). The movement continued through the years to develop the Environmental Protection Agency (EPA). The United States still has not signed an agreement or set a law towards prohibiting the export of e-waste to the developing countries. The electronics industry is a very large market that is "worth about $233 billion in 2010, Americans now own about 3 billion electronic products, with a turnover rate of about 400 million units annually" (Grossman 2010). However, many studies have suggested "that U.S. consumers do value the environmental benefits of more environmentally benign products" (Teisl and Roe 2005, 83). The United States has developed the Electronic Device Recycling Research and Development Act in July 2009 in order to encourage the sustainable design for electronics and to stop the illegal dumping of e-waste to developing countries, but this Act still has not become a law (111^{th} Congress 2009). Laws in each state continue to be developed. Out of the 51 states in the United States, only 26 have comprehensive e-waste laws in place and six states have released only disposal bans or began making studies on e-waste (Campaign for Recycling 2011). The United States is seen to be following the EU with many of their directives towards products and their effects on the environment, such as California's Electronic Waste Recycling Act (EWRA). "Other states such as Minnesota, Maine, Maryland, New Jersey, Tennessee, Vermont, Washington, and Wisconsin have laws similar to RoHS" (Shina 2008, 156), which is also a European directive to reduce harmful substances.

2.3.3 Sustainability in Other Countries

"The Green movement arose in western Europe, most prominently in what was then West Germany, in the late 1970s and early 1980s" (Coleman 1994, 163). These Green parties continue to exist and place pressure on their national governments. "The European Commission believes that REACH will enhance the innovative capability and competitiveness of the EU chemicals industry. One impact of such regulations is that they force suppliers to develop more sustainable products for the large European market" (Martin and Schouten 2012, 116). The European Union (EU) was the first continent to set standards and restrictions on products and their development process in order to be safer for the environment. For example, the EU effectively banned several materials with its restrictions on hazardous substances (RoHS) directive, such as "lead, mercury, hexavalent chromium, polybrominated biphenyls (PBBs), and polybrominated diphenyl ethers (PBDEs) with proposed limits in products of 0.1 percent for all and with a limit of 0.01 percent for cadmium by June 30, 2006" (Shina 2008, 1). In addition the EU also developed the WEEE directive, which "is aimed to have designers incorporate methods which lend themselves to easy dismantling of products for recycling at the end of their life cycle" (Shina 2008, 155).

2.4 The New Consumer

Consumers are becoming more knowledgeable about the current effects that products are having on the environment (McDonagh 1998; Sharma et al. 2008; Karna et al. 2001; Davis 1993; Herbig 1998; Smith 1998). Consumers do value the corporate social responsibility methods and believe that businesses should be placing the efforts to give back to the community, as well as work to reduce their negative impacts on the environment (Yoshimura 2010). With the internet, consumers have easy access to discuss companies in social websites, write reviews about products, and criticize the lack of effort towards corporate social responsibility. These new consumers are becoming a large majority of populations in North America, parts of Europe, and parts of Asia. The new consumer is also specifically characterised, "according to several studies, is well-educated, belongs to the middle or upper-middle class, has good income, often a woman in her lower middle age or middle age, has children, and lives in Northern Europe or North America" (Bostrom and Klintman 2008, 36). A consumer practicing environmentally friendly behaviour would mean that they attempt to choose better transportation options; they attempt to reduce their household energy and purchase products that are considered more energy efficient, they purchase food that is organic and try to purchase from companies that are attempting to reduce their own negative environmental effects. It also refers to the consumer reflecting "concern about the effects of manufacturing and consumption on the natural environment" (Wagner 1997, 1).

The new consumers have shown in several polls that they are willing to pay more for an environmentally friendly product (Salzman 1998). In addition, statistics have shown that "61% of Canadians are eager for their country to take a leadership role in setting targets to combat climate change. Per capita waste disposal in Canada is increasing at a rate of about 6% every year" (Eco Friendly Emporium 2011). However, "the average American is responsible for about 15,000 pounds of carbon dioxide emissions each year. This per capita number is greater than that of any other industrialized country. In fact, the United States – a country with 5% of the world's people – produces nearly 25% of the world's total greenhouse gas emissions" (Gore 2006, 305). American consumers are also increasing their purchases of green products, in fact, "in 2009, The Green Revolution, a survey by Grail Research, found that 85% of US consumers buy green products" (Pinochet 2011). The demand for these products has been proven to be increasing, and companies are becoming aware that behaving more environmentally friendly and producing more environmentally friendly products is critical to their long-term success.

2.5 PC Companies and Sustainable Design

"Sustainable development style investing is most prominent in the United States, where socially responsible investing (SRI) grew from $1.2 trillion in 1997 to $2.2 trillion in 1999" (Feltmate et al. 2006, 183). In addition, "the Canadian sustainable investing market has grown exponentially in the last two years" (Guardian Ethical Management 2008). There is a growing "societal demand for businesses to assume broader responsibilities and clearer accountability for their impacts on the environment and the human condition" (Martin and Schouten 2011). Companies from a variety of fields have improved their business efforts into becoming more environmentally friendly, and Verdantix, an independent analyst firm, calculated that in "in 2012, corporate spending on innovation to push product sustainability differentiation will climb to $12 billion in the U.S.; $1.6 billion in the U.K.; $500 million in Canada and $400 million in Australia" (Metcalfe 2011). These calculations further emphasize the importance of improving the methods used to develop more environmentally friendly products.

The focus of this paper was on companies that develop PCs, such as laptop and desktop computers. These products are constantly being innovated in order for companies to stay ahead in competition; however, they are not being designed to last for more than a few years. PCs are quickly becoming obsolete and are the most popular electronic products that are purchased by consumers (Harrison Group 2010). "To compete effectively in this industry, firms have had to acquire the ability rapidly to develop and introduce new products based on the latest technological advances" (Shirley 1992, 89). In addition, "electronics manufacturers that can compress the time for getting a product to market gain a strong competitive advantage" (Landers et al. 1994, 19). Nonetheless, the "integration of factors concerning environmental impact during manufacture, use, and disposition of the product is an emerging issue in design of electronics" (Siddhaye and Sheng 2000, 113). For example, "improvements in computer power efficiency can have a significant positive effect on the environment" (Smerdon 2000, 15). It is becoming increasingly important for the product to be "designed so that it is easy to manufacture in the plant and easy to repair in the field" (Landers et al. 1994, 17). This would require more time taken during the design phase of the product's development in order to ensure that the product is less harmful to the environment.

There is usually a team involved when designing an electronic product before getting it to the market where designers and "engineers cooperate with assembly operators, test technicians, and maintenance personnel to achieve designs that are both producible and maintainable (Landers et al. 1994, 288). However, this study focuses on designers and their role in developing electronic products, because the designer's decisions have been shown to be critical to the environmental impacts caused by the product, which would be explained more in a later chapter. Traditionally, the designers for electronic products would not interact much with the manufacturers to understand the difficulties and impacts associated with their design choices; however, now that the environment is a growing issue, designers are using the process of concurrent design and sustainable development (Veerakamolmal and Gupta 2000, 70). "Concurrent design is a process that involves simultaneous and interactive team participation across various functions in a corporation. Sustainable development helps ensure that corporate plans are prepared and monitored continuously to achieve predefined short- and long-term goals" (Veerakamolmal and Gupta 2000, 70).

There are many benefits with designing electronics that are safer for the environment, because "by eliminating the hazardous materials at the source, the need for extensive and special testing of operators, waste treatment facilities, and landfills would be removed, and the recycling programs could be made much simpler" (Shina 2008, 2). There are already several preferred methods for electronic assembly that would have significant impacts on the product's effects on the environment, such as minimising the part count, minimising assembly surfaces, maximising part compliance, designing for top-down assembly, improving the assembly access, and designing for modularity (Landers et al. 1994, 291-294). A top-down assembly in electronic design and manufacture would mean that the parts are assembled in a "sandwich, or layer, fashion, with each part being placed on top of the previous one, using straight-line motions" (Landers et al., 1994, p. 292). In addition, "a modular structure can help reduce the costs of assembly, maintenance, and end-of-life recovery" (Veerakamolmal and Gupta 2000, 73).

2.5.1 International and National PC Companies

The study analysed the differences between international PC manufacturers and local Canadian and American PC manufacturers. The international manufacturers chosen for this study were based on the high effort they are placing towards being regarded environmentally friendly and how much effort they are placing towards improving the environmental friendliness of their PCs. These manufacturers were also chosen to be diverse in addition to their high efforts, for example, one manufacturer may only be using one type of eco-label to certify their PCs and another manufacturer may be using a variety of different eco-labels to certify even one PC. This would provide a better understanding of the different environmental goals that manufacturers tend to have once compared between one another. The international manufacturers that were chosen for this study are Acer, Apple, ASUS, Dell, HP, Lenovo, LG, Panasonic, Samsung, Sony, and Toshiba. The national manufacturers are the Canadian and American manufacturing companies that specifically develop PC computers. The Canadain and American manufacturing companies were chosen for comparison in this study because Canada and the United States rank among the top among the most unsustainable countries and as large contributors to e-waste. These national manufacturers were not chosen based on their efforts towards sustainability; however, they were all analysed to realize the importance of helping these companies improve their current methods of developing products in order to be regarded as being environmentally friendly. The Canadian manufacturers are CiaraTech, Eurocom Corporation, MDG Computers Canada Inc., and Stealth.com Inc. The American manufacturers are Gateway, Lotus Computer, NCS Technologies, Inc., System76, Inc., and DakTech Computers. Table 1 illustrates the comparison between the international and national PC companies.

International

	acer		ASUS	DELL	hp	lenovo	LG	Panasonic	SAMSUNG	SONY	TOSHIBA
Company Name	Acer Inc.	Apple Inc.	ASUS	Dell	HP	Lenovo	LG Corp.	Panasonic	Samsung	Sony	Toshiba
Certifications	ENERGY STAR 5.0	EPEAT Gold ENERGY STAR 5.0	EPEAT Gold ENERGY STAR 5.0 RoHS Compliant EU Ecolabel GreenASUS	EPEAT Gold ENERGY STAR 5.0 Blue Angel TCO Certified RoHS Compliant ISO9001 & ISO14001	EPEAT Gold ENERGY STAR 5.0 C-UL-US Mark TCO Certified ISO9001 & ISO14001	EPEAT Gold ENERGY STAR 5.0 ISO14001	ENERGY STAR 5.0 TCO Certified RoHS Compliant ISO14001 LGE Eco-mark CarbonFree® Certified	EPEAT Gold ENERGY STAR 5.0 RoHS Compliant ISO 14001	EPEAT Gold ENERGY STAR 5.0 EU Ecolabel TCO Certified Edge	EPEAT Gold ENERGY STAR 5.0 RoHS Compliant ISO14001	EPEAT Gold ENERGY STAR 5.0 RoHS Compliant Toshiba Eco-Utility
Headquarters	Xizhi, New Taipei Taiwan	Cupertino, California, United States	Beitou District, Taipei Taiwan	Round Rock, Texas, United States	Palo Alto, California, United States	Beijing, China Research Triangle Park, North Carolina, United States, Singapore	Seoul, South Korea	Kadoma, Osaka, Japan	Samsung Town, Seoul,South Korea	Minato, Tokyo, Japan	Minato, Tokyo, Japan
Products	Desktop Computers Laptops Storage & Servers, Scanners & Printers, Televisions & Tablets, Video Projectors	Desktop Computers Laptops Tablets & MP3s Smart Phones	Desktop Computers Laptops Storage & Servers	Desktop Computers Laptops Storage & Servers Scanners & Printers Televisions Smart Phones	Desktop Computers Laptops, Storage & Servers Scanners & Printers Televisions, Digital Cameras & PDA	Desktop Computers Laptops Storage & Servers Scanners & Printers Televisions Peripherals	Desktop Computers Laptops & Storage Home Appliances Televisions & Tablets Mobile Phones Air Conditioning	Mobile Phones Laptops, Home Appliances, Home Communication, Televisions	Desktop Computers Laptops Home Appliances Camcorders Televisions & Tablets Digital Cameras	Desktop Computers Laptops eBook Readers Camcorders Televisions & MP3s Digital Cameras	Desktop Computers Laptops, Scanners & Printers, Home Appliances, Televisions & Tablets, Air Conditioning & Heating
Year Established	1976	1976	1990	1984	1939	1984	1947	1918	1938	1946	1939
Take-Back Program	Yes Depending on the Country, but Charges a Fee	Yes Free, and Sometimes Purchased from Consumer	Yes Free	Yes Free	Yes Free Depending on the Country	Yes Free Only in the United States, but Other Countries Pay a Fee	Yes Free Only to Consumers, but Businesses Must Pay a Fee	Yes In the United States, Japan & Europe	Yes Free	Yes Free	Yes Free Sometimes it is bought from Consumer
Page on Website for Sustainability Efforts	Yes Provides Report	Yes Provides Report for Facilities and for Products	Yes Provides Report	Yes Provides Report	Yes Provides Report	Yes Provides Report	Yes Provides Report	Yes Provides Report	Yes Provides Report	Yes Provides Report	Yes Provides Report

National Canadian / National American

	National Canadian					National American						
	CIARA	EUROCOM	MDG	NORTHERN MICRO		Gateway.	ABBCORE TECHNOLOGIES	JETTA		NCS	system	
Company Name	CiaraTech	Eurocom Corporation	MDG Computers Canada Inc.	Northern Micro Inc.	Stealth.com Inc	Gateway Subsidiary of Acer	Abbcore Technologies	Jetta	Lotus Computer Inc.	NCS Technologies Inc	System76, Inc	DakTech Comput
Certifications	ENERGY STAR 5.0 EPEAT Gold for Desktops C-UL Mark ISO9001-2000	ENERGY STAR 5.0 Only for One Desktop	EPEAT Gold ENERGY STAR 5.0	EPEAT Gold ENERGY STAR 5.0 ISO9001:2000 ISO14001 RoHS Compliant	RoHS Compliant ISO9001	ENERGY STAR 5.0	N/A	N/A	N/A	EPEAT Silver ENERGY STAR 5.0 ISO9001:2008	N/A	N/A
Headquarters	Saint-Laurent, Montreal, Quebec	Nepean, Ontario	Oakville, Ontario	Ottawa, Ontario	Woodbridge, Ontario	Irvine, California	Lilburn, Georgia	Monmouth Junction, New Jersey	Orlando, Florida	Gainesville, Virginia	Denver, Colorado	Fargo, N Dakota
Products	Desktop Computers Laptops Storage & Servers	Desktop Computers Laptops	Desktop Computers Laptops Tablets HDTVs	Desktop Computers Sell Another Brand of Laptops	Panel PCs Laptops	Desktop Computers Laptops	Desktop Computers Laptops Storage & Servers Car Computers	Laptops	Desktop Computers Laptops	Desktop Computers Laptops Storage & Servers Tablets	Desktop Computers Laptops Servers	Desktop Comput Laptops Servers

2.5.2 Why National PC Companies are Slow to Adapt

There are a number of benefits when a company considers becoming more environmentally friendly. As previously mentioned, not all companies have decided to move towards developing more environmentally products. The national companies are facing pressure in the market because they "must meet the high standard being set by global competitors" (Landers et al. 1994, 4). Sustainability within the company has been shown to provide more opportunities instead of risks. However, there are several reasons why there is a large difference between an international and national PC company's sustainability initiatives.

- **Too many confusing metrics used to measure sustainability:** There are a variety of tools developed to aid in calculating environmental aspects of a product. Companies are finding it difficult to learn each tool in order to develop one product, and they are also finding difficulty in choosing a certain tool over another (Laughland and Bansal 2011).
- **Confused if it would be a threat or opportunity to the company:** "It is difficult to judge which of these risks warrants attention, and often more challenging to prioritize them" (Laughland and Bansal 2011).
- **More government incentives should be in place for sustainable initiatives:** The government is not enforcing enough laws to encourage companies to make changes in their business methods to be considered more environmentally friendly. The lack of incentives is regarded as one of the reasons as to why several companies are not taking sustainability in their company more seriously.
- **High costs associated with training employees:** The employees that may have been with the company for several years may not necessarily be very knowledgeable about the effects that products are having on the environment, and not familiar with designing

environmentally friendly products. High investment costs by the company may be needed in order to train employees to consider the environment in their product decisions (EPA 1997, 9).

2.6 Eco-Labels: Development and Certification Process

"Sustainable development is not a new concept;" (Worster 1993) however, green labels or eco-labels are still considered a new development. "Both public agencies and non-profit groups have taken steps to improve the consumer's awareness of natural and social capital, often through product labelling" (Thorpe 2007, 68). They were first developed in Europe in 1978 and with their success they are now found around the world, but they are mainly used on products in developed countries in both Europe and North America. "Eco-labelling is a voluntary approach to environmental performance certification that is practiced around the world. An 'eco-label' identifies a product that meets specified performance criteria or standards" (Federal Electronics Challenge 2007). Usually the criteria are based upon "having [the product] manufactured by processes and procedures with low or minimal environmental impact" (Royal Society of Chemistry 1998). There are a variety of eco-labels available that are used in order to communicate how environmentally friendly a product is to consumers. "Demand for products with eco-labels are growing" (Ecolabel Index 2010), and they were originally developed as a method of informing the consumer that the product is in fact environmentally friendly and not a form of greenwashing. Eco-labels are used as a marketing tool, which offers a competitive advantage for the company's product, and to allow consumers to make better choices for the environment during their purchasing decisions (Ehrenfeld 2008).

The certification is done either by a first-party organization, second-party organization, or a third-party organization, which may also be a government organization. A first-party certification "equates to a self-declaration. The rigor and credibility of such claims, therefore, is less certain than claims that have been independently certified" (Greenguard Environmental Institute 2010). A second-party certification "means that an industry, trade or special interest group that gains revenue from the sale of certified products, has critical involvement in the certification, either through administration of the certification program, verification of the claims or creation of the standards and methods. Second-party certifications are very common and often portrayed as third-party" (Greenguard Environmental Institute 2010). A third-party certification "refers to certification programs in which all aspects of the certification program, from claims verification and standard design to administration of the program, are conducted and run by an independent body whose only ties to manufacturer or industry are fees for assessment services" (Greenguard Environmental Institute 2010). It has been around three decades since the first green label was introduced and there are already over 400 labels found on a wide range of products from various industries. According to Laughland and Bansal (2011) "It seems as if there is a veritable cacophony of metrics, standards, and certifications."

Consumers are increasingly becoming aware of the value of purchasing a product with an eco-label, and usually their initial reasons are not about their thoughts of the environment. For example, "an Energy Star computer in sleep mode consumes about 80% less electricity than it does in full-power mode and can save up to $55 per monitor yearly and about 135 kilograms of carbon dioxide emissions" (Vasil 2007, 292). The Blue Angel was the first eco-label to be developed, which was in 1978, and since that time eco-labels continued to be developed to amount to a variety of eco-labels that businesses may have certify their products. An eco-label certification can be issued by an organization that could be for-profit or non-profit, a government organization, or even issued by the company itself. The eco-labels differ from one another by either focusing on one product attribute, such as energy or carbon, while other labels consider multi-attributes such as the product's life cycle (Ottman 2011). Eco-labels also differ from one another based on the requirements they need in order for the product to meet certification criteria. Most certifications are voluntary and it is not required by law for the company to meet the specific requirements of a certain eco-label. The only eco-labels that are required by law are one found in Japan and the other in China, which are known as the Energy Saving Labelling Program: Japan and the China Energy Label. All of the eco-labels that were developed by a government organization are third party certified, and the eco-labels that were developed by a PC company are regarded as first party certified. All the organizations for the eco-labels require documents and a fee to be paid so that companies can earn the eco-label for their products.

2.7 Life Cycle Analysis

"Environmental impacts from any product system will vary due to any number of factors, including source, type and quality of raw materials; fuel mixes; manufacturing processes and technologies; use of pollution control strategies; transportation distances; and the treatment of waste" (Crawford 2011, 48). As the concept of sustainability continues to gain more consumer recognition and demand, the PC companies have already begun working on reducing the environmental impacts of their products. A change in the production process and more attention to the actual life cycle of the product is necessary in order to decrease the product's environmental impact.

> Sustainable production is dematerialized production. In its narrowest sense, it means minimizing energy and material extraction and throughput per unit of economic output. This entails, inter alia, product durability, energy efficiency, transforming wastes into raw materials, product redesign, and supplanting physical goods with knowledge goods (Toner and Bell 2006, 6).

In order to conduct a life cycle analysis (LCA) when developing an electronic product, it would require an interdisciplinary approach to work towards improving each stage of the product's life cycle, from the time it was manufactured to the time that it is ready to be discarded. "LCA started to be applied for many industrial products because there is an acute need for understanding how to deal with solid waste with less environmental impact" (Chang 2011, 36). A LCA would include analysing "all of the processes involved in sourcing, production, distribution, use, and recovery of the product" (Fiksel 2009, 125) in order to decrease their harmful effects on the environment. Every part of the process of the product development would need to be upgraded and improved to have lower environmental impacts. "The aim is to ensure that the entire product is designed to be disassembled and recycled. This, in turn, will require different design features and a use of different materials" (Toner and Bell 2006, 7). There are two key objectives for conducting an LCA for a product, which are "to help manufacturers, designers, and consumers identify and/or compare the environmental performance of one or a number of products, processes or services in order to determine the most environmentally friendly option across the entire life cycle of the product or service; or to provide a basis for identifying areas of potential improvement in the environmental performance of a particular product or process" (Crawford 2011, 61). LCA may be used by the company to determine where the most harmful environmental impacts are being taken place during the product's lifecycle, and it would offer the opportunity for the company to improve that area of the product's life.

"The first studies to look at life cycle aspects of products and materials date from the late sixties and early seventies, and focused on issues such as energy efficiency, the consumption of raw materials and, to some extent, waste disposal" (EEA 1997, 13). However, LCA is still considered a new tool and is still being introduced into the production methods of designers, engineers, and manufacturers. "As far as industry is concerned, the procedure of achieving an eco-label does not include actually performing an LCA of a product" (EEA 1997), because most of the eco-labels require more criteria to be met in addition to a LCA for that product, such as design for disassembly and longevity. "Adopting a life-cycle approach can result in financial gains for the company by shedding costs and gaining from recycling" (Dorf 2001, 211); however, there are a few limitations with using LCA. For example, it only calculates quantifiable data and does not take into account of the products noise, smell or toxicity (Ecobilan 2011). In order for sustainable design to take place the "designers must extend their views to consider the full utilization of materials and the environmental impact of the material life cycle as well as the product life cycle" (Dorf 2001). There are a number of software and web-based tools developed to help companies assess the environmental impact of their products, and "the most commonly used and sophisticated of these being those such as SimaPro (Pre Consultants 2010) and GaBi (PE International 2010). These tools all cover a wide range of impact categories and life cycle stages and often allow comparisons to be made between alternatives" (Crawford 2011, 112).

2.7.1 Interdisciplinary Design Tools

In order for a PC to be regarded as an environmentally friendly product to consumers the company must manufacture the PC according to the necessary criteria to earn an eco-label. Each eco-label has a specific list of criteria, and some of the eco-labels have very similar criteria when compared among one another. The criteria in order to meet the eco-label requirements cause an interdisciplinary collaboration between the people in the company because they involve a range of techniques and methods in order to be achieved. "Designing and manufacturing green products requires appropriate knowledge, tools, production methods, and incentives" (Dorf 2001, 122). These can be done by using specific programs that help calculate a certain stage in the product's life cycle or it can be done through changes in their supply chain management. When a company wants to make certain changes in their business or production methods to earn a label, it must first assess where it currently is with its environmental footprint, "from transportation and waste habits to pollution to energy and water use. Some of this information can be found with a thorough examination of company and employee practices; others may require a professional audit or consultant" (Spors 2010). Once these audits are made it "may uncover that due to an insufficient training budget, personnel are not familiar with proper labelling procedures" (EPA 1997, 9). Since a number of companies are substantially changing their production methods indicates that producing environmentally friendly products and earning eco-labels indeed has market value.

2.7.2 LCA Phases and the PC Design Process

As a result of the increasing pressure for companies to develop products that are safer for the environment, companies are requiring their employees to be aware of the factors to consider in order for the product to become more environmentally friendly. These pressures are arising from the consumers demanding environmentally friendly products, legislations coming into place which are banning certain substances, and a possible increase in the brand's value. "For many companies these new pressures will require a new approach to life cycle management activities that will involve a more significant role for designers and engineers" (O'Hare 2011, 1). In the past, the designer and engineer were hardly involved in process of developing more environmentally friendly products, because it "has generally been the preserve of a small number of experts within an organisation e.g. Compliance Manager responsible for restricted substances, LCA expert responsible for carbon foot printing etc" (O'Hare 2011, 2). It is also better for "eco design activities [to] be undertaken in the early stages when there is maximum potential for improving environmental performance and when changes to the product design are easier and cheaper to implement" (O'Hare 2011, 2).

The method that designers are using in order to develop more environmentally friendly products is with the use of LCA tools to help calculate the product's impacts. Designers and engineers are still being introduced to these LCA tools and not many professionals are aware of the different options that are available. "Environmental impacts are just one of many constraints a designer must consider during product development and hence only a very limited amount of time and effort can be spent on them" (O'Hare 2011, 4). A quick and easy process for designers to understand how to develop more environmentally friendly products is critical within companies, because the time to market must be less than the competitors in the industry. Another issue between designers and LCA tools is from "the vast multitude of tools now available makes the process selecting an appropriate tool a complicated and time-consuming task. Designers do not have time to go through such a process and so end up using inappropriate tools, or none at all" (O'Hare 2011, 4).

There are two methods that can be used by the designer in order to improve the product's effect on the environment during the design process, which are either to analyse a finished product and to understand the improvements that need to be made to implement them into the new design or to analyse the potential environmental impacts of the product during the design development process. The first process is known as "remedial", where designers "try to correct the environmental problems once they have been created," and the second process is known as "prevention", where designers focus their "attention on those decisions and actions which give rise to the problems in the first place" (Melnyk et al. 2001, 8). If the designer decides on the remedial process then they must first understand its Bill of Materials (BOM). "The BOM shows a list of components used to assemble the final product," which in the case of electronics includes the components used for the product's packaging, printed circuit board, the materials used during the final assembly, paint, housing, and the raw materials (Yung et al. 2011, 72). The only issue with the designer analysing a finished product, is that it is difficult to understand the type of production processes that took place during the product's manufacture in the BOM. This would require more research through the company to be made in order to calculate the full LCA for the electronic product. This method is more time consuming and difficult than to work on improving the factors that affect the LCA during the actual design process. In order to choose the prevention process, the designer has to be aware of the different phases of the life cycle of a product. These phases are "(i) selection, acquisition and use of raw materials (materials phase); (ii) manufacturing phase; (iii) packaging, transportation and distribution phase; (iv) installation and maintenance phase; (v) use phase and (vi) end-of-life phase (reuse, recycle, incineration disposal, etc.)" (Yung et al. 2011, 75). Prevention has been shown to be more effective in reducing the environmental impact of a product than the remedial process.

There are five stages of measurement that are typically calculated during the LCA, which are "(i) energy consumption, (ii) emissions to air, (iii) emissions to water, (iv) emissions to soil and (v) waste" (Yung et al. 2011, 75). The materials phase alone uses 62% of the energy consumption, and 80% of the emissions to air (Yung et al. 2011, 75), and that further emphasizes the importance of the design phase. Figure 1 illustrates the five stages of measurement and their level of impact within the different LCA phases.

