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Environmental Product Information Flow

Communication of environmental data to facilitate product improvements in the ICT sector

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Abstract

With the shift in emphasis from process to product-oriented policies and programs within government and industry in the European Union, there is a created need to manage impacts from products throughout their entire life cycle. This has in turn has created both a demand for and supply of environmental product information to various actors in the product chain that ultimately influences and determines the environmental performance of products.

This research investigates the current flow of environmental product information within the Information and Communication Technology (ICT) sector from a product chain perspective. It examines how environmental product information flow influences the environmental performance of ICT products both from the product development and product end-of-life management perspectives. The research has highlighted that while industry is taking significant steps towards collecting product data throughout the supply chain there are current gaps in the flow to downstream actors such as retailers, consumers and end-of-life facilities.

These issues need to be addressed in order to improve the overall environmental performance of ICT products. Examples found in literature and the active research that address these gaps are provided within the body and main findings of this paper. Key findings of the research are examined in the context of the "essential requirements" found within the Working Paper for a Directive on the impact on the environment of electrical and electronic equipment (EEE). It was found that the requirement for estimating the lifecycle inputs and outputs and the associated environmental impacts would be most difficult to meet without a comprehensive strategy. However, the requirement for information to be passed along to downstream stakeholders provides incentives to fill the identified gaps found in this study.

Executive Summary

Within the European Union and globally there has been a recent focus of attention on the environmental impacts associated with electronic and electrical equipment (EEE). Initial government focus has begun to address the environmental impacts associated with product disposal, including the use of finite resources and hazardous waste generation. Producer responsibility legislation has been passed in eight Member States and also at the Community level, with the approval of the WEEE Directive by the European Commission. More recently product-focused policies that take a more holistic approach to environmental aspects of EEE have been articulated through the Commission's integrated product policy (IPP) Green Paper. The Working Paper on the impacts on the environment from EEE, is considered to be a representation of many of the elements of IPP listed in the Green Paper, and focuses on improving the environmental performance of EEE by influencing design considerations.

At the same time original equipment manufacturers (OEMs) are developing environmental management systems and eco-design programs to manage the environmental impacts associated with the production of their products. Industry has also begun to take a more proactive life cycle approach to improving the environmental performance of EEE, from raw material extraction to end-of-life disposal. Public and Corporate customers are increasingly demanding that manufacturers supply components and products that have improved environmental performance.

These trends have created both a demand for and supply of environmental product information along the ICT product chain. Environmental product information flow is required to improve the environmental performance of products, not only by manufacturers and their suppliers, but also customers and end-of-life facilities. However, increased data flow has inherent costs associated with it and must be weighed against the potential benefits it can provide. If environmental product data being generated are not used to improve the environmental performance of products or reduce risk, then the value of such activity is questionable.

It is the aim of this research to investigate how the flow of environmental product information along the ICT product chain influences the environmental performance of finished products from a total life-cycle perspective. By determining the connection of various channels and interfaces of current environmental product data flow to pre-determined environmental improvement criteria, it is anticipated that is possible to draw conclusions on what an efficient (balance between economic, social and environmental) level of data flow along the product chain may include.

To fulfil this aim a literature review is conducted to understand the relevant flows of environmental product information in the ICT product chain from the manufacturing supply chain, retailers consumers, governments, and end-of-life perspectives. This is presented in *sections 3 and 4* of the research and provides a basis for comparison with the findings from actual experiences of actors in the product chain. The situation in reality is provided by interviews with actors in the ICT product chain mainly from the perspective in Sweden.

What has become evident through the investigation of product environmental information flow and the linkage to product environmental improvements is that, although information is important for product improvement, it is not the driver for the change. From the findings in this research, it would appear that it is the key legislative, policy, (WEEE, RoHS, IPP, EEE, etc.) and market drivers (public & corporate purchasing) that are influencing product design, end-of-life management and subsequently environmental improvement, more directly than the actual flow of environmental product information.

In addition when discussing what an efficient amount of environmental product information flow might entail, it appears that this is highly dependent on the OEM environmental strategy and the level of responsibility it assumes for the lifecycle of the product.

There has been a considerable amount of effort by numerous manufacturers to document the environmental attributes of their products. This increased demand for information from corporate and public purchasers has created the need for the ICT manufacturing sector to standardise information requests to facilitate efficient data flow. This has been demonstrated as Industry Associations in Europe, Japan, and the US have or are in the process of developing standardised formats for this purpose. Given the varying needs for this information, such as customer demands, legislative compliance and maximising end-of-life value, complete declarations of material content component or product weight is considered to be representative of efficient in this case.

As these initiatives progress, the level of information concerning material content of ICT products will be substantially greater than it is today, providing opportunities to improve products. Depending on the success of these initiatives, data requests could be expanded to include information on material and energy inputs and outputs along the manufacturing chain.

Despite this increased knowledge, end-of-life treatment facilities operated independently of OEMs require more information than they are now receiving concerning the location of hazardous materials in components and products, including knowledge of the DfE aspects of products. Interfaces need to be developed that allow for this information to be communicated to treatment facilities in an efficient, cost-effective manner.

What has been less obvious to determine is what an efficient level of environmental product information might entail concerning private consumers. Although industry favours ISO Type II declarations, they have rarely been promoted or marketed to consumers at retail stores in Sweden. Arguments put forth by the ICT industry against the use of Type I eco-labels are somewhat justifiable given the short development times in which products are brought to market. However, the options for a suitable alternative to stimulate demand for environmentally improved ICT products in the private consumer market are uncertain.

Standardisation of product data in general has been highlighted as key to promoting improved flow of information and subsequently improved environmental performance of ICT products. Specifically, the harmonisation of eco-labelling criteria, life-cycle inventory data documentation, chemical legislation and material declaration formats are necessary considering the international structure of the ICT sector.

Key findings concerning efficient information flow are examined in the context of the "essential requirements" found within the Working Paper for a Directive on the impact on the environment of electrical and electronic equipment (EEE). It was found that the requirement for estimating the lifecycle inputs and outputs and the associated environmental impacts would be most difficult to meet without a comprehensive strategy in place, given the lack of information currently available in the product chain today. However, the requirement for information to be passed along to downstream stakeholders provides the necessary incentives to fill the identified data gaps found within this research.

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1. Introduction

1.1 Background – Statement of the Problem

Traditionally, both governments and industry have tended to focus their environmental policies and programs towards addressing process-related environmental impacts from manufacturing activities. Large investments by companies towards ‘end-of-pipe’ technologies to manage air and water emissions were common practise in the 1980’s. Governments went to great lengths to monitor and enforce pollution emission targets imposed on businesses.

However, more recently there has been a shift in focus from process type considerations to more of a product-focused approach. By viewing environmental aspects from a product perspective, the entire life cycle of the product is considered, from raw material extraction to end-of-life disposal. European governments and international organisations have recently been developing product-focused policies and regulations, voluntary product stewardship initiatives, mandatory extended producer responsibility (EPR) programs, integrated product policy (IPP), as well as expanded environmental criteria for procurement and environmental labelling schemes.[1]

Industry has also begun to embrace product-oriented approaches by shifting environmental focus from solely process-oriented environmental management towards product and supply-chain focused programs and activities. Product development strategies that incorporate eco-design and procurement are commonly being implemented in companies more and more frequently. Management systems are being developed to not only address environmental impacts of processes, but of products and entire product chains as well.

The electrical and electronic equipment (EEE) sector provides an interesting example of this shift in policy approaches. EEE production is one of the fastest growing sectors of the manufacturing industry today. New applications of EEE are increasing substantially, as new products are becoming more and more a part of people’s daily lives. At the same time the rate of technological improvement of these products has lead to a situation where they are replaced much more rapidly than in the past, creating increased demand for raw materials and subsequently a significant amount of waste. EEE also contains many hazardous chemicals and components, and if not properly treated can pose environmental problems when the products reach their end-of-life.

This has prompted individual member states including Sweden, Italy, The Netherlands, Belgium, Austria, Germany, Denmark, and Finland to introduce national legislation concerning the waste management of this product group. In light of this, the European Commission’s DGXI Environment Directorate has produced two draft directives on Waste Electrical and Electronic Equipment (WEEE) and Restrictions on the Use of Hazardous Substances (RoHS), both of which have been recently approved by the Commission.

More recently DG Enterprise, has released a Draft EEE ‘new approach’ Directive, also referred to as the ‘design directive’. This measure aims at addressing the impact on the environment from electrical and electronic equipment, at the same time ensuring that the EU internal market functions properly. It takes a holistic perspective, considering the various environmental effects throughout the product

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[1] Environment Canada. (1998). *Understanding the Environmental Aspects of Electronic Products: A Life Cycle Assessment Case Study of a Business Telephone*. Ottawa: Environment Canada. p. 1

life cycle. DG Enterprise claims the EEE Directive reflects the EU determination to integrate sustainable development and product policy into other policy areas, including enterprise policy.[2]

Customer pressure, legislation and company specific initiatives have increased the demand to develop environmentally improved products. **Product-focused policies have created both an increased demand and supply of environmental product information along the entire product chain**. By taking a more holistic approach towards addressing the environmental concerns associated with products there is a need for a greater coordination between all the actors involved. Communication of product data are needed both to facilitate the goals of government and industry to improve the environmental performance of products and to present and market the positive results. In some cases product data flow is mandated specifically in the legislation, and at other times it can develop in response to legislation. Voluntary eco-labelling schemes have not only created the demand for environmental product data flow towards consumers, but have created the need for systems to collect the data along the supply chain. To improve the environmental performance of Electrical and Electronic Equipment (EEE), manufacturers have embraced such programs and tools as eco-design, environmental management systems, and life cycle assessment (LCA). In order to implement these efforts, product data are required from all actors in the product chain. Information concerning the product flows in many directions and in various formats.

Increased data flow has inherent costs associated with it and must be weighed against the potential benefits it can provide. If environmental product data being generated are not used to improve the environmental performance of products or reduce risk, then the value of such activity is questionable. The EEE Directive as it reads today, will increase the demand and supply of product environmental information along the chain substantially. **In light of this, more knowledge on the link of environmental product information flow to product improvement is urgently needed.**

1.2 Aim of the Research

It is the goal of this research to investigate how the flow of environmental product information along the ICT product chain influences the environmental performance of finished products from a total life-cycle perspective. By determining the connection of various channels and interfaces of current environmental product data flow to pre-determined environmental improvement criteria, it is anticipated that is possible to draw conclusions on what an efficient (balance between economic, social and environmental) level of data flow along the product chain may include.

The conclusions made concerning ‘efficient’ environmental product information flow will be systematically compared with the “essential requirements” of the Working Paper for a Directive of the European Parliament and of the Council on the impact on the environment of electrical and electronic equipment (EEE) (Version 1.0). This ‘New Approach’ directive calls for some far-reaching implications for ‘current business practices’ in the ICT sector concerning product environmental information flow. It is expected that insight concerning efficient environmental product information flow compared with the requirements outlined in this initiative could aid in the on-going discussion concerning the suitability of this approach by the European Commission.

1.3 Scope and Limitations

Electrical and electronic equipment (EEE) covers a broad spectrum of products used by businesses and consumers. As defined in the WEEE Directive (Waste from Electrical and Electronic

[2] DG Enterprise Press Release. (2001). *Commission launches a new approach to free movement of green electrical goods.* [On-line] - Available http://europa.eu.int/rapid/start/cgi/guesten.ksh?p_action.gettxt=gt&doc=IP/01/313|0|RAPID&lg=EN [20 April, 2001]

Equipment), EEE includes equipment that is dependent on electric currents or electromagnetic fields in order to work properly, and includes equipment for the generation, transfer and measurement of such currents and fields. It applies to products that are designed for use with a voltage rating not exceeding 1000 Volts for alternating current and 1500 Volts for direct current.[3]

EEE is further divided into 10 categories of which the Information and Communications Technology (ICT) sector is delineated. ANNEX IB provides a list of indicative product families that fall under the category of ICT. The content of this list is presented below and provides a mental picture of the types of products that make up the ICT equipment sector.

- Centralized data processing:
- Mainframes, Minicomputers, Printer units
- Personal computing: PCs Lap-tops, Printers
- Facsimile
- Electrical and electronic typewriters
- Pocket and desk calculators
- User terminals and systems
- Telex
- Answering systems
- Copying equipment
- Telephones: Cellular, Cordless & Pay telephones

The scope of this research will be limited to include product environmental data flow pertinent to the ICT classification of EEE. The ICT product group is undoubtedly the fastest growing product family by sales in the EEE sector. Product introduction cycles are decreasing more rapidly than in any other category of EEE, exemplifying the problem of obsolescence and associated waste implications.

Due to the international structure of the ICT production chain and relative markets it is difficult to focus exclusively on any particular geographical region. Therefore, international developments concerning product data flow will be included where deemed appropriate. However, a European context, with particular emphasis on initiatives in Sweden, is considered to be the primary focus area of this research

Although environmental data flow applicable to ICT *products* is central to this research, *process* related data are sometimes also referenced. Since this research aims to identify what information flow regarding product attributes will inherently lead to environmental improvements, process data cannot be totally excluded from the scope. This is in light of the incredible resource intensity of certain portions of the manufacturing chain discussed in *section 2.3*. Although, this information may not be applicable to all actors in the product chain, it is important for measuring the environmental improvement of ICT products. However, given the time frame associated with this research, it is not feasible to incorporate all process related data flow.

Defining of Product Environmental Information Flow

The definition of product environmental information flow used in this thesis can be visualised on two levels. The first level implies the flow of absolute environmental information concerning the physical attributes of the product such as the material and chemical constituents, energy consumption, weight,

[3] Commission Proposal COM (2000) 347 provisional. Proposal for a Directive Of The European Parliament And Of The Council on Waste Electrical and Electronic Equipment. p. 57.

upgradability, reusability, recyclability, etc. This information is communicated to actors outside of the manufacturing chain, such as retailers, consumers and end-of-life facilities. The second level entails the flow necessary to generate and collate the absolute data in the supply chain. Original Equipment manufacturers (OEMs) are responsible for gathering product environmental information in the supply-chain and must develop systems to retrieve information and store it in data warehouses.

Important to also distinguish is the level of environmental improvement of products that shall be considered when determining the linkage to product environmental data flow. Brezet (1998) distinguishes four levels of improvement according to the type of change taken, and the eco-efficiency level attained. Eco-efficiency was coined by the WBCSD in 1991 and is defined as declining resource consumption per value added. [4&5] Jansen and Vergragt (1992) claim that in order to become sustainable[6] within the next 50 years, the level of environmental pollution from production processes and products must be reduced to 40% of what it is today, representing an improvement in eco-efficiency of products by a factor of 20.[7] As a provisional target, an improvement factor of 4 has been estimated as a necessary level to be achieved within the next 15 years[8].

The illustration below depicts the 4 levels or types of changes from eco-design efforts, as a means of attaining the improvements needed to reach sustainability in the next 50 years. These include, Product improvement, Product redesign, Function innovation and System innovation.

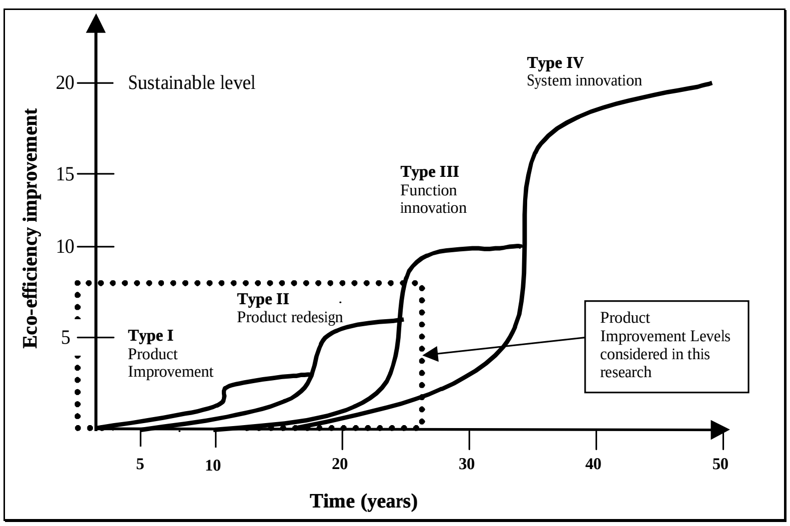

Figure 1-1: Product Improvement Levels Considered

Product improvement implies partial changes and enhancement to products already existing in the market. In this level production processes and the product itself stays relatively the same with eco-efficiency

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[4]WBCSD. (2000). Eco-efficiency: Creating more value with less. [On-line] Available: (http://www.wbcsd.org/newscenter/reports/2000/EEcreating.pdf, [2001, August 3]]

[5] As defined by the WBCSD: Eco-efficiency is achieved by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity through out the lifecycle to a level at least in line with the earths carrying capacity. In short it is concerned with creating more value with less impact.

[6] Sustainable level considering expected population growth, carrying capacity and production growth

[7] Jansen, L., Vergrat, P. (1992). *Sustainable Development: A Challenge to Technology*. Leidschendam, Netherlands: Ministry for Housing, Physical Planning and Environment.

[8] von Weizsäcker, E.U., Lovins A.B., Lovins, L.H. (1997). Factor Four: Doubling Wealth, Halving Resource Use. London: Earthscan.

improvements at the most around factor 2 or 3.[9] Product redesign involves the replacement or improvement of components with the use of non-toxic materials, improved recycling and disassembly, improved product distribution, parts reuse and energy-use reduction with respect to all components over the life-cycle of the product. Eco-efficiency improvement can be as high as a factor of 5.

Product improvements of Type-1 and Type-2 are considered within the scope of this research. Type-3 and Type-4 are only considered where practical examples exist in the literature. This approach may seem unmotivated at first, but considering the perspective of this research it is justifiable for the following reason. The aim of this research is to determine the linkage of product environmental information flow to product improvements for the ICT sector to be compared to the provisions of the EEE Directive. Since the directive addresses the sector as a whole, placing requirements for product information flow on all manufacturers placing products on the market, far reaching innovations cannot be applied in general to the entire sector.

This research incorporates a broad approach by investigating environmental product flow along the entire product chain. By considering all actors in the chain, the methodology provides an appreciation of the complex interactions and tradeoffs involved. However, this approach has its limitations especially considering the time frame of this study. Time restrictions do not allow for detailed analysis of the factors affecting environmental product information flow, therefore often generalising the complex scenarios. This must be considered when interpreting the recommendations put forth concerning efficient flow.

1.4 Methodology

In order to understand the current flow of environmental product information along the ICT product chain a comprehensive literature review has been undertaken and presented in *Sections 3 and 4* of this thesis. Background information pertaining to the structure of the ICT product chain, existing forms of communication tools, demand and supply factors and subsequent data flow along the chain have been instrumental in providing a point of departure for this research.

This background knowledge has provided the basis for determining what factors are imperative when considering what an efficient level of environmental information might entail in the ICT product chain, sufficient to lead to environmental improvements. The issue of defining 'efficient' level of environmental information that is necessary to improve the environmental performance of ICT products is dealt with in the following context.

The issue of environmental improvement must first be defined, for which a number of sources of information have been used. Supporting life cycle assessment (LCA) studies relevant to the ICT sector, eco-label criteria and design guidelines have been used to understand where the major life cycle impacts from ICT products occur. With an understanding of the impacts and causes of the impacts, categories of improvement criteria are suggested. In addition to LCA studies, the Swedish Chemical Strategy proposed criteria for the phase out of dangerous substances is incorporated into the improvement criteria mentioned above.

An efficient level of environmental product information flow is considered in this case to be when information flow is at a level that leads to environmental improvements in products without sub-optimising economic and technical aspects while at the same time considering all relevant and future legislation.

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[9] Brezet, Han., Rocha, Cristina. (2001). Towards a model for product-oriented environmental management systems. In M. Charter & U. Tischner, Sustainable Solution: Developing Products and Services for the Future p. 247. Sheffield: Greenleaf Publishing.

Given the developed methodology for determining environmental improvement criteria, existing experiences of environmental data flow will be presented according to the position in the product chain and environmental improvement category that is addressed. These existing experiences (found in the literature) should assist with the task of determining where gaps exist in product environmental data flow to adequately address improvement criteria suggested earlier.

Qualitative informal interviews with key actors in the ITC product chain, including component and subassembly suppliers, OEM manufacturers, retailers, public purchasers, government authorities, Industry Associations, product information system project coordinators, and treatment facility operators will provide a platform to assess the current demand/supply of environmental information in reality. This will assist in qualifying any differences in current flow of environmental data compared with data needed to meet the improvement criteria. Subsequently, any identified environmental product information flow demand can be assessed in relation to the factors that determine efficiency, including a balance between legislative demands, technical considerations and costs.

2. The ITC Equipment Industry Sector

By no means a complete assessment of the ICT industry, this chapter of the research aims to provide the reader with a general understanding of the ICT product chain with a focus on the manufacturing and distribution industry. Information on the structure and location of the industry provides a background to understand the complexities associated with the flow of environmental information in the manufacturing sector of the ICT product chain. Further in the chapter, life cycle environmental impacts of ICT products are discussed in order to highlight where product improvements efforts can be focused. In the end of this section environmental improvement criteria are suggested, based on input from identified life-cycle impacts and eco-label criteria, which are used throughout this thesis as a benchmark to investigate the level of environmental product information flow necessary to improve the environmental performance of products.

2.1 Profile of the Industry

ICT equipment sector companies, as with all electronics companies, are under extreme pressure to bring to market innovative products that are cheaper, smaller, lighter, and better quality than the previous models, all in shorter time cycles. This demand has created a trend towards a shift in labour intensive manufacturing capacity to areas where operating costs are substantially lower, mainly South East Asia. Despite this trend, electronics manufacturing continues to play a vibrant role in the economies of North America and Europe and Japan.

Original equipment manufacturer's or OEMs (more accurately described now as original brand-name owners) have traditionally owned and operated manufacturing capacity for much of the components and assemblies included in finished products. However, the most prominent recent trend in electronics sector is the move by OEMs to contract out manufacturing to electronic manufacturing service providers (EMSs) or contract electronic manufacturers (CEMs). Despite this, OEMs in Japan, Europe and the United States continue to dominate the design of ICT equipment, while benefiting from reduced overhead costs and reduced manufacturing time as a result of shedding manufacturing infrastructure. This re-positioning of the traditional manufacturing sector has substantially increased the need for improved communication between component manufacturers, CEMs and OEMs. OEMs are now demanding that CEMs provide component traceability, by providing serial numbers of every part in the finished product. This has driven the need for integrated data collection among contract manufacturers that also has implications to improve the flow of environmental data as a 'tag along' item.

Pacific Rim countries lead the production of active and passive components and the assembly of printed circuit boards for the world market. Japan has been the undisputed leader in the Asian electronics manufacturing industry and continues to provide the equipment necessary to manufacture advanced electronic products throughout Asia.[10] However, governments in countries such as South Korea and Taiwan, continue to financially support research and development for companies in an attempt to capture some of Japan's market share in semi-conductor design and flat screen display manufacturing. Singapore is a attracting a lot of investment in research and development from foreign firms in North America and Europe, increasing its reputation as the 'intelligent island'. Malaysia continues to build its semiconductor and electronic component manufacturing, however still lagging behind other Asian nations.

As the economies of these nations continue to strengthen the associated labour costs also continue to rise and as a result companies have been moving labour-intensive parts of production (IC packaging

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[10] WTEC. (1997). Electronics manufacturing in the Pacific Rim. [Online]. Available: http://itri.loyola.edu/em/toc.htm. [2001, May 19]

and testing) to counties such as the Philippines, Thailand, Indonesia and China. This has forced Pacific Rim countries to focus on developing proprietary technologies and production of higher value added components that require more capital-intensive investments.

Asian nations are making it increasingly more attractive for foreign companies from Europe, North America and Japan to move their most capital-intensive facilities to this region. Also, with future consumer markets expected to expand enormously in this region as rising income levels fuel increased demand for electronic products, companies are positioning themselves to participate in these growth markets. Countries such as Korea, Singapore, Taiwan and Malaysia are working at loosening the reliance on Japan, Europe and US technologies to become more competitive in the global markets.