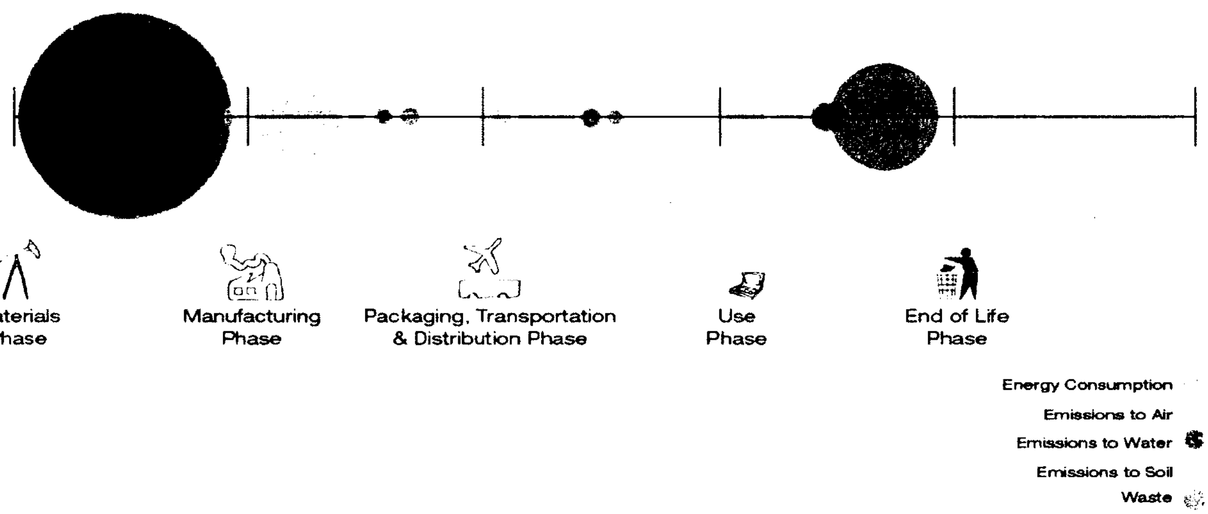

Figure 1 Five Stages of Measurement in Relation to the LCA Phases

It is understandable from Figure 1, that the Materials Phase has the largest impact on the environment based on the LCA's five stages of measurement. Designers are mostly involved in the materials phase, which shows that they can have a significant contribution to a product's impact on the environment and its overall LCA. The figure also emphasizes that "the design process is very important compared to other stages, with respect to optimizing environmental performance" (Bhander et al. 2003, 261). When focusing on conducting an LCA for PCs in the category of consumer electronics, it differs from conducting an LCA from other electronic devices because PCs are generally developed to have a shorter life span. Conducting an LCA for electronics is complex, expensive, and time consuming since "data for semiconductors or a PC assembly are more extensive and more difficult to catalogue" (Laurin et al. 2006, 6). In addition, "electronics contain valuable materials that can be reused and/or recycled, including precious metals such as gold, silver, and palladium" and "many electronic products contain toxic materials that are covered by hazardous waste regulations" (EPA 2003, 1). There are many steps required to manufacture a PC and all its components, however, the focus of this study was only on the process where the designers input is involved. Designers have trouble understanding exactly how to start when it comes to designing an environmentally friendly product, and "many firms have struggled to include environmental concerns in making design decisions" (Lenox et al. 2000, 84).

During the development of the electronic product it is the designer's role to choose the right materials, which means considering "the energy consumption not only of producing a final product, but also that consumed for making the associated raw materials" (Yung et al. 2011, 75). It is considered that "every design decision is an environmental decision" (Melnyk et al. 2001, 9). Designers are associated with the three P's that are affected by their design decisions, which are "(1) product design (how it is designed, materials used in it, environmental impact of its use, environmental impact of its disposal); (2) process (decisions made related to how the product will be produced); and, (3) packaging (the protective materials used in delivering components to the process or in delivering the product to the customer)" (Melnyk et al. 2001, 10).

The designers who develop electronic products, such as PCs are responsible for making a few critical decisions during the product's material phase that would have a significant impact on the product's environmental effects throughout the rest of the development stages. The designers in a

PC company work in teams with engineers to create "a preliminary layout of the product, material selection, manufacturing processes and dimensions" (Trotta 2010, 318). The designers are responsible for making the necessary enhancements to their material choices in order for them to be friendlier for the environment, and they are required to understand the different effects that their material choices may have on the environment during the manufacturing phase and how they can be effectively disposed at the end of the product's life. "Designers' actions are of particular importance as their decisions can have long-term consequences on the environment" (Crawford 2011, 168). The designers also work on how the different pieces of the product can fit together, and in order for the product to be environmentally friendly, the types of substances that are used to join certain materials together should also be taken into consideration during the product's design. The designer would test different material alternatives and analyse the types of effects they would have on the environment in order to make better choices.

IBM, for example, found a solution for allowing its PC designers to develop more environmentally friendly products by asking "each business unit to assign one member of its product design team to serve as a 'strategy owner' for [environmentally conscious products] issues" (Lenox et al. 2000, 88). Since that time, IBM has required reports in order for designers to explain their progress. Depending on the division, certain product design groups took the initiative lightly and have not made great effort, while "others took the initiative to heart and designated effective strategy owners or even devoted resources to creating [environmentally conscious product] teams. At one division, a product manager hired four additional engineers to aid the strategy owner" (Lenox et al. 2000, 88). Since then, the design team has made changes to create their products designed for disassembly with snap-fits on PC housings, reduce their energy consumption, and become Energy Star compliant (Lenox et al. 2000, 91). The issues that IBM found in this process were that "people had to be convinced to volunteer for the specialists roles. To speed the emergence of specialists, IBM provided training and intergroup learning opportunities," which was a lengthy, expensive, and time consuming process for the company (Lenox et al. 2000, 92).

A product example would be the Apple II computers, which were designed with "white cases, tight rounded curves, and lines of thin grooves for both ventilation and decoration" (Isaacson 2011, 133). The designer is responsible for ensuring that the product is both functional and aesthetically pleasing. The product must also be designed to meet the requirements of the company, echo the brand's image, and maintain the quality that is expected from consumers. "At most other companies, engineering tends to drive design. The engineers set forth their specifications and requirements, and the designers then come up with cases and shells that will accommodate them" (Isaacson 2011, 344). Apple was different, because the design would be approved first and then "the engineers had to make their boards and components fit" (Isaacson 2011, 344). Foam models would usually be made of the final design for the product by a team of designers and engineers, which would then be tested for any possible alterations and improvements. This example explains that the level of the designer's current involvement in the environmental aspects of the product depends on the company that they are working for.

The designer cannot conduct a full LCA on their own; however, if they focus on their own role for improving the product's impact they can significantly reduce the harmful effects that the product is having on the environment. "The choice of the right tool and/or method, for the right purpose, used by the right person and at the right moment, is a crucial issue, which should be fully interrelated with the companies' ecodesign strategy as well as their organization and management" (Mathieux et al. 2003, 237). The choice of better materials would cause less of an environmental impact at the end of the product's life and during the production process, and designers would be using more efficient resources if they reduce the weight and size of the product. The amount of total waste generated is affected by the choices made during the design phase, and there are many tools that have been developed in order to aid the process for designers to make more sustainable choices. "LCA tools need to be developed and integrated into the design process to aid decision-makers and designers in identifying resource wastage and process outputs directly and indirectly associated with the life cycle of the product and system while designing them" (Bhander et al. 2003, 255). Studies also suggest that "product developers should be aware of the use and benefits of the broad range of eco-design tools and techniques now available, and be confident of choosing the most relevant tools for the job" (Bhander et al. 2003, 258). In addition, "because future product behaviour is determined in the early phases of design, the entire life cycle of a product has to be taken into account at the planning and design stage" (Bhander et al. 2003, 258).

Designers have an increased responsibility when it comes to designing a product that is safer for the environment. "The design process is the core issue to the development of environmentally superior products," and it offers "the greatest opportunity to improve the environmental performance of a product" (Bhander et al. 2003, 255, 259). Designers are still having issues on processing all the information and fully understanding how to successfully develop an environmentally friendly product. "Having to address too much information and too many requirements pushes the designer into a position where selectively disregarding some tasks is a necessary evil" (Bhander et al. 2003, 265). This is growing in importance because "if the focus on the relationship between products and environmental problems continues to grow, the demand for designers with special knowledge about sustainable product design will also increase" (Bhander et al. 2003, 265). Designers are already being "submerged in a vast and complex range of regulatory and professional responsibilities and no matter how much of an essential aspect of the design process environmental considerations must be, they do pose an even greater demand on professionals' limited time and resources" (Crawford 2011, 176).

2.7.3 General Tools for Environmental Design

"We are accustomed to thinking of industry and the environment as being at odds with each other, because conventional methods of extraction, manufacture, and disposal are destructive to the natural world" (McDonough and Braungart 2002, 6). Design for Environment (DfE) is one of the most popular ways that manufacturers, engineers and designers use when trying to make their products better for the environment. "The product design and development phase influences more than 80 percent of the economic cost connected with a product, as well as 80 percent of the environmental and social impacts of the product, incurred throughout its whole life-cycle" (Charter and Tischner 2001, 120). Manufacturing processes that consider the environment have become known as green manufacturing, which "encompasses source reduction, recycling, and green product design" (Dorf 2001).

There are a large number of tools available for designers, manufacturers, and engineers to calculate the environmental effects of their design decisions, and they range from being either software tools or tools available directly off the web, and they are also known as LCA tools. Some of the popular tools include conducting a LCA and Design of Experiments, which is "an excellent methodology to investigate green materials and process alternatives" (Shina 2008, 34). Some of the tools consider more aspects to calculate than others, and some consider the full lifecycle of the product while others only look at calculating a single piece of criteria. The most common aspect that the tools aid designers in doing when designing environmentally friendly products is to guide their materials selection, and most of them also offer the opportunity to compare several different materials together in order to understand which of the material may have fewer environmental effects. There are several limitations; however, with "one of the biggest issues with current LCA tools is akin to that for LCA in general: that there will always be a lack of reliability or a degree of incompleteness associated with the software outputs" (Crawford 2011, 112).

2.8 Interdisciplinary Aspect

The study has focused on the materials phase during the LCA, which includes the role of the designer; however, the study is interdisciplinary since designers need to work in teams in order to develop an environmentally friendly product. "Many companies are now starting to express the need for environmentally literate product designers but are having major difficulties in recruiting the right people, as traditional product designers have not been trained to deal with sustainability or even environmental issues (Charter and Tischner 2001, 122). There are many different factors to consider when trying to develop an environmentally friendly product that would meet eco-label criteria. The study established a connection between the eco-labels and

LCA tools and communicated that connection to designers with the use of a toolkit composed of two different design tools, which will be discussed in depth in the Results and Discussion chapter.

Companies seem to have the most difficulty as to where to begin when developing products that are safer for the environment, since "the green knowledge base for product development is widely distributed and not readily available within the organisation, in the design or process teams" (Shina 2008, 2). It is important for designers to be aware of their role with designing products that are safer for the environment. The "design team must understand how the properties and application of environmentally friendly materials and processes affect the product" (Shina 2008, 248), and this includes an understanding if the materials would be as strong, aesthetically pleasing, and functional as the traditional materials being used for the product. This places a lot of new challenges on designers within PC companies to be aware of these eco-label criteria and how they can effectively meet them in order to remain competitive in the industry. The outcome of the study was the development of a toolkit to be used by designers in order to develop environmentally friendly PCs that meet the eco-label criteria, and the verification of the value of the proposed toolkit for designers within the industry.

CHAPTER 3

METHODS

Chapter 3 is organized into eight sections. Sections 3.1 and 3.2 describe the reasons for each research method used in the study. Sections 3.3, 3.4, 3.5, and 3.6 describe the details each method used in the study. Sections 3.7 and 3.8 provide the ethical considerations and the outcomes that were expected from the study.

3.1 Rationale for Research Methods

A toolkit designed to facilitate the process of meeting eco-label criteria for personal computers (PCs) is expected to be of high value among professionals in the field. Conducting a life cycle assessment (LCA) for products is not a new process; however, a LCA for electronics is still considered expensive, difficult and time consuming (Goldberg 2000, 126; Laudise and Graedel 1998, 55). A LCA also falls short from calculating all the criteria required to meet eco-label certification criteria. The professionals that are involved with the process of developing environmentally friendly PCs consist of designers, engineers, and manufacturers, that include assembly operators, test technicians, and maintenance personnel, which was explained in an interview with José Vera, from Professional Engineers Ontario (PEO). They collaborate within the company in order to discuss the specifications and requirements of the product, and they are all required to collaborate with one another to meet the criteria of the various eco-labels. This chapter will discuss the methodologies chosen for addressing the four following research questions:

How do the LCA tools chosen for this study help with meeting eco-label criteria for PCs?

How are the eco-label criteria not being met with the LCA tools for calculating the environmental impact of PCs?

How much are PC designers involved in the process of meeting eco-label criteria?

How would a toolkit developed for PC designers facilitate the process in choosing the suitable LCA tool for meeting eco-label criteria?

3.2 Measurement Instruments and Setting

In order to for each of the four research questions to be addressed, it required the process of methodological triangulation. The qualitative method was used for this research with critical reviews, interviews, a survey, tables to compare the data, and a workshop to test the enabling tool that was developed as a result of the first three research methods; which would be discussed in detail in the following chapters. The survey provides quantitative results that are discussed and analysed in a qualitative form in order to provide the necessary information to answer the third research question. The interviews and survey were not focused on targeting professionals from a particular country. The study was looking at the eco-labels developed for PCs around the world, so the contribution from professionals worldwide would be of equal value. Having a toolkit developed to facilitate the process of PCs meeting eco-label certification criteria may allow the national and international companies to increase their development of certified PCs and in turn decrease the amount of energy being consumed and the percentage of e-waste sent to landfills. Figure 2 shows the different research methods that were conducted in this study and the research questions that they specifically help answer.

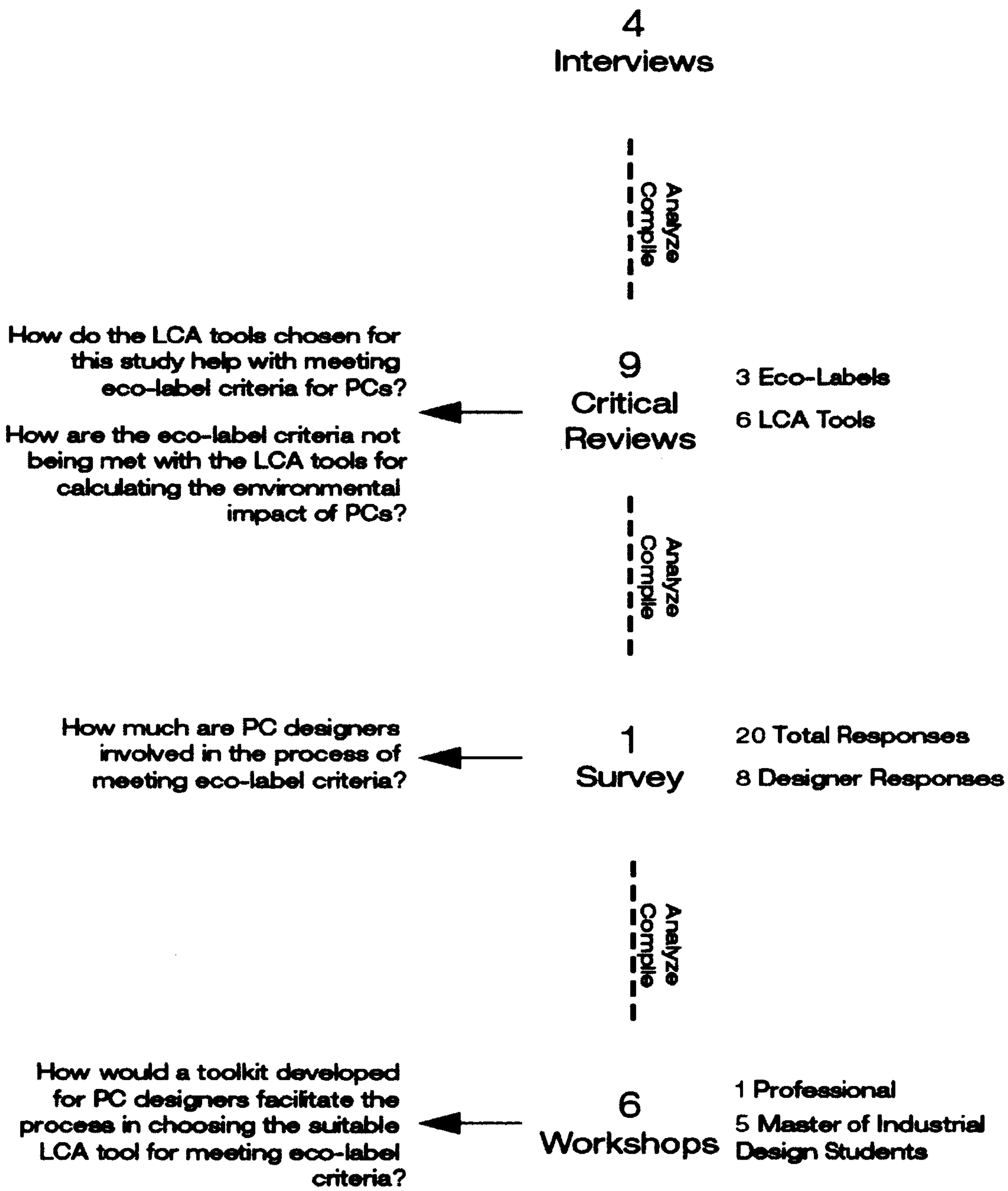

Figure 2 Research Methods used in Relation to the Four Research Questions

3.3 Interviews

The first research method that was conducted were the interviews made with professionals that are experienced with working with the LCA tools or have knowledge about eco-labels and their required criteria. The interviews took place through a phone discussion on Skype, and they were used to support the information provided within the critical reviews written about the eco-labels and LCA tools.

3.3.1 Sample/ Participants

The participants were a convenience sample and were found through professional groups on the website, LinkedIn. Each interview took around 20 minutes, and the four interview participants included:

- Jeff Omelchuck, EPEAT executive director from Green Electronics Council in Portland, Oregon.
- Thomas Redd, manager of the Consumer Science Working Group at the Sustainability Consortium
- Robert Cifarelli, segment marketing specialist from ASUS
- José Vera, standards and guidelines development coordinator at Professional Engineers Ontario (PEO)

3.3.2 Data Analysis

Half of the interview respondents discussed their views on the eco-labels and what makes eco-labels so valuable for companies to achieve for their products. The other half of the interview respondents were used to answer the third and fourth research questions by specifying their current roles in developing more environmentally friendly electronic products, and to understand how the development of the toolkit may be particularly valuable to designers in the industry.

3.4 Critical Reviews

3.4.1 Sample

The second research method that was performed in this study were the critical reviews, which were written about the most well-known eco-labels around the world, and the most well-known LCA tools. The critical reviews were used to formulate the necessary data to analyse the first and second research questions. These research questions required a thorough study of the thirty-two eco-labels found globally that certify environmentally friendly PCs, in order to understand their differences in criteria, objectives, and the countries where they are considered to be valid eco-labels. The critical reviews written about Energy Star, Blue Angel, and China Environmental Labelling were discussed in the Results and Discussion chapter; as well as the six critical reviews that each analysed a different LCA tool. These critical reviews provided a better understanding about what factors each tool helps calculate and their differences between one another.

3.4.2 Data Analysis

The nine total critical reviews of the eco-labels and LCA tools would be developed by using secondary research, blogs, journal articles, books, and websites. Since there are a total of thirty-two eco-labels found globally to certify PCs, they would be separated into a set of groups and one critical review would be written about an eco-label from each group. The three groups would be Canada and the United States, Europe, and Asia. The eco-label that was chosen from each group was based on its popularity within the country or region. The data collected in the critical reviews would be to understand the criteria to be met from each eco-label to certify a PC, and to determine if the organization that developed the eco-label suggests methods or tools in order for users to meet those criteria. A comparison was made between the eco-labels for understanding the differences among their criteria required to certify a product, and the findings were gathered and illustrated in Table 2, Table 3, Table 4, and Table 5 provided in the Results and Discussion chapter.

To answer the first and second research question it was necessary to understand how the eco-label criteria were not being met with the LCA tools chosen to be analysed for this study. The tools were divided into two groups being either software tools or web-based tools, and the tools were chosen for the critical reviews based on their popularity in the industry. The critical reviews for the LCA tools were based on secondary research and the data that was collected would have the purpose of providing the understanding on what their functions are, who they are specifically designed for, and how they analyse and present the data. The critical reviews and tables of the eco-labels and LCA tools were analysed and then compared between each other for understanding how much the eco-label criteria are actually being met with the LCA tools for calculating the environmental impact of PCs. The final comparison of the compiled data was also illustrated in a table in the next chapter.

3.5 Online Survey

A survey would be used to formulate the necessary data to analyse the third research question. The survey was prepared by using FluidSurveys, which was created by a Canadian company and it is a service available on the web. The survey would be distributed to experts in the field that are familiar with developing personal computers, such as designers, engineers, and manufacturers. The questionnaire for the survey is provided in Appendix C. The goal of the survey was to understand how many professionals are still unaware of the LCA tools available and how many are actually involved with meeting eco-label criteria. The survey was also used to understand which tools the designers are familiar with using in order to contribute to meeting eco-label criteria and the types of difficulties they are currently having with using the LCA tools during the development of their products.

3.5.1 Sample/ Participants

The online survey questionnaire would take eight minutes to complete and it was distributed to participants that were selected as a purposive sample through professional groups in LinkedIn, and it was also posted on organization's websites, such as the Ontario Centre for Engineering and Public Policy, the Association of Canadian Industrial Designers and the Industrial Designers

Society of America. The questions ranged between multiple-choice questions, yes or no questions, and likert-scale questions.

3.5.2 Data Analysis

The data from the survey would be compiled and illustrated into a set of diagrams to illustrate the various responses. The survey findings would allow more insight into what the professionals particularly value of the tools they use, and the functions they hope the tools may include in the future. The final analysis of the survey and interview responses would provide the necessary conclusions of how the valuable the toolkit may be to designers.

3.6 Enabling Tool and Workshop

3.6.1 Creation of the Enabling Tool

The main outcome of this research would be the enabling tool that was developed, which is the toolkit to facilitate the process for designers to choose the LCA tool that would best suit their needs depending on the type of eco-label criteria they are trying to meet. The toolkit was based off an analysis of the research and critical reviews of the eco-labels around the world and their relation to the six LCA tools chosen for this study. A method to clearly separate the data into a toolkit that would be understandable for designers required research into previously developed design tools.

There are a variety of design tools that are used to present information specifically for designers. They are more understandable to designers than the tools developed specifically for other fields such as engineering or business management. For example, tools such as a Flowchart Diagram, Paired Comparison Analysis, Grid Analysis, Conjoint Analysis, Analytic Hierarchy Process, and Kepner Tregoe Decision Making all require a mathematical process of assigning weights to evaluate alternatives. Business managers and engineers have already dealt with most of these types of tools; however, most designers do not have experience with these business management and engineering tools that require some previous knowledge in order to know how to use them. If the tool for this research were being developed for engineers it would be through the flowchart diagram, because it is a simple and understandable tool that does not require a set of calculations like the other tools in order to reach the final result. An example of how the flowchart diagram would have looked for this study is shown in Table 2. Some design tools are explained below in order to clarify the reasons for the tools chosen to be used in the toolkit.

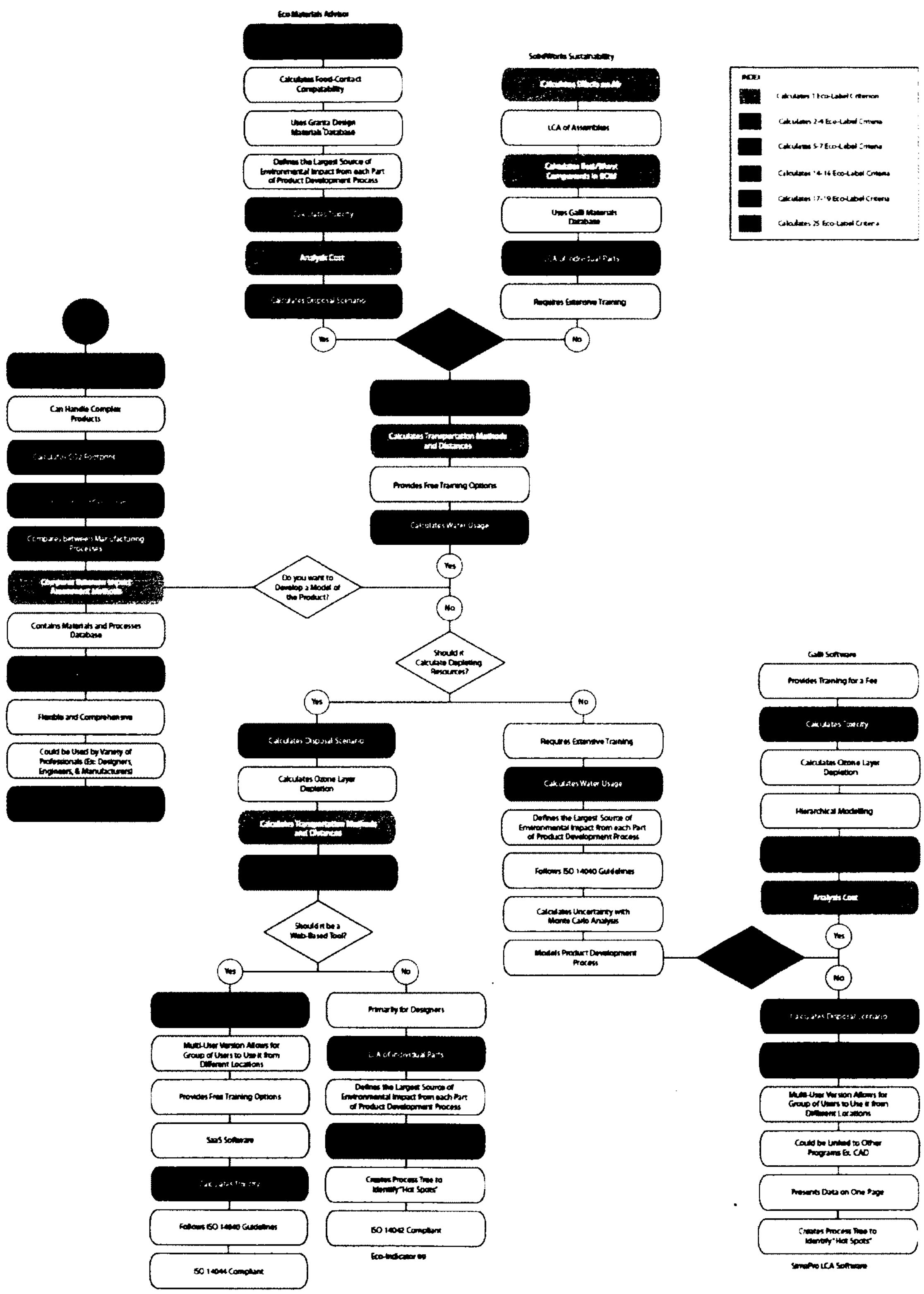

Table 2 Flowchart Diagram

Offering Map

An offering map basically illustrates a service and helps designers understand the different options that the service provides for users. The tool does not have a specific format "could be described by words or could be illustrated by images, but most frequently it is visualized through a graph" (Offering Map 2009). The tool could be used in two ways, which are either to simply illustrate the service to the user, or to illustrate possible solutions to the service. This tool is effective for illustrating the varied options available and how the user may specifically use those options, and this can be a valuable tool in helping users in make decisions.

System Map

A system map is similar to an offering map; however, it is mainly used to illustrate the technical organization of the service. For example, it would specify "the different actors involved, their mutual links and the flows of materials, energy, information and money through the system" (System Map, 2009). The system map is a diagram that uses a series of arrows, visual illustrations, and text in order for the user to have a complete understanding of how the technical organization works. The use of these different methods for communicating the idea to the user would allow for a simple and easy to understand visual representation of the different functions provided by the system being illustrated.

Issue Cards

Issue cards are a different type of media used in order to illustrate information to the user. "Each card could contain an insight, a picture, a drawing or a description; everything is able to suggest new interpretations of the problem and to induce the assumption of a different point of view" (Issue Cards 2009). Issue cards are basically used as physical references to certain objects, activities or illustrations and provide a brief explanation of the object, activity or illustration that is on the card. Not only is this tool simple to use, but it is valuable since it is an interactive tool that can be used by a group of people at one time.