The world electronic components manufacturing industry will continue to consolidate, as the technical and capital demands of next-generation microelectronic devices strain the resources of many vendors. This trend is increasing at an alarming rate today. A United Nations survey has predicted that massive-scale consolidation in the electronics industry will effectively eliminate medium sized businesses. The World Commodity Survey from the UN Conference on Trade and Development suggests that large manufacturers will acquire others to become global giants, while smaller niche market companies will profit from specialisation. Although, the industry will drastically change shape the survey concluded that the industry would still contain more than 100 companies by 2005.[11]

2.2 Description of the Product Chain

The combined chain of actors or stakeholders that are involved in the total life cycle of the product is often called the product chain or product life cycle.[12] Product chains include flows of products, raw materials, currency and the associated information channels to coordinate it all.

A simplified model is presented below that provides the reader with a visual representation of the typical actors in the chain considered for this research. In reality the product chain, particularly the manufacturing supply-chain is far more complex and detailed than depicted in the model. Although government authorities are not explicitly listed in the model, they are an important component influencing all actors in chain in some form or another. Other actors not included in the model but nonetheless important to the product chain are financial institutions, insurers, Industry Associations, NGOs and transport enterprises.

[11] EDTN Network. (2001). Consolidation ‘wipe out’ by 2005 says UN survey. [Online]. Available: http://www.electronictimes.com/story/OEG20010802S0003 [2001, August 2]

[12] Garcia, Raquel. (2000). Product Chain Management to Facilitate Design for Recycling of Post Consumer Plastics: Case studies of polyurethane and acrylic use in vehicles. Lund: IIIEE Communication 2000:2. p. 10

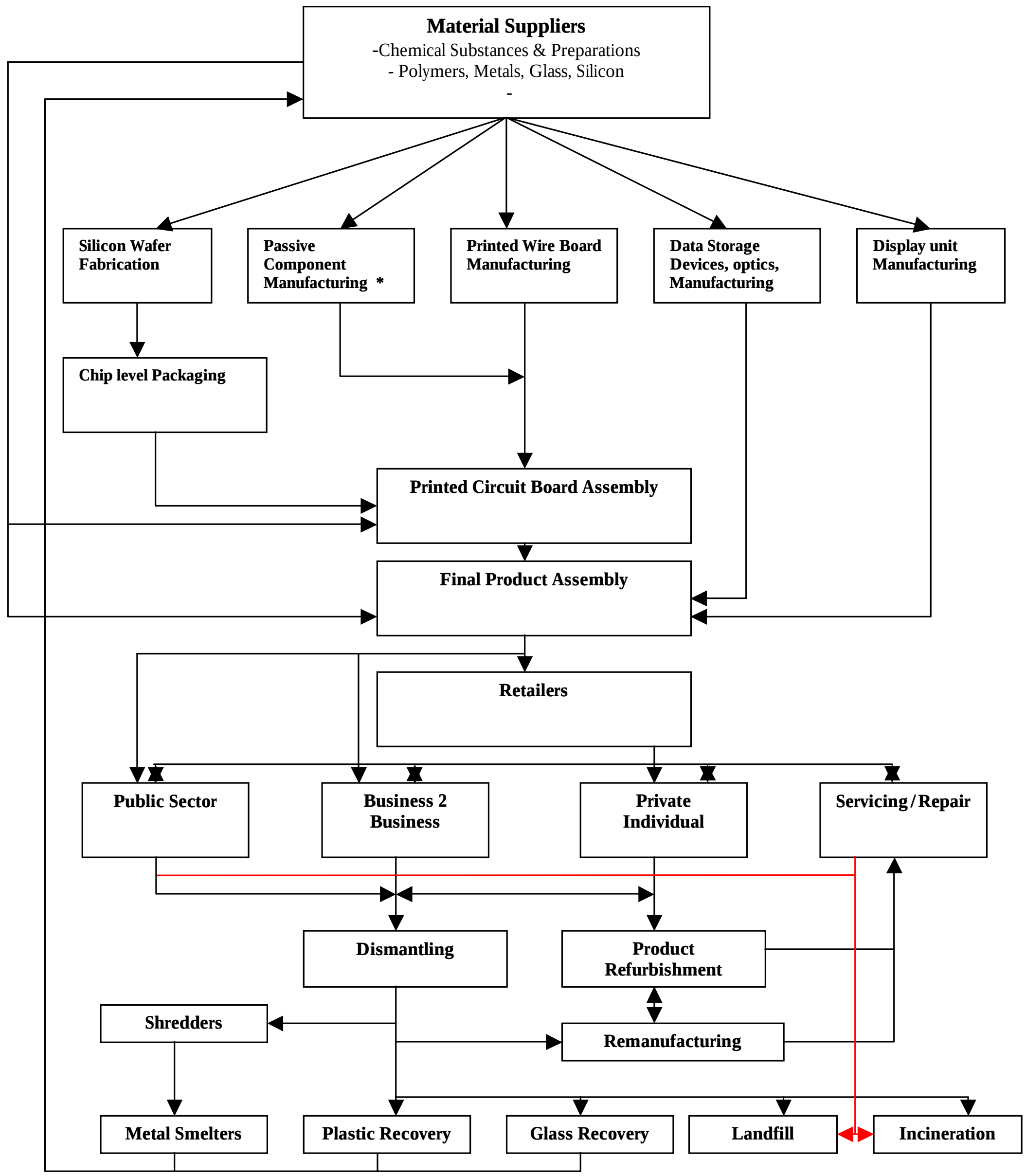

Figure 2-1: Representation of the Actors in the ICT Product Chain

2.3 Life Cycle Environmental Impacts of ICT Equipment

Before discussing the negative environmental impacts associated with ICT products, it is important to acknowledge the potential contribution towards sustainable development that ICT applications can provide. Two examples are cited to emphasise this point in practice.

The use of ICT has the potential to drastically reduce business travel and hence the demand for fossil fuels and the associated environmental impacts such as localised air pollution and the emission of greenhouse gases. Through video-conferencing enabled by ICT technologies face to face business trips can be eliminated or drastically reduced minimising yearly travel between firms. Similarly, work anywhere, anytime logic has the potential to reduce transportation impacts substantially.

ICT technologies can also reduce the environmental burden within the entertainment sector. Cinemas currently use projectors that require celluloid film to display movies. Most of this material ends up as waste only after a few weeks of use. Considering that one movie release (7000 copies distributed to European Cinemas) can consume up to 28,000 km of this film, by switching to digital files and High Definition (HD) technology, considerable waste could be avoided and the quality of the picture improved. Reduced material and chemical emissions related to the manufacture of film could also be avoided, not to mention the reduced transportation and associated fossil fuel use and emissions associated with distribution. Similar reductions in environmental impact are also found associated with digital cameras and video recorders, which are becoming more and more affordable with every new product generation.

However, when considering the environmental problems associated with the equipment itself, there are some general observations from life cycle analysis (LCA) studies that highlight where the greatest impact occurs. Depending on the lifetime of ICT products, the greatest impact is related to the use phase of the products lifecycle. Electrical energy consumption used during operation and the associated environmental impacts such as the formation of photochemical smog, acid precipitation, greenhouse gases and the depletion of non-renewable resources account for this. It should be noted, however, that often the case with LCA studies in the ICT sector is the fact that chemical substances often do not have sufficient data concerning their risk to human health and the environment. Therefore, their contribution is not always fully accounted for and accurately reflected in the total impact scenario for the electronic product studied. This accompanied with the fact that current societal concern is greatest with respect to regional and global climate change issues, is herby noted but not substantiated.

The following section outlines the main environmental impacts associated with the lifecycle of ICT products that are currently being marketed. Environmental impacts associated with historical products are mentioned where applicable. In addition, options for improved environmental performance during the manufacturing stage through Clean Technologies have been noted. These however, are only representative of efforts that are being undertaken and are by no means a comprehensive analysis of existing technologies.

Materials present in ICT products can pose environmental impacts during multiple phases of the product lifecycle. Materials used in products will be presented in *section 2.3.1*, however a general inventory of common materials and substances found in assembled ICT products is presented in *section 2.3.4.*

2.3.1 Raw Material Extraction

There are numerous materials that are extracted from the environment that are used for the production of ICT products. Typical metals include copper (Cu), iron (Fe), aluminium (Al), cadmium (Cd), chromium (Cr), nickel (Ni), lead (Pb), tin (Sn), lithium (Li), indium (In), bismuth (Bi), silver (Ag), gold (Au), platinum (Pt), palladium (Pd), beryllium (Be), gallium (Ga) etc. Other elements commonly used include antimony (Sb) arsenic (As), boron (B) and phosphorus (P), silicon (Si). Fossil fuels are used both as a source of energy as well as a source of raw materials for the production of polymers, additives and basic chemicals.

Extraction of minerals from the environment is mostly via mining and entails moving large quantities of material in the process. Often the mineral of interest is embedded in other unwanted material and must be removed in the process causing extensive waste by-products. Therefore the use of energy and the creation of waste are the two main impacts associated with the mining process. Loss of habitat and visual pollution are also associated with mining operations. Fossil fuels used to manufacture polymers, additives and basic chemicals often have air emission impacts associated with the extraction process.[13]

2.3.2 Production/Manufacturing

With all ICT products, a number of 'building blocks' are assembled in different combinations to make unique product types. All ICT products contain printed board assemblies (PBA), in which components such as integrated circuits or processors, capacitors, resistors etc. are mounted on printed wire boards. Data storage, reading and writing components, antennas, sensors, connectors, cables and wiring, housings, and batteries are commonly found in ICT products. Computers and other ICT products require video display units (VDU) of either the cathode ray tube (CRT) or liquid crystal display (LCD) formats. Considering the scope of this thesis, it would be unrealistic to be able to describe all the environmental impacts associated with manufacturing of these 'building blocks'. For this reason, only the most significant processes are described in the section below.

Integrated Circuit Manufacturing

To produce an integrated circuit (IC) four key production steps are required including, (1) crystal growing, (2) wafer fabrication, (3) testing and die (chip) cutting, and (4) wire bonding and packaging. Since the most environmentally significant stages include wafer fabrication and wire bonding they are briefly discussed below.

Wafer production is extremely energy and chemical intensive. In the manufacturing process very thin layers of silicon dioxide (SiO_2), aluminium and occasionally copper, are deposited on elemental silicon wafers. Following an oxidation step to protect the surface, photolithography and etching are used to imprint patterns into the surface, using different PAHs, halogenated organics and acids. Additional layers of SiO_2 are added and the etching process is repeated, followed by a final process called metalisation and passivation that provide the surface of the wafer with a protective seal. These processes require considerable amounts of energy, chemicals and bulk gasses that result in emissions of perfluoro compounds (PFCs), acid fumes, organic solvent and hydrogen chloride vapours. Due to the need for ultra-clean surfaces for circuits to function properly, large amounts of de-ionised water is required, that results in wastewater issues.[14]

Once wafer fabrication is complete, individual integrated circuits are mounted on metal alloy lead-frames and assembled into ceramic or plastic (thermo-set) packages. The lead-frames alloys that are typically used include copper or nickel-iron and are often coated with a thin layer of silver or silver-palladium in areas where gold is used to connect the chip to the lead-frame.[15] These processes typically are heat energy intensive and produce both material waste (epoxy, thermo-set plastic and ceramics) and metal and solvent bearing wastewater. Flame-retardants are added to the epoxy for fire safety issues, with tetrabromobisphenol A (TBBA) a bromine-based retardant most commonly used. Bromine-free alternatives have been developed recently and some semi-conductor manufacturers have begun to incorporate them.[16] The environmental issues associated with the use of brominated flame

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[13] Kliejn, R. et al. (1999). Electronic Consumer Goods case report. [Online]. Available: http://www.leidenuniv.nl/interfac/cml/chainet/ECG.html [2001, May 27]

[14] Gutowski, Timothy G. et al. (2001). *WTEC Panel Report on Environmentally Benign Manufacturing.*. International Technology Research Institute, Loyola College. p. 81

[15] Hedermalm, P., Carlsson, P., Palm, V. (1985). Waste from electrical and electronic products: A survey of the contents of materials and hazardous substances in electrical and electronic products. Nordic Council of Ministers. Tema Nord 1995:554. p. 20

[16] Bergendahl Carl-Gunnar. (2000). Electronics Goes Halogen-free: International Driving Forces and the Availability and Potential of Halogen-free Alternatives. *In 2000 IEEE International Symposium on Electronics and the Environment. ISEE-2000.* 53-58.

retardant (BFR) in ICT products are mostly confined to end-of-life phase and will be discussed in *section 2.3.5* below.

Printed Wire Board Manufacturing

Printed wire boards provide the platform for which electronic components such as processors or ICs, capacitors, resistors and other components are mounted. Typical PWBs manufactured today are composed of epoxy polymers and fibreglass composite material and have multiple levels (four to five). The composite material provides structural integrity and electrical insulation and is designed to withstand temperatures in the range of 140 °C to 160 °C, which are typical for Sn/Pb soldering processes.

Copper, either plated or etched, provides electrical circuitry within the PWB. Etched copper lines (within the plane of the boards) are typically passivated using an oxidation process that is water, energy, and chemical intensive. Connectivity between layers for the majority of boards is provided by plated through holes (PTHs). Plating baths, used for PTHs and for surface metalisation, use large amounts of water and complex chemistries (organic and inorganic compounds).[17] Energy is required to operate large industrial presses that are used to form the laminate boards. Solid waste is generated from the drilling process and trimming of the boards to the correct size and can be as much as 50% of the total material budget.

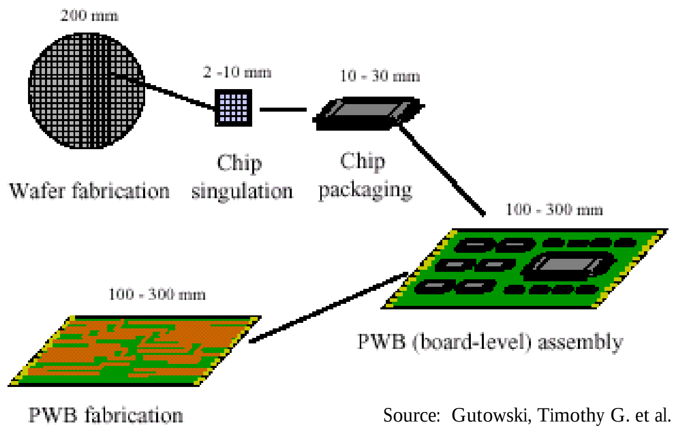
There have however been recent advances in technologies that have reduced the impacts associated with the manufacture of PWBs. For example, IBM has developed a laminate material derived from renewable resources (lignin derived from pine trees). DuPont commercially introduced a permanent resist that eliminates the need for the copper passivation (oxidation) process. These technologies use significantly less water and produce less waste than conventional PTH constructions.

Although many technological initiatives in PWB design have been driven by the need for greater efficiency and size reduction, there are inherent environmental benefits. These technologies require fewer layers for the equivalent amount of wiring which reduces the amount of raw material needed. Since the amount of drilling is minimized or eliminated, there is also less solid waste. The minimisation of the PWBs creates the need for more precise handling and alignment of the boards during the production process. By moving from mechanical alignment to vision alignment less waste is created during the trimming of the PWBs.

[17] Gutowski, Timothy G. et al. (2001). *WTEC Panel Report on Environmentally Benign Manufacturing.*. International Technology Research Institute, Loyola College. p. 82

Printed Board Assembly

Most completed PWBs today are prepared for board-level assembly using tin-lead (Sn-Pb) solder. The boards are heated to the melting point of the solder and packaged ICs, capacitors, resistors, and other components are placed on the boards, typically using pick-and-place mechanical systems. Flux (substance used to facilitate the flow of solder) must be removed from PBA after the soldering process. CFC's and trichloroethane solvents were previously used to remove the flux, however, recently these have been replaced by de-ionised water. Typical wastes associated with this process include waste solder, copper, spent solvents, scrap PWBs and organic vapours[18]. Figure 2-2 below illustrates the manufacturing steps that lead to the completion of the PBA.



Source: Gutowski, Timothy G. et al. (2001).

Figure 2-2: Stages in the assembly of PBAs (excluding capacitors, resistors and other components)

The use of Sn-Pb solder dominates the environmental concerns for this process and is a key area of concern for electronics end-of-life. However, recently in response to the RoHS Directive's ban on the use of lead in EEE products *(see section 3.1.2)* the electronics industry has been investigating and implementing alternatives for the tin-lead soldering process. This implies that other alloys will be used, requiring increased temperatures to melt the solder. Therefore all components and the PWB themselves must be able to withstand the increased temperature profiles needed. There are a number of trade-offs that seem apparent with the substitution of lead, which are further expanded in *section 3.1.1*.

Video Display Units (VDU)

Two dominant VDU types are widely used in the ICT sector today, cathode ray tube (CRT) and liquid crystal display (LCD). CRT) monitors are still the predominant technology used. Most medium to smaller sized CRT displays are manufactured in Japan and other parts of Asia. CRT's are comprised of a number of main components, which include an electron gun attached to the neck of the CRT, a deflection field, a funnel and faceplate. Essentially, the electron gun emits an electron beam that is guided through the deflection field to the funnel and finally imposed on the faceplate, to form the desired image. Inside the faceplate there is a very thin layer of fluorescent materials that glow when the electron beam hits it. The faceplate, neck and funnel are made from glass composite materials containing PbO, which is a major problem associated with the end-of-life phase if not properly treated.

The manufacturing process requires large quantities of heat energy to form and join the glass sections of the CRT. Substantial amounts of chemicals at various stages in the production are used and associated wastes include, spent solvents and vapours, acids, oxidizers, carbon slurry, surfactants,

[18] Gutowski, Timothy G. et al. (2001). *WTEC Panel Report on Environmentally Benign Manufacturing.*. p. 83.

chromate, solutions of phosphorus-containing substances, organic solvents, alcohol, caustics, chelating agents, silica based coatings, ammonia, zinc, aluminum and liquid and lacquer wastes.[19]

The manufacturing process for LCD's is more complex than that of CRT manufacturing in terms of types of material used and processing steps. In a recently published article that presents preliminary results of an LCA comparing LCD and CRT monitors, it was found that LCD monitors have more relative burdens on the environment associated with the manufacturing stage than CRTs.[20] Out of 16 impact categories only energy use and solid waste were greater for CRT manufacturing. Although less energy is required for the production of LCDs, sulphur hexafluoride (SF_6) is used as a process material and accounts for significant global warming impacts.

2.3.3 Transportation

Due to the global nature of the ICT equipment-manufacturing sector, transportation and distribution can represent a considerable environmental aspect. In addition, the increasing trend towards Just in Time (JIT) manufacturing practices has the potential to increase the impacts from transportation, primarily as a result of valuing time efficiency over shipping efficiency[21]. The value of components relative to their weight also is a deciding factor in increased air transportation. The increased use of air over ship transport to distribute electronic components around the world creates larger per unit environmental impacts associated with global warming and air pollution.

2.3.4 Use Phase

LCA studies consistently show that the highest impact associated with ICT products occurs in the use phase from impacts connected to energy consumption. Electricity consumed by office equipment in Europe equates to approximately 50 TWh currently and is expected to grow to 80 TWh by 2010.[22] This is compared with the total electrical consumption in Sweden of 143.3 TWh for domestic uses and 55.3 TWh for industry in 1999.[23]

During the use of some ICT products resources are consumed other than energy, such as batteries, toner and ink cartridges, data recording media, solvents, cleaning fluids, etc. These so called 'consumables' result in waste generation. Disposal of batteries in particular poses an environmental problem associated with the use phase. Although battery composition is now moving more towards nickel metal hydride (NMh) and more recently Lithium (Li) composites, in the past Nickel-Cadmium (NiCd) batteries were used for portable devices such as mobile phones and computers presenting an issue if not disposed of properly. Although, law in the EU requires collection programs for NiCd batteries, actual collection rates are relatively low, meaning that many batteries typically end up in the municipal waste stream and are landfilled or incinerated.

Electromagnetic fields (EMF) are created by VDUs, radio transmitters and receivers in mobile telephones. Although not proven scientifically, EMFs from CRTs are suspected of causing eye and

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[19] Johansson, D. (2000). The influence of Eco-labelling on Producers of Personal Computers: The potential for eco-labelling as part of an IPP approach for reducing chemical risks related to PCs in Sweden. Lund: IIIEE Communications 2000:03. p. 23

[20] Socolof, M. et al. (2001). Life-cycle Environmental Impacts of CRT and LCD Desktop Monitors. *In 2001 IEEE International Symposium on Electronics and the Environment ISEE-2001*. (119)

[21] Muller et al. (2000) Product based Environmental Performance Indicators: A methodology for selecting and supporting environmental metrics. *In 2000 IEEE International Symposium on Electronics and the Environment. ISEE-2000*. 93-98

[22] Baynes, A. et al. (2001) Environmental technologies and their business drivers. In M. Charter & U. Tischner, Sustainable Solutions: Developing Products and Services for the Future (344). Sheffield: Greenleaf Publishing

[23] Statistics Sweden (2001). Summary: Use of Heat and Electricity. [Online]. Available: http://www.scb.se/sm/en11sm0101%5Finenglish.asp [2001, September 6].

skin problems in some sensitive individuals.[24] Incidences of eye pain, headache, difficulties in closing eyes, sleeping difficulties and skin irritations similar to sun burns have been reported symptoms of electromagnetic hypersensitivity. Similarly, mobile phone research has not been able to scientifically link EMFs to any negative health effects. However, there are studies that indicate changes in human reaction times, effects on cell cultures, breaks in DNA strands and changes in transmission through the blood-brain barrier.[25] The on-going extensive research will eventually increase the fund of knowledge about health risks associated with mobile phone and VDU use.

Materials of Concern in ICT Products:

There are a number of materials of concern that are contained in ICT products that have the potential to be released during product use, recycling or disposal which have the potential to pose risk to human health or the environment.

Metals and Metalloids: Arsenic is used as a dopant in the manufacturing of semi-conductors to make the silicon conductive. The use of gallium arsenide is also used as a semi-conductor substrate for high-speed integrated circuits. However, it is important to note that these substances are contained in ICT products in concentrations far below those found naturally in soils, essentially eliminating any product-related environmental problems.[26] Beryllium is used as an alloy with copper for electrical contacts and springs for switching applications. It is also used as an integrated circuit substrate material and some lightweight housing applications.[27] Beryllium oxide fired to ceramic form is used as heat sink electrical insulators for electrical systems and devices.[28]

Cadmium may be used as a surface finish on printed board assemblies, or as a surface coating or plating on metals used in ICT products. Silver cadmium oxide is also used as contact alloys for relays and switches. Cadmium telluride and cadmium sulphide forms part of the building block materials for some photovoltaic cells.[29] Chromium VI is used as an anti-corrosion coating applied to metals that are susceptible to oxidation. Typically metal frames and housings used within ICT products can be treated with chromium VI. Chromium VI is also used as a hardener in surface coatings.

Tin-lead solder is currently the most common solder used to attach components such as capacitors, resistors and IC to printed wire boards. However, lead in the form of PbO is found in the glass of Cathode Ray Tubes (CRTs) primarily in the neck and the funnel, with lower concentrations in the faceplate.[30] Lead from CRTs is the single largest contribution of lead to the municipal solid waste stream from ICT products. The use of lead-acid batteries is primarily limited to large ICT products such as back-up batteries for use in case of power outages. Lead can also be found as a stabiliser in plastic components and has also been used as a molding agent in plastic manufacturing making the

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[24] Johansson, D. (2000). The influence of Eco-labelling on Producers of Personal Computers: The potential for eco-labelling as part of an IPP approach for reducing chemical risks related to PCs in Sweden. p. 26

[25] Ahlberg, Helena (Helena.Ahlberg@tco.se). (2001, August 16). Re: TCO 01 Certification – Mobile Phones. E-mail to Chris van Rossem (christopher.van-rossem.001@student.lu.se)

[26] Hedermalm, P., Carlsson, P., Palm, V. (1985). Waste from electrical and electronic products: A survey of the contents of materials and hazardous substances in electrical and electronic products. p. 21

[27] Bowman, Heather (Heatherb@eia.org). 2001, August 9). Re: Electronic Industry Alliance (2000) Material Declaration Guide. E-mail to Chris van Rossem (Christopher-van.Rossem.002@student.lu.se)

[28] CEFIC et al. (2000). Guidance Document on the Appliance of Substances under Special Attention in Electric & Electronic – Products. Version 02. CEFIC, EACEM, EECA, EICTA, EUROMETAUX. p. 15

[29] Bowman, Heather (Heatherb@eia.org). 2001, August 9). Re: Electronic Industry Alliance (2000) Material Declaration Guide. E-mail to Chris van Rossem (Christopher-van.Rossem.002@student.lu.se)

[30] Hedermalm, P., Carlsson, P., Palm, V. (1985). Waste from electrical and electronic products: A survey of the contents of materials and hazardous substances in electrical and electronic products. p. 39

plastic more pliable.[31] Mercury use in ICT products manufactured today is primarily contained to the backlight of liquid crystal displays. However, in older products mercury is sometimes contained in electrical switches and relays.

Precious and Rare Metals: Nickel is used as a surface finish for metal components for protection against corrosion. Nickel is also an alloy element for stainless steel components. Gold is decreasingly being used in ICT products. It has been used however, as a surface treatment for PWBs, and for the connections between the lead-frame and the silicon chip. Platinum and Palladium have been used in PWB surface and component finishes.

Halogenated Flame Retardants: Chlorinated and brominated flame-retardants are used in various plastic components as a fire protection measure. There are five main applications for flame-retardants in ICT products including in component encapsulations (ICs), cables, connectors, the product housing, and PWBs. In *section 3.1.3*, there is a chapter that outlines the most common types used today as well as alternatives to BFR. Nearly two thirds (59%) of the EEE industry's BFR consumption is destined for housings; printed wiring boards account for 30%; connectors & relays for 9% and wire & cabling for 2%.[32]

Short-Chained Chlorinated Paraffins (SCCPs): There is not a large usage of SCCPs in ICT products, however small amounts of are present in Mid-Chain Chlorinated Paraffins (MCCPs). The MCCPs are used as secondary plasticiser or flame-retardants for PVC or chlorinated rubber in cable insulation.[33]

Liquid Crystal Displays: More than 1000 substances can be used to form the liquid crystals in LCDs. In the early 1990's there was some reported concern over the use carcinogenic azo dyes[34], however more recent toxicological tests performed on liquid crystals have shown otherwise. For example, in a statement from the German Federal Environment Agency concerning the need for special disposal requirements of LCDs, the Agency proclaims that based on eco-toxicological tests there is no justifiable reason for such measures due to the content of the liquid crystals.[35] The selected liquid crystals tested (manufactured by Merck, Chisso Corporation and Dainippon Ink) were said to represent more than 90% of the substances on the market at the time. In addition, under the EU waste directive (91/689/EEC) LCDs without back light are not defined as hazardous waste.

PVC has been used for product housings due the inherent flame retardant properties that it contains. Considering the recent focus on environmental issues associated with incineration and landfill its use in ICT application has decreased. However, lower prices of other polymer materials such as ABS or PC has influenced the shift away from PVC to larger extents than environmental issues.

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[31] Bowman, Heather (Heatherb@eia.org). 2001, August 9). Re: Electronic Industry Alliance (2000) Material Declaration Guide. E-mail to Chris van Rossem (Christopher-van.Rossem.002@student.lu.se)

[32] Bromine Science and Environment Forum (2000.) An introduction to Brominated Flame Retardants. [Online]. Available: www.bsef.com [2001 July 14] p. 7

[33] CEFIC et al. (2000). Guidance Document on the Appliance of Substances under Special Attention in Electric & Electronic – Products. Version 02. CEFIC, EACEM, EECA, EICTA, EUROMETAUX. p. 6

[34] Hedermalm, P., Carlsson, P., Palm, V. (1985). Waste from electrical and electronic products: A survey of the contents of materials and hazardous substances in electrical and electronic products. p. 42

[35] German Federal Environmental Agency. (2001). Liquid Crystals in Liquid Crystal Displays: Statement of the German Federal Environmental Agency Concerning the Ecotoxicology of Liquid Crystals in Liquid Crystal Displays [Online]. Available: http://www.umweltbundesamt.de/uba-info-daten-e/daten-e/lcd.htm [2001, September 9].

2.3.5 End-of-Life (EoL)

According to the European Commission approximately 90% of all WEEE in the European Community is landfilled, incinerated or recovered without any prior treatment. Since ICT products contain considerable amounts of "substances of concern" input of hazardous materials into the disposal or recovery channels is expected.[36]

Incineration of ICT Waste

When ICT products containing brominated flame-retardants are thermally treated in municipal incinerators there exists the potential for extremely toxic polybrominated disbenzo dioxins (PBDDs) and polybrominated disbenzo furans (PBDFs) to form. Besides being extremely toxic to both humans and the environment, dioxins are persistent and known to have endocrine disrupting properties.[37] In addition, copper, which is a major component of ICT, products acts as a catalyst to form dioxins during the combustion process.

Poly vinyl chloride (PVC) is a common plastic found in ICT products and when incinerated has been shown to produce hazardous flue gas emissions. There has been considerable dispute over the chances of dioxins and furans forming when PVC is incinerated in controlled municipal incinerators. When temperatures are above 800°C the probability of dioxins forming are rare.[38]

Landfilling of ICT Products

Disposal of ICT products in municipal landfills has the potential to cause negative environmental impacts. Depending on the quality of the landfill the impacts associated with leaching of toxic metal and chemical substances will of course vary. However, over time it can be determined with some certainty that all landfills will eventually begin to leach substances through the geo-textile liners. The main concern with the landfilling of ICT is the associated leaching and evaporation of hazardous substances contained within the product.

Plastic components containing brominated flame-retardants and cadmium have the potential to leach from the plastic when landfilled. Lead contained in video display units (VDU) can also dissolve from the leaded glass in cathode ray tubes (CRT) when coming in contact with acidic leachate found in sanitary landfills. In older WEEE products mercury contained in electrical switches and PCB's from electrical condensers can be released when the equipment is crushed during transportation, handling or the landfilling process. Both metallic and dimethylene mercury has the potential to vaporise and migrate to the surface to be emitted to the atmosphere.

Recycling of ICT Products

Despite the positive environmental effects related to reuse and recycling of ICT products, if not properly pre-treated before recycling, negative effects can be expected. Research has shown that both dioxins and furans are formed when the metal fraction contained in printed boards assemblies (PBA) is reclaimed. This is in light of the fact that many PBAs have traditionally contained brominated flame-retardants. Plastic housing of PC's and other ICT products often contain brominated flame retardants and when extruded during the recycling process the formation of dioxins and furans. As a result most plastic parts of ICT products are not recycled in fear that they may contain brominated flame-retardants. Air emissions containing heavy metals such as cadmium and lead can arise when products are recovered.

Since a common method of recycling WEEE today includes mechanical shredding of products without prior disassembly, a number of concerns arise as a result. Halogenated flame retardants in plastics and PCB's in older equipment, when shredded, may be dispersed into the recovered metals and the shredder waste. Beryllium oxide contained in some components poses a potential health risk

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[36] Commission Proposal COM (2000) 347 provisional.

[37] Miller, G.Tyler. (2000*). Living in the Environment: principles, connections, solutions, Eleventh edition.* Pacific Grove: Brooks/Cole Publishing Company, p. 61

[38] Commission Proposal COM (2000) 347 provisional., p.14

to recycling staff when liberated during the shredding process. Toxic dust may be released which is known to cause Chronic Beryllium Disease (CBD) when there is prolonged exposure.

2.4 Development of Product Environmental Improvement Criteria

In order to develop environmental improvement criteria for ICT products used in this thesis, a number of existing sources have been consulted in the process. This has included reviewing life cycle assessment (LCA) studies on typical ICT products, including a personal computer (PC), mobile phone, and a radio base station to understand inputs and outputs of material flow and their relative impact on the environment at various life cycle stages. ISO Type I, II, III labelling scheme criteria has been especially supportive in developing the criteria used in this thesis. This methodology to develop improvement criteria is justifiable as eco-label criteria can be used as a measure of what is being publicly discussed and dealt with commercially by the ICT industry.

The European Eco-label unit of the European Commission (DG XI.E.4.) commissioned an LCA study to determine appropriate selection criteria for the product group Personal Computers (PC)[39]. A generic PC unit was selected and a life cycle inventory and impact assessment was performed to create a baseline case. A number of improvement scenarios were modelled and their lifecycle profiles were compared to the base case. The report claimed that the most significant improvements to PCs could be achieved if both the monitor and control unit energy consumption was reduced, if extension of the product lifetime was achieved, and if take-back and recycling of the product was ensured. Additionally, the report suggested to eliminate of use of brominated flame-retardants. Less significant improvements could be expected if recycled material was used in new products, if lead-free soldering was used and if all packaging is recycled.

Similarly, according to Nagel (2000) product or component innovation (or environmental improvement) is measurable by 5 key tangibles. These include 1) *recycled material content* 2) *minimum mass* 3) *minimum use of energy* 4) *minimum of environmentally hazardous substances* 5) *maximum reuse* 6) *maximum recyclability, when reuse is not feasible.* The degree of feasibility of the above tangibles differs with respect to product changes or innovations.

Given the above considerations *five environmental improvement categories are proposed*. Accompanying each category are examples of criteria or data requirements found in eco-labelling and declaration programs that represent information that is needed to improve the environmental performance of products.

1. Material/Substances Contained in Products, Packaging or Consumables:
Products:

a) Product weight
b) Battery type and weight
c) Presence of hazardous/substances of concern including,

Flame-retardants

- Declaration of type used in plastic components, printed wire boards, product housing, other plastic parts
- plastic parts greater than 25g must not contain halogenated flame retardants
- printed wire boards must not contain PBB and PBDE flame retardants
- Chloroparaffins 10-13 C atoms, not present in parts heavier than 25 g

Organic Compounds

- CFC, HCFC, PCB, PCT not present in products or used in manufacturing process

Polymers

- product cover (housing) or chassis does not contain PVC

[39] Atlantic Consulting, IPU. (1998). LCA Report: EU Ecolabel for Personal Computers. Environment Directorate: European Commission.

- Mechanical plastic parts > 25 g must not be painted, lacquered, varnished (end-of-life purposes)
- Mechanical plastic parts > 100 g shall be made of the same plastic (end-of-life purposes)

Recycled material

- CRT glass should contain minimum 2% recycled monitor glass

Metals

- Lead in mechanical plastic parts greater than 25 g – not present
- Mercury not present in products
- Beryllium oxide not present in products
- Cadmium not present in plastic materials and CRT's
- Cadmium in LCD screen must be declared
- Antimony not present in mechanical plastic parts greater than 25 grams

Batteries

- Labelled according to EU Directive 93/86/EEC if hazardous
- Declaration batteries defined as hazardous in the EU Directive 91/157
- Batteries must not contain mercury or cadmium

d) Packaging:

- Declaration of packaging used
- Materials not present in packaging
    i. Heavy metals according to 94/62/EC – Packaging Directives
    ii. CFC's, HCFC – in polystyrene
- Collection system exists for packaging
- Plastic packaging is marked according to DIN 6120, ISO 11469, or ISO 1043-1to4
- User manual and documentation is printed on non-chlorine bleach paper
- Product documentation to list post consumer content

e) Consumables:

- Cadmium is not present in inks, photo conductor
- Selenium is not present in photo conductors, if yes a recovery system is available
- Recycled paper meeting ENV 12281: 1996, can be used in the product

2. Direct emissions during product use

a) dust, ozone, voc, styrene: printers fax and copiers (mg/m^3) (IT Företagen)
b) Low Frequency Electromagnetic Fields (EMF) for PCs, Portable PCs and Monitors

3. Energy efficiency of product- use phase

a) power consumption of product
    - on-mode (W)
    - stand-by mode (W)
    - deep sleep mode (W)
    - off-mode (W)

b) energy savings options listed within the owners manual
c) product meets Energy Star requirements

4. Extendibility of Product life

a) upgradability options: processor, memory and cards, hard disk, CD ROM can be changed and or upgraded
b) Number of years listed for spare parts and service
d) Modular design (EU Flower)
e) Special tools not needed for upgrading products

5. End-of-life

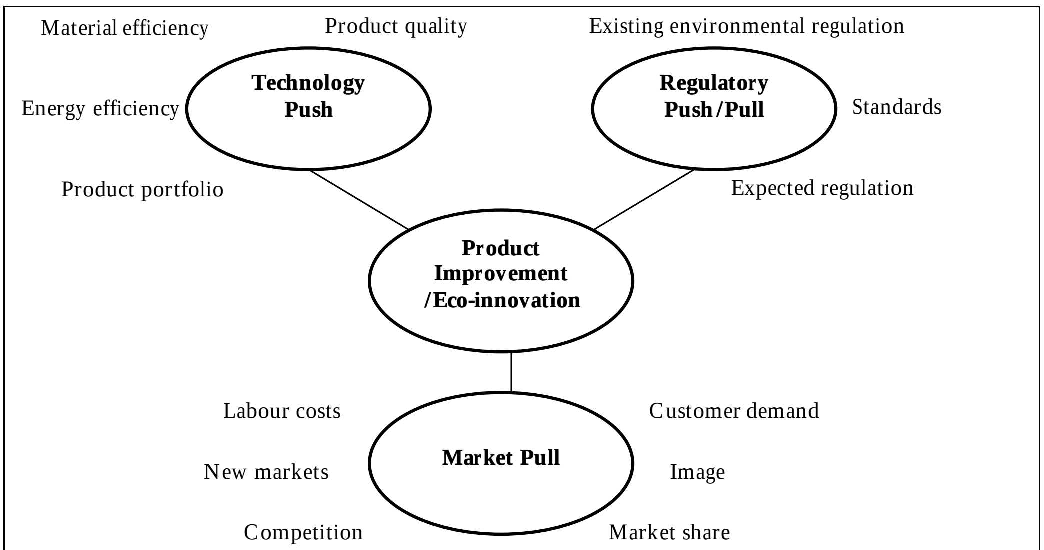
a) Designed for disassembly – avoidance of glue, welding, painting of material
b) Plastic parts > 25 g are ISO 11469 marked for easy identification

c) Instructions on how to prepare the product for disposal are included in the owner's manual
d) Large mechanical plastic parts consist of one material or of easily separable materials
e) Declaration of housing material type
f) Declaration of type of electrical cable insulation material. (usually PVC)
g) Take-back of the product is provided and information is provided in the manual
h) Information must be provided on reusable/recyclable parts and materials

Concerning measuring improved environmental performance of ICT products as a result of design considerations; simple metrics can be applied for most of the categories. Energy efficiency progress can be measured in terms of a percentage of reduced energy consumption during use for subsequent products. Absolute levels of energy consumption can be presented to consumers in a standardised way so that products can be compared at any point in time. Material consumption can be measured in a similar way using product weight as the metric. Substances of environmental concern can be declared and reported in standardised formats. Recyclability can be expressed as a percentage of the product weight that is recyclable, if standardised definitions are employed and geographic location is considered. However, extension of lifetime is much harder to benchmark and illustrate within design criteria.

3. Selected Determinants of Environmental Product Information Flow and Product Improvements

This section of the thesis provides the reader with an overview of the most important drivers identified in this thesis that are influencing how ICT products are developed and managed to reduce their associated environmental impacts. When discussing environmental product information flow and how it is connected to the environmental performance of ICT products, it is useful to have an understanding of the main factors that are influencing how products are developed and managed throughout their lifecycle. Each of determinants discussed has an inherent connection to the flow of environmental product information in the product chain. Each of the selected determinants will be briefly outlined, and illustrated how they have influenced the flow of environmental product information. Figure 3-1 below illustrates the main determinants and how they influence eco-innovation or product improvements.



Source: Cleff and Rennings (1999)

Figure 3-1: Selected Determinants of Environmental Innovation

The selected determinants may affect information flow at different parts and between certain actors of the product chain, for example end-of-life, business to business, private consumers or in the production stages. In some cases, environmental product information flow is mandated by regulatory and or policy instruments, in others it is in response to customer requirements for product information or the need for product information for strategic decisions, product development or marketing. This section aims to provide an overall picture of the main factors that are influencing information flow in the ICT product chain.

3.1 Regulatory & Policy Instruments

Increasingly in Europe the introduction of product focused policies and regulations take a more 'holistic' approach to dealing with environmental problems. Product policy brings about a situation whereby all market actors - producers, retailers and consumers - are involved in an ongoing effort to reduce the impacts, which products have on the environment. In general, legal requirements on products and producers concerning placing products on the market will create the demand for and supply of information along the product chain. Since the fruition of a finished product depends on so many actors in the supply chain, the flow of material content information is particularly important. This is especially applicable when there are legislative restrictions or bans on the use of certain materials or substances. The requirement for the finished product to conform to standards and/or regulations puts considerable pressure on the OEM to comply. This in turn leads OEMs to place pressure on upstream parties to ensure that these materials are not present in the parts, components, sub-assemblies. Increasingly, the demand for full disclosure of information on the materials and substances in parts components is seen as a precautionary measure aimed at understanding what implications of future legislative restrictions will affect the status quo.

Regulatory and policy instruments also affect how products already on the market are impacting the environment. For example, waste legislation determines how products should be handled at the end-of life stage to reduce the environmental impacts. Information is thus required by end-of-life facilities concerning where hazardous materials are located and proper treatment methods. Information pertaining to how the product is designed to facilitate reuse or dismantling need to be communicated to ensure that effort upstream is not lost when the product reaches its end-of-life. Legislation and policy may also influence how new products are developed that will lead to environmental improvements.

3.1.1 Directive on Waste Electrical and Electronic Equipment (WEEE)

The Directive on Waste from Electric and Electronic Equipment has recently been approved by the Commission and is currently being discussed in the European Parliament and the Council of Ministers. The earliest date that the directive could be finalised is sometime in the Spring 2002, requiring national legislation to be implemented by 2004 in Member States. The WEEE Directive aims to prevent the generation of EEE waste, increase reuse, recycling and other forms of recovery, and reduce the environmental burden associated with the end-of-life phase of ICT products. It is debateable whether the provisions will actually influence the design of ICT products to stimulate environmental improvements, however this is discussed in later sections of this study.

The directive covers a wide scope of EEE products including 10 categories of product groups ranging from small & large household appliances, ICT equipment, electrical and electronic toys, tools, to medical devices. Under the directive producers of EEE are required to take-back free of charge consumer end-of-life products. Commercial customers, however, can be charged for this service. Although, still uncertain at this time, collection of WEEE will most likely remain the responsibility of local municipalities to finance. There is a minimum requirement of four kilograms per person per year (4 kg/person/yr.) of WEEE by the year 2006. More detailed collection targets will be set once data are collected on the number of products sold in the EU.

Producers have the responsibility to manage WEEE collected at municipal collection points and by retailers. Required treatment methods and recycling quotas are also outlined in the directive. For all separately collected ICT WEEE, 75% by weight of the product must be recovered with component, material and substance re-use and recycling equalling 65% by weight. For ICT products containing CRTs the rate of recovery is 75 % by weight with component, material and substance re-use and recycling being 70% by weight.

At a minimum certified treatment facilities are required to remove and separately treat the following substances, preparations and components listed in the box below.

- PCB containing capacitors
- Mercury containing components, such as switches
- Batteries
- Printed circuit boards
- Toner cartridges, liquid and pasty, as well as colour toner
- Plastic containing brominated flame retardants
- Asbestos waste
- Cathode ray tubes
- CFC, HCFC or HFC
- Gas discharge lamps
- Liquid crystal displays of a surface greater than 100 square centimetres and all those back-lighted with gas discharge lamps

Individual Financial Responsibility
Producers have the option to establish an individual take-back system to collect and treat the waste produced from their products. However, this does not restrict manufacturers from forming consortiums with competitors to manage the waste collectively. Historic waste - waste produced and marketed prior to the enactment of the legislation - will be the collective responsibility of all current producers of similar goods.

Significance to Environmental Product Information Flow
Besides placing economic responsibility for the disposal of ICT products on producers, the directive outlines a number of responsibilities of national governments and producers to supply information to other actors in the product chain. The information to be provided is meant to directly reduce the environmental burden of products.

Promotion of the take-back system is the responsibility of Member States ensuring that consumers have the necessary information concerning the collection and return systems available to them and the meaning of the recycling symbol to be placed on EEE products falling under the scope of the directive. Producers are required to mark products so that consumers can easily identify them as separate waste. The symbol to be used is already implemented in the EU Directive 93/86/EEC. In order to increase diversion of ICT products from landfill and incineration to certified electronic treatment facilities it is important that consumers are aware of the proper disposal methods.

Member States shall ensure that producers provide, as far as it is needed by treatment facilities, appropriate information to identify the different electrical and electronic equipment components and materials, and the location of dangerous substances and preparations in the electrical and electronic equipment.

By 2007, Member states are responsible to collect and report annual statistics concerning the quantities and categories of products placed on the market, collected and recycled, both in absolute numbers and by weight. This information is important for the Commission to evaluate the diversion rate of EEE products to determine if the Directive is reaching its recovery targets.

3.1.2 Directive on the Restrictions of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS)

The Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS) was originally included in provisions of the WEEE Directive. It has been subsequently moved to become its own directive falling under Article 95 of the EC Treaty. The directive bans the use of cadmium (Cd), Mercury (Hg), Lead (Pb), hexavalent chromium (chromium VI) and two brominated flame-retardants polybrominated diphenylethers (PBDEs) and polybrominated biphenyls (PBBs) by the 2006 with exceptions in some applications (see Appendix 1). These substances are to be banned from EEE products because of the associated impacts when improperly disposed of in incinerators or landfills. According to the Commission, even though the WEEE Directive mandates the separate collection of EEE products the 'soft' recovery rate of 4kg/person/yr will still allow for significant disposal of ICT, and therefore the ban of these substances is required.

As a result of the ROHS Directive, there is currently intense interest in the electronics industry in alternative technologies and material systems for the tin-lead (Sn/Pb) solder and halogen-free flame-retardants. Subsequently, Japanese electronics manufacturers have been moving forward with the development in an attempt to increase European market share in advance of the final legislation.[40] In fact the Japan Electronic Development Agency (JEDA) has reported in its 2000 roadmap that the Japanese industry will reach the "full use of lead-free solders in all new products by 2003.[41]

European and US OEMs have also begun to incorporate the alternative materials in response from customer demand, although still hesitant to adopt technologies that are largely believed to be less reliable and not clearly of environmental benefit.[42] It is extremely interesting how the proposed backdrop RoHS legislation has become part of the competitive structure within the ICT electronics industry. Briefly mentioned below are the main alternatives that are being considered by industry for Sn/Pb and brominated flame-retardants.

Lead Free Solder

The move to lead-free solder is the first step towards lead-free electronic products. However, the physical properties of this alloy make it ideal for the fastening of components to the PWB and therefore substitutes are often resisted. For example, tin-lead solder can withstand many thermal excursions and still maintain its reliability. This may not be an issue for ICT products, but for applications where temperature differences vary (automotive applications) this is a necessary requirement. Some of the substitutes so far have had problems achieving this reliability.

Current alloy substitutes that appear to be most promising are tin-silver-copper (Sn/Ag/Cu). This alloy has a relatively low melting point (approximately 217°C, whereas tin-lead is 183 °C) and with similar reliability to Pb. The increased melting temperature of Sn/Ag/Cu translates to processing temperature requirements of 260 °C, translating to increased energy demands and associated environmental emissions.