Affinity Diagram

An affinity diagram is a tool used for organizing large amounts of information and illustrating their relationship among one another. This tool is used in both business and design. The diagram is mainly composed of text and it is helpful for allowing the user to determine the contents that contain similarities and where areas of improvement may be needed. "The result is a sort of verbal and visual representation describing the first exploration of design solutions" (Affinity Diagram 2009).

Mind Map

A mind map is a tool where the user has a main idea in the centre of the diagram and it illustrates the connections that could be made with that main idea. Basically the connections are a set of "signs, lines, words and drawings are used in order to build a system of thoughts around the starting point" (Mind Map 2009). It provides the user with an opportunity to explore various connections to a certain area, and it also helps "break large projects or topics down into manageable chunks, so that [the user] can plan effectively without getting overwhelmed" (Mind Maps 2012).

Blueprint

A blueprint is a diagram that illustrates a service in detail and shows its basic structure on how it works. It allows the opportunity for the "designer to focus and establish the key user interactions, the role of the service provider and the touch points to be designed in the future phases"

(Blueprint 2009). It is basically a breakdown of a certain service or experience and illustrates how each of the factors work together and their importance within the system.

Customer Journey Map

The customer journey map allows the user to follow the areas on the map that illustrates the different experiences that will take place before getting to the end result. With this tool "the interaction is described step by step as in the classical blueprint, but there is a stronger emphasis on some aspects as the flux of information and the physical devices involved" (Customer Journey Map 2009). It is a valuable tool because it allows the user to visually understand the types of experiences in a sequence. The user can gather several different customer journey maps to understand the differences and types of implications to be had with each.

A system map is mostly used to illustrate a certain layout of how a system works and a blueprint is used for showing the relation between the factors being analysed and their importance within the system. Affinity diagrams are valuable for dividing factors into groups for finding areas that need improvement, customer journey maps are used for illustrating a sequence of events, and mind maps are used for understanding the connections associated with a main idea. However, the goal of the design tool for this study was to show the relationship and differences between the different choices available of the LCA tools. The design tool was supposed to be able to clarify to the user that certain LCA tools would help meet eco-label criteria, and a description of those eco-labels was also to be made available in the toolkit.

Electronic designers for devices such as PCs usually work in a set of teams in order to produce the final product. In certain cases now, such as with IBM, one designer is responsible for being the strategy owner, which is basically the manager of helping the rest of the designers in the team to understand how to develop the product to be more environmentally friendly. In order to clearly describe all the information to the designer, a set of design tools would need to be used that work together to allow the designer to come to a final decision. The tools that seemed the most suitable for the purpose of this study were the offering map and issue cards. The offering map, as previously mentioned, is useful for illustrating the varied options available and how the user may specifically use those options, and this can be a valuable tool in helping users in make decisions. The issue cards provide a drawing, description, and insight into a certain factor in order to provide more clarification to the user. The offering map would illustrate the different LCA tool options for the designer and their relationship among one another. The issue cards would be used to illustrate the different types of eco-labels available, and each card would refer to the offering map to understand how the LCA tools would help meet the eco-label criteria. The set of tools would be combined within a toolkit that would contain a manual explaining how the tools work together in order for the designer to use them correctly to make their decision on the LCA tool they should use to meet eco-label criteria during the development and design phase of their product.

3.6.2 The Workshop for the Toolkit

The toolkit would be tested with a professional in the field of PC design, and it would also be tested through a workshop that included a few of my colleagues from the Master of Industrial Design program at Carleton University. It would be valuable to receive criticism from emerging designers who are unfamiliar with the research, because it would prove how understandable the toolkit may be for PC designers who are unfamiliar with developing environmentally friendly products. The workshop took place in the Azrieli Pavilion building with five Master student participants. The workshop was not meant for a group of students to analyse the toolkit together, because the participants were encouraged to offer their individual opinions and comments by testing the toolkit. It was hypothesized that testing the toolkit and answering the questionnaire about the toolkit, which is explained in the next section, would not take longer than fifteen minutes. This resulted in the individual workshops with the students to be scheduled at fifteen minute intervals from one another. The toolkit was also sent to a professional designer in the industry in order to understand their view of the toolkit and what improvements they believe should be made to make it more effective. The professional designer that tested the toolkit for this study was John Anastasiadis an industrial design-product development consultant, with clients that include HP and LG.

3.6.3 Improving the Toolkit based on Feedback

Each student was offered a short questionnaire to fill after they finished testing the toolkit, and the questionnaire for the students is in Appendix B. The individual comments provided more insight into how each student would understand the toolkit in their own way. Fortunately, each student was capable of testing the toolkit and answering the questionnaire within the fifteen minute time frame of the individual workshop. The professional participant that agreed to test the toolkit had the toolkit sent to them electronically and then they answered a series of questions about the benefits and defects on their opinion of the toolkit. The responses were valuable in understanding how the toolkit could be possibly improved to become more understandable and effective. The questions that were asked to the professional are found in Appendix A.

3.7 Ethical Considerations

The online survey had the respondents remain anonymous, and they could voluntarily decide to respond to the survey by accessing it through a link on professional blogs or organization websites. A pilot test was done for the survey to ensure the necessary time required to respond to the questions. The server used was Canadian, which would not cause issues with federal security policies and would guarantee the respondents confidentiality. The interview respondents were sent a letter of invitation to participate in the research with the explanation of how the data will be used. They were offered fourteen days in which they may choose to withdraw their responses for the research, and they also had the option to decide not to answer certain questions during the interview. This research received ethics clearance by the Carleton University Research Ethics Board on January 10, 2012, and a copy of the ethics clearance is provided in Appendix D.

3.8 The Outcomes that Were Expected

The outcomes that were expected from this research would be that the LCA tools do not help with meeting all of the eco-label criteria necessary to certify PCs; however, they do meet a significant portion of the required criteria. The study further emphasized the importance for designers to contribute to the environmental design for the product, and the significant impact they can have on the overall environmental effects of the PC. The study would then verify the value of the toolkit based on interviews and the survey, which were expected to convey the particular importance of this type of toolkit to be developed. This toolkit is expected to provide a simpler and less expensive method of meeting eco-label criteria, which can be used by designers in both international and national companies. It is also expected to help raise the designer's awareness of their possible roles in reducing the environmental effects of PCs, and help them understand the different LCA tools they may use in order to do so.

CHAPTER 4

RESULTS AND DISCUSSION

Chapter 4 is organized into seven sections. Section 4.1 provides a better understanding of the different types of eco-labels used for PCs. Section 4.2 explains the findings from the interviews that were conducted. Sections 4.3 and 4.4 provide the critical reviews and explain the findings made from those critical reviews. Sections 4.5, 4.6, and 4.7 explain the findings that were made from the survey, the workshops, and the changes made to the toolkit as a result of the workshops.

4.1 Eco-Labels for PCs

The fact that businesses strive to earn these eco-labels for their personal computers (PCs) signifies that they do add to the market value and that there is a significant consumer demand for these labelled products. Since there is not a defined market value or data about the actual market penetration that eco-labels have in the industry, a comparison was made among the eco-labels from each region in the world and on the efforts that each company is placing on meeting those eco-label criteria for their PCs. The eco-labels that are used within Canada for communicating the sustainability of personal computers are shown in Table 3. The eco-labels that are used within the United States for communicating the sustainability of personal computers are shown in Table 4. The United States use more eco-labels for their personal computers compared to Canada, which causes the United States to have a higher number of third-party certified eco-labels. Europe and Asia also have their own eco-labels developed to certify personal computers and also use eco-labels developed in the United States, which are shown in Table 5 and Table 6.

Certification Name	CarbonFree® Certified	C-UL Mark	C-UL-US Mark	ENERGY STAR	Electronic Product Environmental Assessment Tool (EPEAT)	EU Ecolabel	TCO Certified	TCO Certified Edge
Governing Organization	Carbonfund.org Foundation	Underwriters Laboratories	Underwriters Laboratories	Natural Resources Canada	Green Electronics Council	European Commission	TCO Development	TCO Development
Year and Certification	2007 Third-Party Certified Non-Profit	2009 Second-Party Certified Non-Profit	1998 Second-Party Certified Non-Profit	2001 Third-Party Certified Non-Profit	2006 Third-Party Certified Non-Profit	1992 Third-Party Certified Non-Profit	1992 Third-Party Certified Non-Profit	2009 Third-Party Certified Non-Profit
Focus	Carbon Emissions	Safety Chemicals	Safety Chemicals	Energy Efficiency	Energy Efficiency, Material Selection, Product Longevity, & End-of-Life Management	Lifecycle Environmental Impact	Usability and Lifecycle Environmental Impact	Leading Edge in Usability and Lifecycle Environmental Impact
Objectives	Inform Consumer about Company's Efforts Towards Reducing their Carbon Footprint and Emissions Caused by the Product	Manufacturers can Show Consumers, Competitors, & Regulators that their Products meet Safety Demands	Manufacturers can Show Consumers, Competitors, & Regulators that their Products meet Safety Demands	Build Awareness, Promote Action, Promote Growth in Product Sales	Help Consumers Evaluate, Compare & Select Electronic Products Based on their Environmental Attributes	Help Consumers Distinguish Greener, More Environmentally Friendly Products and Services	Allows Consumers to Choose Technology Designed for both Usability and the Environment	Allows Consumers to Choose the Leading Technology Designed for both Usability and the Environment
Products	Textiles, Food, Building Products, Cleaning Products, Cosmetics, Paper, Home Appliances, Machinery & Equipment, & Consumer Electronics	Home Appliances & Computer Equipment, Furnaces & Heaters, Fire Extinguishers & Sprinkler Systems & Thousands of Other Products	Home Appliances & Computer Equipment, Furnaces & Heaters, Fire Extinguishers & Sprinkler Systems & Thousands of Other Products	Major Appliances, Heating Equipment, Cooling and Ventilation Equipment, Lighting Electronics, Office Equipment, Windows, Doors and Skylights	Electronics	Textiles, Building Products, Cleaning Products, Cosmetics, Paper, Home Appliances, Consumer Electronics & Others	Electronics	Electronics
Criteria To Earn Certification	Based Upon a Product Life-Cycle Assessment of a Product's Carbon Emissions	Product must Comply with the Appropriate Safety Requirements of the Country and the UL Requirements	Product must Comply with the Appropriate Safety Requirements of Both Countries and the UL Requirements	Product must be More Efficient than the Minimum Guidelines of that Country	Evaluates products on 51 environmental criteria in eight categories, including materials use, design for end of life, and packaging	Evaluates products by how Low the Environmental Impacts Throughout its Lifecycle are.	Evaluates products on Whether they are Designed for Both the Environment & High Performance	Add on to the base label, promotes excellent work in a certain area that is chosen to focus on
Countries Where it is Located	Canada United States Brazil Australia	Canada	Canada United States Mexico	North America Europe	North America Europe, Mexico Japan, China Taiwan, Singapore Brazil, Puerto Rico	58 Countries Including Canada and the United States	77 Countries Including Canada and the United States	77 Countries Including Canada and the United States

Certification Name	CarbonFree® Certified	C-UL-US Mark	ENERGY STAR	Electronic Product Environmental Assessment Tool (EPEAT)	EU Ecolabel	TCO Certified	TCO Certified Edge	TerraCycle	Green ASUS	LGE Eco-mark	Blue Ar
Governing Organization	Carbonfund.org Foundation	Underwriters Laboratories	Environmental Protection Agency (EPA)	Green Electronics Council	European Commission	TCO Development	TCO Development	TerraCycle	ASUS	LG Corp.	Federal Environ Conser Nuclear
Year and Certification	2007 Third-Party Certified Non-Profit	1998 Second-Party Certified Non-Profit	1992 Third-Party Certified Non-Profit	2006 Third-Party Certified Non-Profit	1992 Third-Party Certified Non-Profit	1992 Third-Party Certified Non-Profit	2009 Third-Party Certified Non-Profit	2005 Second-Party Certified For-Profit	2000 First-Party Certified Non-Profit	2004 First-Party Certified Non-Profit	1978 Third-P Certifie Non-Pr
Focus	Carbon Emissions	Safety Chemicals	Energy Efficiency	Energy Efficiency, Material Selection, Product Longevity, & End-of-Life Management	Lifecycle Environmental Impact	Usability and Lifecycle Environmental Impact	Leading Edge in Usability and Lifecycle Environmental Impact	Recyclability	Recyclability, Manufacturing, & Procurement	Environmental Impact	Health, Water,
Objectives	Inform Consumer about Company's Efforts Towards Reducing their Carbon Footprint and Emissions Caused by the Product	Manufacturers can Show Consumers, Competitors, & Regulators that their Products meet Safety Demands	Build Awareness, Promote Action, Promote Growth in Product Sales	Help Consumers Evaluate, Compare & Select Electronic Products Based on their Environmental Attributes	Help Consumers Distinguish Greener, More Environmentally Friendly Products and Services	Allows Consumers to Choose Technology Designed for both Usability and the Environment	Allows Consumers to Choose the Leading Technology Designed for both Usability and the Environment	Informs Consumers that the Product is no Longer Waste, and can be Collected and Sent to TerraCycle	Informs Consumers that the Product is One of the Greenest Offered by the ASUS Company	Informs Consumers that the Product is One of the Greenest Offered by the LG Company	Help Co Distingu More E Friendly Among Product
Products	Textiles, Food, Building Products, Cleaning Products, Cosmetics, Paper, Home Appliances, Machinery & Equipment, & Consumer Electronics	Home Appliances & Computer Equipment, Furnaces & Heaters, Fire Extinguishers & Sprinkler Systems & Thousands of Other Products	Major Appliances, Heating Equipment, Cooling and Ventilation Equipment, Lighting Electronics, Office Equipment, Windows, Doors and Skylights	Electronics	Textiles, Building Products, Cleaning Products, Cosmetics, Paper, Home Appliances, Consumer Electronics & Others	Electronics	Electronics	Textiles, Food, Cleaning Products, Cosmetics, Home Appliances, Waste Management, & Consumer Electronics	Electronics	Electronics	Building Cleanin Printers Applian & Equip Textiles Waste
Criteria To Earn Certification	Based Upon a Product Life-Cycle Assessment of a Product's Carbon Emissions	Product must Comply with the Appropriate Safety Requirements of Both Countries and the UL Requirements	Product must be More Efficient than the Minimum Guidelines of that Country	Evaluates products on 51 environmental criteria in eight categories, including materials use, design for end of life, and packaging	Evaluates products by how Low the Environmental Impacts Throughout its Lifecycle are.	Evaluates products on Whether they are Designed for Both the Environment & High Performance	Add on to the base label, promotes excellent work in a certain area that is chosen to focus on	Evaluates Whether the Product is Recyclable	Evaluates Products on their Design, Manufacturing, and Procurement	Products must meet Some Domestic and International Environmental Regulations in order to Suit Global Requirements	Awarde Particul for the which a Standa Health
Countries Where it is Located	Canada United States Brazil Australia	Canada United States Mexico	North America Europe Japan Taiwan Australia	North America Europe, Mexico Japan, China Taiwan, Singapore Brazil, Puerto Rico New Zealand, Australia United Kingdom	58 Countries Including Canada and the United States	77 Countries Including Canada and the United States	77 Countries Including Canada and the United States	North America, Brazil, Argentina, Mexico, Sweden, Israel, Turkey, & United Kingdom	International	International	United Europe Australi Japan Republi Spain
Country of	United States	United States	United States	United States	European Union	Sweden	Sweden	United States	Taiwan	South Korea	Germar

Certification Name	ENERGY STAR	Electronic Product Environmental Assessment Tool (EPEAT)	EU Ecolabel	TCO Certified	TCO Certified Edge	TerraCycle	GreenASUS	LGE Eco-mark	Green IT	ECMA-341: Environmental Design Considerations for Electronic Products	Blue Angel	Cradle to Cradl Certification
Governing Organization	Natural Resources Canada	Green Electronics Council	European Commission	TCO Development	TCO Development	TerraCycle	ASUS	LG Corp.	Fujitsu	ECMA International	Federal Ministry for the Environment Nature Conservation and Nuclear Safety	McDonough Braungart Design Chemis (MBDC)
Year and Certification	2001 Third-Party Certified Non-Profit	2006 Third-Party Certified Non-Profit	1992 Third-Party Certified Non-Profit	1992 Third-Party Certified Non-Profit	2009 Third-Party Certified Non-Profit	2005 Second-Party Certified For-Profit	2000 First-Party Certified Non-Profit	2004 First-Party Certified Non-Profit	2003 First-Party Certified Non-Profit	2004 First-Party Certified Non-Profit	1978 Third-Party Certified Non-Profit	2005 Second-Party Certified For-Profit
Focus	Energy Efficiency	Energy Efficiency, Material Selection, Product Longevity, & End-of-Life Management	Lifecycle Environmental Impact	Usability and Lifecycle Environmental Impact	Leading Edge in Usability and Lifecycle Environmental Impact	Recyclability	Recyclability, Manufacturing, & Procurement	Environmental Impact	Energy Efficiency, Material Selection, & Manufacturing	Energy, Toxic Substances, Waste	Health, Climate, Water, & Resources	Material Health Material Reutiliz Renewable Ene Use, Water Stewardship, ar Social Respons
Objectives	Build Awareness, Promote Action, Promote Growth in Product Sales	Help Consumers Evaluate, Compare & Select Electronic Products Based on their Environmental Attributes	Help Consumers Distinguish Greener, More Environmentally Friendly Products and Services	Allows Consumers to Choose Technology Designed for both Usability and the Environment	Allows Consumers to Choose the Leading Technology Designed for both Usability and the Environment	Informs Consumers that the Product is no Longer Waste, and can be Collected and Sent to TerraCycle	Informs Consumers that the Product is One of the Greenest Offered by the ASUS Company	Informs Consumers that the Product is One of the Greenest Offered by the LG Company	Informs Consumers that the Product is One of the Greenest Offered by the Fujitsu Company	Indicates that Requirements and Recommendations for the Design of Commercially Viable, Environmentally Conscious Products	Help Consumers Distinguish Greener, More Environmentally Friendly Products Among Other Similar Products	Help Consumer Distinguish Gre More Recyclabl Products that a Safe for Human Environmental I
Products	Major Appliances, Heating Equipment, Cooling and Ventilation Equipment, Lighting Electronics, Office Equipment, Windows, Doors and Skylights	Electronics	Textiles, Building Products, Cleaning Products, Cosmetics, Paper, Home Appliances, Consumer Electronics & Others	Electronics	Electronics	Textiles, Food, Cleaning Products, Cosmetics, Home Appliances, Waste Management, & Consumer Electronics	Electronics	Electronics	Electronics	Electronics	Building Products, Cleaning Products, Printers, Food, Appliances, Machinery & Equipment, Paper, Textiles, Tourism, & Waste Management	Building Produc Cleaning Produ Electronics, Foo Appliances, Ma & Equipment, P Textiles, Transp & Others
Criteria To Earn Certification	Product must be More Efficient than the Minimum Guidelines of that Country	Evaluates products on 51 environmental criteria in eight categories, including materials use, design for end of life, and packaging	Evaluates products by how Low the Environmental Impacts Throughout its Lifecycle are.	Evaluates products on Whether they are Designed for Both the Environment & High Performance	Add on to the base label, promotes excellent work in a certain area that is chosen to focus on	Evaluates Whether the Product is Recyclable	Evaluates Products on their Design, Manufacturing, and Procurement	Products must meet Some Domestic and International Environmental Regulations in order to Suit Global Requirements	Products must be efficient in their Energy Usage and be Developed using More Environmentally Friendly Materials	Awarded to Products that Follow its Recommendations for the Products Design in order to improve the Environmental Performance	Awarded to those Particularly Beneficial for the Environment & which also fulfill high Standards of Health & Safety	Awarded after t Materials and Manufacturing Practices are Te in Five Categori
Countries Where it is Located	North America Europe	North America Europe, Mexico Japan, China Taiwan, Singapore Brazil, Puerto Rico New Zealand, Australia United Kingdom	58 Countries Including Canada and the United States	77 Countries Including Canada and the United States	77 Countries Including Canada and the United States	North America, Brazil, Argentina, Mexico, Sweden, Israel, Turkey, & United Kingdom	International	International	International	United States, Canada, European Union	United States Europe Australia Japan Republic of Korea Spain	United States France Germany Netherlands Spain Switzerland
Country of Origin	United States	United States	European Union	Sweden	Sweden	United States	Taiwan	South Korea	Japan	Switzerland	Germany	United States

Certification Name	ENERGY STAR	Electronic Product Environmental Assessment Tool (EPEAT)	EU Ecolabel	TCO Certified	TCO Certified Edge	GreenASUS	LGE Eco-mark
Governing Organization	Natural Resources Canada	Green Electronics Council	European Commission	TCO Development	TCO Development	ASUS	LG Corp.
Year and Certification	2001 Third-Party Certified	2006 Third-Party Certified	1992 Third-Party Certified	1992 Third-Party Certified	2009 Third-Party Certified	2000 First-Party Certified Non-Profit	2004 First-Party Certified Non-Profit
Focus	Energy Efficiency	Energy Efficiency, Material Selection, Product Longevity, & End-of-Life Management	Lifecycle Environmental Impact	Usability and Lifecycle Environmental Impact	Leading Edge in Usability and Lifecycle Environmental Impact	Recyclability, Manufacturing, & Procurement	Environmental Impact
Objectives	Build Awareness, Promote Action, Promote Growth in Product Sales	Help Consumers Evaluate, Compare & Select Electronic Products Based on their Environmental Attributes	Help Consumers Distinguish Greener, More Environmentally Friendly Products and Services	Allows Consumers to Choose Technology Designed for both Usability and the Environment	Allows Consumers to Choose the Leading Technology Designed for both Usability and the Environment	Informs Consumers that the Product is One of the Greenest Offered by the ASUS Company	Informs Consumers that the Product is One of the Greenes Offered by the LG Company
Products	Major Appliances, Heating Equipment, Cooling and Ventilation Equipment, Lighting Electronics, Office Equipment, Windows, Doors and Skylights	Electronics	Textiles, Building Products, Cleaning Products, Cosmetics, Paper, Home Appliances, Consumer Electronics & Others	Electronics	Electronics	Electronics	Electronics
Criteria To Earn Certification	Product must be More Efficient than the Minimum Guidelines of that Country	Evaluates products on 51 environmental criteria in eight categories, including materials use, design for end of life, and packaging	Evaluates products by how Low the Environmental Impacts Throughout its Lifecycle are.	Evaluates products on Whether they are Designed for Both the Environment & High Performance	Add on to the base label, promotes excellent work in a certain area that is chosen to focus on	Evaluates Products on their Design, Manufacturing, and Procurement	Products must meet Some Domestic and International Environmental Regulations in order to Suit Global Requirements
Countries Where it is Located	North America Europe	North America Europe, Mexico Japan, China Taiwan, Singapore Brazil, Puerto Rico New Zealand, Australia United Kingdom	58 Countries Including Canada and the United States	77 Countries Including Canada and the United States	77 Countries Including Canada and the United States	International	International
Country of Origin	United States	United States	European Union	Sweden	Sweden	Taiwan	South Korea

Certification Name	Green IT	Blue Angel	Environmentally Friendly Product: Czech Republic	China Environmental Labelling	Singapore Green Label Scheme (SGLS)	China Energy Label
Governing Organization	Fujitsu	Federal Ministry for the Environment Nature Conservation and Nuclear Safety	Czech Environmental Information Agency (CENIA)	China Environmental United Certification Center	Singapore Environment Council	China Energy Label Administration Center
Year and Certification	2003 First-Party Certified Non-Profit	1978 Third-Party Certified	1994 Third-Party Certified	1993 Third-Party Certified	1992 Second-Party Certified	2005 Third-Party Certified
Focus	Energy Efficiency, Material Selection, & Manufacturing	Health, Climate, Water, & Resources	Environmental Impact	Material Impact, Disposal Scenario, Human Health, Water, Carbon and Toxic Emissions, Transportation, Design for Disassembly	Energy Usage, and Manufacturing Processes	Energy Usage, Carbon and Toxic Emissions, and Chinese Environmental Regulations
Objectives	Informs Consumers that the Product is One of the Greenest Offered by the Fujitsu Company	Help Consumers Distinguish Greener, More Environmentally Friendly Products Among Other Similar Products	Indicates that the Negative Environmental Impacts of the Labelled Product were Minimised	Indicates that the Labelled Product is a of Superior Quality and Environmental Performance	Indicates that the Labelled Product Meets Certain Eco-Standards Specified by the Scheme	Indicates that the Labelled Product Consumes Less Energy Compulsory Eco-Labe
Products	Electronics	Building Products, Cleaning Products, Printers, Food, Appliances, Machinery & Equipment, Paper, Textiles, Tourism, & Waste Management	Building Products, Cleaning Products, Electronics, Home Appliances, Textiles, Tourism	Building Products, Cleaning Products, Electronics, Home Appliances, Textiles, Transportation, Cosmetics, Paper	Building Products, Cleaning Products, Electronics, Home Appliances, Textiles, Tourism, Food, Transportation, Paper	Electronics
Criteria To Earn Certification	Products must be efficient in their Energy Usage and be Developed using More Environmentally Friendly Materials	Awarded to those Particularly Beneficial for the Environment & which also fulfill high Standards of Health & Safety	Awarded to Products that have Reduced their Negative Environmental Impacts	Awarded to Products that have Reduced their Negative Environmental and Human Health Impacts	Awarded to Products that have Reduced their Energy Usage and Developed in a Friendlier Process	Awarded to Product that have Reduced their Energy, Carbo and Toxic Chemical Emissions
Countries Where it is Located	International	United States Europe Australia Japan Republic of Korea Spain	United States Czech Republic Taiwan	China, New Zealand	Singapore, Thailand, Vietnam, Indonesia, China, Germany, Australia	China
Country of Origin	Japan	Germany	Czech Republic	China	Singapore	China

International Canada United States Variety of Attributes Single Attribute Most Green/ Third Party Certified Green/ Second Party Certified Less Green/ First Pa

Figure 3 illustrates the main differences between international, national Canadian, and national American companies. The figure described the differences between each company's efforts on implementing a take-back system to take back their old unwanted products, how many certified their product's with eco-labels, and how many have actually communicated on their websites that the product was certified by an eco-label. These differences showed which companies are more committed to developing environmentally friendly products, and how much the company's value sustainability as being part of their corporate identity. Eco-labels from Europe and Asia seem to place particular importance on improving the product's quality as one of their required criteria. In order to calculate the product's quality, it usually depends on the level of reliability that the product offers to the consumer, which is "quality demonstrated over time, and it is defined as the probability that a component, device, equipment, or system will be performing its intended functions for a specified period of time under a given set of conditions" (Landers et al. 1994, 318). The ergonomics of the electronic product is also equally important which is concerned with the physical capabilities, such as height, reach, and lifting capability (Landers et al. 1994, 442). The eco-labels in Asia tend to be located in only a few Asian countries or sometimes even only in one country instead of being found throughout the whole region such as the eco-labels located in Europe.

6
No Label
Companies

2
American
Companies

4
Canadian
Companies

11
International
Companies

All Companies
Green Labels

LG Corp.
Panasonic
Samsung
Sony
Toshiba

11/11
International
Companies

Acer
Apple
ASUS
Dell
HP
Lenovo

International Companies
Green Labels

Stealth.com Inc.

4/5
Canadia
Companies

Canadian Companies
Green Labels

6
No Take-Back
Companies

3
American
Companies

3
Canadian
Companies

11
International
Companies

All Companies
Take-Back System

LG Corp.
Panasonic
Samsung
Sony
Toshiba

11/11
International
Companies

Acer
Apple
ASUS
Dell
HP
Lenovo

International Companies
Take-Back System

Stealth.com Inc.
Eurocom

3/5
Canadia
Companies

Canadian Companies
Take-Back System

6
No
Communication

2
American
Companies

LG Corp.
Panasonic
Samsung
Sony
Toshiba

11/11
International
Companies

Acer
Apple
ASUS
Dell
HP
Lenovo

Stealth.com Inc.