There are a number of other expressed concerns over substituting tin-lead solder. Increased processing temperatures required, mean that both the components (IC, capacitors and resistors) and the PWB that they are soldered to, need to withstand the increased temperatures. Some of the laminates that are used to make PWB have a relatively low glass transition temperature, meaning that new more expensive alternatives are needed. Concern over the workability of the substitutes may cause more waste during processing and less recovery of components during disassembly. Also, important to note that some substitutes contain bismuth (Bi) that serves the purpose of reducing melting temperatures of the alloys. However, Bi is incompatible with Pb, and with many components still expected have Pb finishes on them for the next couple of years, this places restrictions on the applications of Bi. Also, this may have negative consequences for the smelting process of Printed Circuit Boards, as Bi is incompatible with certain metals. Alternative ways of attaching components to

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[40] Murphy, F. Cynthia, Pitts, Gregory. (2001). Survey of Alternatives to Tin-Lead Solder and Brominated Flame Retardants. In 2001 IEEE International Symposium on Electronics and the Environment. ISEE-2001. (309-315). p. 309

[41] Japan Electronic Industry Development Agency. (2001). Challenges and Efforts Toward Commercialisation of Lead-free Solder -Road Map 2000 for Commercialisation of Lead-free Solder- version 1.3 [Online]. Available: http://it.jeita.or.jp/jhistory/english/information/pbfree/roadmap-3.html#2 [2001, September 3]

[42] Murphy, F. Cynthia, Pitts, Gregory. (2001). Survey of Alternatives to Tin-Lead Solder and Brominated Flame Retardants. p. 309

PWB is also gaining attention, such as electrical conducting adhesives that do not require soldering at all, including flip-chip technology.

Life cycle assessment studies have indicated that it is unclear if lead-free solders are more environmentally preferable, when considering material availability; impacts of extraction, increased processing difficulties and end-of-life issues are accounted for.[43]

Alternatives to Halogenated Flame Retardants

There are two primary families of BFR that are used in ICT products today. Polybrominated diphenyl oxides (PBDPO) or polybrominated diphenyl ethers (PBDE) that include decabromodiphenyl oxide (DBDPO), octabromodiphenyl oxide (OBDPO) and pentabromodiphenyl (PeBDO) to form the first family. In the electronics industry DBDPO is the dominant PBDPO BFR used primarily in plastic PC/ABS, ABS computer housings.[44]

The Phenolics form the second BFR family and consist primarily tetrabromobisphenol A (TBBPA or TBBA) and is used for PWB epoxy and electronic plastics. TBBA is by far the most common brominated flame retardant commercially used today.[45] TBBA becomes stable in plastics and epoxy. Most common uses for PBDE include printed wire board laminate material and epoxy for encapsulation of components.

Whether or not TBBA BFRs are persistent or bioaccumulative is still debated within the scientific community.[46] Despite this, companies in Japan and Europe in particular are investigating the alternatives to all BFR and have started to market products without them.

According to a recent study conducted by the Swedish Institute of Production Engineering Research (IVF) there are at least four halogen-free laminates available on the market for PWB.[47] Phosphate ethers and nitrate flame-retardants have begun to be used and mass-produced by Sony for halogen-free PWBs. There are also halogen-free alternatives for the thermoplastics used in the housings of ICT products. Inorganic fillers such as MgO, nanocomposites and red phosphorus have also been explored.[48]

Designing products so that the need for flame-retardants is minimised or eliminated has been recently explored. This can be achieved by using materials with low fuel content and high glass transition temperatures. Also, installing fuses to avoid the potential for overheating and the elimination of oxygen flow substantially reduce the risk of ignition.[49]

Significance to Environmental Product Information Flow

Besides driving the search for more environmentally compatible materials in ICT products, the RoHS directive has created the need for manufacturers to evaluate the potential impact of these bans on current products. Manufacturers will need to assess how these provisions will influence the

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[43] Turbini, L. et al. (2000). Examining the Environmental Impact of Lead-free Soldering Alternatives. *In 2000 IEEE International Symposium on Electronics and the Environment. ISEE-2000.* (46-53).

[44] Murphy, F. Cynthia, Pitts, Gregory. (2001). Survey of Alternatives to Tin-Lead Solder and Brominated Flame Retardants. p. 311

[45] Hedermalm, P., et al. (2000). Brominated Flame Retardants – An overview of Toxicological and Industrial Aspects. *In 2000 IEEE International Symposium on Electronics and the Environment*. (203-208) p. 203.

[46] Hedermalm, P., et al. (2000). Brominated Flame Retardants – An overview of Toxicological and Industrial Aspects p. 206

[47] Bergendahl Carl-Gunnar. (2000). Electronics Goes Halogen-free: International Driving Forces and the Availability and Potential of Halogen-free Alternatives. p. 56

[48] Murphy, F. Cynthia, Pitts, Gregory. (2001). Survey of Alternatives to Tin-Lead Solder and Brominated Flame Retardants. p. 311

[49] Bergendahl Carl-Gunnar. (2000). Electronics Goes Halogen-free: International Driving Forces and the Availability and Potential of Halogen-free Alternatives. p. 56

components, sub-assemblies, and materials that are incorporating into the products that are marketed. This has created the need for material disclosure of parts procured from suppliers. This has prompted manufacturers to request suppliers submit material declarations of their products.

3.1.3 Integrated Product Policy (IPP)

The EU Commission draft policy paper on IPP was released on January 5, 2001 with the purpose to "initiate a public debate on the prospects opened up for all stakeholders, governments and the environment in the greening of products and the IPP approach".[50] According to the Commission, the *Green Paper* proposes a "strategy to strengthen and refocus product-related environmental policies to promote the development of a market for greener products".[51] The strategy hopes to build on already existing product policy in the EU, by using the "so far untapped potential to improve a broad range of products and services throughout a products life-cycle". It introduces the role that IPP can play in sustainable development, through more sustainable production and consumption of products and services.

What it essentially provides is a vision of what IPP is, providing a framework that articulates boundaries and direction for the majority of member states that have not developed product policies. It also attempts to clarify the appropriate allocation of responsibilities between the EU and member states that have already developed frameworks for product policy.[52]

In suggestions aimed at manufacturers, the report states that producers should be encouraged to disseminate information on the environmental impacts of their products more widely.[53] Eco-design guidelines (e.g. design for cleaner production, design for durability, design for reuse, recyclability, etc.) should be developed and encouraged by the Commission and supported by design standards. Through 'New Approach' legislation, in which objectives are set by governments and implemented through standards drawn up by independent bodies, environmental aspects of products should be reviewed. The Commission intends to cooperate with standardization bodies and relevant stakeholders to integrate systematically environmental characteristics into product standards.

According to the Commission there are a number of instruments that could stimulate actors to follow a life cycle approach. Included in the list are environmental management and audit systems EMAS and ISO 14001, environmental reporting, LIFE Programme and research development.

Significance to Environmental Product Information Flow

Within the IPP Green Paper there is a dedicated chapter outlining the importance for stakeholders in the product chain to have and use information on the life cycle impacts of products and components for which decisions are being made. The commission specifically points out key areas where increased information is needed which are listed below.

- Manufacturers should know the environmental profile of the components they are incorporating in their products
- Designers should examine life cycle impacts of their choices and have easy access to existing lifecycle data and methodologies to do so

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[50] Commission of the European Communities. (2000). *Green Paper on the Contribution of Product –Related Environmental Policy to Sustainable Development: A Strategy for an Integrated Product Policy Approach in the European Union*. Com (2000) Brussels. p. 25.

[51] Commission of the European Communities. (2000). *Green Paper on the Contribution of Product –Related Environmental Policy to Sustainable Development: A Strategy for an Integrated Product Policy Approach in the European Union*. p. 3.

[52] Ernst & Young Consultants. (2000). *Developing the Foundation for Integrated Public Policy in the EU.* DG Environment, European Commission, Brussels. p. 9.

[53] ENDS Environment Daily. (2000. *Sweden to give product policy major push, January 12, 2000*. [On-line] – Available: http://www.ends.co.uk [25 January, 2001].

- Producers should pass on information down the product chain to consumers and buyers in an easily accessible form
- Retailers, consumers and buyers should recognize which are greener products

In order to improve the life-cycle performance of a product, it is necessary to understand it. The commission points out that the first step to promoting life cycle thinking within the economy is through the generation and collation of information on the lifecycle environmental impacts of products, through LCI and interpreted by LCA. The commission considers this to be a priority to be achieved by "linking existing life cycle information, and if appropriate set up new databases that conform to agreed upon standards". Current, standardised publicly available databases will be encouraged in cooperation with consumer and industry organizations, including the European Environment Agency (EEA) and national environmental protection agencies.

The commission suggests that tools should be made available that allow a fast check of environmental impacts of products, suggesting abridged LCAs or other methods aimed at SMEs who do not dispose of the expertise to conduct LCAs themselves. Similar tools should also be developed that address the management of life cycle information flow along the product chain. Important to note is that the commission's view that the goal of the IPP approach is not necessarily to require full life cycle analysis for all relevant decisions. "More important is the identification of key information and its translation into a general life cycle thinking".[54]

Obligatory and voluntary instruments to increase the generation and availability of information along the product chain are mentioned in the paper with reference to two initiatives, one in the electronics sector, by EICTA (*discussed in section 4.5.3*) and another in the automotive sector with the recent introduction of international material data system (IMDS).

3.1.4 Working Paper EEE Directive

The first official version of the proposed Electronic and Electrical Equipment (EEE) Directive concerning design, was released in February, 2001. The document, titled "Directive of the European Parliament and of the Council on the impact on the environment of electrical and electronic equipment (EEE)", is considered a Working Paper, and has subsequently been changed from its earlier status as a Draft Proposal.

The objective of the directive is to "harmonise the requirements concerning the design of EEE to ensure the free movement of these products within the EU internal market, aiming to improve their overall impact on the environment".[55] According to the Enterprise Directorate the EEE directive will lead to continuous improvement in the overall environmental impact and resource consumption of EEE, by integrating a holistic approach to environmental product development.

The EEE working paper is a New Approach directive in which 'essential requirements' listed in the directive are developed into technical standards by standardisation bodies, in this case CENELEC, under a mandate by the Commission.

Significance to Environmental Product Information Flow

ANNEX II of the Directive contains the 'essential requirements' necessary under the new approach that form the direction and guidance that standardisation bodies are meant to follow when developing technical standards. These essential requirements form the crux of the directive, outlining the

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[54] Commission of the European Communities. (2000). *Green Paper on the Contribution of Product –Related Environmental Policy to Sustainable Development: A Strategy for an Integrated Product Policy Approach in the European Union*. Com (2000), Brussels. p. 17.

[55] European Commission, Enterprise Directorate. (2001). Frequently Asked Questions Relating to the EEE Draft Proposal. [Online]. Available: http://europa.eu.int/comm/enterprise/electr_equipment/eee/index.htm [2001, May 18].

necessary requirements placed on manufacturers at the design stage that aim to improve the impact on the environment from EEE.

Part A) of Annex II provides the general provisions prescribing that manufacturers perform an assessment of the environmental impact of their products throughout the entire life cycle. The magnitude of environmental inputs and outputs of EEE should be identified and estimated for all life cycle stages. For each life cycle phase certain aspects should be assessed such as predicted consumption of material, energy and other resources, anticipated emissions to air, water and soil, and generation of waste material.

Manufacturers are required to produce an ecological profile of the product in question using the results of the analysis. This ecological profile should describe the significant environmental impacts, concentrating on and prioritising those factors that are capable of being influenced through product design. In order to identify and estimate the environmental inputs and outputs of materials and energy for ICT products, producers will need considerable amounts of environmental product information from all actors in the supply chain from raw material suppliers to end-of-life facilities. This will require information exchange between many actors in the supply-chain as well as the end-of-life stage.

Manufacturers will be required to use the results of the ecological profile to select a suitable design solution, taking into account environmental, technical and economic aspects, creating an optimal balance between these criteria.

When choosing the most suitable design solutions and technological options, the directive lists in Part B) (3) numerous principles that the manufacturer shall apply. Included in the list are general pollution prevention and resource conservation measures, such as the release of hazardous substances. Manufacturers are encouraged to use recycled material and reuse components, systems and subsystems. EEE should be designed for durability, reliability, modularity, upgradability, repairability, and reusability. In order to facilitate the end-of-life management of EEE manufactures shall make use of common component and material coding standards that will assist dismantlers identify components and materials suitable for reuse and recycling.

Manufacturers are required, where applicable, to provide relevant information to parties who are responsible for the product after the design phase. This information obligation includes providing instructions relating to the manufacturing process and providing information for consumers on the significant environmental characteristics. Instructions are to be provided with the product to illustrate to consumers the most appropriate way to use, install and maintain the product in order to minimise its impact on the environment, including where to properly dispose of it. Finally, information on proper disassembly, recycling or disposal is to be supplied to treatment facilities.

3.1.5 Sweden's Chemical Strategy for a Non-Toxic Environment

On February 2, 2001, the Swedish Environment Ministry issued a press release concerning the status of a Government Bill titled "A Chemicals Policy for a Non-toxic Environment. The Bill has now been put before Parliament and clarifies the environmental objective "A Non-toxic Environment", setting out five specific targets and strategies on how to achieve them, listed below.

The five targets:

1. By 2010, data will be available on the properties of all internationally manufactured and extracted chemical substances on the market. In addition, by 2020, as much data as possible will be available on the properties of all unintentionally manufactured and extracted chemical substances on the market.
2. In 2010, products will be labelled with health and environmental information on the hazardous substances they contain.
3. New products will be as free as possible from:
    - carcinogenic, mutagenic or reproduction toxic substances by 2007 if the products are intended for sale to the consumer
    - new organic substances that are persistent and bioaccumulating as soon as possible or by 2005 at the latest
    - other organic substances that are very persistent and very bioaccumulating by 2010 at the latest
    - other organic substances that are persistent and bioaccumulating by 2010 at the latest
    - mercury by 2003, cadmium and lead by 2010 at the latest
4. Health and environmental hazards that are posed during the production or use of chemical substances will continuously decrease up until 2010 in accordance with indicators and key ratios that have been established by the relevant authorities
5. Target values for at least the 100 selected chemical substances that are not covered by target 3 will have been established by the relevant authorities by 2010. The aim is for these guideline values to be eventually established as environmental quality norms

Significance to Environmental Product Information Flow

These targets have obvious implications to the availability of environmental product data. Target 1 outlines the knowledge requirement that data will be available on the health and environmental properties of all chemical substances, not only for new substances entering the market. This increased data availability will facilitate the collection and documentation of data by users of these substances in the manufacturing chain of ICT products. It may also have the effect of influencing the choice of chemical substances that are currently used by ICT product manufacturers. For example, TBBPA – a common flame retardant used in PWB is not subject to phase out under ROHS, but may bioaccumulate in organisms. Therefore, applying these future guidelines, a manufacturer may choose to discontinue its use.

Target 1 is the necessary precursor for Target 2 in that if products are to be labelled with health and environmental information on the hazardous substances they contain, then the producers must have access to information on properties of the raw materials that are used, especially chemical substances. This is necessary for manufacturers to be able to aggregate data throughout its supply-chain. Target 1, provides the building blocks that are needed to obtain Target 2. The environment ministry in order to achieve this target will encourage the EU to develop a EU-common system of health and environmental information for goods that are not chemical products.

Target 3 outlines the time frame for the restriction and/or phase out of carcinogenic, mutagenic, reproduction-toxic, persistent and bio-accumulating substances in products, with specific reference to the heavy metals mercury, cadmium and lead. Specific criteria have been suggested for determining which substances will fall under this requirement in the Swedish Chemicals Committee report "Non-hazardous products- Proposals for implementing new guidelines in chemicals policy (SOU 2000:53).

Phase-out Criteria for persistent and bioaccumulative organic substances

The Committee proposes phase-out from *2005 of new substances*, and from *2015 of existing substances* that are so persistent and bioaccumulative:

- That their half-life is longer than 8 weeks (in a simulation test at 20°C), and
- That their bioconcentration factor is higher than 2000, or
- That they are judged to meet these criteria based on other reliable scientific studies or internationally accepted calculation methods

Furthermore, the Committee proposes phase-out from 2010 of existing substances that are so persistent and bioacculmulative:

- That their half-life is longer than 26 weeks (in a simulation test at 20°C), and
- That their biaconcentration factor is higher than 5000, or
- That they are judged to meet these criteria based on other reliable scientific studies or internationally accepted calculation methods

Carcinogenic, mutagenic and Reproduction-toxic substances

- The substances that are to be covered by the guidelines are the substances that are classified as carcinogenic, mutagenic, or reproduction-toxic within category 1 or 2 according to the EC's dangerous substances directive (67/548/EEC).

Metals and Metal Compounds

- New products shall, in accordance with the guidelines, be free from mercury, cadmium and lead and their compounds within 10-15 years
- Metals shall otherwise, in accordance with the guidelines, be used in such a way that harm is not caused to man and the environment. In this context it is particularly important that measures be aimed at the users that lead to a wide dispersal of metals
- Guidelines on carcinogenic, mutagenic and reproduction-toxic properties should also be applied to metals and their compounds, and the guideline on persistent and bioaccumulative substances should be applied to organometallic substances.

Significance to Environmental Product Information Flow

The proposed criteria have the potential to influence the provision of environmental information in a number of critical ways. Cadmium, lead and mercury will be subject to phase out in the ROHS directive as it reads today with noted exceptions, therefore in line with the Swedish guidelines. What is interesting to note is the third bullet concerning the fact that the carcinogenic, mutagenic and reproduction toxic criteria should also be applied to metals and their compounds. In addition, the criteria for persistent and bioaccumulative substances should be applied to organometallic substances. Considering that common metals used in ICT products such as Beryllium, Chromium, Nickel, Palladium, Silver, Tin are known to be moderately toxic, there may be an increased focus on their use.[56] Greater emphasis may be placed on ensuring that these metals are not dispersed in the environment, requiring greater recovery rates and increased metal recovery through recycling.

Under EU Chemical legislation 'new substances' (marketed after 1981) are subject to stringent testing protocols to determine their intrinsic properties. Current EU legislation on 'new substances' is generally considered to have been successful in testing and assessing chemicals.[57] However, 'existing substances' have never been subjected to a systematic testing regime. When the requirement for testing and notification of new substances was introduced in 1981, substances already on the market were exempted. The fact that the EU Commission and Sweden have indicated existing substances will

[56] Miller, G.Tyler. (2000). Living in the Environment: principles, connections, solutions, Eleventh edition. Pacific Grove: Brooks/Cole Publishing Company, p. 60

[57] Commission Proposal COM (2001) 88 final. *White Paper: Strategy for a future Chemicals Policy*. p. 11

undergo classification and risk assessments has important implications. Considering that existing substances dominate the market over new substances by a factor of 15[58] and that systematic evaluation of 'new substances' has revealed that around 70% of them are classified as dangerous (e.g. carcinogenic, toxic, sensitising, irritant, dangerous for the environment),[59] this should alert industry, concerning the choice of existing substances used in products today.

3.2 Market Forces

3.2.1 Eco-labelling of ICT Products

Consumer demand for products that are less environmentally harmful is an important competitive driver that encourages product improvement by companies. Assuming that demand for environmentally adapted products is present, there needs to be a mechanism to communicate the environmental properties of products to potential customers. In an attempt to stimulate demand for better performing products in the market, governments and NGO's in the late 1980's began to establish independent third-party eco-labelling schemes designed to do just this. Establishing environmental criteria to be met by companies that wish to differentiate their product with an eco-label encourages product improvements. In addition, by providing consumers with reliable, condensed and easily understandable environmental information concerning products the demand for these products can be stimulated. This enables producers and retailers to market the environmental attributes of their products in a clear, concise and credible format.

There has been a recent proliferation of eco-labelling schemes in various countries worldwide that often cover the same product groups with however, widely varying criteria. For complex products that are marketed worldwide this has been flagged as a potential trade barrier issue. As a result, the International Standardisation Organisation (ISO) has developed a set of guidance standards - ISO 14025 - that distinguish three types of environmental labelling, Type I, II, and III. Definitions provided by ISO of each type are listed below:

Type I environmental labelling program: voluntary, multiple-criteria-based third party programme that awards a license which authorises the use of environmental labels on products indicating overall environmental preferability of a product within a product category based on life cycle considerations.

Type II environmental labelling (self-declared environmental claims): environmental claim that is made, without independent third-party certification, by manufacturers, importers, distributors, retailers or anyone else likely to benefit from such a claim.

Type III environmental declaration: quantified environmental data of a product under pre-set categories of parameters set by a qualified third party and provided within a Type III environmental programme**.**

Type III environmental declaration program: Voluntary programme, providing Type III environmental declarations based on LCA according to the ISO 14040 series verified by a qualified third party.

The use of eco-labels in the ICT sector is currently a topic of debate among industry and governments. Types I, II, and III are all used in the sector to communicate the environmental attributes of products. *Section 4.4* describes the most significant labels used in the ICT sector today. Clearly Type II labels are the preferred mechanism by OEM manufacturer's to communicate

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[58] Commission Proposal COM (2001) 88 final. *White Paper: Strategy for a future Chemicals Policy*. p. 16

[59] Commission Proposal COM (2001) 88 final. *White Paper: Strategy for a future Chemicals Policy*. p. 24

environmental information to consumers. However, the standard Type II declarations used (ECMA TR/70 or the IT Företagen) are more representative of Type III labels with the exception that they are not based on LCA nor are they third party verified.

Interesting to note, is that the concept of environmental product declarations (now Type III) when first proposed by the Swedish EPA in 1988, were more representative of the ECMA TR/70 or IT Företagen formats and not the current Type III labels requiring full LCA studies based on the ISO 14040 series standards.

Significance to Environmental Product Information Flow

The influence of eco-labels on product environmental information flow can be considered from two perspectives. In the absolute sense, the information concerning the attributes of the product that distinguish it as environmentally preferable are transparently communicated to consumers and the public at large. Secondly, OEMs must establish ways of documenting the attributes of their product design and material choices so that conformance with the eco-labelling criteria can be proven. This implies not only that a system be established to document information along the supply-chain, but dialogue is also needed to communicate the actual requirements to meet the criteria.

3.2.2 Public & Corporate Procurement

Public purchasing organisations, especially in the Nordic Countries, and Germany have put considerable pressure on ICT companies to provide environmental product information concerning products. Environmental requirements concerning the environmental management of the producing company for both process and product related attributes are commonly requested.[60]

Given the fact that in general, national and local governments combined, form the single largest consumer in most countries, there exists a tremendous potential to influence ICT markets towards environmentally improved products. In Europe, public procurement represents 12% of EU GDP on average, but can be as high as 19% in some countries.[61] Simply stated, government organisations have significant purchasing power, which can influence the direction of product development in the ICT sector.

The EU Commission proposal for the Sixth Environmental Action Programme, which covers the years 2001-2010, has identified public procurement as an area that has considerable potential for ‘greening’ the market through public purchasers using environmental performance as one of their purchase criteria.[62] However, public procurement in the EU is subject to rules laid down in the EC Treaty and Community directives that may impede the differentiation of environmentally preferable products. These aspects are discussed in further detail in *section 4.3.2*, which outlines the current flow of environmental product information with the applicable opportunities and limitations for its use.

3.3 Corporate Environmental Management

Companies have responded to the demand from government agencies and market forces by establishing systems, programs and tools that address the environmental aspects of their processes, products or services. There is an inherent demand and supply for product information associated with each of these elements accordingly. Fava et al. (2001), developed an Environmental Management

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60 Kärna, A. (1999). *Managing Environmental Issues from Design to Disposal- A Chain Reaction: Experiences of Product Chain Actors in the Finish electrical and electronics industry.* Helsinki: Federation of Electrical and Electronics Industry. p. 108

61 Commission of the European Communities. (2000). Green Paper on the Contribution of Product –Related Environmental Policy to Sustainable Development: A Strategy for an Integrated Product Policy Approach in the European Union, p. 15

62 Council Proposal COM (2001) 31 final. *Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions on the sixth environment action programme of the European Community: 'Environment 2010: Our future, Our choice'*

Framework that helps to visualise the various systems, programs, tools and strategies that companies employ to manage environmental requirements and goals. The framework provides a useful mapping of determinants of product information flow from the corporate perspective.