4/5
Canadia
Companies

4.2 Interviews

The interviews conducted with the four professionals were used to support the information within the critical reviews of the eco-labels and life cycle assessment (LCA) tools. The interviews with Jeff Omelchuck and Thomas Redd discussed their views on eco-labels and what they believed caused an eco-label to be more popular than another. The interviews with Robert Cifarelli and José Vera discussed their personal opinions on the LCA tools and the importance of using these LCA tools during the development and design stage of the product. For example, Thomas Redd mentioned "Energy Star is very upfront and transparent about what that label is addressing energy consumption, so I think that's probably why it has resonated more with consumers than other labels." José Vera, on the other hand, mentioned "One of the issues I've had with the Solidworks Sustainability is that you can't input an exact location, so if you said this steel came from Shanghai, I can't...we're not allowed to do that you can only say it came from Asia. So that actually makes a huge difference because imagine mainland China versus coastal China, that's a huge trip right there." Thomas Redd shared his view on what is causing Energy Star to be the most popular eco-label within North America, and José Vera provided his insight into the factors that he considers a defect with some LCA tools.

4.3 Critical Reviews of the Eco-Labels and LCA Tools

Energy Star is the most popular eco-label for personal computers within Canada and the United States (Sustainability Consortium 2010). In Europe the Blue Angel label is the most widely known and in Asia it is the China Environmental Labelling eco-label that is used on most personal computers. There are a large number of eco-labels available for PCs, but this study would provide critical reviews for these three most well known eco-labels from each region in the world to provide a better understanding of the basic criteria and requirements for each eco-label.

Figure 4 Energy Star Label

The U.S. Environmental Protection Agency (EPA) developed a voluntary labelling program known as Energy Star in 1992. Energy Star: Canada was established in 2001 and it is verified by a government organization known as Natural Resources Canada. This label is specifically used on products in order to communicate that the product uses less energy than a specified amount and in turn reduces its impact on greenhouse gas emissions and that does not reduce the performance of the product. It has become an internationally known eco-label that is used in countries such as the United States, Australia, Canada, and within Europe. "The Energy Star label has become the most sought after stamp of approval for appliances and electronics" (Orloff n.d.). Thomas Redd, the Manager of the Consumer Science Working Group at the Sustainability Consortium, mentioned "Energy Star is very upfront and transparent about what that label is addressing energy consumption, so I think that's probably why it has resonated more with consumers than other labels." The label is used to certify a wide range of products in over 60 product categories, beginning only with computers and monitors; and then expanding its product categories to include office equipment, mobile phones, lighting, home electronics, major appliances, homes, commercial and industrial buildings, as well as residential heating and cooling equipment. The Energy Star label further expanded its product base when EPA decided to partner with the U.S. Department of Energy. The label has been proven to be a great success and is also credited with motivating businesses to improve their product's energy consumption levels. "Energy Star has successfully delivered energy and cost savings across the country, saving businesses, organizations, and consumers about $18 billion in 2010 alone" (History of Energy Star n.d.).

The criteria that need to be met in order for the company to have the product certified by the Energy Star label include calculating the financial saving potential, having a long battery life for the product, low energy consumption, an efficient power supply, maintain safety performance, calculate the unit shipment data, meet the user interface standard, and to offer an extended warranty. The focus of the

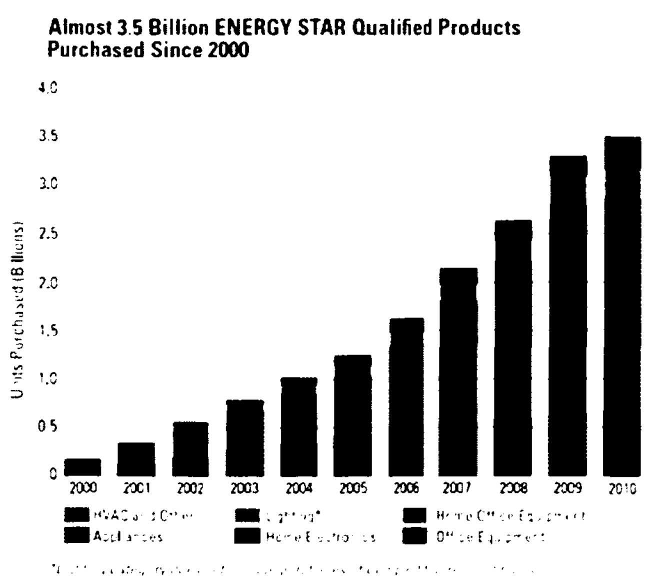

Figure 5 Amount of Energy Star Qualified Products Purchased Since 2000 (EPA, 2010)

criteria is to reduce the amount of energy consumed by the product.

Consumers are particularly attracted to the Energy Star label on products because the products with the label provide an opportunity for the consumers to save money on their monthly energy bill. It is one of the most popular eco-labels used for products and it can be located on a product's packaging, website description, and the label is also sometimes placed as a sticker on the product itself. It is estimated that "if all computers sold in the United States met Energy Star requirements, around 1.5 billion dollars each year would be saved through energy costs, and the reduction in greenhouse gasses would be equal to approximately the amount of emissions from 2 million vehicles" (Rus 2011). In the product's design for mobile electronics, Energy Star certified products are found to "place computers (CPU, hard drive, etc.) into a low-power "sleep mode" after a designated period of inactivity. Simply hitting a key on the keyboard or moving the mouse awakens the computer in a matter of seconds" (Computers for Consumers n.d.). Companies that submit their products to be considered for receiving an Energy Star label, would have a competitive advantage as well as a marketing advantage over other companies that are selling products seen to be less energy efficient. There are currently over "20,000 organizations that have partnered with EPA, achieving significant environmental and financial benefits (EPA 2010). There are different types of Energy Star certification requirements, such as with "version 4.0, you must use a power supply that has a minimum efficiency of 80 percent with a power load of 20%, 50% & 100% and have greater than 0.9 PFC. Version 5.0 increases the requirement by requiring an efficiency of 82%/85%/82% with a PFC greater than 0.9" (Intel Reseller Center n.d.).

The Shelton Group is an organization that is "an advertising agency focused exclusively on motivating mainstream consumers to make sustainable choices" (Suzanne Shelton 2011). Karen Barnes, the Vice President of Insight at the Shelton Group, has shared a few diagrams from a survey in one of the reports developed by the organization that is shown below. The survey was conducted with consumers from the United States.

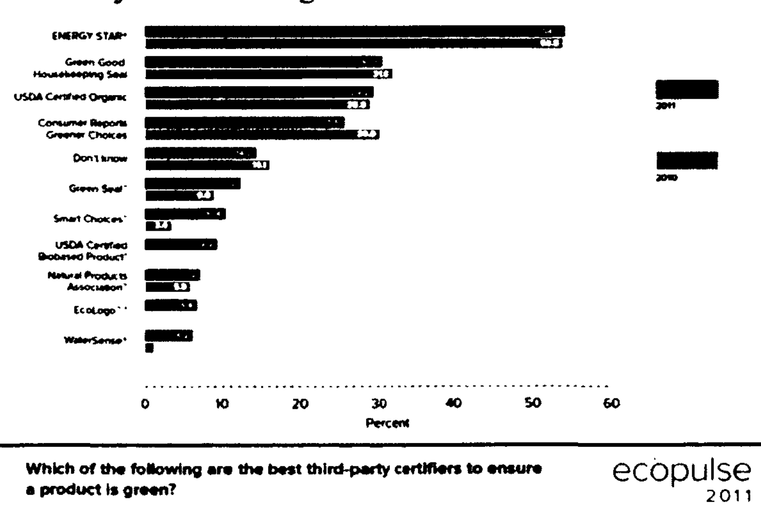

Figure 6 The Best Third-Party Certifiers to Ensure a Product is Green (Ecopulse 2010)

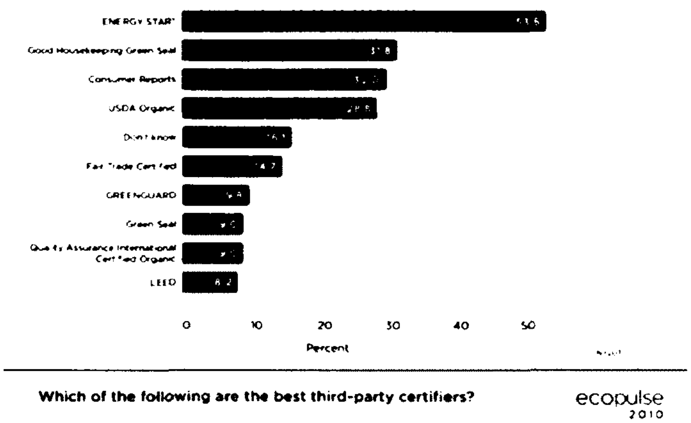

Figure 7 The Best Third-Party Certifiers (Ecopulse 2010)

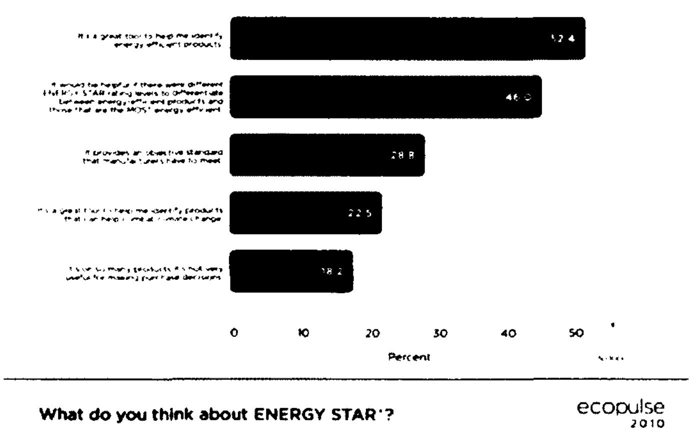

Figure 8 What do you think about Energy Star? (Ecopulse 2010)

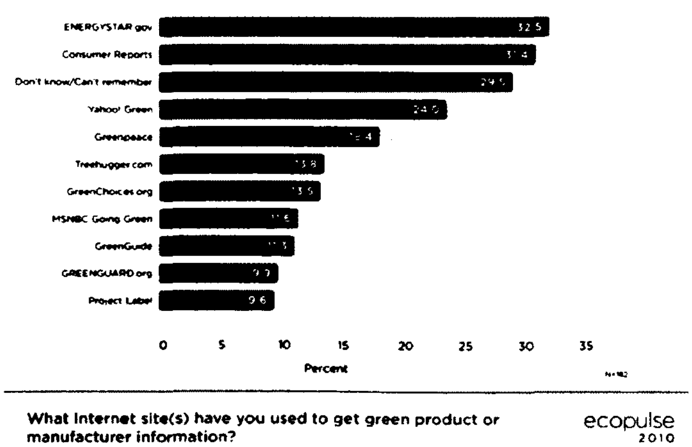

Figure 9 What Internet Site(s) have you used to get Green Product or Manufacturer Information? (Ecopulse 2010)

The diagrams showed that consumers trust the Energy Star label and their claims over other types of labels. Although the largest number of consumers trust the Energy Star label, they are still requesting for more information to be provided on the label by claiming that they would prefer different ratings for the same label in order to understand which products are considered the most energy efficient compared to other products. Information should be concise, meaningful, relevant and accurate. Natural Resources Canada claims that "the power of the Energy Star symbol is its simplicity. No special knowledge is needed to select an energy-efficient product – the Energy Star symbol on a product or its packaging or in its advertising or literature identifies the product as one of the most energy efficient on the market" (Energy Star in Canada 2011).

The certification requirements in order for a product to receive the Energy Star label are updated every few years. For example, as of April 2010 it has become mandatory for manufacturers to submit a lab report along with their product for assessing whether it will receive the label. Energy Star products must provide significant energy savings, the high performance expected by consumers, and savings on the consumer's energy bill must be greater than the extra amount spent to purchase the energy efficient product. It is requested by EPA for the Energy Star label to be placed in a clearly visible spot on the product in order for the consumers to easily differentiate products from one another. EPA will revise product's certification statuses when the basic standard requirements have been changed, when performance or quality are not up to par, when consumers do not notice changes in their annual energy bill, or when technological changes have been done to the product. In addition, "most products, but not all, that qualify in the U.S. automatically qualify in Canada" (Natural Resources Canada 2009).

Although the Energy Star label has received wide recognition and success, it has also been subject to many claims of being used on greenwashed products. The Government Accountability Office (GAO) has published a report that has exposed many faults in the Energy Star certification system that has caused issues with the actual reliability of the label and claimed that it is vulnerable to fraud and abuse. GAO found that products were not being tested properly enough to understand whether the product met the manufacturer's claims of the environmental friendliness for the product. This accusation towards the label's greenwashing has caused the government to tighten the requirements for the Energy Star certification process. In the United States "tax breaks are sometimes available for Energy Star products consumers buy as part of a broader government effort to encourage Americans to consume less fuel" (Wald and Kaufman 2010). One of the issues with the Energy Star label is that it only assesses the power consumption of the product and that the full life cycle of the product is not considered.

The Energy Star Most Efficient label has been developed in 2011 as an extension to the current Energy Star label. It was designed to be used for communicating which products are regarded the most environmentally friendly towards their energy consumption. However, the Energy Star Most Efficient label does not apply to personal computers.

Figure 10 Energy Star Most Efficient label

APPENDIX

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Figure 11 Blue Angel Label

The Blue Angel is an eco-label that was developed in Germany and can now be found on products around the world. There are currently "a total of about 11,500 products are Blue Angel eco-labelled," and although the eco-label is most popular with suppliers in Germany and around Europe; "22 percent of [the suppliers] are foreign" (The Blue Angel in Numbers 2011). The Blue Angel was first developed in 1978, making it "the first and oldest environment-related label for products and services in the world" and has 90 product categories that carry the Blue Angel eco-label (The Blue Angel n.d.). The product categories range between electronics to cleaning products and survey results have shown a high familiarity of the eco-label and that consumers aim to purchase products that are awarded the eco-label (The Blue Angel in Numbers 2011). It has had continued success over the years and each product category has its own set of required criteria in order for the product to carry the label. The criteria are defined by the German Federal Environment Agency and it is a voluntary third-party eco-label.

The motivation behind the development of the Blue Angel was to allow consumers to feel more comfortable about the products they were buying. The eco-label does not only analyse the effect of the product on the environment but also the effect of the product on people's health. It is supposed to be regarded as a trustworthy label that "is awarded to products and services which - from a holistic point of view - are of considerable benefit to the environment and, at the same time, meet high standards of serviceability and health and occupational protection" (What's Behind It n.d.). The main focus of the criteria for the eco-label with electronic products is to have the products use reasonably less amount of energy than the other products in its category. The remaining required criteria for receiving the Blue Angel on the electronic product include having recyclable packaging, having the product Energy Star and TCO Certified compliant, contain fewer harmful substances, conduct a life cycle assessment, meet ergonomic standards, and to have the product able of being disassembled by one person. The criteria require effort from designers, and manufacturers, and engineers to collaborate when developing the product.

The Blue Angel eco-label has four main protection goals, which are written on a blue strip under the label in order to be easily identified by companies and consumers. The four protection goals include protecting the climate, protecting resources, protecting health, and protecting water. The Blue Angel eco-label illustrating each of the four protection goals is in Figure 9.

The Blue Angel eco-label is considered a comprehensive environmental label that is different than other labels because it considers all aspects of the product. Since it is issued from the government, consumers have been shown to have a high amount of trust for the label. Companies must submit an application proving the product's compliance with the eco-label criteria, and then the environmental jury meet in

Figure 12 Four Protection Goals of the Blue Angel (What's Behind It n.d.)

order to assess whether the company may be allowed to advertise the product with the eco-label. The environmental jury is composed of "representatives from environmental and consumer associations, trade unions, industry, trade, crafts, local authorities, science, media, churches and federal states" (Who is Behind It n.d.). Once the application has been approved, there is an annual fee that the company must pay depending on the amount of annual sales that the company makes from the product that is advertised with the Blue Angel eco-label (Eurofins Product Testing 2011).

The Blue Angel eco-label has been since used by companies as a valued marketing tool that offers "the opportunity to show the environmental advantage of their products," and the Blue Angel continues to have growing success as it is "recognised more and more outside Germany" (Eurofins Product Testing 2011).

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Who is Behind It. n.d. The Blue Angel. http://www.blauer-engel.de/en/blauer_engel/who_is_behind_it/index.php (accessed December 2011).

China Environmental Labelling
Eco-Label
Critical Review

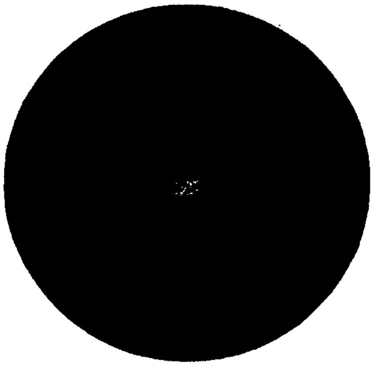


Figure 13 China Environmental Labelling Eco-Label

The eco-label known as China Environmental Labelling was developed in 1993 by the State Environmental Protection Administration (SEPA), and is awarded by the China Environmental United Certification Centre (CEC), and it is one of the most popular eco-labels developed in Asia. It is a voluntary third-party certified eco-label that is trusted by many consumers in Asia, because it has been stated that it "is the label with the strictest criteria" (Green Choice Beijing 2007). The eco-label was developed "in order to promote environmental protection and to enhance exports and trade" within China (Archived Events 2002). By 2006, the eco-label has had a large growth of popularity in the market since "assessments have been conducted for 800 enterprises, and 12,000 products have been awarded the environmental label" (China Environmental Labelling Program 2011). By 2011, the number of certified products by the eco-label grew to over 40,000 and the number continues to increase (TerraChoice 2011).

In order to confirm that the product meets the China Environmental Labelling required criteria the product is inspected at the site of the company and a product being sold would randomly be chosen for inspection. The products that receive the eco-label will also be inspected annually to confirm that they are still being developed to meet the eco-label criteria (China Environmental Labelling Program 2011), since the eco-label is allowed to be used on the product for a total of three years before it expires. There are a total of seventy-three product categories that can be certified by the China Environmental Labelling eco-label, such as computers, footwear, and household detergents. The goal of the China Environmental Labelling eco-label is to allow consumers to see a form of proof that the product is indeed better for the environment compared to other products in its category. The illustration on the eco-label "displays mountains, the sea and the sun in its centre, symbolising mankind's dependency on the environment, surrounded by ten circles, which stand for the public participation in environmental protection efforts" (Green Choice Beijing 2007).

The strict criteria that the China Environmental Labelling requires in order to certify an electronic product, such as a computer monitor and displays, range between calculating the metal concentrations within the battery, the entire life cycle assessment of the product, and making sure that the product has a recyclable structure and joining design in order for it to be easily disassembled and recycled by the mandatory take-back program of the company that developed the product. The criteria are not only focused on encouraging manufacturers to develop products that are better for the environment, but the eco-label also stresses on the safety performance and display exposure rate in order for the product to be better for the consumer who decides to purchase the product.

APPENDIX

Archived Events. 2002. Green Council. http://www.greencouncil.org/eng/event/archive_detail.asp?id=45 (accessed December 2011).

China Environmental Labelling Program. 2011. Green Council. http://www.greencouncil.org/eng/greenlabel/china.asp (accessed December 2011).

Green Choice Beijing. 2007. Environmental Consumption and Labelling. http://www.fon.org.cn/greenchoice/index_eng.php?var1=content/resources/decorating/decorating_5.htm (accessed December 2011).

TerraChoice. 2011. Global Ecolabelling Trends Abound in Taipei. http://terrachoice.com/2011/11/28/global-ecolabelling--trends-abound-in-taipei/ (accessed December 2011).

The three critical reviews of the most popular eco-labels from each region in the world are used as examples to explain that each eco-label is different than the other. Each eco-label has its own list of required criteria that the product needs to have met before being awarded with the eco-label. The critical reviews also clarify that each eco-label have its own specific objective based on what they are supposed to communicate to consumers at the point of purchase once used on products. This information is important to understand in order to understand the type of information that should be clarified to the designer once trying to choose an eco-label to certify the PC with the use of the toolkit developed in this study. Third party eco-labels are the most common type of eco-labels being developed to certify products, as shown in Figure 14, which illustrates a set of figures that categorize the eco-labels as being either first, second or third-party certified from each region. To continue with the example offered previously in the Literature Review about the national and international companies and the discussion about their differences; Table 7 illustrates examples of products from each company and the eco-labels used to certify them. It is clear from the table that most companies are using the eco-labels as a form of marketing and try to communicate their efforts on developing products that are friendlier to the environment. Some companies do not have any certifications for their products, while others would range between one to four different certification labels for one product.

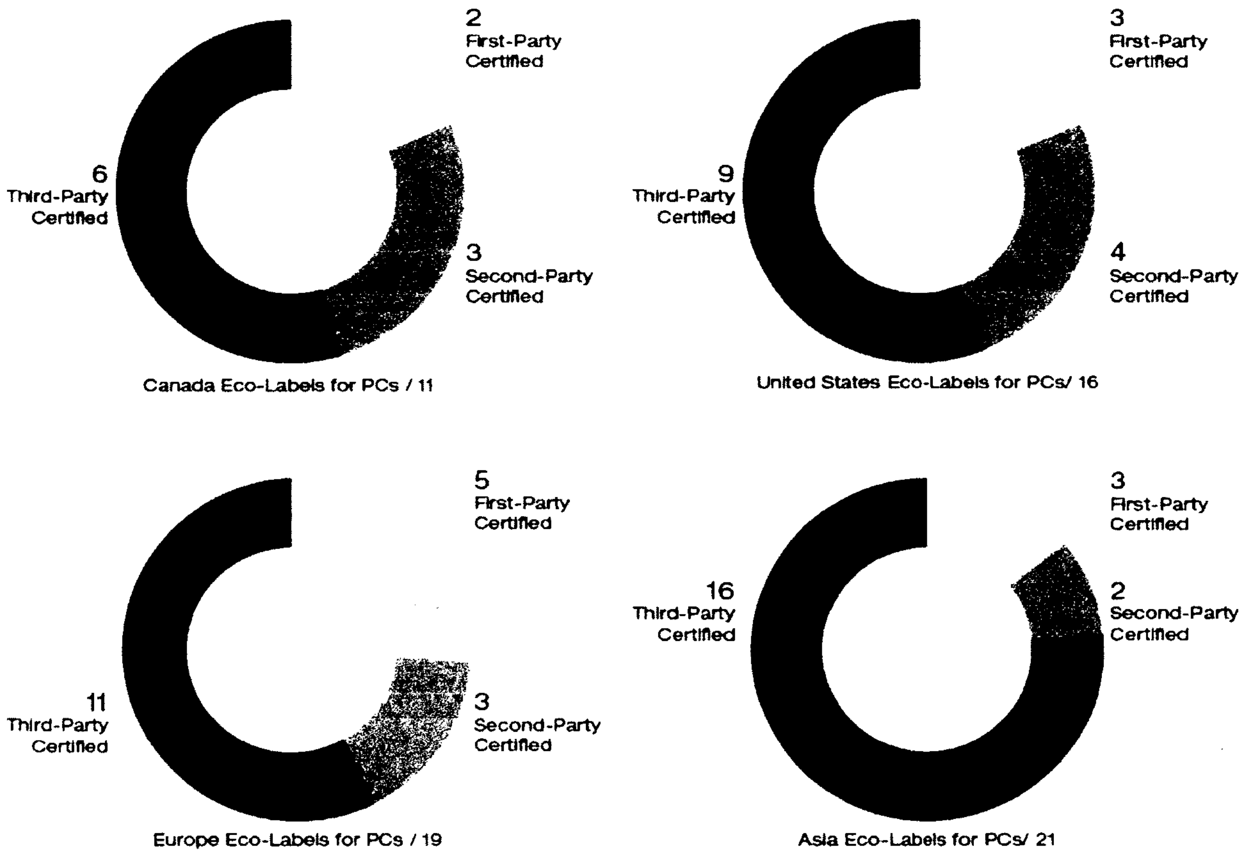
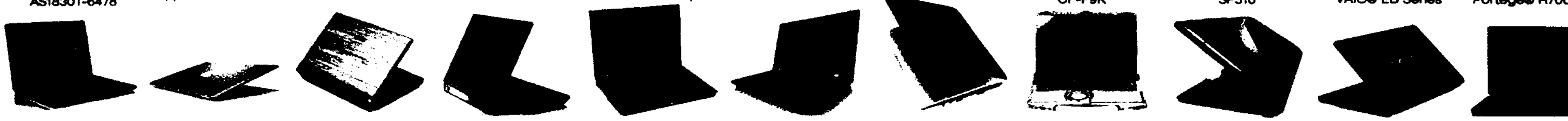


Figure 14 Types of Eco-Labels from each Region around the World

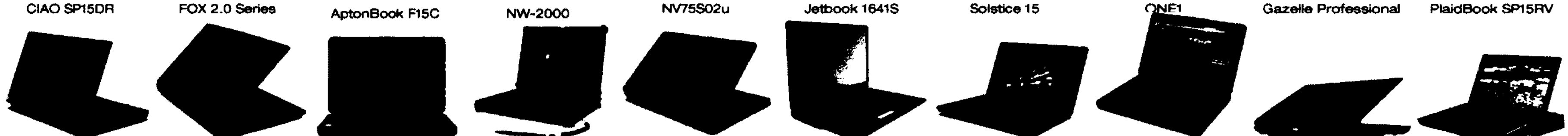
International



	Aspire TimelineX AS1830T-6478	Apple Macbook Air	ASUS U53Jc	Dell Latitude E6510	Elitebook 8440p	ThinkPad L420	LG X140	CF-F9K	SF510	VAIO® EB Series	Portégé® R70
Company Logo	acer		ASUS	DELL	hp	lenovo	LG	Panasonic	SAMSUNG	SONY	TOSHI
Certifications	ENERGY STAR 5.0	EPEAT Gold ENERGY STAR 5.0	EPEAT Gold ENERGY STAR 5.0	EPEAT Gold ENERGY STAR 5.0 RoHS Compliant	EPEAT Gold ENERGY STAR 5.0 C-UL-US Mark	EPEAT Gold ENERGY STAR 5.0	ENERGY STAR 5.0	EPEAT Gold ENERGY STAR 5.0 RoHS Compliant ISO 14001	EPEAT Gold ENERGY STAR 5.0	EPEAT Gold ENERGY STAR 5.0 RoHS Compliant	EPEAT Gol ENERGY S RoHS Com Toshiba Ec
Certification Located on Website Next to Product	Yes in Words and Label	Yes in Words	No	Yes in Words	Yes in Words and Labels	Yes in Words	No	Yes in Words and Labels	No	Yes in Words	Yes in Wor and Labels
Battery Life	Up to 8 Hours	Up to 7 Hours	Up to 10.5 Hours	Up to 6 Hours	Up to 6 Hours	Up to 6 Hours	Up to 9 Hours	Up to 7 Hours	Up to 7.5 Hours	Up to 3.5 Hours	Up to 8 Ho
Warranty	1 Year Limited Warranty	1 Year Limited Warranty	2 Year Standard Limited Warranty 1 Year on Batter	1 Year Limited Warranty	1 Year Limited Warranty	1 Year Limited Warranty	1 Year Limited Warranty	3 Year Limited Warranty	1 Year Limited Warranty	1 Year Limited Warranty	3 Year Star Limited Wa 1 Year on E
Price, Size and RAM	$599.99 11.6" 3GB RAM	$1,299 13" 4GB RAM	$1,050 15.6" 4GB RAM	$1,772.49 15.6" 4GB RAM	$1,699 14" 4GB RAM	$599 14" 4GB RAM	$490 10.1" 2GB RAM	$2,899 14" 2GB RAM	$798.97 15.6" 4GB RAM	$899.99 15.5" 4GB RAM	$1,299 13.3" 4GB RAM

National Canadian

National American



	CIAO SP15DR	FOX 2.0 Series	AptonBook F15C	NW-2000	NV75S02u	Jetbook 1641S	Solstice 15	ONE1	Gazelle Professional	PlaidBook SP15RV
Company Logo	CIARA	EUROCOM	MDG		Gateway.	JETTA		NCS	system76	DakTech
Certifications	C-UL Mark	N/A	EPEAT Gold ENERGY STAR 5.0	RoHS Compliant	ENERGY STAR 5.0	N/A	N/A	EPEAT Silver ENERGY STAR 5.0 C-UL-US Mark RoHS Compliant	N/A	N/A
Certification Located on Website Next to Product	Yes with Label	No	No	Yes with Label	Yes in Words and Label	Picture shows Label But No Words nor Proof	No	Yes in Words	No	No

4.3.1 Software Tools

The software tools that were analysed in this study include Eco Materials Advisor, Eco-Indicator 99, SimaPro LCA Software, Solidworks Sustainability, and GaBi Software. The majority of these tools perform a complete LCA for the product, as well as calculate the energy usage and the product's carbon footprint. Each one of these software tools have several features that distinguish them from one another in certain criteria that they additionally calculate such as toxicity, estimating the cost, or by assessing whether the product is up-to-date with government regulations. The SimaPro LCA Software, for example, "is the world's most widely used LCA software" (Schuppe and Ho 2002). SimaPro LCA Software is similar to Eco-Indicator 99 but it offers more advanced measurements with calculating carbon footprint and energy usage. There is also a SimaPro Multi-User version available which allows a group of users to use the program from different locations. Solidworks Sustainability, on the other hand, evaluates the full life cycle of the design, compares materials and their effects on the environment, and generates reports on how sustainable a design is. Generating reports is valuable since it is found that "reporting can be expensive," which is especially true for the national companies (Bennett and James 1999, 62).