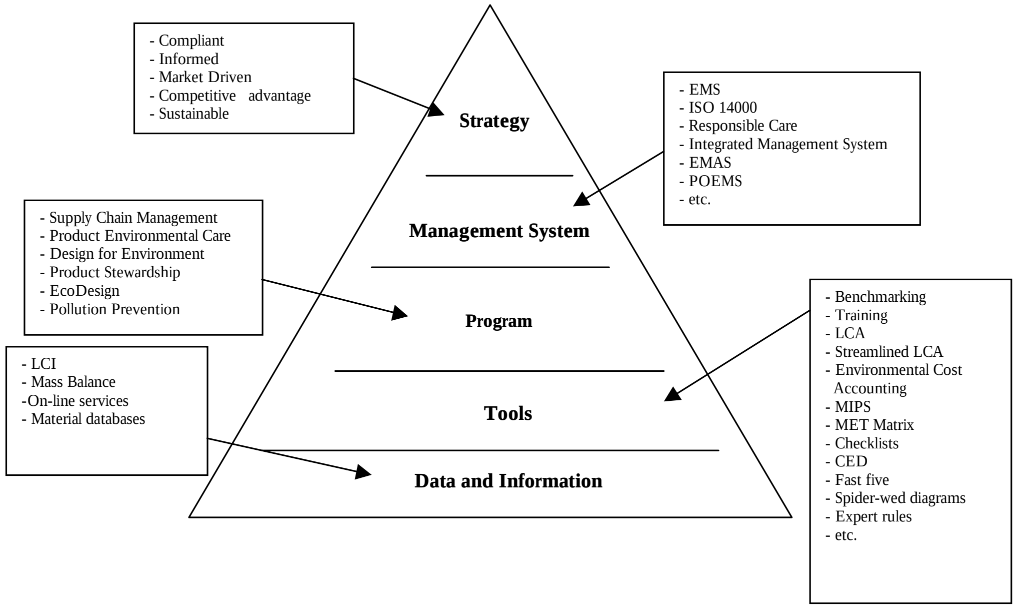


Figure 3-2: Environmental Management Framework, adapted from Fava et al.

According to the authors, environmental management activities are guided by the selection of an environmental strategy. Five generic strategies have been developed from extensive interviews with companies addressing environmental concerns in practise. Explanations of the five strategies are found below.

- **Compliant -** An organisation decides it will be in compliance with all environmental, health, and safety regulations. This is the minimum level of Environmental Strategy an organisation can adopt.
- **Informed -** An organisation is in compliance, tracks key activities beyond compliance, and participates in external activities such as trade associations. It spends time and resources collecting information.
- **Market-Driven -** An organisation responds not only to regulatory requirements, but also is reactive to its customers' environmental expectations by providing leading product/service and operational performance.
- **Competitive Advantage -** An organisation is not only in compliance, but understands its environmental market opportunities and proactively uses that knowledge to create markets where it has sole or leadership market positions.
- **Sustainable -** An organisation proactively integrates economic growth; environmental, health, and safety, and social well being into its operations for competitive advantage and long-term viability.

Each strategy chosen in turn drives the different programs, techniques and tools, which the company uses to manage and implement their environmental activities. The management system provides the general direction and structure to implement the strategy. The authors make an important point concerning the critical importance for companies to understand the environmental issue that they are trying to solve before implementing any technique. For example, a company that is trying to address the environmental aspects of its products may decide to implement a combination of LCA, DfE, and supply-chain management (SCM). LCA could be used to gather data along the supply chain and identify where the greatest impacts are associated with the product. DfE and SCM could be used to implement tools such as design checklists and supplier requirements to address the issues identified by the LCA. Environmental management systems and programs such as DfE and SCM with their associated tools and data requirements are considered the most applicable to product environmental improvement and will be expanded on in further sections of this thesis.

Depending on the strategy taken by companies in the ICT sector varying degrees of environmental product information will be required. As companies move towards more sustainable strategies greater cooperation and flow of environmental product information between all actors in the product chain is necessary. Not only are businesses gathering and sharing information concerning production and product improvement measures, they are also actively communicating these efforts to consumers to build market share.

3.3.1 Environmental Management Systems (EMS)

With the number of companies that are implementing environmental management systems (ISO 14000 or EMAS) increasing, the demand for data collection for metrics associated with environmental aspects is creating both a supply and demand for environmental information. The establishment of an EMS in a company may be a result of both internal and external pressure to do so. For example as previously mentioned in *section 3.2.1* a company may want to improve its image concerning its environmental performance, but needs a method of identifying and managing the environmental aspects associated with its business. Similarly, a company may seek to find resource and cost savings and the establishment of an EMS is aimed at identifying where inefficiencies are located. Or perhaps the company's corporate clients or public purchasers have requested that an environmental management system be established. Regardless of the reason for implementing an EMS, the collection of important environmental information is inevitable.

Although, most of the data collected as a result of the Environmental Management System concerns processes, calculations can be developed to allocate proportionally to the products that are produced. Theoretically if all companies in the product chain accounted for their own environmental burden associated with the raw material, component, subassembly or final assembly, then all the necessary data needed to compile a life cycle inventory is essentially available. Then the process of conducting a full LCA for the product might be quite feasible.

4. Examples of Environmental Product Information Flow

This section intends to introduce the reader to the various channels of environmental information flow along the EEE product chain. By providing examples of product environmental information flow found in the literature, this section provides a theoretical background that will provide a basis for the comparison of the results of interviews with product chain actors. Interfaces for environmental product information flow have been categorised according to where they occur in the product chain. Three main categories have been identified that include the (1) manufacturing supply chain and retailers, (2) consumers, and (3) end-of-life facilities. In each of these sections, examples are provided that illustrate to the reader how product flow is connected to the environmental improvement criteria described in *section 2.4.*

Further in the chapter in *section 4.5,* examples of environmental product data acquisition strategies for materials use and LCI data in the product chain are presented that illustrate industry and government response for the need of increased environmental product information.

4.1 Information Flow and Product Improvements

Companies that have committed themselves to improving the environmental profile of ICT products require strategies to manage the information flow within their own organisations and along the product chain. There are a number of defined programs that have been established that provide the framework of environmental improvements within organisations. Such include environmental supply chain management (SCM), green product procurement and Design for Environment (DfE) that take a more focussed position regarding product attributes. Eco-labels of various formats provide a mechanism for manufacturers to promote the environmental attributes of their products to consumers.

When considering the product improvement criteria outlined in *section 2.4* it can be seen that if environmental improvement of a finished product is the goal, interaction between all or most actors in the chain takes place. By taking one environmental improvement criteria - material use - this point can be illustrated well. Suppose that a certain halogenated flame retardant is targeted as a substance of concern by government authorities, customers (public or private), or the OEM themselves (risk avoidance or to meet eco-labelling criteria). In order to address this issue the OEM could make an inquiry to all supplies, through an environmental questionnaire to determine if, where, and how much of this substance is present in their products.

Depending on the number of suppliers and the number of suppliers to suppliers the degree of complexity and the ability of the first tier supplier to answer the questionnaire will vary. This inquiry may take months or even years to finish. Assuming that the OEM ascertains that this material is present in the product and wants to phase it out, it needs to assess the economic impact of substituting the material or avoiding the need of flame-retardants completely. Economic data will be needed concerning the cost of the substitute material, as well as how this substitution will affect environmental performance of production attributes, the use phase, and end-of-life costs and impacts as well (assuming that financial responsibility is borne by the manufacturer).

Assume that in this case the economic and environmental trade-off analysis showed that substitution was feasible and that appropriate suppliers have successfully been able to accommodate the request. The OEM may ask the supplier to provide a material declaration, outlining the constituents of the components or part supplied. Now, the manufacturer may want to communicate this information to one or more stakeholders either to comply with regulation, or customer demands. If a conformity assessment is required the OEM may need to have supportive evidence that the flame retardant is no longer used. The OEM may supply the material declarations from all applicable suppliers as evidence or at least be able to document in case regulators ask it for. Similarly if an eco-label is being sought, the OEM will need to show that the product meets the criteria.

As discussed previously, in Nordic Countries ICT product environmental attributes are often communicated through the IT Företagen's eco-declaration, and include disclosure on the use of brominated flame-retardants. The marketing department can use this declaration to satisfy consumer demands for information in a standard format. Consumers can compare the information on the declaration to make informed comparisons about product attributes. End-of-life facilities could possibly use the declaration to assist in identification of treatment options for the product considering that no brominated flame-retardants are present in the product. Polymers without BFR can be recycled where there may be negative consequences to recycling polymers with the flame retardant present.

This example just touches on the various flows and formats of environmental product information in the ICT product chain. It illustrates the complexity of information flow in the product chain from a very simplified viewpoint. Further examples are provided in the following sections below.

4.2 Manufacturing Focused Information Interfaces

4.2.1 OEM Perspective

It is not surprising that the greatest demand and supply of environmental product information is associated with OEMs. Finished goods that are marketed under brand names are the culmination of many actors' efforts in the supply chain and are mainly coordinated by the OEM or actors that are representing them. This associated responsibility, coupled with the main drivers listed above (legislated information demands, market demands and corporate environmental goals) creates the need for OEMs to develop strategies to collect and warehouse product environmental data.

With this central role in the product chain, OEMs have the potential or are now in the process of both demanding and supplying product environmental information along the ICT product chain. According to Brinkley and Mann (1997), in order to devise an effective collection strategy for environmental information, it is important to first understand how the information will be used.[63] Potential uses for product environmental information by OEMs include: product design assessment (Eco Product Development), regulatory requirements review/assessment, and marketing/customer support. This provides a useful framework in which to discuss product environmental information flow from the OEM perspective.

[63] Brinkley, A., Mann, T. (1997). Documenting Product Environmental Attributes. *In 1997 IEEE International Symposium on Electronics and the Environment*. (52-56) p. 52.

Eco Product Development and Product Assessment

In order to determine where environmental information flow is needed for eco-design initiatives in organisations, it is first necessary to briefly explain typical product development processes deployed by electronic organisations involved in design. Karlsson (1997) compared four practitioner approaches to industrial product development based on six phases of deployment. This provides an excellent conceptual framework for the developmental process. The following table outlines the phases proposed along with supporting literature defining the product development framework.

Table 4-1: Phases of Product Development: Classification by various authors

	Andeasen & Hein	**F Olsson**	**Arthur D Little**	**Pahl & Beitz**
Phase 0	Recognition of need	Need	Orientation, pre concept	Task
Phase 1	Investigation of need	Product Type	Product definition and specification	Planning and clarifying the task
Phase 2	Product principle	Principle product	Product conception and design	Conceptual design
Phase 3	Product design	Primary product	Product development and engineering	Embodiment design
Phase 4	Product preparation	Product preparation	Manufacturing preparation and engineering	Detail design
Phase 5	Execution	Product launch	Market introduction and feedback	-

Various functions within the organisation are involved in the product development process at any given time. According to Karlsson, the most active functions are design, production and marketing while purchasing, finance and other functions are involved intermittently. *Table 4-2* below outlines the roles that each of these functions play in the product development process.

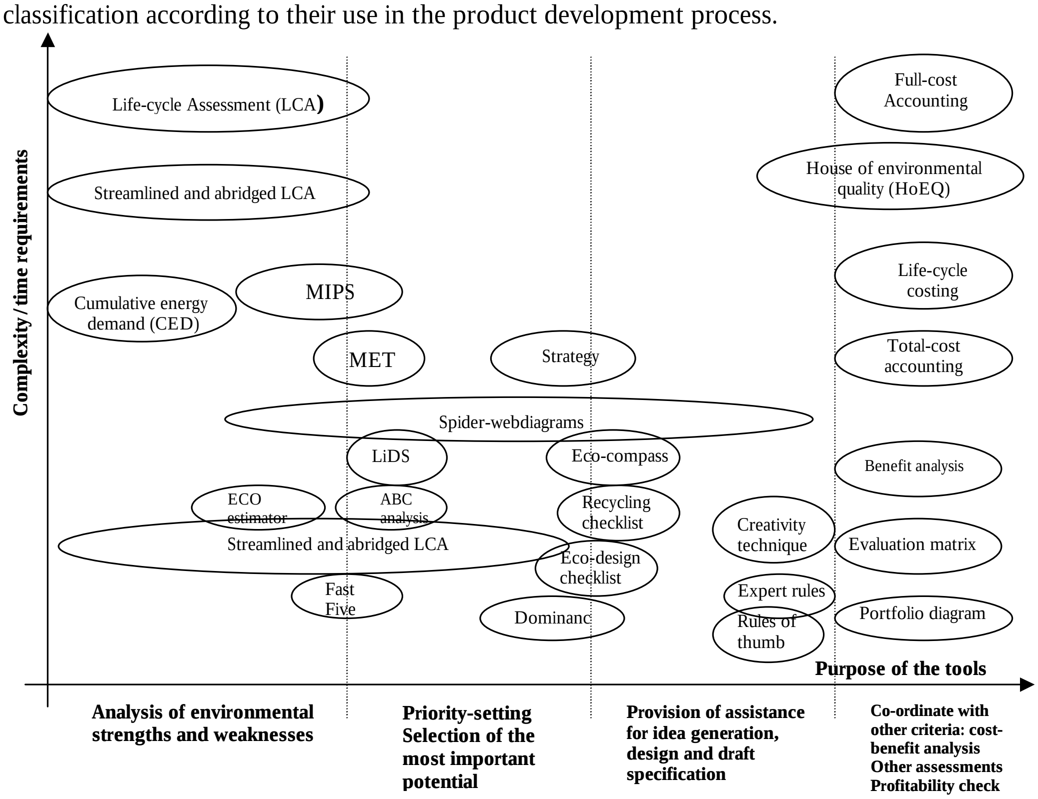
Table 4-2: Product Development Process: Roles of various corporate functions

	Marketing	**Design**	**Production**	**Finance**
Phase 1	Analyse need, Market opportunity	Possible product types	Production alternatives and consequences	Business opportunity and alternatives of finance
Phase 2	Market research, consumer needs, competition, and market readiness	Criteria, suggestions and evaluation of product alternatives	Production suitability and recommendation	Business goal and analysis of its feasibility
Phase 3	Market strategy and price setting	Product design, competent choice and prototype tests	Production layout, cost estimation	Profit analysis and resource acquisition
Phase 4	Market tests, sales and advertisement preparation	Product adjustment and drawing	Procurement of tools, storage, build-up and purchase routines and test series	Investment follow-up and launch study
Phase 5	Sales and customer training	Failure elimination and staff training	Timing of production and cost follow up	Result analysis and analysis of the future

Similarly, Eco-design or DfE programs that aim to improve the environmental performance of products are closely aligned to the product development framework discussed above. Eco-design can be defined as environmentally conscious product development and design, or design for environment (DfE).[64] It describes a systematic approach that aims to entrench environmental aspects in product planning, development and design processes at the earliest possible opportunity. This implies that environmental aspects are incorporated into overall criterion factors such as functionality, profitability, reliability, safety, ergonomics, technical feasibility and aesthetics. In fact, successful implementation of eco-design initiatives found in relevant literature stress the importance of integrating eco-design into the regular product development process.

Eco-design Tools & Information Flow

There are many tools that companies use to assist with the implementation of Eco-design programs that in some cases supply product environmental information or demand environmental product information in others. Tischner (2001) has developed a model that categorises the most important and useful eco-design tools according to their purpose and complexity. In the model there are four categories of tools that: 1) analyse environmental strengths and weaknesses of the existing product or design 2) tools that prioritise and select the most important potential improvements, 3) implementation tools that provide assistance for idea generation, design and draft specification 4) Tools that coordinate with other important criteria such as cost-benefit analysis, economic feasibility studies among others. *Figure 4-1* below provides a visual representation of the various tools and their classification according to their use in the product development process.



Source: Tischner (2001). Tools for Eco-design and Sustainable Product Design

Figure 4-1: Classification of eco-design tools and their use in the product development process

Analysis of environmental strengths and weaknesses

Particularly important to information flow to facilitate product improvement is the first category in which environmental strengths and weaknesses of the product or design are analysed. This step

[64] Tischner, Ursula. (2001). Tools for ecodesign and sustainable product design. In M. Charter & U. Tischner, *Sustainable Solution: Developing Products and Services for the Future* (263). Sheffield: Greenleaf Publishing.

involves the identification, quantification, evaluation and prioritisation of harmful issues associated with the product. LCA based on ISO standards involves a detailed study of all the associated inputs and outputs of the product system in question and includes goal and scope definition, life cycle inventory, and impact assessment and evaluation steps of the procedure.

Depending on the approach of gathering data, (life cycle inventory) this process is very time consuming and subsequently very expensive. For this part of the assessment, data concerning all inputs (energy, materials and chemical substances) and outputs (emissions to air, water, land and products) must be assembled for all the life cycle stages of the product from raw material extraction through to final disposition of the product. Although there may be data available in LCI databases, there exist a number of uncertainties that are addressed in *section 6.1.2.* Considerable effort has been made in trying to standardise LCA methodology as well as how to document LCI data.

Collaboration efforts between branch networks and some individual EU Member countries have been established in an attempt to make available LCI data to interested stakeholders. Within the ICT sector the use of traditional LCA studies is not usually a function of the design team, and in fact relatively few companies have conducted them to date. LCAs conducted on ICT products have most often been carried out by environmental departments or expert consultants[65]. More often the results of LCA studies have been influential in developing general design guidelines that designers can refer to during the design process. Software tools have been developed to aid LCA implementation with some using predetermined LCI data information for materials and processes that allow for a very quick assessment of the product in relatively short periods of time.

Cumulative energy demand (CED) analysis is a method that is used to quantify from a life cycle perspective the energy demands of the product that can be used as a measure of environmental impact. Similarly, MIPS analysis is a quantitative measure of the material and energy input required during a products life cycle, expressed as material expenditure. Environmental impact is then represented in terms of total material input in relation to actual or potential units of service. There are a number of checklists and matrices that are less complex and time consuming that are used by designers or environmental functions within companies to analyse the strengths and weaknesses of products. For example the Material and Energy inputs/outputs, Toxic emissions output (MET) matrix is an example of this.

Important to note is that with all the above methods there is an inherent demand for environmental information from the supply chain, with the primary focus being upstream to raw material and component suppliers. With abridged LCA and the MET matrix, data used for the assessment consists of previously compiled information on processes and materials and does not accurately reflect the reality of the individual product circumstance. This is important to note as production processes and materials typically used in the manufacturing of ICT products are rapidly changing and relocating to other areas in the world.

Priority setting and Design Objectives

According to Tischner (2001), once the environmental strengths and weaknesses of a product or possible product design have been determined it is necessary to prioritise improvement possibilities for further design work. Priorities are determined according to the environmental impacts that represent the greatest importance and which the company can influence. Current and future external issues such as regulation and customer needs and requirements should be considered appropriately.

Tools used to set priorities & objectives include spider diagrams and portfolio diagrams that provide a qualitative categorization and display of the environmental qualities of a product based on the most important criteria. Two well-known models used in industry today are the Life-cycle Design Strategy

[65] McAloone, T.C. (2000). Industrial Application of Environmentally Conscious Design. London: Professional Engineering Publishing Limited. p. 88

(LiDS) wheel developed by Brezet & van Hemel and the eco-compass developed by Fussler with James.[66] The LiDS wheel or ecostrategy wheel contains eight strategies representing eight points on the wheel. The strategies include; New Concept Development, Selection of low-impact material, Reduction of Materials usage, Optimisation of Production Techniques, Optimisation of Distribution Systems, Reduction of Impact During Use, Optimise Initial Lifetime, and Optimisation of End-of-Life System.

Important to note is the fact that spider-web diagrams are useful for not only developing design strategies but also for analysis of environmental strengths and weaknesses and implementation of design options.

Provision of design assistance

Checklists, expert rules, spider-web diagrams and rules of thumb are the most predominate tools used to provide guidance on defining and implementing the chosen eco-strategy for designers in a straight forward manner. These tools provide actors involved in product development process with simple non-analytical information necessary to familiarise themselves with the important aspects of eco-design. Where product development times are restricted and available staff and finances are limited these tools still allow for the topic of environmental quality to receive appropriate consideration during the product development stage. Checklists are intended to ensure that when products are developed nothing is forgotten concerning the chosen design strategy.

Typical checklists employed by firms include:

- Banned and restricted materials in products and processes
- Material selection Checklists: Preferable Materials
- General eco-design checklists
- Design strategy Checklists: (LiDS)
- DfR, DfD – Design for recycling, design for disassembly checklists
- Waste avoidance and pollution prevention checklists

Expert rules and rules of thumb are intended to communicate the product brief and defined requirements to everyone participating in the planning process. They provide a mechanism to help keep in mind the general environmental design criteria during the while generating new ideas.

Coordination with other criteria

Environmental considerations can be considered only one of many requirements that a product must meet. Typically other variables include aspects such as marketability, profitability, and technical feasibility. Multi-criteria tools such as environmental cost accounting methods and environmental house of quality help to coordinate these aspects when design approaches are evaluated at various stages in the planning process.

For example environmental cost accounting methods identify and collate costs incurred during its development and production phase including marketing, planning, construction, procurement, transport, production, distribution and service. These costs can be weighed against the environmental improvements that the product provides. With total cost accounting or full cost accounting methods, costs acquired during the products entire lifecycle are determined. In addition to the costs associated with the development and production phase, the use and end-of-life costs are also accounted for.

Material Selection

The choice of materials used in ICT products can influence its overall environmental impact lifecycle substantially. As a result manufacturers have developed lists of materials that either ban or restrict the

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[66] Tischner, Ursula. (2001). Tools for ecodesign and sustainable product design. p.

use of certain materials that are known or suspected to cause negative impacts. These lists subsequently guide designers and their suppliers in material selection and development of new components or parts. Since impacts from materials and substances may occur at any of the lifecycle stages of the product, a lifecycle perspective and analysis is required to accurately determine what the best choice of material truly is. Legislation and customer requirements guide the choice of materials used and materials which are to be banned from use. They play an important role in the selection of material to be used.

In addition to legal and customer requirements, OEM designers often need guidance on what materials are most appropriate from an environmental perspective. Guidelines or strategies will direct the designer to choose materials that have low energy content, are non-hazardous, non-exhaustible, recyclable or are recycled material. **IDEMAT** is a tool for material selections in the design process that was developed by TU Delft in the Netherlands. It provides a technical database with information concerning materials, processes and components, putting emphasis on environmental considerations. It allows designers to search and compare information on the different material, component or processes that are applicable to the product they are designing. Information concerning the mechanical, physical, thermal, electrical and optical properties can be found along with information about possible processing technologies and applications for a material, price and environmental information. The environmental "properties" are displayed in a graph presenting the environmental effects normalized with the European effect scores, associated with the production of one kg of the particular material. Two LCA software output formats, the Eco-indicator and EPS-indicator for each material provide a "quick" analysis of environmental impact of that material.[67]

There are of course considerations other than environmental that must be taken into account when selecting materials and substances. These include a wide range factors such as physical properties (size, weight and shape of the material needed) and mechanical factors that relate to the ability of the material to withstand stress, its strength, wearability etc. Material choice should consider the processing and fabrication type used referring to the ability to shape and form the material in question. Intended life of the product plays an important role in selection of material as does cost and the availability to meet the required amounts. The above factors illustrate the dynamic complexity of material selection requiring many considerations other than the environment when designers make choices. The problem is that often there lacks a mechanism for this to occur.

The European Association of Consumer Electronic manufacturers (EACEM) in 1994 published (now revoked) a 'black list of hazardous substances' typically used in consumer electronic products.[68] EACEM claimed the reason for publishing the list was pressure from consumer interest groups on the sector to provide material disclosure of various materials that appear in products. However, this list was criticised by European Chemical Industry Council (CEFIC) as being based on weak and incomplete scientific and technical information. The chemical industry argued that the list proposed a de facto boycott of a number of chemicals, which are legally produced and /or marketed in the EU.