4.3.2 Web-Based Tools

The web-based tool that was analysed in this study is Sustainable Minds. There are more web tools developed than software tools and the majority of them are used to guide materials selection. A few of these tools also only would calculate one aspect of the product, such as the calculation for safer chemicals. Product Ecology, for example, claims to aid in establishing the criteria for a product by EPEAT standards; however, the program only provides a checklist of the criteria which may be obtained on the EPEAT website. The CleanGredients tool only calculates for safer chemicals, but Sustainable Minds has a number of key features such as being able to analyse the product within any stage during its life cycle, it is compatible with CAD or PLM systems, compares materials, processes, and life cycle assessments, it methodology is considered to be proven and trusted, and it generates reports in graphs or tables. Sustainable Minds does not only include the ecological damage that may be caused from the product, but it also mentions the resource depletion and possible human health damage. The "best-selling tools worldwide include SimaPro and Sustainable Minds" and a critical review has been written about each including several other popular software tools, explaining their features and clarifying why they were chosen for this study (Clarke 2011). Table 8 shows a comparison among the features of several of the software and web-based tools. Below are the critical reviews of each of the LCA tools that were analysed in this study. The goal of these critical reviews was to understand what each LCA tool helps calculate and if each of the LCA tools provides certain calculations that make them unique compared to other LCA tools.

Figure 15 Autodesk Inventor Software

The Eco Materials Advisor is a tool that is located within the Autodesk Inventor Software for no added cost, and it was first introduced into the software in 2011. The tool was developed by Autodesk in partnership with Granta Design, and it enables users "to make more sustainable design decisions by exposing information on environmental impact, cost, and performance to guide materials selection" (Introducing Eco Materials Advisor 2011). The software is compatible with Auto-CAD, allows 3D prototypes to be developed and for motion simulation so that the user could test their products better to avoid problems once they are manufactured. The tool may be used by professionals to help make better environmental decisions during the early stages in the design process.

The Eco Materials Advisor mainly focuses on the materials used within the product, and uses "eco audit" technology to ensure that the suggested materials to use for the product are environmentally friendly. The program has a specific tab called Environments where the user browse a list of materials and assign materials to the product, generate PDF reports to illustrate the impacts of the final product, and it provides alternative analysis of how the impact of the product may change if a different material were used which can also be generated into a report illustrating the differences. The tool also allows the user to have their product undergo an eco impact analysis, which "estimates key environmental and cost indicators: CO2 footprint, embedded energy, water usage, estimated raw cost of materials, RoHS (Restriction on Hazardous Substances), food compliance, and end-of-life behaviour" (About Eco Materials Advisor 2011). This would offer designers and engineers the opportunity to make better product material and process decisions to meet some of the criteria required for eco-labels. Figure 15 shows an example of the Eco Materials Advisor dashboard within the Autodesk Inventor software.

The Eco Materials Advisor tool provided for free with the Autodesk Inventor software is known as the base version of the software, which has a materials database of only 50 materials. The base version also does not include the option of

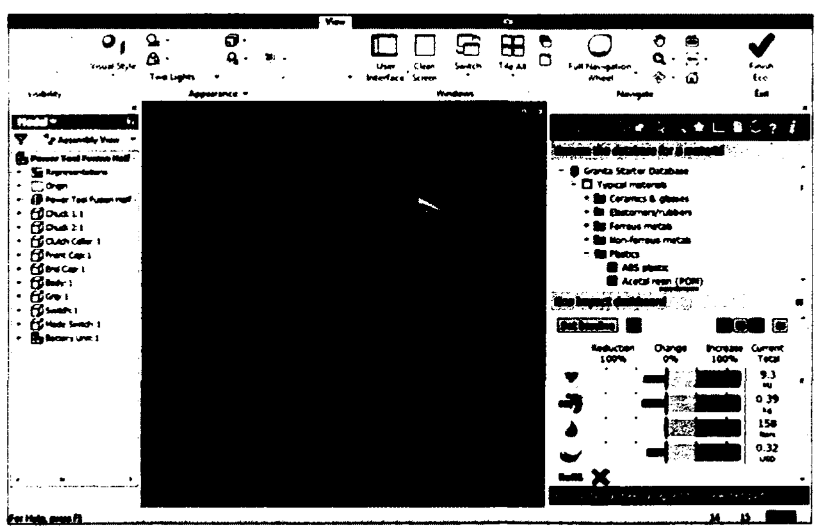


Figure 16 Eco Materials Advisor Dashboard (CleanBiz Staff 2011)

calculating the transportation option nor the use phase. The amount of material options that users may choose within the full version of the software is extensive, since it "draws information on over 3,000 different materials on Granta Design's database and tests which would be the most cost-effective and environmentally friendly substitute for the materials proposed in the initial design" (CleanBiz Staff 2011). The full version is available for users at an additional fee. If the user is not certain about the particular grade of the material that they are planning to use for the product, they may select a material from the "Typical Materials" database, which shows the more commonly used materials for products. Materials and processes may be changed at any time during the design process.

Another benefit of the Eco Materials Advisor compared to other sustainability tools in the market, is that it also calculates the technical performance of the product which would help in assessing the product's durability (Detailed Workflow Guide 2011), and it calculates the food-contact compatibility in order to assess whether the product is safe around food. The dashboard also would provide the option of viewing which part of the product is having the greatest impact on the key environmental and cost areas that were previously described. If the material has negative effects on the environment, the user may search for a more environmentally friendly material without sacrificing technical performance by specifying mechanical constraints. The designer or engineer do not "need to develop expertise in the area" of sustainable design for using this tool (About Eco Materials Advisor 2011). Autodesk does offer options for the user to become more familiar with the LCA tool by either viewing YouTube videos on how to use it or by attending free web seminars.

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About Eco Materials Advisor. 2011. Granta Material Intelligence. http://inventor.grantadesign.com/en/about.asp (accessed September 2011).

CleanBiz Staff. 2011. Autodesk Dives Deeper into Sustainable Design. http://www.cleanbiz.asia/story/autodesk-dives-deeper--sustainable-design (accessed January 2012).

Detailed Workflow Guide. 2011. Sustainability Workshop. http://sustainabilityworkshop.autodesk.com/resource/eco-materials-adviser-detailed--workflow-guide (accessed January 2012).

Introducing Eco Materials Advisor. 2011. Granta. http://inventor.grantadesign.com/en/ (accessed September 2011).

Figure 17 PRé Consultants Logo

"Eco-Indicator 99 is a life cycle impact assessment tool developed in 1999 by PRé Consultants, located in the Netherlands, and it is ISO 14042 compliant. Eco-Indicator 99 helps designers to make an environmental assessment of a product by calculating eco-indicator scores for materials and processes used" (Eco Indicator n.d.). The eco-indicator is basically a single calculation that would signify the level of harm that the product would have on the environment. It is life cycle assessment (LCA) impact software and "is primarily a tool for the designer. It allows the designer to make their own LCA with the help of 100 pre-defined LCAs for commonly used materials and processes" (Software Tools n.d.). The scores are known as eco-points, they are developed for each stage in the life cycle of the product, and the tool also provides an overall score for a combination of all the steps life cycle of the product. The results of the scores can then be translated into a set of graphs. These eco-points determine whether the product is good or negative for the environment, such as when the eco-points are high then the product has negative impacts on the environment and when the eco-points are low then the product would have lower impacts on the environment. The tool is programmed to understand which resources are decreasing in availability and causes those resources that may be used in the product's life cycle to result in higher eco-points.

The first version of the software was developed in 1995 and was known as Eco-Indicator 95. The two versions of the software are very similar; however, Eco-Indicator 99 is said to be more complex with the fact that it contains more environmental aspects for the materials and processes. The environmental aspects are eco-points for a set of defined materials and processes that are contained within the software's database that the user may use as a reference. Eco-Indicator 99 has been enhanced and developed by collaborating with LCA experts in order to significantly improve the software's calculation methodology (Ministry of Housing, Spatial Planning and the Environment 2000). It is also "one of the most widely used impact assessment methods in LCA" (Contribution to Impact Assessment Research n.d.). This tool is specifically used for product design and it claims to be valuable to the designer for the purpose of allowing the designer to "consider which elements and stages of the products life-cycle cause most impact and can be focused on during redesign activities" (Eco Indicator n.d.).

The Eco-Indicator 99 software basically provides scores and evaluations of "materials, production processes, transport processes, energy generation processes, and disposal scenarios" (Ministry of Housing, Spatial Planning and the Environment 2000). In order to calculate the disposal scenarios, the software begins by dividing the materials between those that can be recycled and those that would be sent to the landfill in order to understand an estimate of its effects once it has reached the end of its life. The user can disassemble the product under analysis within the software in order to analyse each of the components used and to find the weight of each material, which is expressed in kg. An eco-point would be provided for each component separately and the software would also calculate the overall eco-point for the LCA of the product. The software calculates the impacts that the product would have in three main categories, which are human health, ecosystem quality, and resources (Impact Assessment n.d.). For calculating the effects on human health "damage models were developed for respiratory and carcinogenic effects, the effects of climate change, ozone layer depletion and ionizing radiation" (Impact Assessment n.d.). In addition, "damage to ecosystem quality is expressed as the percentage of species disappeared in a certain area, due to the environmental load (Potentially Disappeared fraction or PDF)" (Impact Assessment n.d.). The software is capable of calculating the amount of resources, minerals and fossil fuels, which are available in a certain area and use it towards understanding the overall impact the product would have towards those resources being used.

Once the user begins with using the product they must specify whether they are analysing only one product design or comparing between a set of different designs for the product. If the user is only calculating the LCA of one product design without making comparisons, then the software would provide an estimated calculation of its overall impacts. The decision to compare several product designs would require the input of more product details to provide a more accurate analysis towards understanding which product design would have the smallest overall impact. Many assumptions need to take place when calculating the LCA of the product, because it must be assumed that the consumer would disassemble the product and dispose of it properly, and that the energy consumption of the product would be equal to the amount that was expected. The user can also input assumptions for the data that they are missing in order to have an estimated end result; however, this only raises the level of uncertainty and illustrates that the software would not provide very accurate calculations. Figure 17 shows an example of a fully completed form in Eco-Indicator 99 of the weight and indicators of a coffee machine. Figure 18 illustrates the process tree that can be generated within the software in order to allow the user to understand the largest impacts throughout the product's life cycle. "The size of the process blocks is proportional to the relative importance of the process" (Ministry of Housing, Spatial Planning and the Environment 2000, 21).

Product or component
coffee machine

Project
example

Date
14-4-2000

Author
PRé

Notes and conclusions
Analysis of a coffee machine, assumption: 5 years' use, 2 x per day, half capacity, keep hot for 30 minutes

Production (Materials, treatments, transport and extra energy)

material or process	amount	indicator	result
polystyrene	1 kg	360	360
injection moulding PS	1 kg	21	21
aluminium	0.1 kg	780	78
extrusion Al	0.1 kg	72	7
steel	0.3 kg	86	26
glass	0.4 kg	58	23
gas-fired heat (forming)	4 MJ	5.3	21
Total [mPt]			536

Use (Transport, energy and possible auxiliary materials)

process	amount	indicator	result
electricity low voltage	375 kWh	37	13 875
paper	7.3 kg	96	701
Total [mPt]			14 576

Disposal (Disposal processes for each material type)

material and type of processing	amount	indicator	result
municipal waste, PS	1 kg	2	2
municipal waste, ferrous	0.4 kg	5.9	2.4
household waste, glass	0.4 kg	-6.9	-2.8
municipal waste, paper	7.3 kg	0.71	5.2
Total [mPt]			2
Total [mPt] (all phases)			15 114

Figure 18 A fully completed form in Eco-Indicator 99 (Ministry of Housing, Spatial Planning and the Environment 2000, 20)

Figure 19 The coffee machine process tree (Ministry of Housing, Spatial Planning and the Environment 2000, 21)

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Eco Indicator. n.d. Tools. http://ecodesign.lboro.ac.uk/index.php?section=73 (accessed September 2011).

Impact Assessment. n.d. Product Ecology Consultants. http://www.pre-sustainability.com/content/eco-indicator-99 (accessed January 2012).

Ministry of Housing, Spatial Planning and the Environment. 2000. *Eco-Indicator 99 Manual for Designers: A Damage Oriented Method for Life Cycle Impact Assessment.* Netherlands: Ministry of Housing, Spatial Planning and the Environment.

Software Tools. n.d. Eco Design. http://www.ecodesign.at/methodik/software/index.en.html (accessed January 2012).

Figure 20 GaBi Software Logo

GaBi Software was developed by PE International in 1992 and it is available in four languages, which are English, German, Japanese, and Danish. PE International has over 20 years of experience of conducting "almost 100 LCA and Ecodesign assessments in the field of electronics for products like cell phones, computers, servers, semiconductors, etc" (Electronics n.d.). The price of the software ranges between $780 for the educational version, and $11,712 for the professional version. "GaBi is the most used product sustainability solution by LCA practitioners in business. Over 10,000 users including over 35% of Fortune 500 companies, leading industry associations and SMEs rely on GaBi Software" (Benefits n.d.). GaBi Software provides several training options depending on the part of the software that the user wishes to enhance their knowledge on. The company provides training sessions for beginners and advanced users for a fee. The training typically takes two days and would take place at one of the PE International offices or there is also the option of having one of the consultants come to the user's company to conduct the training there. Some of the companies that are current users of the GaBi Software include Dell, HP, Sony, and Toshiba.

In addition to the life cycle assessment, GaBi Software is designed to calculate a number of environmental effects of the product, such as the carbon footprint, GHG emissions, waste, water usage, and energy consumption. It allows the user to make comparisons between different alternatives and this would cause the user to reduce the product's overall environmental impact. The software is also useful for conducting a cost analysis by "designing and optimizing products and processes for cost reduction" (GaBi 5 n.d.). The aspect that makes GaBi Software unique is that it also considers the social responsibilities and effects during the manufacturing process. This means that the software considers the environmental, as well as the social effects the product may have. The final calculated results can be presented in a report directly generated from the software.

GaBi Software does not provide the option for the user to model the product within the same software; however, the software allows the user to develop a diagram that would model the production process and environmental impacts. It has an "intuitive user interface, drag-and-drop feature, hierarchical database manager and advanced search function," which allows the user to have flexibility when modelling by inputting their data or data from the database (Functionalities n.d.). It provides the user with the option to either visualise the processes by Sankey diagrams, "allowing a quick overview of mass, energy or even cost flows shown as proportional to quantity," or the user may decide to use process images in order to simplify the visual presentation of the diagram. An example of the Sankey diagram and the diagram simplified with process images are shown in Figure 20 and Figure 21.

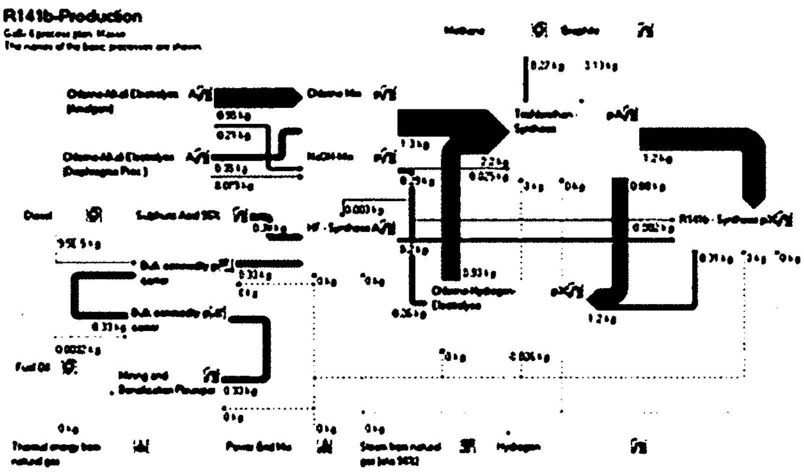

Figure 21 Sankey Diagram (Visualization, n.d.)

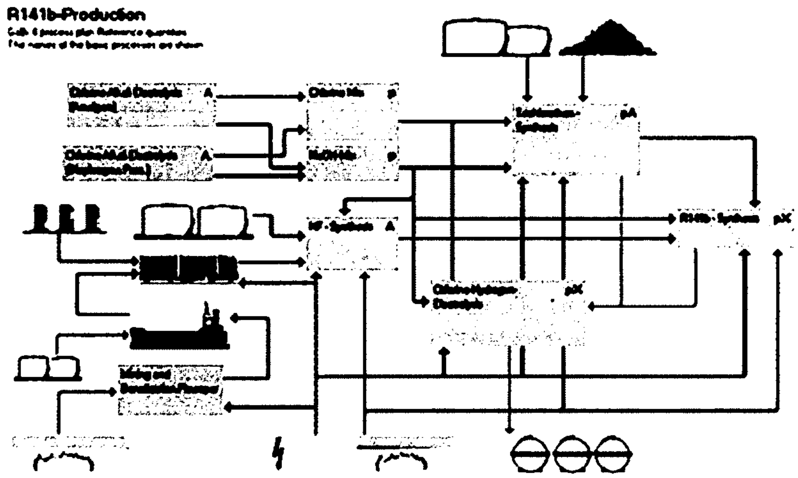

Figure 22 Diagram with Process Images (Visualization, n.d.)

The GaBi Software includes GaBi 5, GaBi DfX, GaBi Publisher, and GaBi Reader. GaBi 5 is the latest version of the GaBi Software for calculating the environmental, economic, and social impacts of products. The software also includes all major impact assessment methodologies within its database, such as "TRACI 2.0, CML 1996, 2001, and 2007, Ecoindicator 95 and 99, Ecological Scarcity Method (UBP), EDIP, USEtox and ReCiPe" (Impact Methodologies n.d.). These impact methodologies would allow the software to additionally calculate several environmental impacts, such as the global warming potential, human toxicity, radioactive radiation, acidification, and ozone layer depletion. Figure 22 is an example of how the software illustrates the impact methodologies to the user. The user may decide to have all the data presented on one window or separated by a series of tabs. The drag-and-drop feature within the software is to facilitate the modelling process by using the GaBi Plan editor. "GaBi's grouping feature allows [the user] to quickly and easily categorise the visual display of the model and the results of the study according to different criteria" (Modeling n.d.).

GaBi DfX is focused on allowing the user to consider the different regulations that exist for the product they are developing, these regulations also apply to electronic products, and the software also is focused on assisting with Design for Environment. It is an LCA software that could analyse very complex products, which "includes a standard interface to import LCA-relevant data directly from Bill of Materials (BOM)" (GaBi DfX n.d.). GaBi DfX includes the option of Design for Environment (DfE), where the user can calculate alternatives, classify the material composition, identify optimisation potentials, conduct a life cycle analysis, and model the product structure (Design for Environment- DfE n.d.). It simplifies the process for designers to understand the order of disassembly and joining technologies used for the product by allowing them

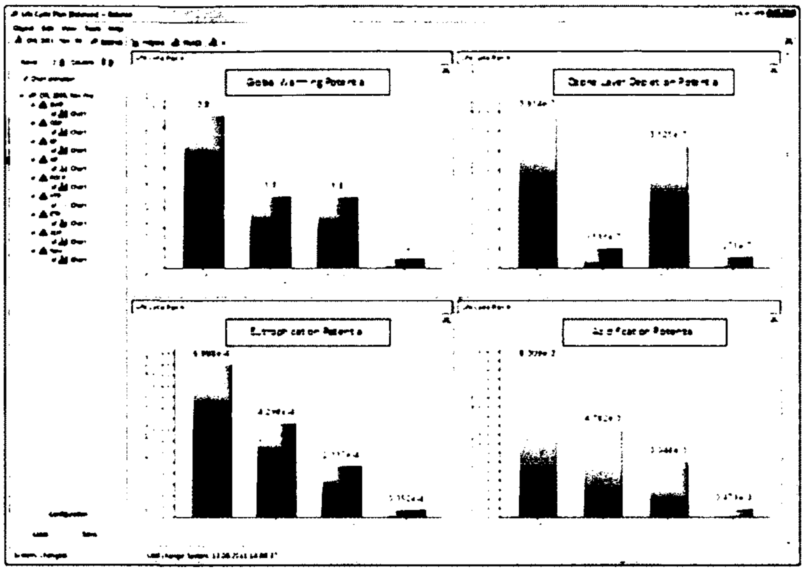

Figure 23 Illustration of impact methodologies (Results, Interpretation and Reporting n.d.)

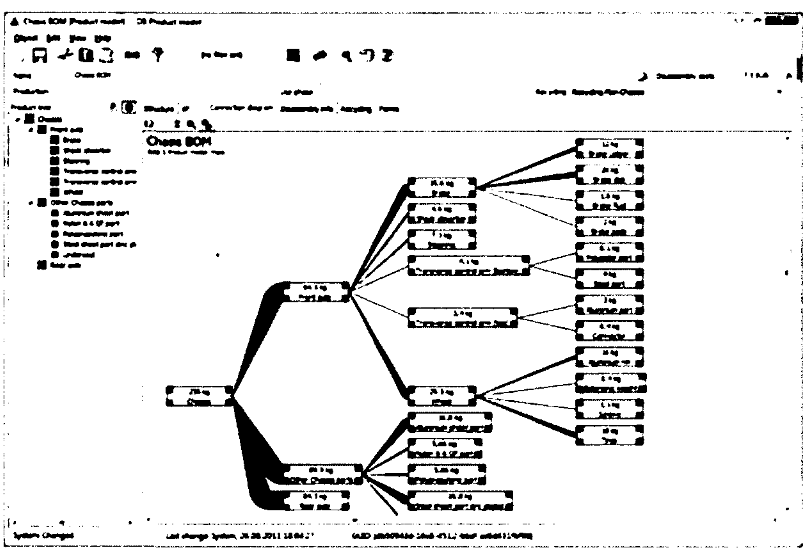

Figure 24 Connection Diagram in GaBi DfX (Connection Diagram n.d.)

to develop a connection diagram. Figure 23 shows an example of the connection diagram that can be developed within GaBi DfX.

The GaBi Publisher is an add-on to the GaBi Software that allows the user to develop interactive reports from their calculated results that may be exported into files that can be sent to others within the company that do not use the GaBi Software. The GaBi Reader was developed for professionals who are not familiar with conducting an LCA. The GaBi Reader accesses the interactive reports and allows the user to improve their designs by being able to visualize the environmental impacts of the product. The GaBi Reader accessed by either using the web or directly on the user's desktop. The web version provides the users in the company the opportunity to communicate and have a chance to contribute on improving the products environmental impact.

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Figure 25 SimaPro LCA Software Logo

SimaPro LCA Software was developed in 1990 by PRé Consultants and it has "over a thousand users in 80 countries, SimaPro continues to be the most successful LCA software worldwide" (SimaPro LCA Software 2011). It allows the user to calculate the full life cycle of the product and it follows the guidelines set by ISO 14040. The software has two main different versions that include the professional versions or the educational versions. The professional versions offer three different options, which are SimaPro Compact, Analyst, and Developer. SimaPro Compact offers faster and less detailed results than SimaPro Analyst, and SimaPro Developer offers extra features such as linking to other software. The educational versions also offer three different options, which are the classroom version, faculty or campus license, and advanced PhD version. The educational versions can only be used "by academic institutes for teaching purposes and cannot be used for commercial activities including paid research" (SimaPro LCA Versions 2011). It can be found in several different languages that include Italian, German, Japanese, Spanish, and Dutch. SimaPro LCA Software may be the most popular LCA software used, but it does not calculate as many environmental aspects of the product compared to other software tools.

It "is famous for its flexibility in handling different impact assessment methods" (European Commission 2010). It has a total of 17 impact assessment methods, and it could also be used by product designers to calculate the carbon footprint and environmental impact of the product, as well to develop a report documenting all the environmental specifications of the final product. The software also provides calculations for the product's energy usage, recyclability, and disposal scenario. The results can also be displayed to the user in either a graph or a table and "allows [the user] to calculate uncertainty in [the] inventory results using a Monte Carlo analysis. A Monte Carlo analysis gives [the user] an indication of how reliable, complete and representative [their] results are" (The Features of SimaPro n.d.). It can be linked to other programs such as "CAD/ CAM systems, to give a product designer or architect feedback on design choices, Enterprise Resource Planning (ERP) systems, to show a regular update of the impact of material, energy and transport flows in the company, and Product Lifecycle Management (PLM) systems, to give insight in the environmental issues in PLM" (SimaPro Connectors n.d.). The software also contains a database which allows the user to easily compare between "thousands of processes, plus the most important impact assessment methods" (SimaPro LCA Versions 2011). There is also a SimaPro Multi-User version available which allows a group of users to use the program from different locations. There is an option in the SimaPro LCA Software to calculate the network to understand the largest impacts that each part of the development process is having on the environment, which is illustrated in Figure 25.

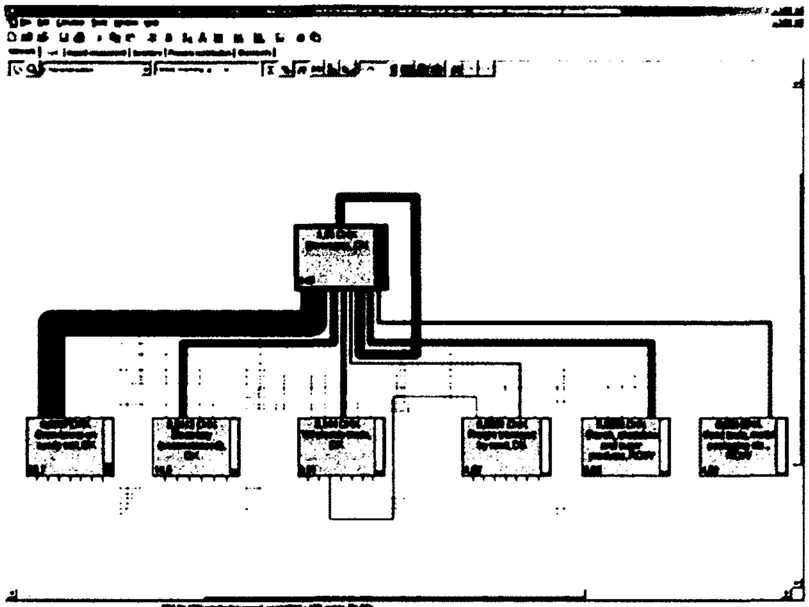

Figure 26 Calculate Network Option in SimaPro LCA Software (Weidema 2010)

Figure 25 represents that "the environmentally most important inputs to a process can be found by following the thickest streams of the Figure" (Weidema 2010).

The SimaPro LCA Software attempts to simplify the process of calculating the life cycle analysis of the product by allowing all of the calculations and information to be presented on one window in the software. The software also allows the user to create a process tree to identify any 'hot spots' and find any particular areas in the product or process that are more harmful to the environment (The Features of SimaPro n.d.). The software was designed to be used by various disciplines that concern themselves with calculating the life cycle analysis of the product including designers, manufacturers, engineers, and project managers.

APPENDIX

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SolidWorks Sustainability
LCA Tool
Critical Review

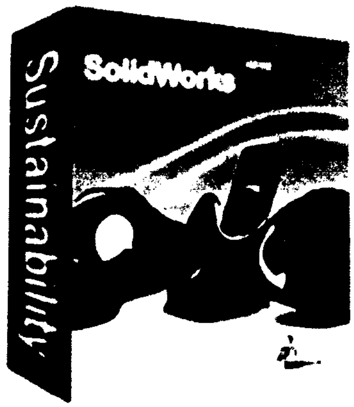

Figure 27 SolidWorks Sustainability Software

SolidWorks Sustainability software was developed by Dassault Systèmes Solid-Works Corp in 2010 and is available separately from the SolidWorks software for purchase. "SolidWorks is the leading 3D computer aided design (CAD) technology, providing intuitive, high-performance software helping users design better products" (PE International n.d.). The software is designed to be user friendly and easy to understand for calculating the life cycle assessment (LCA) of products, and it has also won the Best New Green Product Innovation honour at the global GREEN AWARDS™ 2010 in London. It is designed for the engineers and product designers who already use the SolidWorks software in order to help them make more environmentally sound decisions when developing their products. SolidWorks Sustainability is considered to be easy to use since it is integrated in the product modelling software that most professionals are already familiar with using during the design and development process. This software is available in a total of fourteen languages and is used around the world. In order for Dassault Systèmes SolidWorks Corp to successfully develop an LCA software, they collaborated with PE International to use the database found in GaBi software within their own program, which is regularly updated with new information on impact data for materials and processes.

The software company provides several free training options to allow the user to become more familiar with the new SolidWorks Sustainability features and benefits. Documents, demonstrations, and tutorials are provided for users. In an interview with José Vera, the standards and guidelines development coordinator at Professional Engineers Ontario (PEO) and a previous SolidWorks Sustainability design instructor at Humber College, when asked about the types of improvements he may suggest about the software he mentioned "one of the issues I've had with the Solidworks Sustainability is that you can't input an exact location, so if you said this steel came from Shanghai, I can't...we're not allowed to do that you can only say it came from Asia. So that actually makes a huge difference because imagine mainland China versus coastal China, that's a huge trip right there." This shows that SolidWorks Sustainability cannot be regarded as a completely accurate software by its calculations; however, it is suggested by the company to consider all the results being "within +/- 20% and should be used as an estimate" (Product FAQs 2012).

SolidWorks Sustainability Xpress is a plug-in released in 2009 that designers using the SolidWorks software may install in order to be able to assess the environmental impacts of their product designs. The plug-in is available for download at no additional cost for Solid-Works 2009 users, and is already provided within the SolidWorks 2010 software and the other software versions that follow. The difference between Solid-Works Sustainability and SolidWorks Sustainability Xpress is that "SolidWorks Sustainability provides a complete dashboard of LCA information so you can determine the environmental impact of assemblies. SolidWorks SustainabilityXpress, which comes with SolidWorks 2010, allows you to see detailed LCA information on individual parts" (SolidWorks Sustainability 2012). It evaluates the full life cycle of the design, compares materials and their effects on the environment, and generates customizable reports to communicate how environmentally friendly the product was calculated to be. Basically, SolidWorks Sustainability includes the same features as SolidWorks Sustainability Xpress but additionally calculates the "LCA of assemblies, support for configurations, expanded reporting capabilities for assemblies, user inputs for energy consumption and transportation methods, support for the new Assembly Visualization functionality" (Features 2012). The SolidWorks Sustainability software also generates a Bill of Materials (BOM) once the product is complete with an explanation of the best and worst components that have been used.

The software illustrates the carbon footprint, total energy consumed, effect on air, and effect on water used in a series of individual diagrams that can be exported for presentation in PDF reports. These individual diagrams are presented in the Environmental Impact Dashboard located at the side of the software screen as the user works on the product design (Features 2012). The life cycle stages that the software considers is the "raw materials extraction, material processing, part manufacturing, assembly, product use, and end of life" (SolidWorks Corp. 2010). This would aid the designer or engineer to make more environmentally friendly product design decisions. The software also helps the designers or engineers choose better materials for the environment that are similar to their initial selection by providing options for comparison. An example of the Environmental Impact Dashboard and the find similar materials tool is in Figure 27. SolidWorks Sustainability Xpress does not provide an assessment of the custom materials, but to only the materials that are already offered to the user in the software database.

APPENDIX

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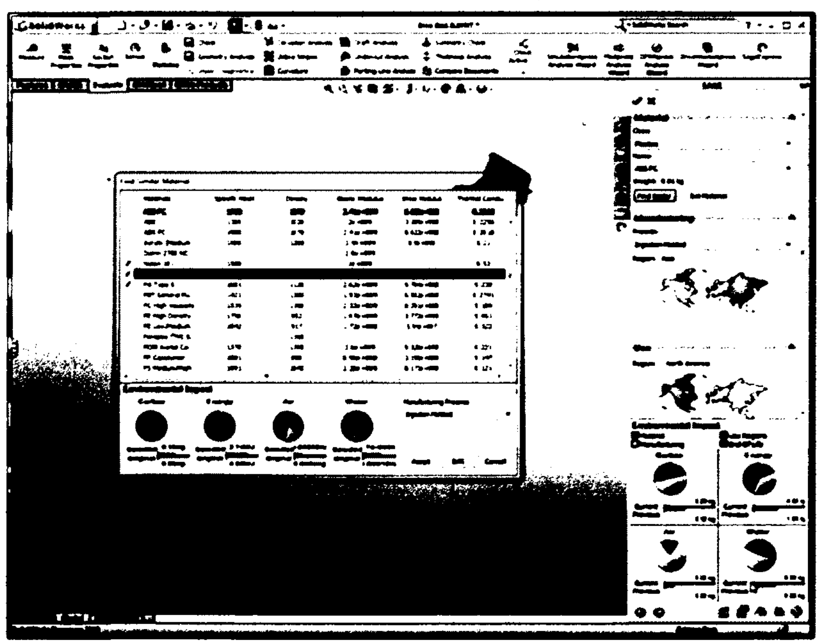

Figure 28 Environmental Impact Dashboard and Find Similar Material (Media Gallery 2012)

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Figure 29 Sustainable Minds Logo

Sustainable Minds was launched in 2009 by a Boston based software company and it is web-based tool that calculates the full life cycle of the product as well as its human health impacts. It allows the users to "credibly estimate, evaluate, compare and track the life cycle environmental and human health performance of products – in the earliest stages of design" (Product 2011). Sustainable Minds may be used by designers, engineers, manufacturers, consultancies, educators, and students. The tool helps finalise the decisions made during the product planning stage that would be too expensive to change once the detailed concept is set. "Operationalizing greener product design starts with bringing life cycle thinking and a whole product systems approach to the beginning of the design process" (When & How to Use 2011). It is based on the guidelines of the ISO 14040 life cycle framework for product assessments, and is ISO 14044 compliant. It allows the user to compare among materials and processes in order to understand the most environmentally friendly options.

Sustainable Minds has a number of key features such as being able to analyse the product within any stage during its life cycle, it is compatible with CAD or PLM systems, compares materials, processes, and life cycle assessments, and it generates reports in graphs or tables. The tool allows the user to choose from "240 materials and process, covering the bulk of currently available design choices for North American products" (Puma 2009). The tool does not only include the ecological damage that may be caused from the product, but it also calculates the resource depletion and possible human health damage. Since there is no product considered entirely environmentally friendly, the tool would allow the user to develop different concepts of the product by choosing different manufacturing processes and materials in order for the user to compare the environmental and health effects from the concept choices to understand which choice would have the largest impacts. Having the user understand the significant differences between several material and process choices would have a large impact on the types of choices made for the design, manufacture, and engineering of the product. Figure 29 shows how the program conducts the product comparison. Another benefit of Sustainable Minds is that it is a "SaaS software," which means that the data is continuously updated about new and current processes and material effects (Eco-Concept + LCA Software 2011). The online tool may be accessed for a fee that would depend on whether the user is purchasing the web-based tool for a single user or for a group, which is between $1400 for one person to $20,000 for twenty-five people. It is considered to be a more affordable LCA tool compared to its other software competitors.

The user begins the process by developing a Bill of Materials (BOM) for their product on the web-based software and specifying their goal. The user would use the BOM as the basis for making comparisons with other possible choices that may help to reduce the overall environmental and human health impact of the product. The user can access “Impact Factors of more than 600 materials, processes, use phase consumables, end of life processes, and transportation modes” (Eco-Concept + LCA Software 2011). The company ensures the privacy of the customers that use the web-based software by providing them with their “own server with branded URL – company.sustainableminds.com” (Services 2011).

The fact that Sustainable Minds calculates the human health impacts makes it a unique tool from the other LCA tools that are currently available. It specifically looks at the “photochemical smog, human respiratory, human toxicity, and human carcinogens” when calculating the impact on human health (Methodology 2011). For the ecological damage it considers “global warming/carbon emissions, acid rain, eco-toxicity, ozone depletion, and water eutrophication” and it assesses the depleting resources (Methodology 2011). It also does not require any previous training nor does the user need to be an expert in knowing how to calculate the life cycle assessment (LCA) for a product. Sustainable Minds can be used in a number of locations around the world, which are within North and South America, Australia, and Asia. It is also specially “optimized for electro-mechanical products” such as calculating the LCA for consumer electronics (Product 2011). It offers members chances to view webinars about how to use the software to become more familiar with the features, which also provides the opportunity for professionals to connect with one another and discuss their ideas.

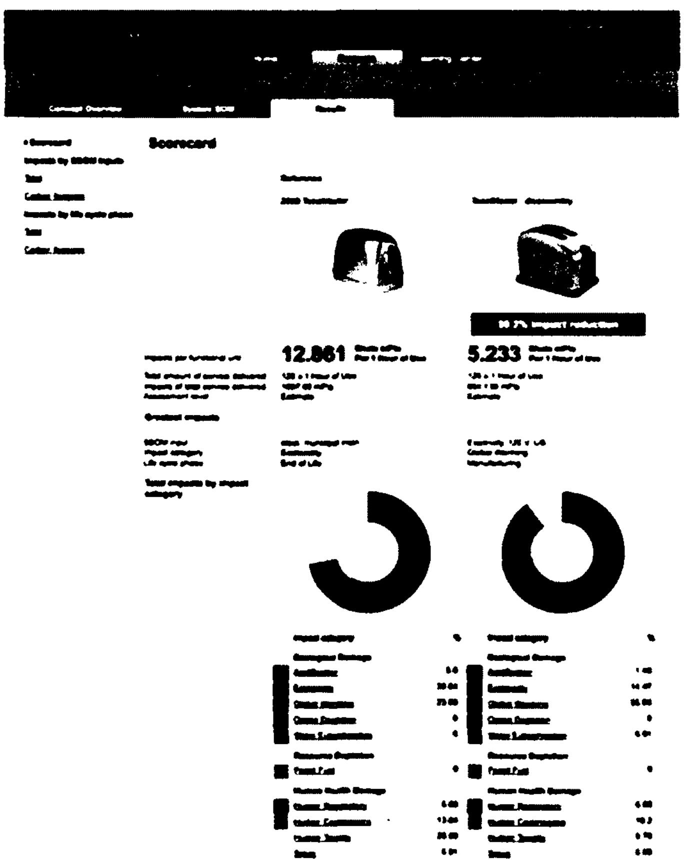

Figure 30 Product Comparison in Sustainable Minds Program (Eco-Concept + LCA Software 2011)

APPENDIX

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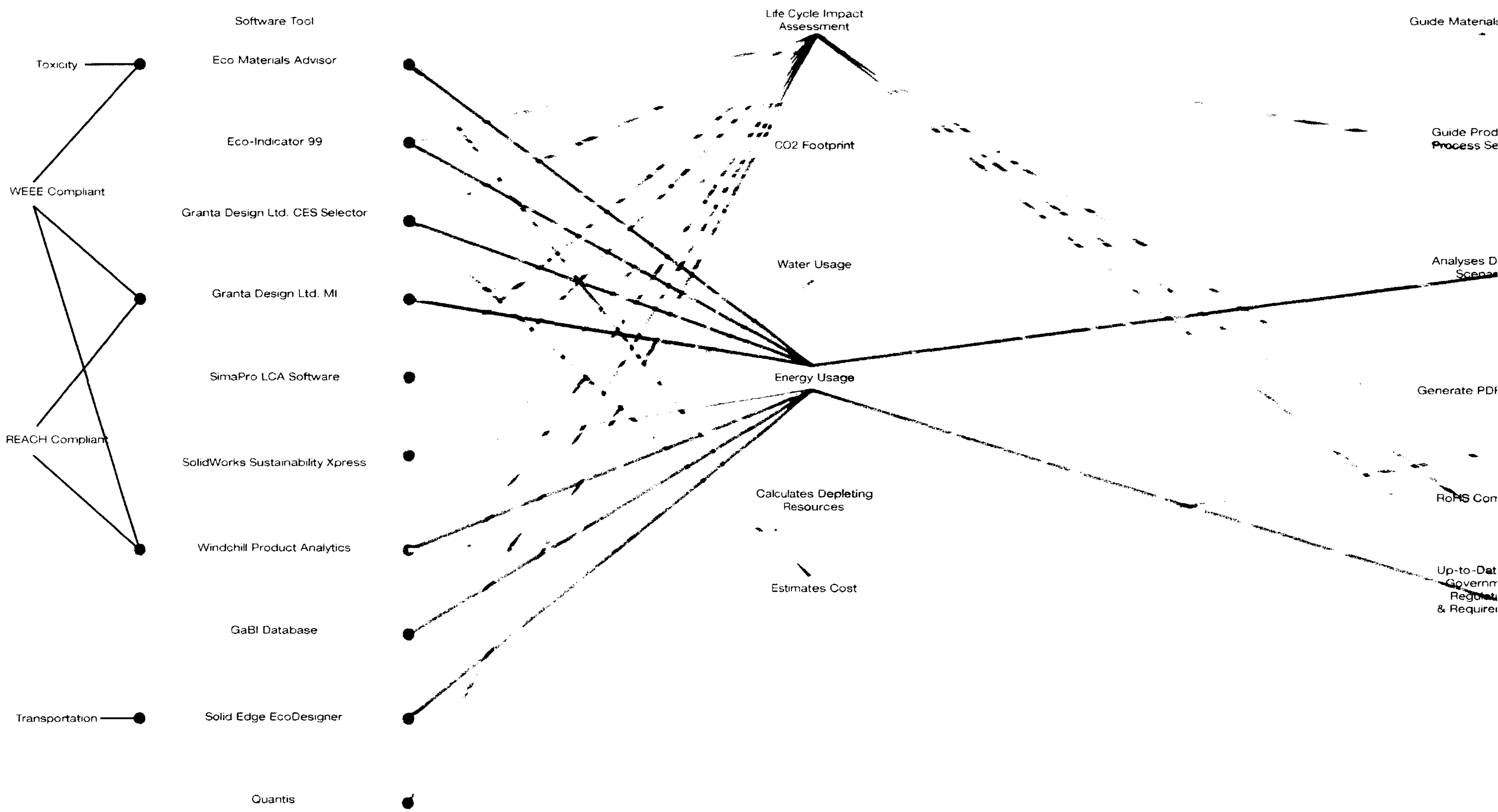
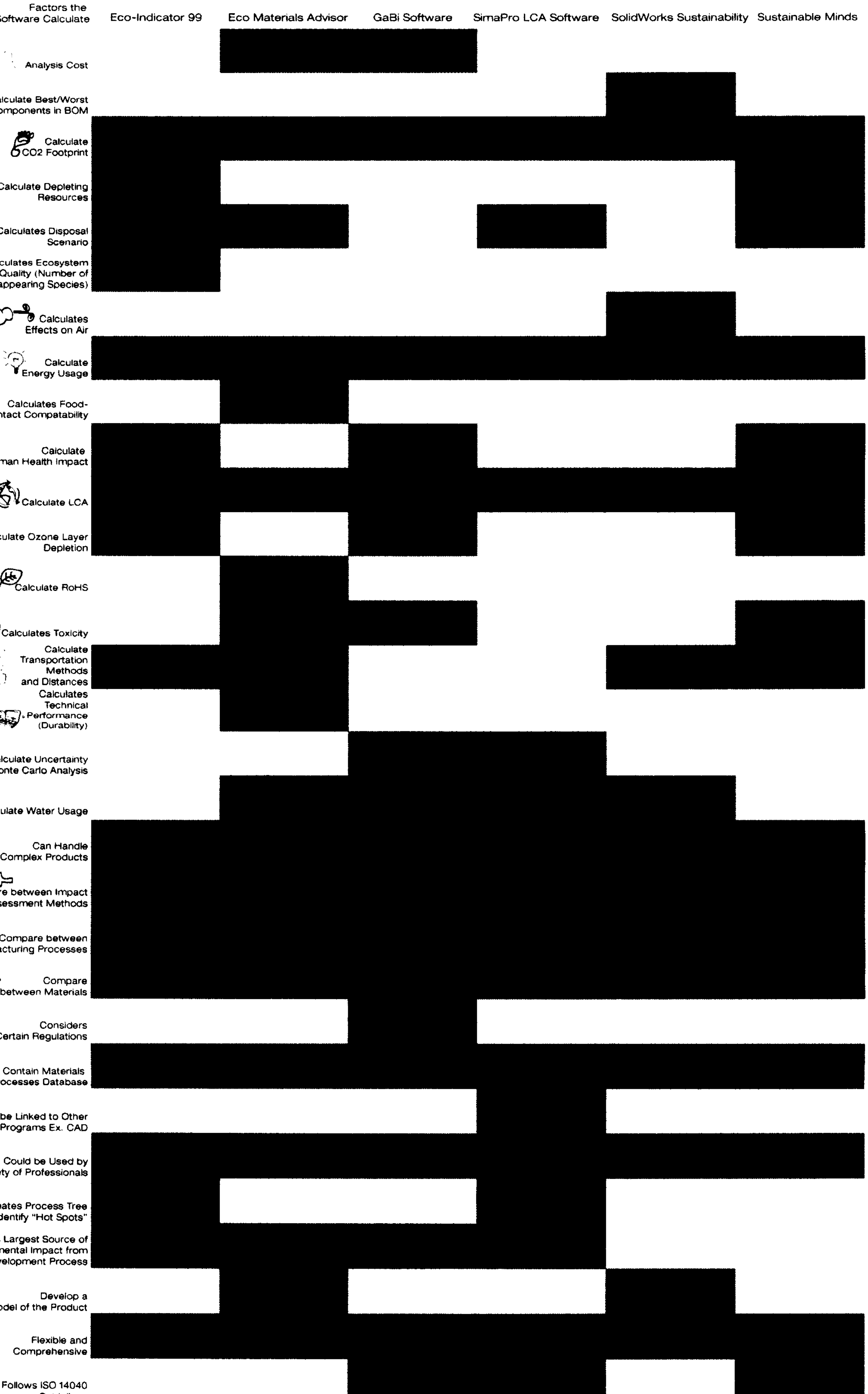


Software Tool
Toxicity
Eco Materials Advisor
Eco-Indicator 99
WEEE Compliant
Granta Design Ltd. CES Selector
Granta Design Ltd. MI
SimaPro LCA Software
REACH Compliant
SolidWorks Sustainability Xpress
Windchill Product Analytics
GaBI Database
Transportation
Solid Edge EcoDesigner
Quantis
Life Cycle Impact Assessment
CO2 Footprint
Water Usage
Energy Usage
Calculates Depleting Resources
Estimates Cost

4.4 Critical Reviews Comparison: Eco-Labels and LCA Tools

Designers who develop PCs can benefit from having a better understanding of the types of LCA tools they may use in order to help them develop more environmentally friendly products. Eco-labels are growing in importance and their rapid increase over the past three decades emphasizes the importance of allowing designers to quickly understand the different types of eco-labels and their different criteria in a fast and easy process. The first two research questions required analysing the LCA tools and eco-label criteria to see how they relate to one another to understand how effective the LCA tools actually are when attempting to meet the eco-label criteria. The information from the critical reviews were compiled and analysed in order to provide the necessary data to answer the first two research questions. Table 9, 10, 11, and 12 illustrate the findings that were made as a result of the information compiled from the critical reviews of the eco-labels and LCA tools. Table 9 shows the LCA tools and the different functions they each help calculate; the term functions is used to describe the environmental impact assessment methods that each of the LCA tools specifically calculate.


Factors the
oftware Calculate
Eco-Indicator 99
Eco Materials Advisor
GaBi Software
SimaPro LCA Software
SolidWorks Sustainability
Sustainable Minds
Analysis Cost
lculate Best/Worst
mponents in BOM
Calculate
CO2 Footprint
Calculate Depleting
Resources
Calculates Disposal
Scenario
culates Ecosystem
Quality (Number of
appearing Species)
Calculates
Effects on Air
Calculate
Energy Usage
Calculates Food-
ntact Compatability
Calculate
man Health Impact
Calculate LCA
ulate Ozone Layer
Depletion
Calculate RoHS
Calculates Toxicity
Calculate
Transportation
Methods
and Distances
Calculates
Technical
Performance
(Durability)
lculate Uncertainty
onte Carlo Analysis
ulate Water Usage
Can Handle
Complex Products
e between Impact
essment Methods
Compare between
cturing Processes
Compare
between Materials
Considers
Certain Regulations
Contain Materials
ocesses Database
be Linked to Other
Programs Ex. CAD
Could be Used by
ty of Professionals
ates Process Tree
dentify "Hot Spots"
Largest Source of
nental Impact from
elopment Process
Develop a
odel of the Product
Flexible and
Comprehensive
Follows ISO 14040


tor 99
Eco Materials Advisor
GaBi Software
SimaPro LCA Software
SolidWorks Sustainability
Sustainable Minds
None

Table 9 listed in the column all of the different environmental impact assessment methods, or factors, from the six LCA tools and the top row listed each of the six LCA tools. The comparison was made from the LCA tool factors and the LCA tools in order to understand the similarities and differences that the tools would have among one another. This table clarified that some of the LCA tools all calculate similar factors, but also are each unique by calculating certain factors that would not be found in all of the other LCA tools. The column in Table 10 illustrated the eco-label criteria from all of the criteria from the eco-labels for PCs located around the world. There are a total of thirty-two eco-labels for PCs found globally and all of their criteria was collected and listed in this table. The row has listed the six LCA tools as well as "none," because the table was making a comparison between the eco-label criteria and the LCA tools in order to understand which eco-label criteria can be calculated by the six LCA tools. Table 9 provided the necessary information in order to understand what the LCA tools each calculate, and that information was used to understand which of the six LCA tools would calculate those criteria. When all the criteria were combined, they amounted to a total of 62 eco-label criteria, and Table 10 showed that the LCA tools are capable of meeting 31 of the 62 eco-label criteria. This meant that the LCA tools only meet half of all the criteria necessary for the eco-labels. However, this study was focusing on the designer's role during the product development process, which takes place during the material's phase in the LCA. The majority of the 25 required criteria that need to be met during the materials phase were calculated by the LCA tools, with only 10 not calculated. Table 11 also illustrated the eco-label criteria in the column but the row listed the different phases of the lifecycle. Table 11 clarifies where each of the eco-label's criteria fits into the different LCA phases to show which criteria the designer is specifically responsible in calculating. The column in Table 12 listed each of the thirty-two eco-labels found globally for

PCs, and the row listed each of the different phases in the life cycle as well as the "none" option. Table 12 was used to clarify the types of professionals that are needed when attempting to meet the criteria for a specific eco-label. For example, from looking at Table 12, a designer would understand that they are not involved with calculating the necessary criteria for the C-UL Mark eco-label. It was not expected that the LCA tools would calculate all the necessary eco-label criteria for PCs around the world, because these LCA tools were not developed specifically for that purpose.

rials Phase
Manufacturing Phase
Packaging, Transportation & Distribution Phase
Use Phase
End of Life Phase
None

Table 12 LCA Phases and Eco-Labels

Eco Labels	Materials Phase	Manufacturing Phase	Packaging, Transportation & Distribution Phase	Use Phase	End of Life Phase	None
		2				
	6	10		1		2
		3		1		1
		3		1		1
	2	5	1	2		
	9	6	[illegible]	1	1	1
	2					
						1
	3	4				1
	5	2	1			
	3	1	1			[illegible]
	10	8	1		[illegible]	1
	6	4	1			1
	7	5	1		1	1
	3	5		1	1	2
	9	11	1	2	1	2
	3	2				
	9	10	1	1	1	1
		1				2
	1	3				
	8	7	1	1	2	3
		4	1			
	9	8	1	1	1	1
	3	5	1		1	1
	3	8	1	1		1
		1				
		3				
	7	8	2			1
	4	2	1			1
	2	2				1
		3				
	5	4	[illegible]			1

INDEX
Calculates 1-3 Eco-Label Criterion
Calculates 4-6 Eco-Label Criteria
Calculates 7-9 Eco-Label Criteria
Calculates 10-12 Eco-Label Criteria

4.5 Survey Analysis: Designers Contribution to Meeting Eco-Label Criteria

The research has shown that designers have a significant role in meeting eco-label criteria, by having analysed the total 62 eco-label criteria from the eco-labels for PCs found globally, and having illustrated in Table 11 and Table 12 that designers are responsible for calculating 25 from the total 62 eco-label criteria for PCs. Designers are concerned with the materials phase in the LCA and their decisions impact the rest of the phases within the LCA, which emphasizes the importance of allowing designers to calculate the environmental impacts of their design decisions. Although the study has explained that designers are involved in meeting eco-label criteria, it also depends on the type of eco-label the company is trying to meet for their product. There are some eco-labels, such as CarbonFree Certified, that do not require the input from the designer. However, the eco-labels that consider a larger variety of criteria in order to certify a product do involve the designer's role in the process, such as the EU Ecolabel. The survey that was sent to professionals for this study received a total of twenty respondents. The results of the survey are shown in Figure 31, and the results showing only the eight responses from designers are shown in Figure 32.