Subsequently, two new guidance documents have been produced by CEFIC in cooperation with four industry associations including EACEM, EUROMETAUX[69], EECA[70], and EICTA[71] (known as C4E). "**Excerpts from legal Provisions of Restrictions on Substances for Applications in Electric and**

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[67] TU Delft. Idemat On-line (2001). [Online]. Available: http://www.io.tudelft.nl/research/dfs/idemat/index.htm, [2001, July 24]

[68] European Chemical Industry Council. (1998). From a potential black list to a dialogue. [Online]. Available: http://www.cefic.be/search/ [2001, August 4]. p. 1

[69] EUROMETAUX - European Association of Metals

[70] EECA - European Electronic Component Manufacturers Association

[71] EICTA - European Information and Communication Technology Association

Electronic Products", informs of the relevant legislation concerning chemical use to chemicals commonly used in EEE products.

A second document, "**Guidance Document on the Appliance of Substances under Special Attention in Electric and Electronic Products**" provides users and companies comprehensive and practical information about chemicals, polymers and metals. This document covers both established properties and the status of assessments currently underway. C4E claim that the document will raise the awareness of those involved in the various stages of the product-life-cycle, through providing appropriate advice about efficient risk management. Information concerning application benefits, reason for special attention, recommendations, current affairs and information pertaining to eco-labels is provided for a variety of metals, chemicals substances and preparations, and polymers.

Regulatory Requirements

Manufactures need information from government authorities on banned substances, labelling requirements and other product standards that relate to the environmental performance of the product. Common restrictions on materials in ICT products must be communicated to manufacturers and hence their suppliers so that products that are sold in various markets around the world conform to all legal requirements. Requirements for labelling products containing certain materials are also common for this sector. In addition to product content requirements, some governments including Japan and Switzerland have recently mandated energy efficiency targets for some ICT products.[72]

Section 3.1 provides an outline of the most important regulatory measures that affect product information flow perceived by the author. However, there also exists a need for environmental information when assessing shipping requirements for products (not addressed in this thesis). Transportation restrictions may arise when products are shipped with certain battery types, magnetic materials, and chemical products (inks, toners, solvents).[73]

Marketing/Customer Support

Primarily public and corporate purchasers, and to a lesser extent private consumers are increasingly demanding that products have less environmental impact. As a result of this demand labelling programs (discussed above) have been established where criteria concerning the environmental performance of ICT products has been established. This has created a demand for information that OEMs must report/communicate and implement if they are to meet the criteria put forth by the label. This poses a challenge to product designers and environmental managers within the company to document product content and environmental attributes.

As described above customer requirements are important considerations in the product development process. Accurate and timely information on the market demand for environmentally adapted products is crucial during the early stages of this process requiring a feedback mechanism.

Data Collection Strategies

How have OEMs responded to the increased need for product environmental information? OEMs that want to concentrate on the environmental performance of their products from a life-cycle perspective communicate this desire to their suppliers of components or to contract manufacturers. Many of the decisions that designers make concerning material to be used, energy consumption requirements, etc.

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[72] Brinkley, A., Mann, T. (1997). Documenting Product Environmental Attributes. p.52

[73] Brinkley, A., Mann, T. (1997). Documenting Product Environmental Attributes. p. 53

in the development process can be communicated to the supplier through regular manufacturing specification formats. From this perspective, product environmental information is inherently known.

When OEMs procure components and subassemblies, purchasing departments may issue questionnaires to determine the environmental performance of the potential supplier. This process has in the past predominately provided questions requiring yes/no answers. For example, common questions could include if the company has an EMS, an environmental policy, a system to track environmental laws, a program for environmental improvement, or if the company has a design for environment program established. Ericsson asks if potential suppliers would be willing to provide material declarations and life cycle inventory data (LCI) concerning the component or sub-assembly. Purchasing can use the results of the questionnaire to rank the environmental appropriateness of potential suppliers to be considered alongside other important variables considering deliverability, price, etc.

Banned materials or restricted substance lists serve as a format to communicate to the supplier that certain materials should be avoided or absent from the product. Ericsson also lists materials and substances that should not be used during the manufacturing process. Substances of concern or restricted lists provide the direction towards phase out goal of OEMs.

OEMs may request further information such as material content and life cycle inventory data, once the contract has awarded. Further questionnaires or reporting templates may be used for this purpose. To date, this process has continued on an individual basis, with each OEM using different questionnaire and declaration formats when requesting information. This issue is further discussed in *section 4.5.3*.

Many OEMs place similar environmental requirements on their suppliers as an initial screening or evaluation mechanism. For example, the following OEMs are known to incorporate environmental requirements that influence the selection of suppliers: Siemens, Philips, Nokia, Bosch, Hewlett Packard, Canon, Fujitsu, NEC, Ricoh, Hitatchi, Matsushita, Sharp, Sony, Toshiba, Motorola, IBM, Dell, Compaq. Although not an exhaustive list, it highlights the industry commitment to improve the environmental performance of ICT products.

4.2.2 Suppliers Perspective

As can be seen from the above section OEMs that design products can influence the environmental profile of the components or parts that makeup finished ICT products. Flow of materials generally starts with material suppliers who in turn convert the material into finished components or parts that will be assembled into the final product. However, this is not strictly a linear flow with material or components often being processed by supplier (a) passed on to supplier (b) for some other treatment or preparation and then back to (a) for further processing. This often complicates the flow of product environmental information.

From *section 4.2.1* it has been shown that OEMs have responded to the information demand from customer demands for information, regulatory requirements, voluntary labelling requirements and or general proactive strategy approaches by distributing questionnaires to suppliers. This has led to a proliferation of different questionnaire formats that suppliers receive on a yearly basis from OEMs. Varying formats for reporting materials with differing threshold limits creates a situation where suppliers are literally swamped with information requests from their customers. This creates not only inefficiencies from the supplier perspective but also for OEMs, resulting in long waiting times for information, if received at all.

Material suppliers are the first stage of the product and supply chain and play an important role in providing environmental information along the chain. Referring to *Figure 2-1*, it can be clearly seen that material suppliers (chemical and base metal) supply product to all parts of the manufacturing chain illustrating that the chain is not linear in nature but rather better described as web like.

Suppliers of these materials are, where applicable, required by European legislation (Directive 67/548) to provide information to customers and end users concerning the substances of concern within the chemical product. In Sweden, provisions are outlined in Chapter 14, Section 8 of the Environmental Code that require manufacturers importers or marketers of dangerous chemicals to provide information about the danger to human health and the environment and provide handling instructions. This information is supplied in the labelling of the packaging, and to professional users also in the form of safety data sheets[74]. All suppliers of chemical products that are dangerous to human health or the environment are responsible for ensuring that this information reaches the user.[75]

Material Safety Data Sheets contain information, for example, on product composition, classification of included substances, first aid instructions, precautionary measures, and information about properties dangerous to human health and the environment. In addition all information of importance for increased safety at the workplace and protection of the environment is also included in the format. This information can form the building blocks for documenting what substances of concern are included in components, subassemblies and ultimately fully assembled OEM products. However, important to note is that information on raw materials that are not classified as dangerous according to the dangerous substance directive (67/548/EEC) cannot be gathered from MSDS.

According to the EU White paper on Chemicals policy, the use of MSDS Safety data sheets are generally considered to be suitable communication tools to provide safety information to users, in spite of numerous shortcomings. The Commission proposes to establish a working group of Member State experts including participation of the European Chemicals Bureau to provide advise on how to ensure better quality of safety data sheets, examine the current information requirements with a view to expand them in order to enable users to carry out risk assessments.

4.3 Consumer Focussed Information Interfaces

4.3.1 Eco-labelling

The concept of eco-labelling was introduced in *section 3.2*, outlining the main ISO categories of labels used within the ICT sector. In this section, the main eco-labelling programs influencing product development will be briefly discussed, although details concerning the individual criteria for each program are out of the scope of this research. General observations concerning the criteria will be mentioned in order to point out any major differences between the programs. What is important to highlight is the market penetration of each system, providing insight into the demand and supply of environmental product information in the ICT sector. The main eco-labels and associated product groups that are considered important by manufacturers of ICT products are listed below in table 4-3 In table 4-4 directly below table 4-3, a representation of the number of licences for each program is provided along with the applicable ISO classification.

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[74] Swedish National Chemicals Inspectorate. (1999). Product Information: a guide to be consulted in the work to classify and label chemical products when preparing safety data sheets. [Online]. Available: http://www.kemi.se [2001, June 7]

[75] Swedish National Chemicals Inspectorate. (1999). Product information: a guide to be consulted in the work to classify and label chemical products when preparing safety data sheets.

Table 4-3: Main eco-labels or eco-declarations influencing product design – ICT product groups

Program	Issuing Country(s)	ICT Product Groups covered
Nordic Swan	Norway, Finland, Denmark, Iceland, Sweden	PCs, Copiers, Printers, Fax machines
EU Flower	EU Member States	PCs, laptops
TCO	Sweden	PCs, VDU (CRT's &LCDs), Mobile telephones
Energy Star	U.S. (other countries under license)	PCs, Copiers, Monitors, Printers, Fax machines, Scanners, Multi-Function devices,
ECMA TR/70	ECMA	Applicable for ICT products in general
IT Företagen	Nordic Information Technology Organisations IT Företagen, IKT Norge, IT-Branceforeningen, Denmark	PCs, Printers, Faxes, Copiers, Communications

Table 4-4: ISO classification and number of licences issued for selected eco-labels and eco-declarations

Type	Based on	ISO Standard	Programs (examples)	Licenses for ICT Products
I	3rd party criteria selection	ISO 14 024	EU: Eco-Flower Blue Angel Nordic Swan TCO*	1 200 43 1200
II	Self-declared environmental claims	ISO 14021	IT Företagen ECMA TR/70	1600 100
III	LCA, 3rd party certified product declaration	ISO PDTR 14025	Individual companies only, no agreed criteria per product group	2
Single Criteria			U.S. EPA Energy Star	5750

* 99% are for displays, 1% are personal computer systems, no printers, copiers and faxes

Source: Hermann, F., Urbach, H-P., Wendschlag, H.. (2001)

As can be seen from the number of licences issued by the above labels, two systems have become *de facto* standards for ICT products. The sheer number of TCO certification (primarily for VDUs), and the Energy Star labelled products illustrates this point. Similarly, this was reported in an IIIEE thesis that investigated the potential for eco-labelling to influence producers of personal computers. The IT Företagen eco-declaration has gained considerable market penetration (80% for PC's, 95-100% for copiers) in Sweden, primarily as a result of its use of a tool in public purchasing contract agreements.[76] These issues will be discussed in *section 6.4*, further in the report.

Comparison of Label Criteria and Parameters to Report

IT Företagen has published an interesting report that compares the criteria of eco-labels to self-declaration systems for personal computers. Included in the comparison to IT Företagen Eco-declaration is the EU Flower, Nordic Swan, Blue Angel, TCO 99 Type I eco-labels and the ECMA TR/70 self-declaration Type II label. The parameters to declare required in the IT Företagen Eco-declaration have been systematically compared with the criteria to be met or parameters to report for each of the other labels mentioned. The report denotes whether or not each program or declaration meets the requirement of IT Företagen. In addition, all criteria or parameters to report that are not found in IT Företagen's declaration are listed and denoted which program they are applicable to. The results have been analysed by this author and presented in *Table 4-5* below.

[76] Björn Axelsson (2001, June 28) Personal interview.

Table 4-5: Number of criteria or attributes to declare in selected eco-labelling and eco-declaration programs

	IT Företagen	**EU Flower**	**ECMA TR/70**	**Nordic Swan**	**Blue Angel**	**TCO 99**
IT Företagen Parameters to declare	49	38	37	36	29	28
All other criteria not in IT Företagen	0	6	4	6	5	11
Total	49	44	41	42	34	39

Although, difficult to draw any concrete conclusions concerning which label or declaration addresses the most environmental aspects of ICT products, some general observations can be made. Not all criteria relate to product specific attributes in the IT Företagen eco-declaration, and include attributes concerning the environmental policy and management system of the company. Important also to note, that in the case of the EU Flower and ECMA TR/70 ergonomics criteria are not addressed, as they do not directly relate to environmental performance. Similarly, the Blue Angel and TCO 99 programs do not address packaging of the product. Also, the Blue Angel program does not address electromagnetic current (EMC) issues, which are considered to be more a health and safety related issue. Generally, the IT Företagen self-declaration system provide opportunity to declare if the products meet the parameters in a yes/no type answers, with absolute product data required for energy consumption, noise characteristics, product packaging, emissions for faxes, printers and copiers. The ECMA TR/70 provides absolute product data and information to the consumer in the form of an environmental profile. For Type I eco-labels all criteria must be met in order to qualify to display the label.

Apart from these issues, upon closer review of the comparison report, the following observations are noted. All of the systems address the environmental improvement criteria introduced in *section 2.4* used in this report in some format. For example, all systems address materials of concern, particularly flame retardants, chloroparaffins, mercury, cadmium, and lead to varying degrees. The Blue Angel and the IT Företagen systems require flame-retardants to be prohibited or declared respectively, down to the PWB level. For emissions during the use phase, this category is not applicable for PCs. All systems require the energy consumption to be reported and for the labelling criteria they must meet levels equivalent to the EPA Energy Star program. Product lifetime extension is addressed in each program with the exception of TCO 99. And finally end-of-life aspects are also addressed in each program.

The self-declaration labels of IT Företagen and ECMA have been developed by industry in response to the rapid advancement of eco-labels for the ITC sector. ECMA Technical Committee 38 was established to address the concern over the proliferation of national ecol-labelling schemes and increased interest on the part of public and institutional customers for environmental product information. The ECMA TR/70 –Product related environmental attributes – report lists a number of parameters that are organised into self-declaration data sheets, which are designed for use by manufacturers and suppliers. The attributes relate to four main categories including; energy consumption, emissions, data on materials and packaging data. ECMA TR/70 uses applicable international standards, guidelines and currently accepted practices to measure and report the attributes.

ECMA has recently investigated how the TR/70 compares with the essential requirements of the EEE Directive. In the study it was found that the TR/70 covers approximately 45% of the essential requirements of the EEE Working Paper, while the EU Flower would satisfy approximately 50%. One precondition of the Flower's 50% is the fact that a TR/70 declaration is to be provided to customers along with the product as stipulated in the criteria of the label.

Similar to the ECMA TR/70, the IT Företagen eco-declaration system developed in response to public and institutional customers in Sweden. Public authorities, such as municipalities and state purchasing organisations were increasingly demanding information from ICT OEMs on product environmental attributes. The requests for information varied considerably and were often not representative of ICT products.[77] A number of organisations, 15 in total, were influential in its development, including the Swedish EPA, KemI, Staskontoret, NGO's and representatives of the municipal sector. The declared parameters include aspects from a number of the aforementioned eco-labelling schemes, particularly the Blue Angel and the U.S. EPA Energy Star. IT Företagen claims that the parameters of the declaration can and should be updated to reflect changes in industry practices and requests for information from public authorities and NGO's. As can be seen by the number of registrations for IT products, over 1700 as of August, 2001, manufacturers are producing these documents for their products, creating the need for documentation systems and creating the flow of information to public purchasers.

4.3.2 Public & Corporate Procurement

It has been repeatedly stated that increasing demands are placed on OEMs to declare information regarding environmental attributes of products primarily from public purchasers in Sweden and Germany. In Sweden, the increased interest lead to a proliferation of varying questionnaire formats and demands for eco-labels that the Swedish IT Association was encouraged to intervene. Discussed above in *section 4.3.1*, this has lead to the development of a standard declaration document that can guide producers (to guide in the development of products) and purchasers (to assist in decision making). Within the EU Commission there is a concerted effort building to promote public procurement as a mechanism to encourage the development of environmentally preferable products.

On July 4, 2001 the EU Commission released an "Interpretative Communication" on Community law applicable to public procurement and the possibilities for integrating environmental considerations into public procurement". The report was in response to a document presented at the European Council in Gothenburg in June 2001. The report "A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development" directs Member States to consider how to make better use of public procurement to favour environmentally friendly products and services.

Its objective is to examine and clarify the possibilities offered by the existing public procurement regime in order to enable the optimum consideration of environmental protection in public procurement.[78] The document follows the different phases of a contract award procedure and examines at each stage how environmental concerns may be taken into consideration. In the following paragraphs the most significant aspects of the report that influence environmental product information flow are discussed.

Most influence can be exerted at the beginning of the public purchasing process, namely when making the decision on the subject matter of a contract. These decisions are not covered by the rules of the public procurement directives, but are covered by the Treaty rules and principles on the freedom of goods and services, notably the principles of non-discrimination and proportionality.[79] For ICT product purchasing, contracting authorities are free to define the subject matter of the contract in the way that they consider to be the most environmentally sound.[80] However, a public authority has to

[77] Axelsson, B. (2001, June 28). Personal interview.

[78] Commission Interpretative Communication COM (2001) 274 final. Commission Interpretative Communication on the Community law applicable to public procurement and the possibilities for integrating environmental considerations.

[79] COM (2001) 274 final. p. 6

[80] Contracting authorities have the possibility to either prescribe the solution chosen, or avoid prescribing requirements which would lead the tenderers to offer products whose production processes would damage more the environment. They could, for example, require recycled paper which is not bleached

observe the general rules and principles of Community law. More precisely, these are the principles regarding the free movement of goods and services as laid down in Articles 28 to 30 (formerly 30 to 36), and 43 to 55 (formerly 52 to 66) of the EC Treaty. [81]

Within the framework of the public procurement directives, there exist different possibilities to integrate environmental considerations into public purchases, notably when defining the technical specifications, the selection criteria and the award criteria of a contract.

In the absence of mandatory references[82], or where they require a higher level of environmental protection than that laid down in standards or legislation, contracting authorities can define the technical specifications related to the environmental performances in line with eco-label criteria and may indicate that products having eco-labels comply with the technical prescriptions of the contract documents.[83]

Costs incurred during the life cycle of a product and will be born by the contracting authority may be taken into account for the assessment of the most economically advantageous tender.

4.3.3 Mandatory Information

Requirements in the WEEE Directive outline that Member States are responsible to promote the take-back of WEEE and inform the public concerning its proper disposal. Member states in particular should educate citizens on the meaning of the label that denotes that the disposal of WEEE products and batteries under EU in regular household waste is prohibited.

In Article 12 of the WEEE Directive, it is outlined that Member States starting in 2007 shall provide the Commission annual statistics information of the quantities and categories of electrical and electronic equipment put on the market, collected and recycled within the Member States, both by numbers and by weight.

The EEE working paper proposes some new requirements for producers to supply information to consumers. This potential requirement was described in *section 3.1.3*, and should be referred to for specific details. However, briefly mentioned the requirements pertain to information for consumers on the significant environmental characteristics. Instructions are to be provided with the product to illustrate to consumers the most appropriate way to use, install and maintain the product in order to minimise its impact on the environment, including where to properly dispose of the product at the end-of-life.

The Swedish Strategy for a Non-toxic Environment lists a specific goal pertaining to mandatory information to be provided to consumers. By 2010, products will be labelled with health and environmental information on the hazardous substances they contain.

4.4 End-of-life Focused Information Interfaces

Reuse, Repair, and Disassembly operations require environmental information concerning the products that they manage. Information on the location of hazardous components is needed by treatment facilities in order to avoid contamination of otherwise useful material streams to comply with legislation and ensure maximum recyclability. Depending upon the age and reusability of the

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[81] COM (1999) 263 final., p. 8 and 9.

[82] Like for instance a European, international or national standard covering also environmental aspects of a product

[83] COM (2001) 274 final. p. 11

product various levels of reuse, remanufacturing, or treatment will occur. Unfortunately today, very little remanufacturing of ICT products is taking place, for a number of reasons discussed below.

4.4.1 Reuse

Although there exists a relatively robust reuse market for some ICT products, there are a number of barriers that inherently prevent the reuse market from becoming more viable. First, since most computer products performance improves significantly with each new product release, the installed product base becomes obsolete before they are worn out. Price is also decreasing for many ICT products, with current year models often being cheaper than the previous year. These variables combined bring the price of used product down more rapidly than in other durable goods, such as automobiles, refrigerators etc.

With the rate of obsolescence being so high, consumers are driven to replace or upgrade their equipment frequently. Manufacturers must create innovative products and compete aggressively for this replacement business or risk losing market share. This drives the introduction of new products to the marketplace. Current reuse markets are incomplete, capturing only a small percentage of obsolete units. Many customers have no convenient option for selling or disposing of their used equipment.

However, reuse may not always be the most environmentally preferable strategy for all ICT products. For example, some significant reductions in energy consumption of monitors in subsequent year product releases may make it more preferable to recycle the product than to continue to use the product in second use applications.

4.4.2 Repair

With the shift to digital technology and the continued miniaturisation of ICT products, repair has become increasingly difficult and specialised.[84] To accommodate for this manufacturers, such as Sony have introduced an exchange and refurbishing program that facilitates the efficient repair of large sales volume products. Customers can bring in their defective products to dealers and exchange it for a refurbished product. Like products are grouped together and shipped to a central location for refurbishment, where broken parts are repaired or exchanged and cosmetic parts are checked. According to Sony average costs of repair have been reduced by 25% and more products are returned to service. The fact that long product lifetimes and high customer satisfaction is key to long term business success, has however not for the most part encouraged OEMs to consider service activities, as they are perceived to be too cumbersome. Sony points out that this mindset must change to the view that many services could be considered a good business opportunity. Examples include new revenue from software sales that upgrade products functionality or new cosmetic parts that satisfy changes in consumers taste.

4.4.3 Disassembly

A common problem associated with disassembly of ICT is the fact that operators have very little data associated with the product's configuration.[85] Researchers have noted that in many cases it is often difficult to obtain product information from manufacturers. This lack of information transfer usually precludes effective reclamation and recycling of products that are disposed. Das & Naik point out that evidence of this occurrence can be seen by the fact that all higher-level disassembly and

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[84] Baynes, A. et al. (2001) Environmental technologies and their business drivers. In M. Charter & U. Tischner, Sustainable Solution: Developing Products and Services for the Future (345). Sheffield: Greenleaf Publishing

[85] Das, S., Naik, S. (2001). The DBOM Standard: A specification for efficient product data transfer between manufacturers and demanufacturers. In 2001 IEEE International Symposium on Electronics and the Environment. ISEE-2001. (241)

remanufacturing taking place is either operated or sponsored by the OEM. These operations have authorised access to most product information that is necessary to effectively carry out the remanufacturing. Such information typically includes computer aided design (CAD) diagrams and a bill of materials (BOM) The BOM contains information on the various parts and sub-assemblies contained in the product with information on how they fasten together.

Given the current infrastructure of the industry (privately owned and operating end-of-life facilities) it is unlikely that OEMs will make available to the public BOM information considered to be highly proprietary. Other obstacles include lack of a standardised coding format and an insufficient communication channel. To address these issues Das & Naik propose a disassembly bill of materials (DBOM) standard that condenses much of BOM information necessary to facilitate disassembly and recycling.

The proposed standard will contain two data tables on 1) parts and their mating relationship and 2) fastener data (how the parts are held together). The DBOM provides guidance for OEMs to aggregate groups of mating parts, as it is not necessary to know all individual parts for disassembly purposes. The DBOM also designates which recycling stream each part is best suited with an estimate of its purity. It is also possible for these tables to be included in product labelling or coded data transfer that can be easily read by treatment facilities.

Profitable disassembly requires that the facility knows the material content of the part or its reuse value as a part. In order to protect the value of the reuse or recycling stream the location hazardous material must be known and removed. The DBOM can address both the issue of material content and location of hazardous materials but has difficulty with reuse value. Reuse value is not easily captured in the DBOM, as manufacturers are not usually willing to note that a part is fit for reuse due to warranty or competitive issues. However, there are other formal networks where recyclers have access to part value that is more appropriate.

Disassembly facilities are invariably focussed on how the product is fastened together to improve efficiency of the disassembly process. Typically disassembly planners spend time learning how a product's parts fit together, before a breakdown plan is proposed. There are a large variety of fasteners used in product assembling that have varying degrees of dismantling difficulty. Within an assembled product there may be more than one set of fasteners and a variety of different fasteners used. The DBOM standard lists the different fastener sets[86], the type used, and the number used in each set. To aid the identification of the different types of fasteners the authors have developed 18 categories that include the relative unfastening difficulty of each.