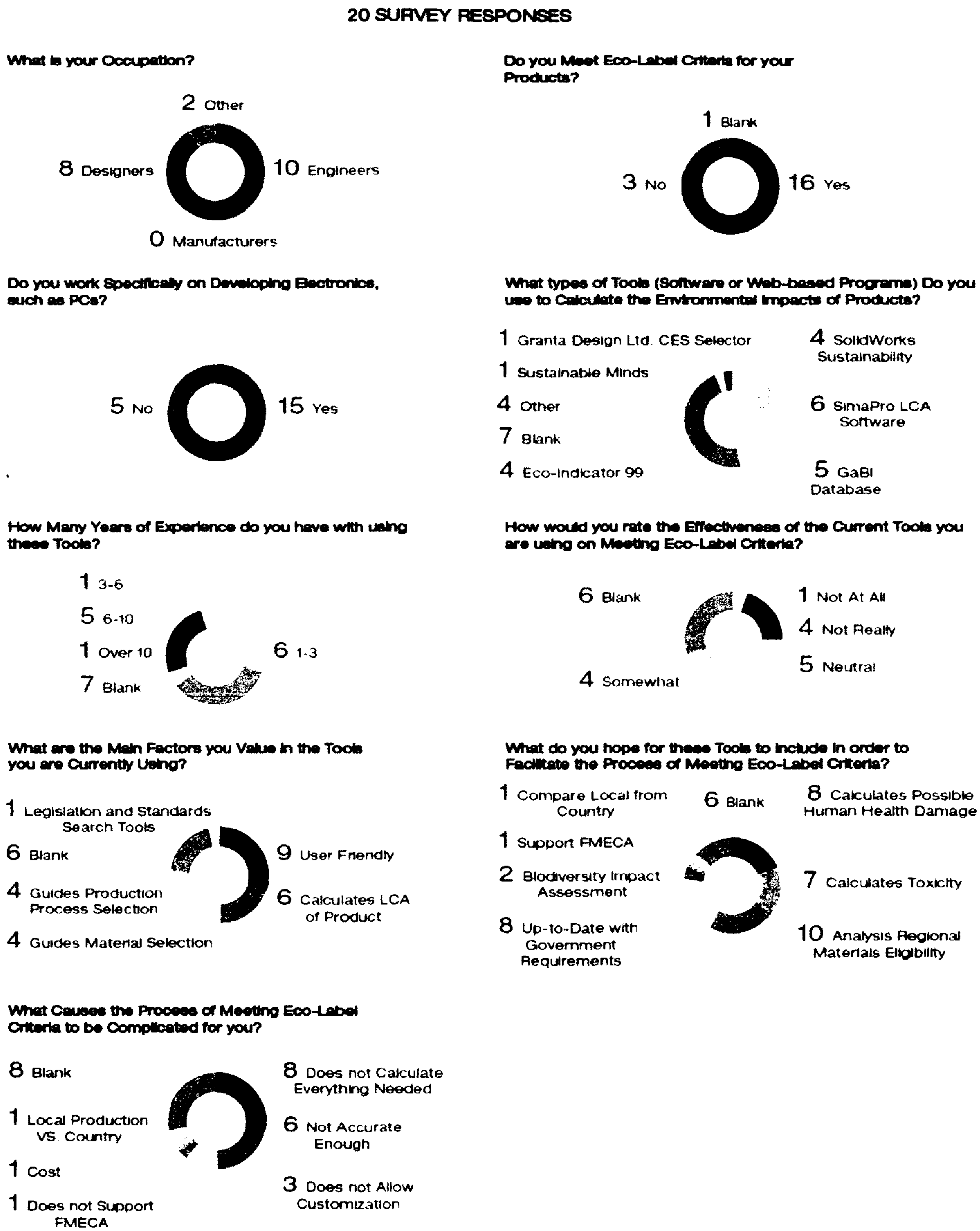


Figure 31 Total Survey Responses

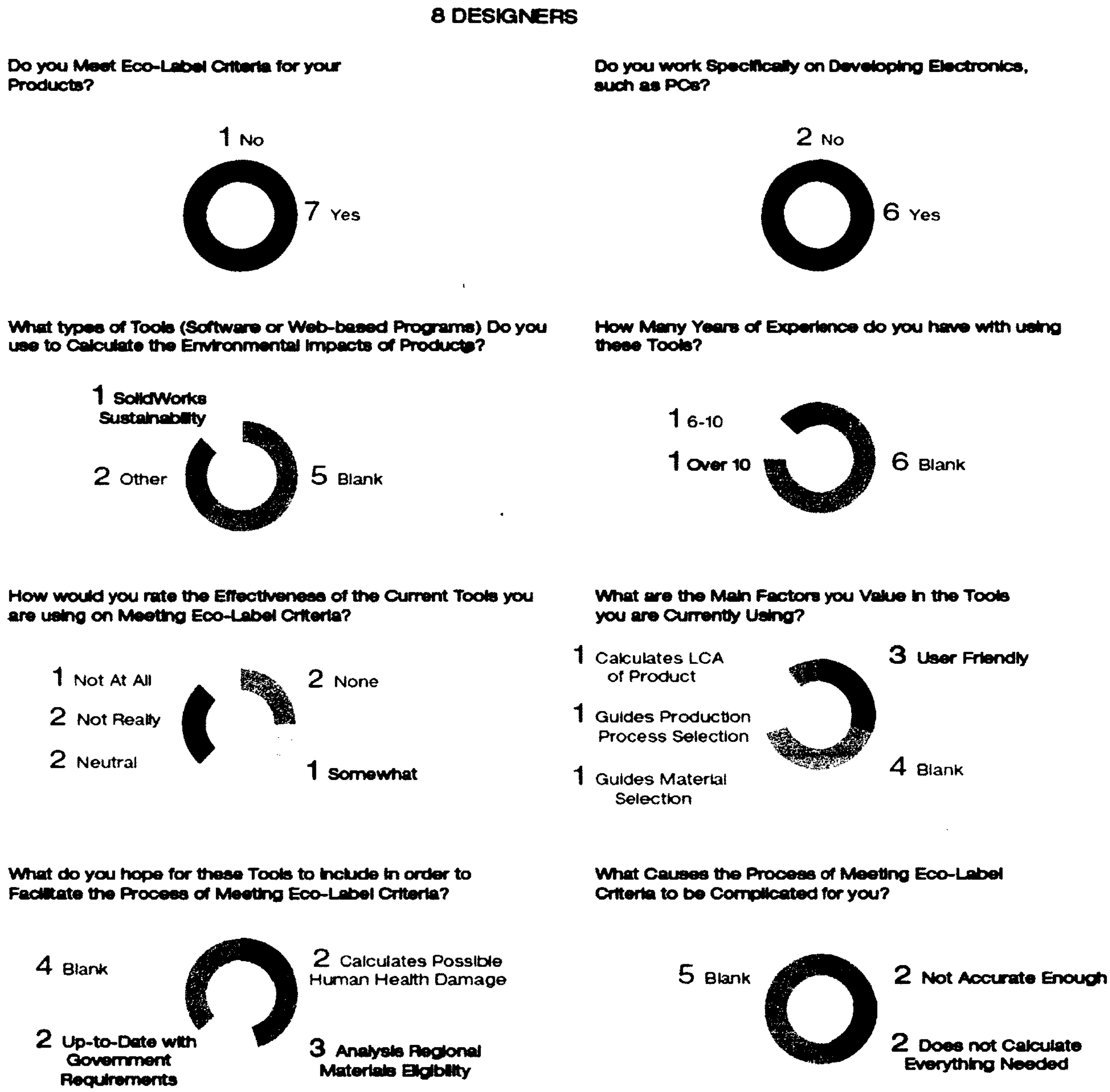


Figure 32 Survey Responses from Designers

The analysis of the survey illustrated the main differences between the designer's responses compared to the other types of professionals. The total survey responses in Figure 31 illustrated that many of the professionals are familiar with the LCA tools; however, Figure 32 illustrated that the majority of the designers are not familiar with any of the LCA tools available. Designers were asked about the types of improvements they may suggest or what they would want the LCA tools to calculate, and their responses were actually factors that the LCA tools already calculate. The survey responses proved that designers are unfamiliar with the capabilities that LCA tools have to offer when it comes to designing a more environmentally friendly PC. The other respondents were either engineers or sustainability analysts, and they have shown that they are more familiar with these LCA tools compared to designers. Although some of the suggested improvements from the engineers and sustainability analysts were already offered in certain LCA tools, the respondents suggested improvements only based on the LCA tools they were currently familiar with using.

Professionals need to become more aware of the different options they have available when choosing an LCA tool to work with for developing their product. When respondents were asked to offer additional comments, several expressed their interest in learning more about the LCA tools and how they may compliment their work as designers. One respondent claimed, "at Philips eco-friendliness is not really integrated in the design process...more of a last step of compliance," while another respondent explained how they hope that these LCA tools would be explained more in universities, "I wish that universities would make it a requirement to introduce the application of such software tools." The survey also proved that professionals do not have enough time to learn the differences between each tool through thorough research, "tools are great but a designer's, engineers and inventor's time is limited. There must be some way of reducing time, complexity while at the same time increasing awareness."

4.6 The Toolkit

The results of the survey and research have emphasized the importance of simplifying the method for PC designers to understand which LCA tool would best suit their needs and their role in meeting the eco-label criteria. The simplified method that was created as a result of this research was a toolkit. The toolkit is composed of an offering map, issue cards, and a manual to explain what the toolkit is for and how the offering map and issue cards are to be used together. The offering map was designed to have the user begin reading from the centre of the map and follow a set of arrows that would show the series of functions, explaining the positives and negatives that each of the six LCA tools have to offer. The offering map provides a simplified method for the designer to understand each of the LCA tool's differences and similarities among one another. Issue cards were developed to describe each of the eco-labels available around the world for certifying PCs. Each of the issue cards provide an explanation of one eco-label on the front and back side of the card, and the illustrations on the front of the card make the connection to the offering map in order for the designer to choose the necessary LCA tool to use for that particular eco-label. The back of the card described the details of the eco-label by explaining the organization behind the label, when it was first developed, the label's objectives, the countries where it is used, and a product example is also provided for each label, as shown in Figure 35.

4.7 The Workshop

The workshop was conducted with a group of master of industrial design students and John Anastasiadis, an industrial design-product development consultant with clients that include HP and LG. The workshop required the students and professional to individually test the toolkit and to then answer several questions about their opinion on it with the goal of understanding how simple they find it was to use. The original offering map that was tested by the workshop participants is shown in Table 13, and an example of one of the original issue cards is shown in Figure 33. The factors that the LCA tools help calculate in the offering map are shown in a point-form list with some of the points being filled with a certain colour. The colours symbolize the number of eco-label criteria that the specific factor helps to meet. Each point is also associated with an illustration in order to simplify the designer's effort in understanding the offering map even further. The challenge in developing this toolkit was to have the tools able to connect and work together so that the designer would not only understand the differences and similarities between the LCA tools, but also understand the differences between the eco-labels and how the criteria are to be met with each of the LCA tools.

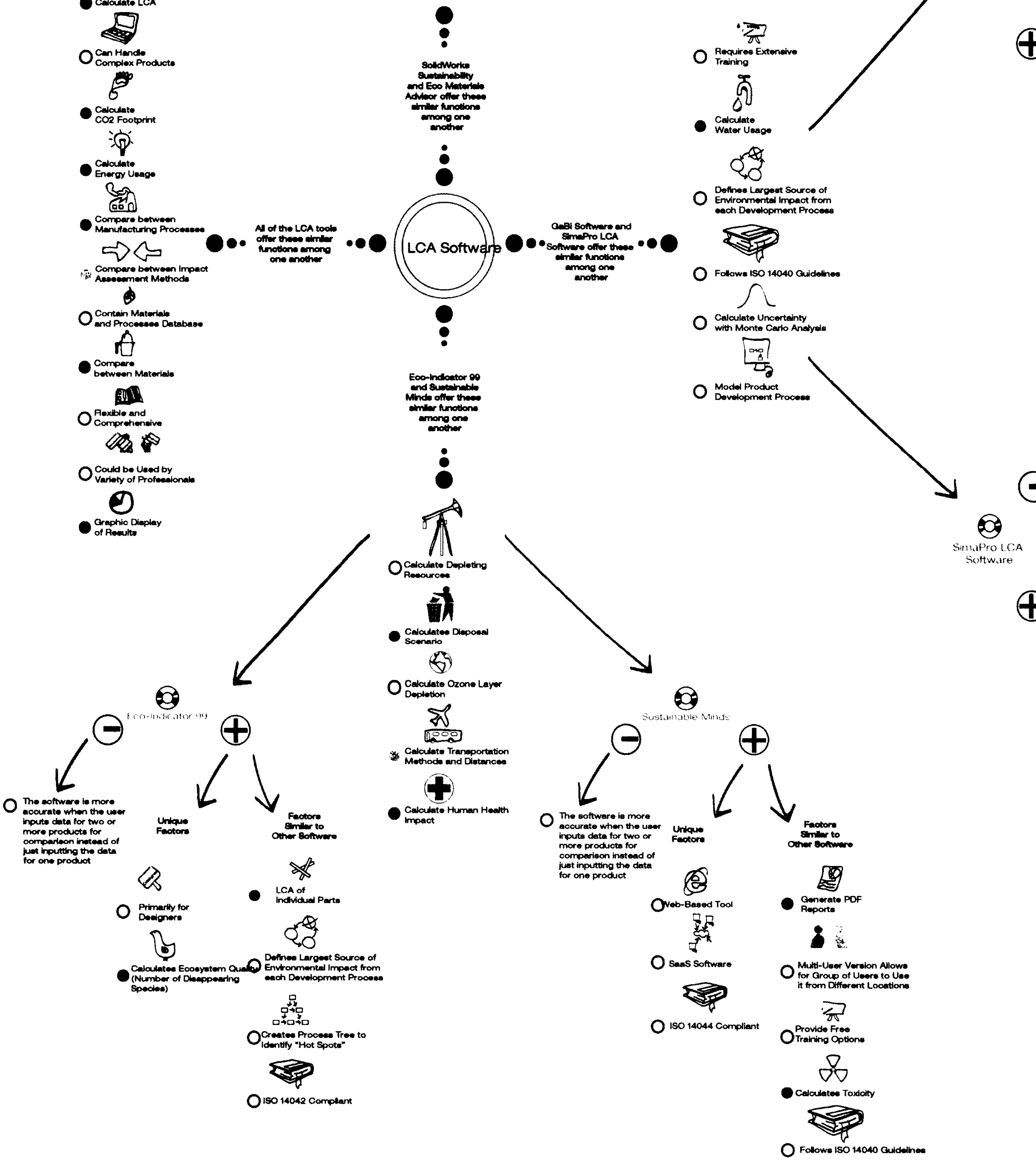


Table 13 Original Offering Map

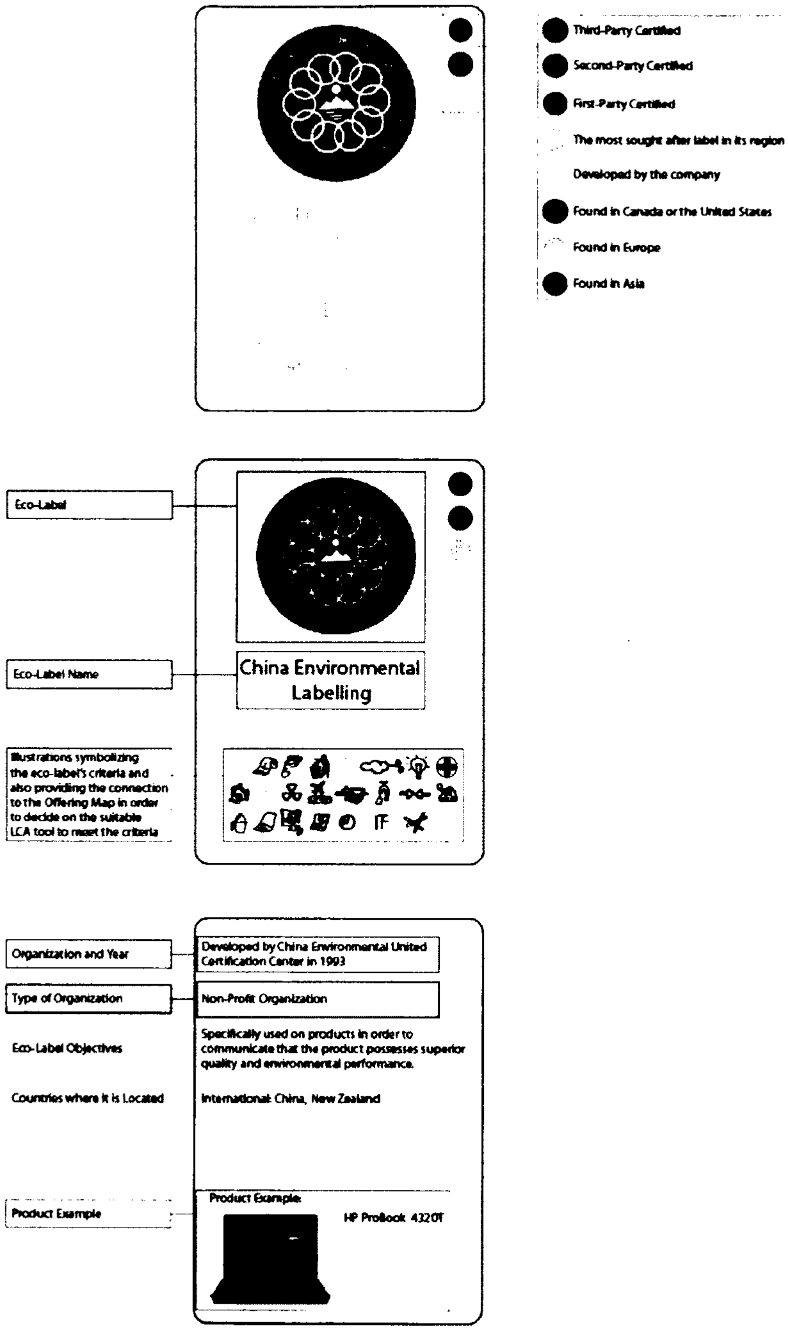


Figure 33 Original Front and Back Side of the Issue Cards

The front of the issue cards would include the same images from the offering map; however, the images displayed in bold colour are the images that are related to the eco-label criteria and what it may need the LCA tool to be capable of calculating. If the images on the issue card are light grey in colour then it would mean that the eco-label does not require those factors to be calculated in order to meet its criteria. This method is believed to facilitate the process for the designer in choosing the correct LCA tool to meet the eco-label criteria. The workshop with the master students and the questionnaire with the professional provided insight into their opinion of the original toolkit and the improvements they each believe should be made, which are explained in Table 14. Photos of the master students using the toolkit and answering the questionnaire are shown in Figure 34.

Participants	Compliments	Suggested Improvements
Student Participant #1	-Explanation in the manual was clear	-Provide explanation of how to use the diagram and cards in a set of steps -The size of the map needs to be larger, and finding the matching symbols is time consuming -Having a sense of hierarchy with the type size may help direct the user to the different areas
Student Participant #2	-The manual was clear to a certain extent once read twice	-Difficult to make the connection between the different symbols, labels, icons, and colours -Provide explanation in steps -Difficult to navigate around the map -Provide a full example within the manual of the connection between cards and map -Colour code the symbols for easier navigation -Clarify where the starting point is on the map

Student Participant #3	-The manual was clear from the images that explained the details of the process and how the toolkit is to be used -The use of a map, cards, and manual make it more interesting and they worked well together -The illustrations help illustrate the different features -Graphically pleasing	-A numbered step by step procedure of how to use the toolkit would be more helpful -Clarify where the starting point is on the map
Student Participant #4	-The toolkit was clear as to how it worked and how the different components were related -The toolkit was well-organized and interesting for a designer to use when dealing with eco-labels	-Provide explanation of how to use the map and issue cards in a set of steps
Student Participant #5	-The idea is strong	-The correlation of information needs further refinement -Provide explanation of how to use the diagram and cards in a set of steps -The use of too many icons is distracting, better to use a more structured method such as letters or numbers for easier navigation
Professional: John Anastasiadis	-Manual does a good job of explaining the options for LCA software -It will help educate designers on the subject of LCA -A poster of the Offering Map positioned in the office will also be nice to have. It can help designers communicate better with operations and	-Dots on the cards are difficult to understand -Dots on the map are difficult to understand and found the radiating centre dots confusing -Make the map easier to read and follow -Make sure it's consistent and don't over design the Offering Map

	non-designer stakeholders	

Table 14 Opinion of the Students and Professional about the Toolkit

Figure 34 Master Students using the Toolkit during the Individual Workshop

As a result of the workshop with the students and professional, changes were made to the manual, offering map, and issue cards in order to make the toolkit more understandable and easier to use. Below are the changes that were made to the offering map:

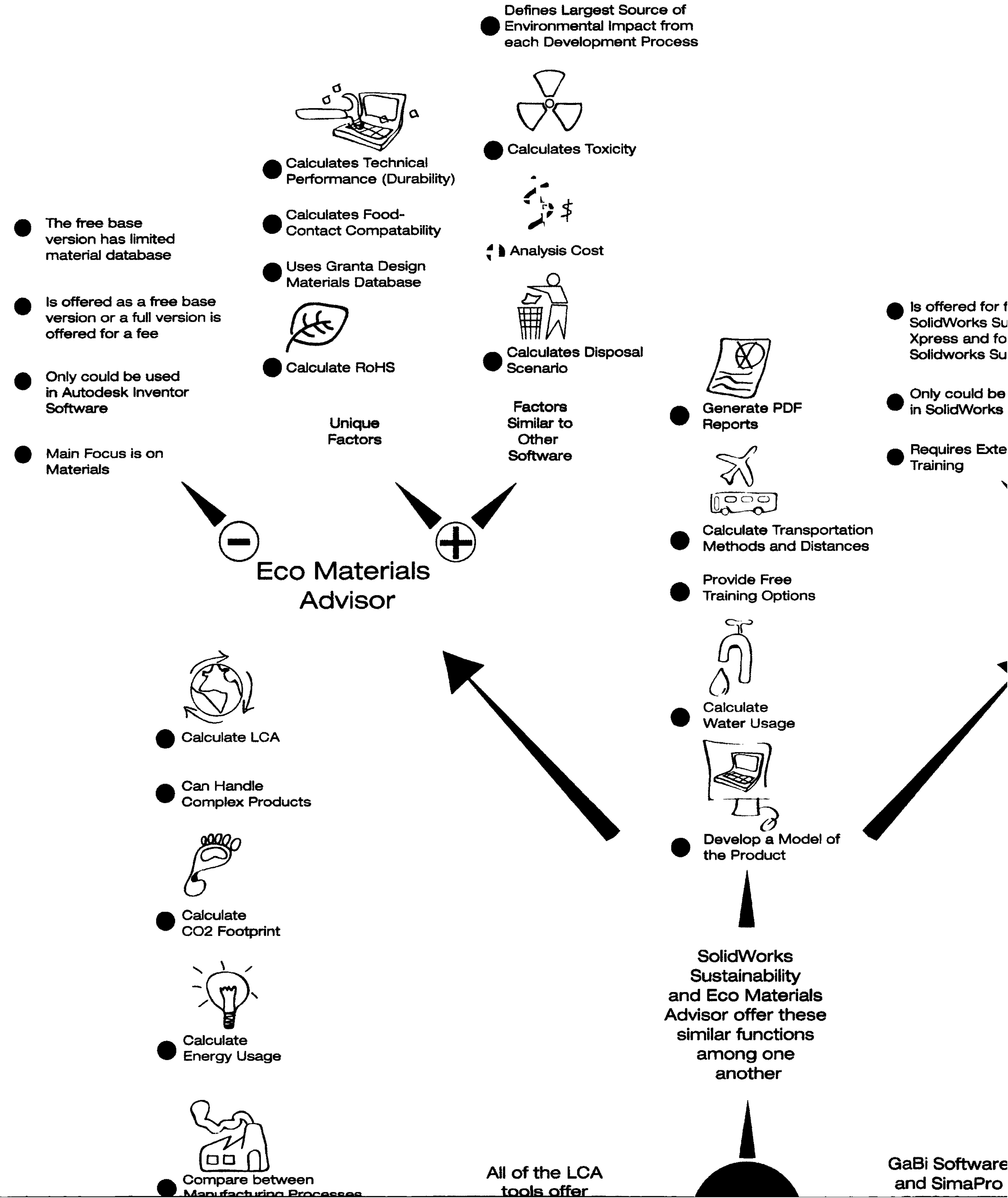
- Removed the circles next to the centre starting point
- Changed 'LCA Software' name in centre starting point to 'START'
- Enlarged the text and graphics
- Changed the hollow black circle points to full black circle points

- Reduced the illustrations to keep only the illustrations that are also used on the cards
- Changed the opaque, full coloured symbols to outlined symbols to match the others on the map and not have extra value
- Not each illustration was made to have its own colour because that would make it crowded and confusing along with the colour of the points, instead the illustrations were given a matching colour of the points beside them, which will create groups of colour on the map and would allow for easier navigation
- Changed the design and colours of the arrows in order to have the user notice the different sections in the map without having to box each section in a separate shape

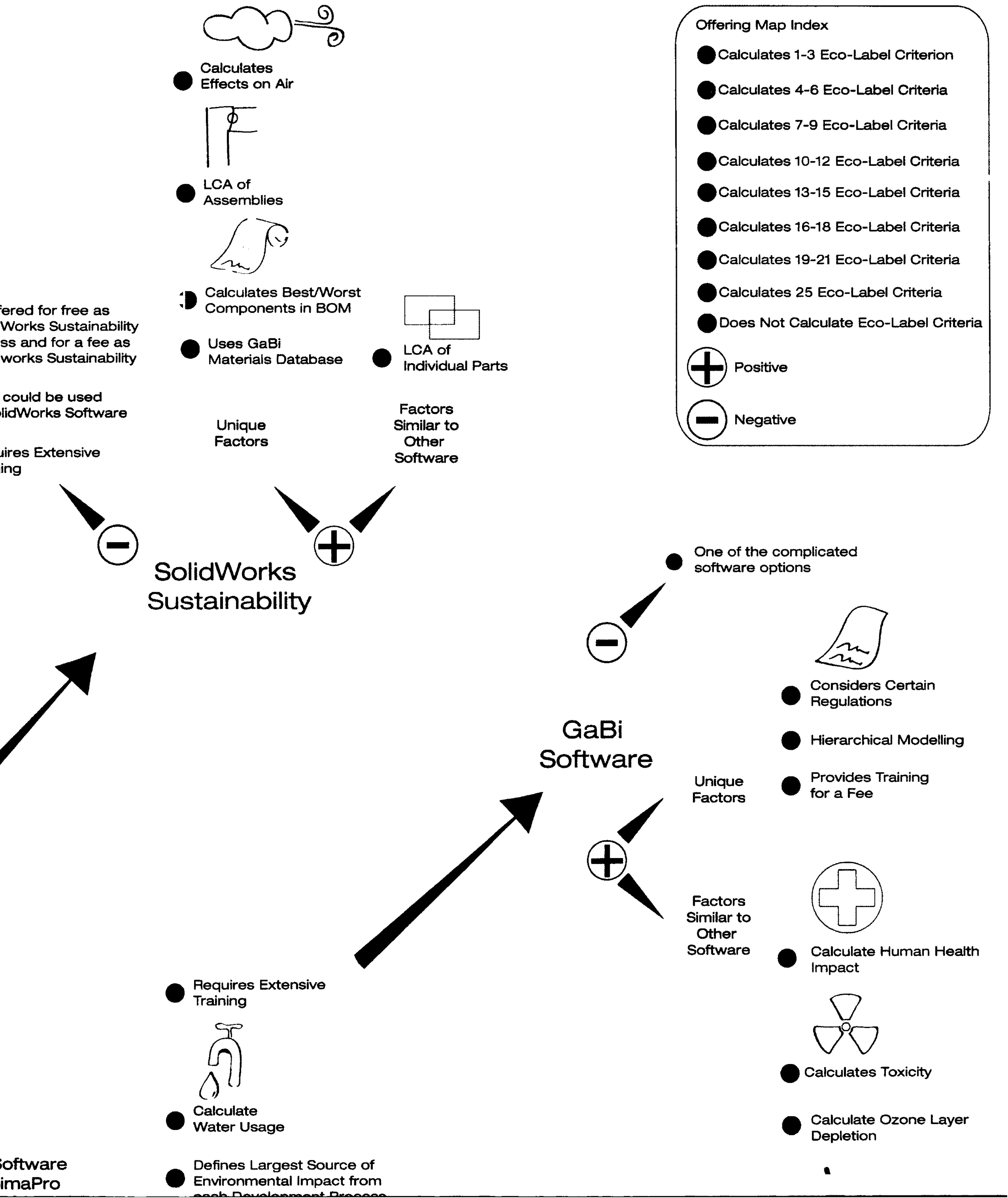
Below are the changes made to the original issue cards:

- Having an index for the issue cards and an index for the offering map became confusing to the users. The circles on the index cards were changed to coloured words
- The blue illustrations on the front of the issue cards were changed to be coloured and match the colours of the illustrations on the offering map. Having them both coloured would allow for easier navigation. The illustrations that are not related to that eco-label will remain greyscale on the issue card.

Table 15 shows the offering map after the changes were made as a result of the workshops, and Figure 35 shows the changes made to the issue cards. Figure 36 illustrates the connection between the offering map and issue cards.



Defines Largest Source of Environmental Impact from each Development Process
Calculates Technical Performance (Durability)
Calculates Toxicity
The free base version has limited material database
Calculates Food-Contact Compatability
Analysis Cost
Uses Granta Design Materials Database
Is offered as a free base version or a full version is offered for a fee
Calculates Disposal Scenario
Calculate RoHS
Only could be used in Autodesk Inventor Software
Main Focus is on Materials
Unique Factors
Factors Similar to Other Software
Is offered for f
SolidWorks Su
Xpress and fo
Solidworks Su
Only could be
in SolidWorks
Requires Exte
Training
Generate PDF Reports
Calculate Transportation Methods and Distances
Provide Free Training Options
Eco Materials Advisor
Calculate LCA
Can Handle Complex Products
Calculate Water Usage
Develop a Model of the Product
Calculate CO2 Footprint
SolidWorks Sustainability and Eco Materials Advisor offer these similar functions among one another
Calculate Energy Usage
Compare between Manufacturing Processes
All of the LCA tools offer
GaBi Software and SimaPro


Calculates Effects on Air
LCA of Assemblies
Calculates Best/Worst Components in BOM
Uses GaBi Materials Database
LCA of Individual Parts
ered for free as
Works Sustainability
ss and for a fee as
works Sustainability
could be used
olidWorks Software
uires Extensive
ing
Unique Factors
Factors Similar to Other Software
SolidWorks Sustainability
Offering Map Index
Calculates 1-3 Eco-Label Criterion
Calculates 4-6 Eco-Label Criteria
Calculates 7-9 Eco-Label Criteria
Calculates 10-12 Eco-Label Criteria
Calculates 13-15 Eco-Label Criteria
Calculates 16-18 Eco-Label Criteria
Calculates 19-21 Eco-Label Criteria
Calculates 25 Eco-Label Criteria
Does Not Calculate Eco-Label Criteria
Positive
Negative
One of the complicated software options
GaBi Software
Considers Certain Regulations
Hierarchical Modelling
Provides Training for a Fee
Unique Factors
Factors Similar to Other Software
Calculate Human Health Impact
Calculates Toxicity
Calculate Ozone Layer Depletion
Requires Extensive Training
Calculate Water Usage
Defines Largest Source of Environmental Impact from
oftware
imaPro

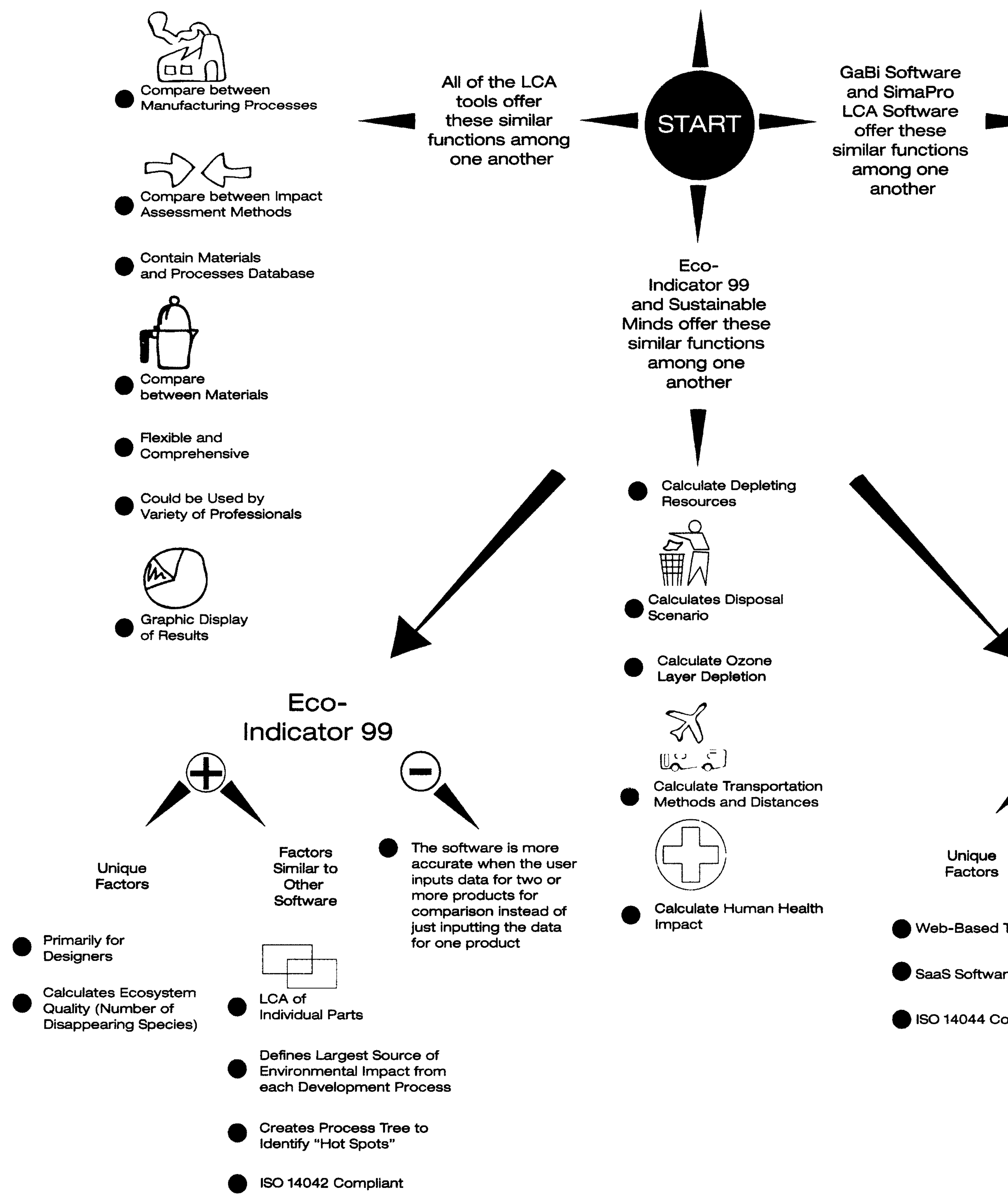
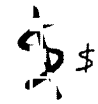


Table 15 The New Offering Map as a Result of the Workshops

Bi Software
d SimaPro
A Software
fer these
ar functions
nong one
another

- Calculate Water Usage
- Defines Largest Source of Environmental Impact from each Development Process
- Follows ISO 14040 Guidelines
- Calculate Uncertainty with Monte Carlo Analysis
- Model Product Development Process

- Calculate Ozone Layer Depletion



- Analysis Cost

SimaPro LCA Software

−

- The amount of detail in the final analysis depends on the version being used
- One of the complicated software options

+

Unique Factors

- Could be Linked to Other Programs Ex. CAD
- Presents Data on One Page

Factors Similar to Other Software

- Calculates Disposal Scenario

- Generate PDF Reports
- Multi-User Version Allows for Group of Users to Use it from Different Locations
- Creates Process Tree to Identify "Hot Spots"

Sustainable Minds

+

Unique Factors

- Web-Based Tool
- SaaS Software
- ISO 14044 Compliant

Factors Similar to Other Software

- Generate PDF Reports
- Multi-User Version Allows for Group of Users to Use it from Different Locations
- Provide Free Training Options

- Calculates Toxicity
- Follows ISO 14040 Guidelines

−

- The software is more accurate when the user inputs data for two or more products for comparison instead of just inputting the data for one product

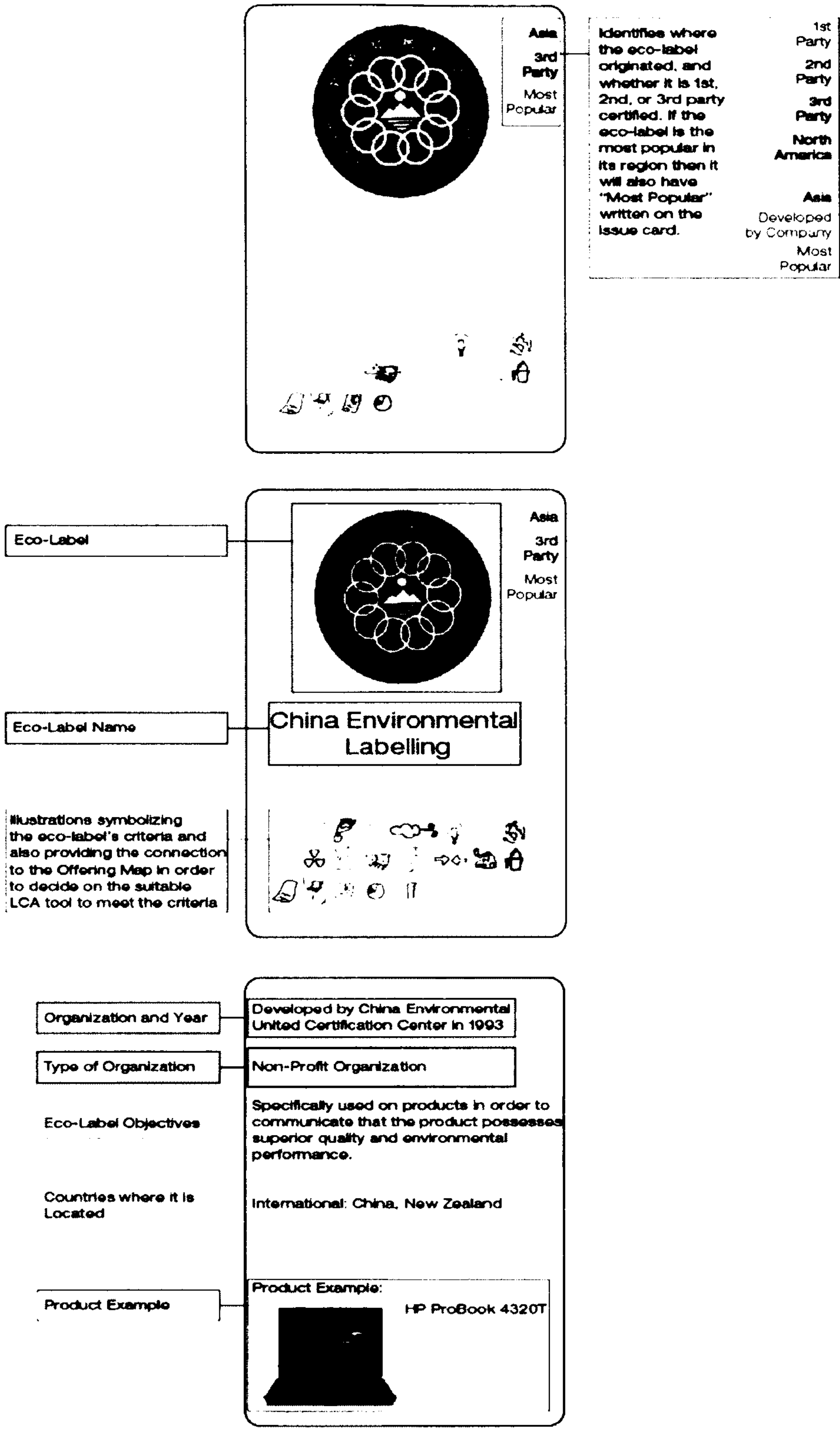


Figure 35 The New Issue Cards as a Result of the Workshops

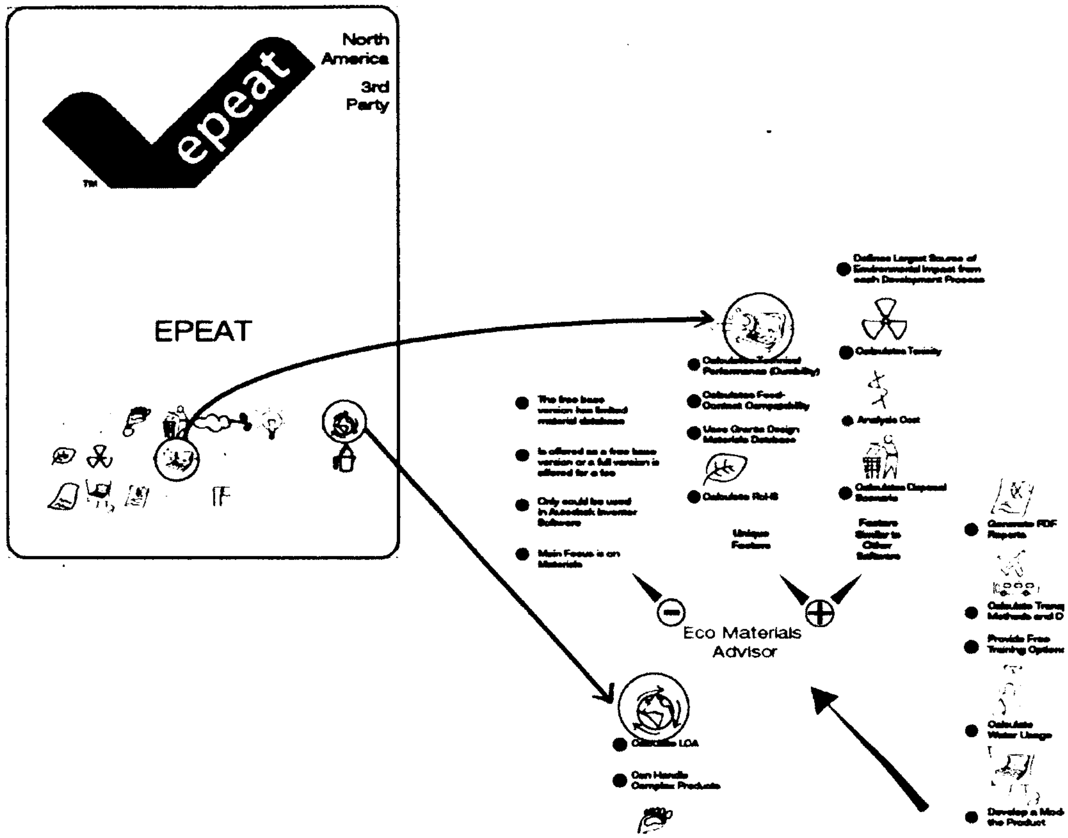


Figure 36 The Connection between the Offering Map and Issue Cards

A logo was developed for the toolkit in order to establish an identity for the toolkit, since it is designed to be sold to PC designers. The logo is shown in Figure 37. The design of the logo was inspired from the three critical reviews written about each of the most popular eco-labels around the world for PCs. The blue square symbolizes energy star, the full circle symbolizes China Environmental Labelling, and the hollow circle symbolizes the eco-labels that are mainly white with an outline of colour, such as the Blue Angel. The orange arrow is one of the arrows located on the offering map. It was appropriate to combine the arrow with the eco-labels since the toolkit establishes a connection between the offering map and issue cards that explain the eco-labels. All the components located within the toolkit are shown in Figure 38.

Figure 37 Toolkit Logo

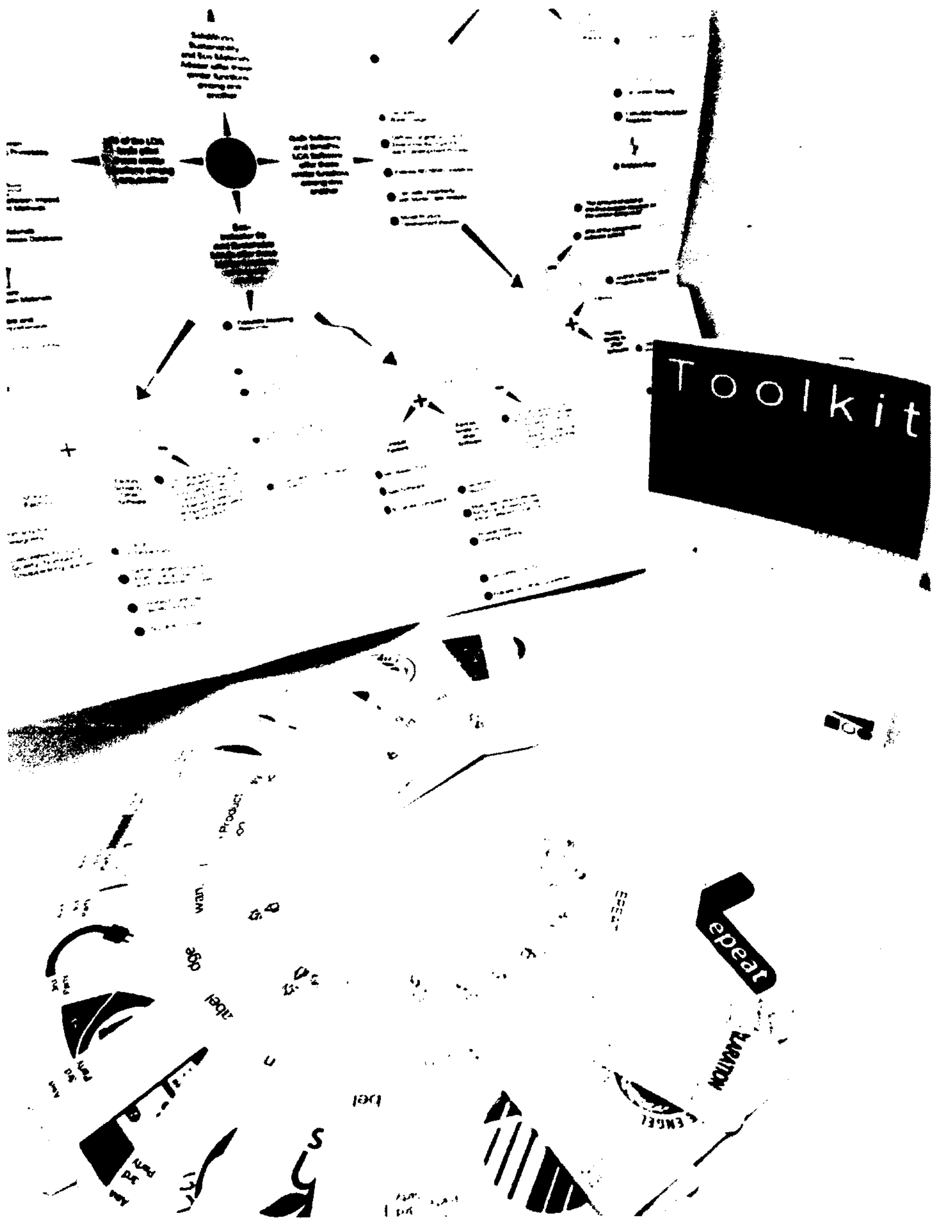


Figure 38 The Offering Map, Issue Cards, and Manual

CHAPTER 5

CONCLUSION

Chapter 5 is organized into three sections. Section 5.1 provides the conclusions. Section 5.2 describes the limitations of the research. Section 5.3 provides suggestions for future research.

5.1 Conclusion

This research developed a toolkit that would facilitate the process for personal computer (PC) designers in choosing the correct life cycle assessment (LCA) tool to use when trying to meet certain eco-label criteria. The toolkit's development was built based on two different literature streams: LCA and eco-labels. The relationship between a LCA and the eco-labels used to certify PCs were analysed to find that LCA tools can help meet a significant number of eco-label criteria and that designers need more awareness as to how these LCA tools can impact their product development process. This relationship was found after making a comparison between the eco-label criteria and LCA tool factors through the use of a table. There was a lack of research on how LCA tools can facilitate the process of meeting eco-label criteria, and how this relationship may be of particular value to designers for developing more environmentally friendly PCs. All the eco-labels to certify PCs from each region of the world were analysed in order to understand how the LCA tools can each contribute to meeting their criteria. Clarifying this relationship to PC designers may help with reaching the goal of becoming a more sustainable society. Designers would understand which LCA tool to use in order of making the process of developing environmentally certified PCs an easier and less time consuming process.

The literature review included several authors, such as O'Hare (2011) and Bhander et al. (2003),who explained that designers are uncertain how to choose a correct LCA tool and designers are unlikely to result in choosing an LCA tool to use during the development of their product. One of the reasons why designers would result in not using an LCA tool during the product development process at all was because of the lack of time that they had in order to research about each LCA tool available in the market. However, these authors have not explained a method that designers may use in order to facilitate this process. The research is considered to be a radical innovation with how it draws from existing bodies of research and establishes new connections that could alter the way PC designers traditionally develop their products. The toolkit is effective for educating designers about LCA tools and eco-label criteria in a short amount of time; in addition, it provides simple tools that would allow designers to choose the most useful LCA tool for meeting certain eco-label criteria in a matter of minutes. It may help enhance the designer's role in the environmental development of the PC, and provide them with the necessary knowledge to know how and where to begin when trying to meet eco-label criteria.

The six LCA tools examined in this study help meet half of the total eco-label criteria from the eco-labels for PCs found around the world, and the majority of the criteria to be calculated by designers during the materials phase can be facilitated with the use of an LCA tool. Designers are currently not too involved when it comes to developing environmentally friendly PCs within the company; however, the research has shown the importance and difference that the designer can make to the product's overall environmental impact through Table 11 and Table 12 within the Results and Discussion chapter. Designers have a significant role in the creation of environmentally friendly electronic products, but are not necessarily aware of how great an impact they actually have on the products environmental effects. The online survey results also provided insight into how little the designer understands the importance of their roles in the environmental effects of the product, and how most believed that the possible environmental effects of the product did not concern their attention and time. The literature review discussed that the materials phase has the largest environmental impacts; however, in reality companies are not taking this into much consideration because they are not training their designers to be aware of the importance of their decisions and the actual environmental effects they each have. With the use of the toolkit developed in this study, designers would have increased awareness on the most popular LCA tools used within the industry, the types of eco-labels they have the option to meet, and their important contribution to meeting certain eco-label criteria.

The toolkit was viewed as an interesting and simplified method aiding the designer to become familiar with a vast amount of information that would have taken a lot of time, otherwise, for the designer to have made the connection between the information on their own. The PC design professional from the workshop also suggested that the tool may be used to communicate with the stakeholders in the company, which further emphasizes the possible value that this toolkit may have for designers in the industry. The literature review showed the importance and growing popularity of eco-labels as well as the importance for designers to become more aware of the different LCA tools available in order to develop more environmentally friendly products. However, the connection was not previously established between the eco-label criteria and LCA tools. This research provided a solution for designers to understand the LCA tools that would help calculate eco-label criteria in a short amount of time with a simplified method. The tools used within the toolkit were two tools that are not usually used together in order to communicate certain information; however, the offering map seemed suitable for communicating the differences, similarities, and positives and negatives that each LCA tool has; and the issue cards were suitable to clarify the differences among the eco-labels in a simplified method. The toolkit was designed to be used interactively since the choice of the eco-label to certify the product may continuously change for the designer based on the country they are trying to sell the product, or based on the type of organization they want to collaborate with in order to certify that product.

There were five methods used within this research in order to develop the toolkit and to verify its value and importance to be developed for designers in the industry. Although the survey received a total of twenty respondents, only eight were designers. The results of the survey provided the claim that designers need more awareness of the different types of LCA tools available and that they are not too involved in meeting eco-label criteria for the company. The majority of the designers responded with a lack of knowledge on the different types of LCA tools available, and their additional comments explained their lack of time and involvement in the environmental aspects of the product. The literature review supported these results because O'Hare (2011), Bhander et al. (2003), and Shina & Sammy (2008) explained their similar views that designers are not aware of the different LCA tools and what they have to offer, and they need to become more involved in the environmental design of the product. The toolkit was tested by only one PC designer and the rest of the participants were Master of industrial design students; however, the goal of the workshop was to mainly understand if the toolkit developed was indeed easy to use, understandable, and effective, so the participants did not necessarily need to be experienced PC designers. The toolkit was tested individually and all the participants were able to understand the toolkit in less than fifteen minutes, the types of improvements that they suggested were also similar to one another and it was concluded that most of the designers who test the toolkit would have similar results and suggestions.

Based on the results of this research paper, one can conclude that PC designers need to have a better understanding of their role in the development of environmentally friendly products, and that they need to have more awareness of the LCA tools that will help them do so. One can also conclude that there is a significant relationship between the LCA tools and eco-labels that designers should take advantage of and that the proposed toolkit will be an important aid and facilitator in the design of environmentally friendly PCs.

5.2 Limitations

The limitation of this research was that this research had the toolkit that was developed tested by designers individually, and was developed to be only used by designers when developing an environmentally certified PC. The research also focused on the six most popular LCA tools in the industry; however, there are over 2000 LCA tools available around the world each with their own set of factors that they are capable of calculating. Another limitation of this research was that it focused on the PC industry and the eco-labels used to certify PCs; however, eco-labels are used in a wide variety of industries that may also find the development of this type of toolkit valuable for their professionals in the company.

5.3 Suggestions for Further Research

Three suggestions for future research are offered.

-First, examine how the toolkit developed in this research can be used effectively by a group of professionals at one time. Can this toolkit be used by different types of professionals required to collaborate once developing a PC?

-Second, examine how more LCA tools can be integrated into this toolkit without it becoming too confusing and still be portrayed as a simplified method of choosing the correct LCA tool for meeting eco-label criteria.

-Third, examine the effectiveness of this toolkit when used in other types of industries.

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GLOSSARY

E-waste	Electronic waste that is composed of several types of hazardous electronic products, such as PC computers, televisions, and printers.
Design for Environment (DfE)	Changes with the design to have less of a harmful effect on the environment, which include "design for dismantling, use of fewer components, use of fewer plastics, use of recycled materials, use of smart, greener materials, removal of hazardous substances, increased functionality, increased energy efficiency, and dematerialisation" (Seeba Global Resource, 2006).
Eco-labelling	Also known as green labelling, and "is a voluntary approach to environmental performance certification that is practiced around the world. An 'eco-label' identifies a product that meets specified performance criteria or standards" (Federal Electronics Challenge, 2007).
Greenwashing	Defined in the David Report (2007, p.4), as "the phenomenon that describes companies and persons that in a false way exploits the green trend."
Life Cycle Assessment (LCA)	Analysing "all of the processes involved in sourcing, production, distribution, use, and recovery of the product" (Fiksel, 2009, p. 125).

New Consumer	Look "at the companies behind the products that they buy and they believe it's important to purchase from companies acting ethically and responsibly" (BBMG, 2011).
Sustainable Development	Defined by the Brundtland report (WCED, 1987, p.8) as meeting "the needs of the present without compromising the ability of future generations to meet their own needs."

APPENDIX A

Interview Questionnaire

- Are you familiar with the LCA tools (software- or web-based program) that are available to facilitate the process of developing more environmentally friendly products?
- What is your role as a designer when it comes to developing an environmentally friendly product in the company? How much are you involved in the process?
- Have you worked on meeting eco-label criteria for a product in your past experience? If yes, what are the challenges you are facing once trying to meet the eco-label criteria? Time consuming? Expensive?
- Was the toolkit simple to understand?
- What do you believe are the benefits that this toolkit may offer for designers in the industry?
- What do you dislike about the toolkit? What improvements would you suggest?

APPENDIX B

Students Workshop Questionnaire

Name:

1. Do you find the toolkit simple to understand?

2. Was the manual clear in explaining the connection between the cards and diagram?

3. What do you dislike about the toolkit? What improvements would you suggest?

APPENDIX C

Survey Questionnaire

This study is analysing eco-labels used for certifying personal computers and the tools (software- or web-based programs) that are used for developing environmentally friendly electronic products and the ones used for meeting the eco-label criteria. For further information, please contact Hala Zohbi, hzohbi@connect.carleton.ca

All the information collected is anonymous and used solely for this study. Your responses are confidential and are in no way traceable to you. The survey would take 8 minutes to complete.

- What is your occupation?

□ Designer
□ Engineer
□ Manufacturer
□ Other (Please Specify)__________

- What types of tools (software- or web-based programs) do you use to calculate the environmental impacts of products?

□ SimaPro LCA Software
□ Eco-Indicator 99
□ SolidWorks Sustainability
□ GaBI Database
□ Greenfly
□ Sustainable Minds
□ Eco Materials Advisor
□ ReCon Tool
□ Other (Please Specify) ________________

- How would you rate the effectiveness of the current tools you are using on meeting eco-label criteria?

□ Not effective at all
□ Somewhat effective

□ Neutral

□ Effective

□ Very effective

- Do you work specifically on developing electronics, such as PCs? If not please specify ____________

- Do you meet eco-label criteria for your products?

□ Yes

□ No

- What causes the process of meeting eco-label criteria to be complicated for you?

□ Time consuming

□ Expensive

□ Do not know how

□ Do not have the right tools to do so

□ Other (Please Specify) _________________

- What are the main factors you value in the tools you are currently using? (You may choose more than one option)

□ User friendly

□ Guides material selection

□ Calculates LCA of product

□ Guides production process selection

□ Other (Please Specify) ________________

- What do you hope for these tools to include in order to facilitate the process of meeting eco-label criteria?

□ Calculates toxicity

□ Calculates possible human health damage

□ Analysis regional materials eligibility requirements

□ Up-to-date with government

□ Other (Please Specify) ________________

- Additional Comments?

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