In addition to the type of fastener used, fastening structure is important to the level of ease of disassembly and must be represented in the DBOM standard. Three structure types have been defined for mating parts. Type I Mating refers to parts that are assembled with separate fasteners. Type II Mating refers to parts that are assembled with fasteners that are integral to one part of the pair. Type III Mating refers to parts that are mating but there is no direct fastening involved.

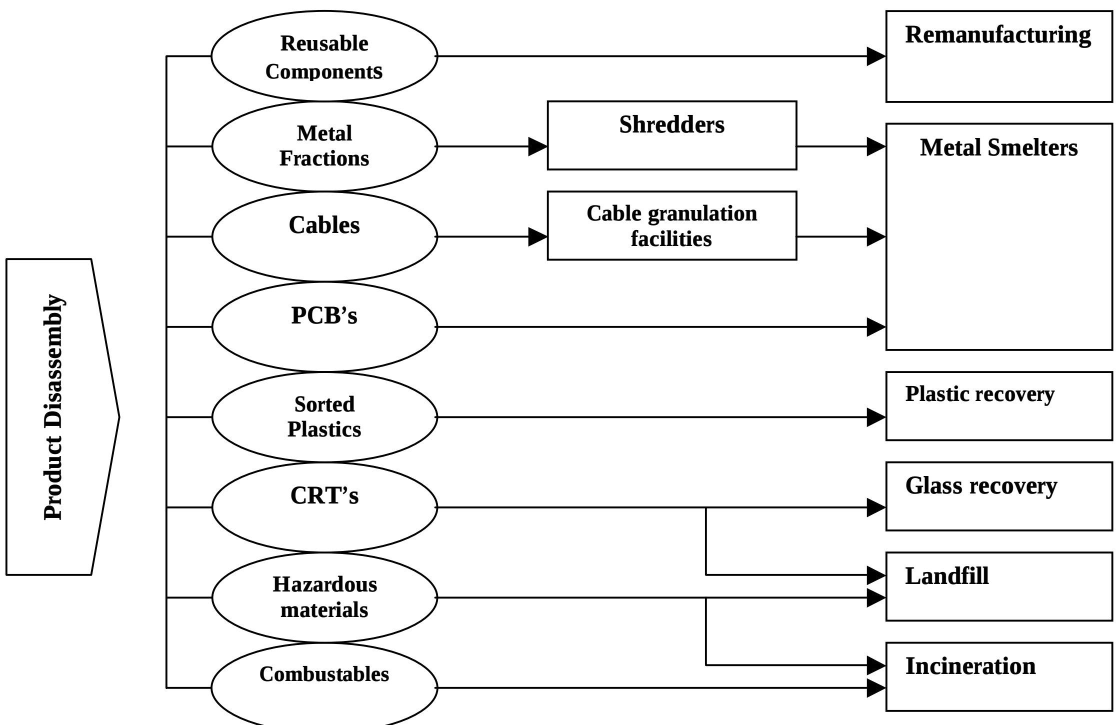
Further consideration in the fastening relationship is the accessibility of the fastening mechanism. Accessibility to the unfastening head or trigger is instrumental in determining the effort needed to disassemble the product. This has typically been left up to the dismantling company at the time of disassembly since this relationship has been difficult to define. However, in the DBOM standard six levels of difficulty are proposed based on accessibility to the unfastening device. Numbers ranging from 1.0 for level 1 and 3.0 for level 6 are assigned to represent access difficulty.

[86] A fastener set is a group of similar fasteners, such as a group of screws, which act as an integral fashion to hold together two or more mating parts.

The final results of the considerations listed above are two tables that document the information in a standard, easily readable format. The first table provides the list of parts and how they are fastened together i.e.) how each part mates with another (if at all) and the type of mating (0-3) corresponding to the appropriate fastener set. The second table provides data concerning the fastener sets, such as the number, type and accessibility of the fasteners in each set. Together the DBOM provides a representation of the physical structure of the product in a disassembly context.[87] The format can be easily transferred to facilities through product labelling or in product manuals. According to the authors the tables can be generated from CAD systems using extendable mark-up language (XML).

The use of this standard not only assists in facilitating disassembly, but also could also be used by OEM design functions to measure the ease of disassembly of designed products. OEMs can use the ease of unfastening and accessibility indices to choose fastening mechanisms that result in the best disassembly opportunities. It is also quite feasible that when manufacturers are negotiating contracts with disassembly facilities that the DBOM tables may be useful in determining appropriate price structures.

Assuming that something like the DBOM standard was adopted by the ICT industry, disassembly processes would likely yield a number of material streams. Using the current recycling disassembly practices in Sweden as an example (considered to be quite extensive) approximately eight material streams could be expected. The diagram below outlines the typical material fractions from Swedish facilities.



Source: Furuhjelm, J. (2000)

Figure 4-2: Common material fractions at disassembly facilities in Sweden

[87] [87] Das, S., Naik, S. (2001). The DBOM Standard: A specification for efficient product data transfer between manufacturers and demanufacturers. p. 246

Within the WEEE Directive, producers are required to provide (not explicitly stated) information as is needed by treatment facilities to identify the different electrical and electronic equipment components and materials, and the location of dangerous substances and preparations in the electrical and electronic equipment.[88] Perhaps this standard could appropriate way of meeting the obligations of the Directive.

ISO 11469 standard provides a generic identification and marking system for plastic products. Design guidelines and eco-label criteria require the marking of plastic components according to the standard so that recyclers can easily identify the plastic type for improved separation capabilities. The standard *Plastics - Generic identification and marking of plastic products* has been supplemented with ISO 1043-4:1998(E) *Plastics- Symbols and abbreviated terms- Part 4: Flame-retardants*, which regulates how to label plastics material containing flame-retardants. Labelling is made by means of FR followed by a code number for the flame retardant being used. For example, FR (40) means that the plastic part contains halogen-free organic phosphorus compounds.[89]

4.5 Development of Environmental Product Information Systems

4.5.1 Internal OEM Systems

Many ICT OEMs use Enterprise Resource Planning (ERP) systems to organise, control and plan their activities. An ERP system can be defined as a collection of multi-module application software, which merges all of a company's various functions into a contiguous and consistent database.[90] Three levels are usually differentiated in an ERP system, including operational, tactical and strategic systems.

Operational databases track information pertinent to the attributes and specifications of the product. Also known as Product Data Management (PDM) systems, these store information on product specifications that include bill of materials (BOM), product features, weight, energy consumption, CAD diagrams, product standards, manufacturing information specs and etc. There exists an opportunity to integrate environmental product information with other information databases within the company, so that various functions within organisations can access data concerning the environmental attributes of products. For example, information concerning detailed material declarations of products can be integrated with PDM information such as the BOM so that information can be commonly referenced. Standardisation facilitates the gathering of environmental product information throughout the supply-chain, which is discussed in more detail in *section 4.5.3*.

4.5.2 External LCI and LCA Databases

In order to facilitate the use of LCA as a support tool in environmental decision-making numerous organisations and governments have been attempting to assemble data on materials, transports and processes. Life-cycle inventory databases both public and private have been established that aim to make LCI data more available to organisations. Lack of data availability severely affects the time needed to conduct LCA studies, making the data acquisition process very expensive. However, there are general concerns over the quality and transparency and compatibility of the data with various software tools on the market. Efforts have been undertaken to address these issues, with some of the more relevant initiatives described below.

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[88] Commission Proposal COM (2000) 347 provisional

[89] IVF Industrial Research and Development Corporation. (2001). [Online]. Available: http://extra.ivf.se/dfee/news/ISOstandard.htm [2001, June 23]

[90] Januschkowetz, A., Hendrickson, C,T. (2001). Product and Process Life Cycle Inventories using SAP/R3. In 2001 IEEE International Symposium on Electronics and the Environment. ISEE-2001. p. 60

Global Spine Initiative CPM, Göteborg, Sweden

Sustainable Product Information Network for the Environment (SPINE) was the result of interdisciplinary projects involving industry and, organisations between 1993 and 1995.[91] Since inception corporate LCA databases and software have been built on the SPINE structure. In 1997 CPM initiated the groundwork to develop a standard for an international LCA data documentation format. Subsequently a new standard ISO 14048 has been established and is currently in the review process (discussed below). According to Carlson, in addition to SPINE being a comprehensive model and practical solution for handling LCA data, it is useful for other informational needs of corporations.[92]

With SPINE a common data format and language has been developed that is consistent with ISO LCA formats. It provides LCA practitioners, corporate environmental managers, and suppliers with a common way of reporting and storing data, which in the long run will aid in comparability and reduce costs associated with data acquisition. Several Nordic companies offer software that is compatible with the SPINE format, including Eco-lab by Nordic Port and EPS developed by Volvo and IVL, which was brought to market by Assess Ecostrategy Scandinavia.

The SPINE initiative does not provide any templates for data acquisition to suppliers for their needs directly. This is the responsibility of the OEMs to coordinate and then submit this data into the SPIINE public database.

When asked what were the main reasons cited for companies to engage in the CPM group and the SPINE initiative, Raul Carlson noted that most companies see the benefits of sharing LCA data to reduce costs and time needed to acquire data. The issue of improved credibility was also noted as a considerable driver. The SPINE initiative does not include information on location of hazardous materials, material content databases, or disassembly instructions etc.

CPM is currently developing a common architecture for an integrated industrial environmental management system (IIEIS). CPM's aim is to define common information storage and communication structures, and system and software modularisation, application programmer's interface (API) and use cases for a number of industrially relevant user situations. By using existing principles outlined in standards such as SQL ANSI 92, ISO 10303, and ISO 14048, a further comprehensive standard can be developed for IIEIS.

UNEP LCI/LCA Initiative

In May 2000 UNEP announced that is working together with SETAC (Society of Environmental Toxicology and Chemistry) to establish the 'Life Cycle Initiative'. Building on the ISO 14040 series of standards this initiative aims to establish best available practice within the field of LCA.

The stated objectives of the Life Cycle Initiative are:

- to harmonise existing bodies of LCA knowledge;
- to stimulate multidisciplinary scientific work under the leadership of UNEP and SETAC;
- to create reviewed, publicly accessible LCI databases and/or information systems with data on energy and raw materials used as well as emissions, in order to facilitate the realisation of the inventory analysis and improve the reliability of its results;
- to guide and expand applications of the impact assessment phase through the establishment of a best available LCIA practice with adequate methods and factors;

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[91] CPM, Competence Center for Environmental Assessment of Products and Material Systems (2001). http://www.glObalSPINE.com [2001, July 10]

[92] Carlson, R. (2001, June 25). Personal Interview

- to ensure that the use of LCA is globally possible for different types of application, including developing countries,
- to present demonstration studies showing the successful application of the developed best available practice.

With the following deliverables:

- A database or information system which is peer reviewed and regularly updated covering a wide range of commonly used processes, materials and products;
- A set of rules for establishing system boundaries; –
- A set of best available Life-Cycle Inventory Assessment methods, models and factors;
- Demonstration studies for worldwide use.

SPOLD

The Society for Promotion of Life-cycle Assessment Development (SPOLD) was established in 1992 as an association of industrial partners that are interested in promoting the development of LCA. Early work in the association concentrated on the development of LCA methodology and efforts to build consensus among governments, industry, environmentalists, professional groups, and academic institutions on the merits of LCA as a decision tool.

With respect to LCI inventory data, SPOLD has published a sourcebook of available life-cycle inventory data sources, subsequently developing the SPOLD format to facilitate LCI data exchange. The creation **SPOLD Database Network** has created an association of European data-suppliers who make their LCI data available in the SPOLD format. Current focus of SPOLD is now to maintain and further develop the SPOLD Format in cooperates with a number of other organisations, including SETAC and ISO working groups on data quality and availability.

A number of commercial software developers have designed their LCA to be compatible with the SPOLD format including TEAM 3.0 by Ecobilan, KCL-ECO 3.0 by KCL, Umberto by Institut für Umweltinformatik Hamburg GmbH, SimaPro 4 by Pré.[93] Concerning LCI inventory data, the EIME database from Ecobilan has one of the most extensive datasets available to date for EEE components and processes.

ISO 14048

As of July 6th, 2001 ISO 14048 became a new technical specification for documenting LCA data. The specification outlines a standard form to report data that can be used as a template for ISO compliant and compatible designs of data forms, questionnaires, database systems and electronic communication systems.[94] In particular, the specification describes the data documentation format for LCI data as described in ISO 14041. By using ISO 14048 format, fully transparent data documentation is said to be achievable for e.g. complete life cycle inventories, individual plants, and production lines.

The development ISO 14048 is an important step in the promotion of standardised and transparent LCI data in the ICT sector. It creates a platform on which LCI data can be exchanged on an international level appropriate for the ICT sectors composition.

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[93] Society for Promotion of Life-cycle Assessment Development (2001). [Online]. Available: http://www.spold.org/whatis.html [2001, August 10]

[94] CPM, Competence Center for Environmental Assessment of Products and Material Systems (2001). http://www.glObalSPINE.com [2001, July 10]

4.5.3 Voluntary Material Declaration Systems

Material declarations form important building blocks for product information systems. The most common format used by companies in the manufacturing supply chain to obtain this information has been in the form of questionnaires. This is not to be confused with Type II declarations such as the SITO Declarations or the ECMA that present data on numerous environmental performance aspects of the product, which is discussed in *section 4.4.* Material declaration questionnaires enable data to be gathered concerning material contents of the product that in turn can be used when this information is to be presented to consumers. Besides this consideration there are many reasons why OEMs require information concerning what materials are present in the products they market. Listed below are 5 common explanations noted by several authors.[95]

- In *section 3.1* it was shown that existing and proposed legislation at the national, EU and international levels are or will restrict the use of certain chemical substances and materials in ICT products.
- Future legislation concerning the use of chemical substances and materials is somewhat unpredictable considering that many of the substances have never undergone risk assessments to determine what environmental or health and safety properties exist. Therefore complete knowledge of materials contained in ICT products is of an interest to OEMs that want to develop a proactive approach to materials declarations.
- Customers, whether they are corporate, public, or private consumers may have additional demands that go beyond legislative requirements.
- Some chemical substances or elements have been shown to negatively effect the recycling process, namely smelting. This is exuberated by the fact that varying recycling processes have different requirements concerning this.
- Precious metals, which can greatly affect both the price of the product and the costs for end-of-life disposal. The most relevant metals are copper, silver and gold.

There are several issues to this approach that have lead to the development of standardised questionnaires that can be used on a regional or international level. The proliferation of varying formats of questionnaires has become a problem for companies that supply materials, components, and sub-assemblies. The amount of time to fill in separate questionnaires has obvious cost implications for suppliers. The advantage to using standardised material declaration formats not only benefits the suppliers, but also OEMs that can expect to receive answers much faster than otherwise. Suppliers would be able to rationalise and prepare the material declarations in advance, therefore making the answers more accessible.

International Electrotechnical Commission (IEC)

In 1996, the International Electrotechnical Commission's (IEC) Advisory Committee on Environmental Aspects (ACEA) set about the task of standardising material declaration questionnaires. The goal of the working group within ACEA was to study the need for and to prepare an outline of a suitable questionnaire. Included in this goal was an important task of identifying if this questionnaire could be applicable for the worldwide market for EEE.

The working group tasks included identifying and documenting existing questionnaires and material declarations used in the EEE sector. Two distinct approaches were identified with the majority containing a list of environmentally relevant substances or materials in weight expressed in % or in parts per million (ppm) either with or without threshold limits to declare. Some questionnaires asked

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[95] Mälhammar, G. (1998). Material Declaration Questionnaire. In 1998 IEEE International Symposium on Electronics and the Environment. ISEE-1998. p. 16

for the materials content down to a certain level (i.e. 99% by weight) complemented with a list of substances to be declared regardless if they were included in the remainder or not.

Important to note with the work that the ACEA group undertook was that fact they identified varying informational needs by actors involved in the management of the EEE product chain. Similar to the list presented in section 3.6.3 above, the working group realised that the associated wishes and needs for material information should be weighed against the effort and possibilities to acquire the information when deciding what the questionnaire should look like.

For this initiative the working group decided on seven principles to guide the process of developing the questionnaire.

- **Principle 1:** The questionnaire or parts of the questionnaire was voluntary and that no parts could be made mandatory. The asking company could also be able to add or remove chemical substances or materials to the list.
- **Principle 2**: The questionnaire should be used only for the declaration of materials in *products***,** excluding *packaging materials* and *production materials.* However, there was a general recognition of the fact that it may be necessary to develop guidelines and/or a questionnaire to deal with production materials and packaging materials.
- **Principle 3**: Chemicals or groups of chemicals must contain a threshold limit, and information about the CAS number and relevant legislation pertaining to that substance.
- **Principle 4**: The questionnaire should be easy to use and as short as possible making use of groups of substances. The format of the questionnaire should facilitate the use of electronic information transfer.
- **Principle 5:** It should only be used for informational purposes and not contain requirements for phase-outs of certain chemical substances or materials. However, list attached could serve as important guidance to the suppliers.
- **Principle 6**: The completed questionnaire should be signed by the appropriate authority with the organisation to facilitate a more serious response.
- **Principle 7**: All information included in the declaration should be handled with the strictest confidentiality.

With the inclusion of principle four, the working group acknowledged that without a complete declaration of all materials it would be difficult to use the questionnaire as a basis for labelling requirements. On the other hand it was mentioned that a complete materials declaration, which also gives complete information of chemicals and materials has associated costs of storing and updating this extensive data set. The working group decided that perhaps the best approach would be allow the company issuing the questionnaire to decide which part of the product should be declared according to the list and which part should have a complete material declaration.

Unfortunately, the IEC did not agree with the working group in ACEA concerning developing the questionnaire in accordance with the principles listed above. According to Mälhammar, (1998) an explanation that the IEC gave to the ACEA working group for its rejection of the proposal was that the “IEC could be put under pressure from manufacturers who didn’t want to see their products on a list of environmentally relevant substances”. The IEC instead decided to develop a guidance document for a standard outline for a materials declaration that companies could use to “fill in substances for which they wanted information”.[96] In October 2000, the IEC has subsequently published a guidance document, IEC Guide 113 – “Materials declaration questionnaires – Basic Guidelines”.

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[96] Mälhammar, G. (1998). Material Declaration Questionnaire. In 1998 IEEE International Symposium on Electronics and the Environment. ISEE-1998. p. 17

However, in the absence of the go ahead for the development of the materials declaration at the IEC level, Ericsson with a number of partners decided to develop a common voluntary questionnaire that incorporates some of the suggestions of the working group as well as the experiences within the cooperating companies. Included in the questionnaire would be information requests concerning material that would assist with DfE initiatives.

Important insight into specific information that should be included in questionnaires included the need for information concerning producer responsibility requirements. At the time of this initiative, the WEEE Directive had not been drafted and the suggestions were based on speculation concerning what the requirements would be in the future. They specifically mention the suggestion of the Danish government that 80% of **copper (Cu), nickel (Ni), platinum (Pt), palladium (Pd), lead (Pb), zinc (Zn), gold (Au)** and **silver (Ag)** be recycled from Peas. Also the requirement that **cadmium (Cd)** and **tin (Sn)** must be recovered as far as possible suggests that at least these elements must be included in material declarations.

Specific mention concerning the need for certain material information when considering end-of-life options in the design phase that meet the legal requirements as well as being profitable. Products must be designed that will not interfere with recycling requirements that ensure the most environmentally adapted treatment, and that there may be varying ways of treating end-of-life products that are preferable from an environmental view point. For instance looking at a standard contract for the smelting of PBAs illustrates this point. Some materials or substances must not be present in the assemblies because they interfere with the smelting process. An associated financial penalty if out of compliance will severely affect the economics of the end-of-life costs and or revenues. For the contract shown, the PBAs must not contain PCBs, radioactivity, tungsten (W), and asbestos.

This point illustrates that OEMs that manage their waste separately from other manufacturers need to know what the elements are present in their products to ensure the least cost is incurred when the products reach the end-of-life stage. Therefore they need this information from their suppliers when considering design options for least cost at end-of-life.

Electronics Industry Alliance (EIA)

Co-ordinated by the Electronics Industry Alliance in the United States, a material declaration guideline was released in February 2000 that aims to standardise material declaration questionnaires for the U.S. industry. It represents an industry-wide consensus concerning the purpose, scope and coverage of material related declarations. The Association points out that the creation of the guidance document is a result of the expressed concern from both OEMs and their suppliers. Due to the proliferation of varying questionnaires received, suppliers note that questionnaires currently used are rarely consistent, often ambiguous, and difficult to complete.

The stated purpose of the guide is to assist manufacturers to develop consistent relevant material declarations questionnaires regarding materials contained in the components and products they purchase for the inclusion into their finished products. The guide lists materials and threshold levels that are to be included in the questionnaires, representing industry consensus. It is explicitly stated that materials listed in the guide do not represent an industry judgement as to the environmental or health impacts of the listed materials. Reasons listed for the inclusion of some materials is that they are regulated in other countries where EIA members sell their products and therefore are required. Some materials have also been listed to allow manufacturers to respond to information requests from customers and recyclers.

The guide is divided into three (3) categories of materials including *controlled, restricted, and materials of interest*. *Controlled materials* are materials that are subject to either a legal ban or a voluntary industry prohibition. *Restricted materials* are materials that are prohibited only in certain applications. *Materials of interest* are materials for which the industry seeks disclosure in order to respond to customer and other inquiries. See Appendix II for the materials listed that correspond to these categories.

A further more detailed list of chemicals that make up the general material categories is included as an appendix to the guide. This list also includes the CAS classification numbers that assists suppliers categorise their materials more efficiently**. Important to note** are the threshold levels that determine whether a material should be reported on the declaration for categories A, B and C.

Category A: Controlled materials states that any intentionally added listed material used during the **production** (if noted on the list) of, or incorporated into **products or components** must be reported. *Category B*: Restricted material states that any intentionally added listed material that are incorporated into **products or components** if used in the restricted applications listed. *Category C:* Mercury is the only material that must be declared regardless of the level in the product, component or sub assembly. All other materials have a threshold level of 1000 ppm, which is the same as 0.1% by mass.

Japanese OEM Initiative

Coordinated by Canon Japan in cooperation with 16 companies, discussions are currently underway to develop a standardised format for environmental questionnaires and material declarations. Japanese ICT companies, on an independent basis, began to develop 'green procurement standards' in 1996, which put requirements on suppliers concerning product attributes such as materials, energy consumption and production methods. Similar to reasons expressed by EIA and the IEC, green procurement standards became far from uniform, creating an enormous burden on the suppliers. OEMs were unable to obtain data when needed. In addition, companies that both procure and supply components had to assess and provide information in many different formats.

The first phase of the initiative has been to decide as a group, the most important parameters that make ICT more environmentally compatible. This is an interesting approach in that the OEMs themselves have decided that they wish not to compete on determining what makes a product more 'environmentally preferable' but on the performance of the product itself. Once the information parameters have been agreed upon the task of the group will be to develop a standardised format for exchanging product information.

The results of this initiative will be made public in the fall of 2001. According to Canon, this project is completely independent of the IEC, EICTA, or EIA initiatives, however, there have been recent discussions between groups concerning each others work. Since similar discussions are taking place in EICTA and EIA, representatives from Canon indicated that perhaps "global guidelines using Japanese companies' experience of investigations" could be established by the Japanese initiative.

European Information and Communication Technology Association (EICTA)

EICTA's supply-chain initiative has been referred to in both the IPP Green Paper and the EEE Working Paper. Several attempts to contact the organisation to discuss the initiative were not successful. It appears that the organisation is not willing at this time to share information on this initiative with the public. However, representatives from Ericsson provided information on the general format of the initiative. The format is very similar to that used by Ericsson to collect material declarations from suppliers in terms of the materials that must be declared. The format is meant to be able to be used by all actors in the supply chain, from raw material suppliers to finished product providers.

Green Pack Data Flow Initiative at IVF

GreenPack, the Green Electronics Packaging & Environmental Data Flow Management initiative at IVF, in Sweden has approximately 25 companies participating in the project including suppliers and OEMs. GreenPack is a joint industrial research and network initiative that has the goal of enhancing the environmental performance of actors and their products in the electronics supply chain.

The GreenPack initiative focuses on environmental improvement of the EEE sector with an important emphasis on economic sustainability. Primary aspects of the project include material data disclosure formats, guiding principles for eco-design and decision-making, and life cycle cost models and procedures for assessing life-cycle economics of electronic products.

The Dataflow initiative, is primarily concerned with the declaration of material data and not LCI data acquisition. GreenPack supports open material disclosure in light of the combinations of drivers, which include current regulatory restrictions of certain material in EEE and expected regulatory restrictions (RoHS, EEE, Sweden's Non-Toxic Strategy). Certain manufacturers also have restrictions on materials that can be used within their branded products and therefore need information from suppliers on the contents of the products supplied. End-of-life recyclers and waste handlers need information on not only where hazardous materials are located but also on where valuable materials such as precious and rare minerals are located.

4.5.4 OEM- EOL Facility Data Exchange

Recently demonstration projects have been set up to address the issue concerning lack of information between OEMs and dismantlers. Hitachi, with financial support from the Ministry of International Trade and Industry (MITI) in Japan, have developed a prototype 'ecological information system' that facilitates data exchange between manufacturers and recyclers[97]. The model provides a platform where information concerning the structure of the product, hazardous material location, and disassembly methodology can be provided by manufacturers and accessed by dismantlers. Similarly, dismantlers are provided a platform or database to input data concerning problems with disassembly, incompatible materials etc., which manufacturers can access.

Hitachi is currently working on the next phase, an extension of this system which provides data with respect to users' needs, maintenance parts, recycled parts, recycling process, etc., throughout each phase of the life cycle, from manufacturing through delivery, use, maintenance, collection and end-processing. One major task remaining is to develop a standardized format for information input and output.

In Europe there are a number of demonstration programs that are underway or completed, including the IDEE system in Berlin that also facilitate the exchange of information between OEMs and

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[97] Ohashi, T. et al. (1999). Ecological Information System: Data exchange system between manufacturers and recyclers. In 1999 IEEE International Symposium on Electronics and the Environment. ISEE-1999. (143)

treatment facilities. The IDEE information system includes 10 international electronics manufacturers and 8 recycling enterprises in which manufacturers provide information on product composition and hazardous component location and assembly plans. Part of the system incorporates a virtual market where a network of authorised members can offer or buy materials and components generated in the program.

5. Case Study: Information Flow in the ICT Product Chain

5.1 Methodology

In order to investigate the supply and demand of product environmental data flow in reality, interviews with key actors in the chain were conducted accordingly. Much of this effort has focussed on the strategies employed at Ericsson since it has been established that OEMs are the most important actor in this respect. However, other stakeholders interviewed included ITC trade associations, product information database coordinators, end-of-life treatment facilities, government officials, retailers, and suppliers to Ericsson. The findings of these interviews are presented in this section in the context of how product environmental information flow is connected to product improvement. In order to simplify the inter-connected structure of product environmental information flow in the product chain this will be done from the perspective of the OEM, in this case Ericsson.

5.2 Manufacturing Chain: Ericsson

When investigating how information flow at Ericsson is linked to environmental improvement, it is useful to frame it in the context of the product development process and how the determinants of information flow, legislative, market and corporate strategic goals, affect it.

5.2.1 Background

Ericsson is one of the largest telecommunication and data communication designers and manufacturers in the world and is represented in over 140 countries, with over 100,000 employees. There are four current business divisions within Ericsson including; Mobile Systems – wireless network infrastructure, Multi-Service Networks - wireline network infrastructure, Data backbone and Optical Networks – high capacity core networks, and Global Services – support and consultancy service. Core business includes business-to-business mobile and fixed networks, including base station and mobile service switching centre hardware.

The environmental policy states that: "Ericsson shall contribute to sustainable development by developing, producing and offering products and services with excellent environmental performance that enables customers to minimise their environmental impact". Ericsson has an appointed an Environmental Director who is responsible for upholding the environmental policy and achieving the company's environmental goals. The Director chairs the Environmental Steering Group, which is made up of representatives from each business unit at Ericsson. Within the environmental organisation competence networks have been established that support top management and line units on key environmental issues.

Ericsson has a number of environmental goals that refer specifically to product environmental improvement. These goals are important determinants of product related environmental information flow. Below are the listed goals found in the Ericsson Environmental report 2000.

- Implement Ericsson's Environmental Management System (EMS) in accordance with ISO14001. Each Ericsson organization is to implement their part, including certification of all factories.
- All major suppliers are to have an environmental management system complying with ISO14001 or equivalent.
- Implement Ericsson 's Design-for-Environment rules.
- Use lead-free solder in 80 percent of new products.
- Eliminate halogenated flame-retardants in printed boards in 80 percent of new products.

- Eliminate the use of beryllium oxide in new products.
- Define and implement Ericsson's system for measuring energy consumption at system level.
- Develop end-of-life strategy for each Ericsson segment.

5.2.2 Interesting Findings

Considering that proactive corporate environmental management and strategy have been identified as important determinants of product information flow, it is not surprising the high level of information flow that was found. The environmental goals listed above have driven the need for increased methods to record and communicate environmental attributes of products. Of course the environmental goals of the company cannot be considered mutually exclusive from legislative and customer pressure, as they directly influence the goals. However, these goals influence the level of information flow not only within the organisation, but also to and from suppliers, customers, and end-of-life facilities.

Product Development

When discussing with Ericsson representatives regarding how environmental product information flow affects the design of new products, some interesting facts emerge. For example, the environmental support function at Ericsson has developed design standards that must be adhered to when designing new products. Guidelines also accompany the standards available to designers that can add further input into decision-making. A working group established by the environmental support function within Ericsson Radio Systems developed the design standard and guidelines. Input for the development came from the group's analysis regarding customer demand, impending legislation and end-of-life treatment.[98] Documented lists of demands and recommendations found in relevant literature also provided input into the standards. Important to note is the fact that Ericsson views the standard as a 'living document' that should be updated as more information becomes available regarding environmental aspects of the product. Subsequently, information gathered in recent life-cycle assessment studies has influenced the document. (more on the use of LCA below).

Ericsson has taken a very proactive position on materials used in products. The company has also developed a list of banned and restricted substances that reflect current and future legislative demands in countries where they are operating. There are two lists for both banned and restricted material and substances that refer to products and processes respectively. Banned substances should under no circumstance be found in products or process with restricted substances requiring a plan of phase-out if included in the product.

In addition complete material declarations are required for all components incorporated in Ericsson products. According to representatives, the company needs to know the complete material content of its products for a number of key reasons.

- Customers are increasingly requesting complete of partial material declarations of Ericsson marketed products
- Environmental labelling requirements (to meet the criteria)
- Producer Responsibility Legislation
- To be prepared for unpredictable changes in legislation and inquiries from the media
- To facilitate Life Cycle Assessment
- To facilitate end-of-life treatment

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[98] Furuhjelm, Jörgen. (2000). Incorporating the end-of-life aspect into product development: Analysis and a systematic approach. Dissertation No.642. Linköping: Department of Mechanical Engineering, Linköping University, p. 266

- To reduce costs associated with hazardous waste products
- To understand the value of the product at end-of-life

This highlights the fact that the demand for product environmental information is guided by all three key determinants that have been identified in earlier sections of the research.

Design Standard

The main areas covered in the design requirement specification include, energy consumption, materials usage and declaration, marking of the product and end-of-life treatment. There are a series of pre-requisites that shall be considered by the designers when evaluating the environmental requirements where product safety and function must always be guaranteed. If conflicts arise between any of the requirements then priority should be in the order of legislation and then energy consumption. The standard has both mandatory requirements and optional requirements that apply to products and design as well as the documentation process. Along with the listed requirement is the motivation for its inclusion.

Energy consumption is viewed as the most important environmental aspect of Ericsson's products.[99] Therefore it is not surprising that there are requirements placed on designers concerning this aspect. Designers are required to verify energy requirement of the product at the system level for the various levels of traffic in the network.

Appropriate marking of products and components is required in order to meet legislation and standards and to support an efficient end-of-life treatment. The requirements concerning marking refer mainly to standardized methods to mark plastic and metal parts, beryllium oxide components, batteries and cables. These marked parts should be placed so that they can be easily located during disassembly and that special tools should not have to be used during dismantling. Products should be designed so that the product can be separated into fractions of mechanics, cables and printed board assemblies.

Materials in the 'banned lists', under no circumstance should be included in products, and substances listed as restricted are not to be used if alternatives already exist. Material declarations are required for all Ericsson products, packaging and components purchased from suppliers.

Ericsson uses the results of LCA studies for a number of purposes within the environmental support function. LCA has been used to determine environmental aspects as part of ISO 14 001 EMS, and to measure continuous environmental improvement. It has been used to communicate environmental performance to customers and other stakeholders as well as to provide a comparison of older and newer products, systems and services. Ericsson also notes that in the future it will be used as a support or decision tool in considering the environmental implications and trade offs between various end-of-life treatment options and DfE activities.[100]

Data acquisition strategies

LCI Data

Data acquisition strategies are important parts of LCA studies. Data concerning the inputs and outputs of all materials and waste are generated in the LCI. To generate this data, Ericsson has had to work directly with the supply chain to gather data concerning materials and processes used, transportation and waste scenarios for each supplier of parts and components. Some data has been publicly available for raw materials, transportation, and limited end-of-life data sets exist. In

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[99] Malmodin, J., von Wachenfeldt., C. (2001, July 7-8) telephone interviews

[100] Weidman, E., Lundberg, S. (2000). Life cycle Assessment of Ericsson Third Generation Systems. In 2000 IEEE International Symposium on Electronics and the Environment. ISEE-2000. p. 141

circumstances where data is not available, modelling techniques have been employed.[101] Ericsson uses the Eco-Lab software developed by Nordic Port as well as the EIME database. This software uses the SPINE format for documenting LCI data. Ericsson has provided the Global SPINE database with documented data sets that have been used to perform LCA studies within the company. This process has been acknowledged as being intensely time consuming and costly, however once the data are collected much of it can be reused for subsequent studies with some revision.[102] This substantially brings the cost down for future applications of LCA. LCI data are not integrated with the Matilda system (discussed below), and there are no immediate plans to implement this.

Materials Database

Ericsson's strategy to address the use of hazardous and potentially hazardous has been articulated in 'banned' and 'restricted lists' and the requirement for complete disclosure of all materials in parts and components. A unique web-based database called 'Matilda' has been set up to facilitate collecting material content information on each component bought or manufactured by Ericsson. This system is compatible with two other internal databases 'PRIM' and 'ELIZA', which contain product specific & design information and a list of approved suppliers, respectively.

Since the system is connected to the PRIM database, components and subassemblies in the products all have unique numbers assigned to them. Therefore, when requesting information from suppliers, the Ericsson supplied number part or component can be referenced when making the declaration. The 'Matilda' database allows for designers, or other environmental personnel to request material declarations from suppliers.

The supply-chain response to the material declarations system has been quite variable among different suppliers. Numerous suppliers have had no problem meeting the requirement and provide the data willingly and timely. Other suppliers have indicated that there will be an increase in the price of components if material declarations are required. Others outright refuse to comply with the request. However, it was noted that it is much easier to declare material contents for small components. For fully assembled computers systems it has been difficult to receive any product information.

Ericsson's experience has been that in general the more complex the product is, the more reluctant the supplier has been to supply information concerning material contents. It has been difficult to determine any particular pattern in terms of manufacturing categories, however, it was noted that companies that supply most of their components to US companies are less willing to disclose information than component manufacturers supplying to Japanese companies.[103] Whereas suppliers that supply mainly to Japanese OEMs are accustomed to supplier questionnaires, US component manufacturers have not had the same pressure. It seems that it is a matter of supply base power that influences the disclosure in this case.

Philips' Semi-Conductor and Component Division supply a number of components that are used in Ericsson products. Philips has developed their strategy independently to request material declarations from its customers. They have developed material declarations for what they call 'families of products' that are made up of various assemblies of core components. There is a wide array of chip encapsulations used (over 250) that could potentially end up in a component supplied by Philips. Philips provides Ericsson (available on the Philips website) with the product declaration that it has developed and has indicated that it cannot use the Matilda format.[104] Interesting to note however, is

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[101] Erixon, Maria. (1999). Practical Strategies for Acquiring Life Cycle Inventory Data in the Electronics Industry. Report 1999:3. Göteborg: Chalmers, Göteborg University.

[102] Von Wachenweld, C. (2001 July, 7). Personal interview

[103] Von Wachenweld, C. (2001 Aug, 7). Personal interview

[104] Klerks, L. (2001 July, 20) Personal interview

the comment made by Philips, that if their declarations had not already been produced, then the Matilda format would be highly applicable.

When asked how Philips gathers its supply-chain material declarations, it was discovered that they use their own independent system using three different questionnaires concerning substances, mixtures and polymers used. Material Safety Data Sheets often assist with the documentation process. The issue of proprietary information disclosure was sited as a major limitation in the process of gathering data from polymer suppliers in particular.

Ericsson employees are currently represented on the European Information and Communication Technology Association (EICTA) supply-chain initiative and the Japanese initiative coordinated by Canon. Ericsson has been influential in encouraging the member companies in EICTA to consider as much detail in the disclosure of material information in the supply-chain. Ericsson has been able to present the arguments for disclosure that it uses to motivate its decision internally. Currently, the sample questionnaire developed by the working group in EICTA is being tested on key suppliers of Ericsson. Results are expected later in the year 2001 that will feed into the refinement of the forms.

Ericsson is ever increasingly using the services of Contract Electronic Manufacturers (CEMs) to manage the manufacturing process, while freeing up more resources to focus on core competences such as design. It was interesting to find that there has been recent interest from Flextronics – one of the largest manufacturing service providers to the electronic sector – to get involved in the documenting material declaration as a value added service.

Communicating the environmental performance of Ericsson products

Ericsson is one of only two ICT companies that have developed a Type III Environmental Product Declaration that is certified by the Swedish EPD™ administered by the Swedish Environmental Management Council for one of its Base Station products. The development of the EPD was considered on a trial basis in order to develop an appropriate eco-labelling mechanism to differentiate Ericsson's products in the marketplace.[105] Most of Ericsson's request for product information comes from corporate clients and little interest from the private retail system. Since Type III declarations require an LCA to be conducted on the finished product, the actual input into the design phase of that product is negligible. However, the result of the LCA has provided the environmental support function with valuable information that can influence future products, through changes in the design standard.[106]

However, the actual use of the declaration itself has had mixed responses from Ericsson. According to one source interviewed at Ericsson, the company expects the demand for this type of information disclosure in the future. The company is concerned about the possible proliferation of differing eco-label schemes in the many countries that they operate in and see the EPD format as the best available option to date. Management within the marketing and communication function have stated that use of Type III labels would probably not continue in the future. Other formats that require less time and cost to develop would be favoured by the industry as a whole. Ericsson currently promotes the use of ECMA TR/70 product profile declaration to communicate environmental product information.

Available on the Ericsson homepage are a complete set of self-declared environmental product declarations for mobile phones based on the ECMA TR/70 format. Ericsson claims that in the absence of an international standard, this format is the most applicable for mobile products. There are no plans to apply for a Type I 'seal of approval label', most likely because most of Ericsson's clients are business-to-business transactions. With the recent sell-off of the mobile phone manufacturing, the

[105] Furuhjelm, Jörgen. (2000). Incorporating the end-of-life aspect into product development: Analysis and a systematic approach. Dissertation No.642. p. 260

[106] von Wachenfeldt, C. (2001 July, 7) Personal interview

marketing division is uncertain if the company will react to the new introduction of the TCO 01 declarations for mobile phones.

Ericsson responds to corporate requests for product environmental information on a case-by-case basis. Since the majority of the requests come from business-to-business customers, the company feels that since the contract value is often very high, it is worth the extra effort to respond on an individual basis. The requests vary significantly between corporate clients, but generally request information about certain materials of concern in products and end-of-life treatment plans. This approach differs from other product groups in the ICT sector. As stated previously, the public purchasing sector in Sweden had requested information so frequently and with varying formats that for IT products that manufacturers needed to standardise for efficiency. This situation has probably not arisen in Ericsson's market because there are relatively fewer customers in the public sector in this product group.

A significant interest for corporate clients is the energy consumption of Ericsson's products. This apparently is an important economic variable when network operators make equipment purchasing decisions.

Take-back Program

For all corporate clients, a free take-back service has been established not only for Ericsson's products, but its competitor's products also. When a corporate client purchases a new Ericsson product, the company will take-back the old equipment regardless of the brand. This has prompted Ericsson to develop the Ecology Management Service project for the European Market, as a value added service to customers to reduce their overall costs. Based in Rijen, the Netherlands a regional recycling logistics operation collects products from corporate customers. Valuable components are removed for service applications in older equipment still in operation. Due to the relatively, low volumes of parts needed for servicing products it is not economical to manufacture new parts, justifying their disassembly. For most equipment the most predominant method of end-of-life treatment is removal of needed spare parts and hazardous materials (batteries and beryllium oxide containing components) prior to shredding. The shredded material is sent to smelting facilities for the recovery of various elemental metals.

Since by weight, the majority of Ericsson's products in Europe are now covered by the manufacturer take-back Ecology Management Service, it is interesting to see how this has influenced product design. Beryllium oxide is now on the Ericsson's banned list of substances not to be present in products. Despite the possible health effects associated with the handling of BeO in the manufacturing processes, its presence affects the end-of-life costs in Europe. From an investigation into recycling practises, it was determined that BeO containing switches had to be removed from the PWB as a condition of the smelting facilities. The switches subsequently had to be disposed of as hazardous waste significantly driving up the costs associated with recycling end-of-life products. This has been one of the primary motives behind banning BeO from products, now that Ericsson absorbs the cost of end-of-life treatment.

Product information is communicated where needed to recyclers at the Rijen facility to assist with the disassembly process. Prior to the establishment of this system Ericsson has conducted a number of pilot projects to understand the implication of the design to facilitate disassembly. Ericsson has gained valuable experience concerning fastening techniques to ease in the disassemble process that has been incorporated into design standards. From the experiences with recyclers in Sweden it was determined that information in databases or manuals is not appropriate as profitability is jeopardised if time is taken to read it. However, labelling of parts and the PWB is requested to aid in the identification of hazardous material and valuable components while on the manual disassembly line. There is an exception to this; metal smelters need to know if and how much mercury and BeO is in the product.

Supplier Outreach

Ericsson has developed a supplier requirement brochure that explains the requirements placed on companies supplying products and components. Requirements cover EMS, design, manufacturing, product information and transportation.[107] An EMS that is in accordance (but not necessarily certified) with ISO 14000 or equivalent was required by 2001. The suppler should have a DfE program in place that minimises the environmental impact of components and products by considering recycled material, energy consumption during manufacturing and reuse, material identification disassembly and choice of material.

Suppliers are not authorised to use the any substances in the banned substances list and must have a plan for phasing out any restricted materials used. Suppliers are required to be able to declare material contents, provide LCI data, and provide disassembly or disposal instructions in accordance with Ericsson's standards. Suppliers must also be able to supply information concerning the transportation of products and components to Ericsson such as packaging type, transportation mode and facility location.

Suppliers have also been notified in a series of letters concerning the goal of reducing the amount of lead, and the elimination of BeO. Ericsson has produced a document that outlines the future requirements of components concerning the increased temperature profiles that are to be expected from the substitution of Pb solder.

Important to note that in the case of Ericsson, most products are sold on a business-to-business channel with customers being predominately large service provides of mobile phone networks, such as Telia and British Telecom.

5.3 Retail

5.3.1 Background

In order to understand current product information flow in the retail sector, four retail chain stores in Sweden that market ICT products were interviewed. OnOFF, Telia, Siba and Expert were asked what information was available to customers concerning the environmental performance of the ICT products that they sold. These retail chains represent the majority of sales of ICT products to the private consumer market in Sweden. Site visits to these stores provided a platform for which to determine from the perspective of a consumer what environmental product information is available to influence purchasing decisions.

5.3.2 Interesting findings

No product environmental data at all was available at the technical support function helpdesk for ICT products at any of the retailers that were questioned. In fact, all four retailers pointed out that in general customers rarely ask for environmental information concerning the performance of ICT products sold.

When questioned about support from manufacturers and/or distributors concerning environmental issues in general, representatives pointed out that since demand is so low for information, there has never been the need to ask for manufacturers support. In circumstances where customers have asked for information that cannot be answered, retailers have pointed to the manufacturers web site for reference.

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[107] Supplier Requirements pg. 5

Interesting to note is that often when ICT products are on display, a placard or brochure is accompanying the product. This serves the purpose of providing important product technical performance attributes of the product to producers. Perhaps it is possible that along with the technical attributes that are presented an ECMA TR/70 or IT Företagen format declaration could be included in the sales literature.

However, staff interviewed at the retail outlets that sold white goods referenced the mandatory EU Energy label. Sales staff has knowledge of the purpose of the label often refer customers to them as a selling feature. Although unsubstantiated, the interviewed retailers selling this equipment have found the energy rating of the products has influenced customers purchasing decisions to some degree. Most often the cost saving opportunity from avoided energy consumption, rather than the environmental benefit, is used to influence consumers purchasing decisions. When asked to what degree the rating influences purchasing decisions, it was estimated that it was an important factor in the decision-making process for a significant percentage of the purchases made in this product group.

5.4 Public Purchasing

5.4.1 Background

The majority of the information gathered with reference to environmental product information demands from public purchasers has been obtained from a report on the evaluation of Statskontoret PC-procurement 2000 framework. Statskontoret, the Swedish Agency for Public Management, provides support to the Government and Government Offices. Statskontoret conducts studies and evaluations at the request of the government, and among many other activities, develops framework agreements for ICT use in public administration. The report mentioned above analyses the environmental requirements within procurement 'request for tender documents' of Statskontoret's ICT Framework Agreements. Representatives from Statskontoret were also interviewed for clarification regarding the framework where needed.

5.4.2 Interesting Findings

Statskontoret puts forth the environmental requirements to be met by suppliers of ICT products in the 'specification of requirements' at the start of the procurement process. In the specification of requirements, the significance of the environmental requirements is specified for the total assessment of the tender response, with respect to pricing, performance, quality, etc. The breakdown of significance of each requirement is as follows. Sixty percent of the weighting is on the product performance qualities and 40% on price. Of the 60% weighting, 22% is environmental requirements, 38% is on the components, 40% of product performance. Therefore environmental requirements account for 13.2% of the total weighting of the award criteria for framework agreements.

Environmental requirements presented are in two categories, mandatory and voluntary. In principle, environmental requirements are determined by a combination of mandatory requirements and award criteria based on how the products meet the voluntary requirements.

Mandatory requirements include:

- Polybrominated compounds are not present in mechanical plastic parts > 25 g
- Antimony compounds are not present in mechanical plastic parts > 25 g
- Cadmium compounds are not present in mechanical plastic parts >25 g
- Components on the motherboard shall not contain mercury content over the amount defined in the EC Directive 91/157/EEC
- Batteries in the product do not contain dangerous substances defined in the EC Directive 91/157/EEC

Along with the mandatory requirements ICT product suppliers must present third party verification of the results. When asked about the use of IT Företagen's eco-declaration as a procurement tool, Statskontoret claims that it does not meet its requirements for third party verification. In addition there are a few requirements that are not represented in IT Företagen's eco-declaration. The requirement for no antimony compounds is absent as an attribute to declare in the IT Företagen eco-declaration. This is however the only requirement that cannot be determined from the eco-declaration, with many more attributes listed in the eco-declaration.

An independent evaluation of the PC Procurement 2000 process conducted by Deloitte and Touche, investigated how the requirements have affected suppliers production methods. All OEMs that submitted tender documents were sent questionnaires. From the results some interesting findings emerged. 77% of suppliers of stationary PCs and 56% of suppliers of portable PC that replied to the survey do not consider in any respect that product design, products or selection of sub-contractors[108]. The suppliers that have been influenced by the requirements report that the mandatory requirements are the reason for this. It is not surprising that the majority of manufacturers have indicated that the requirements have not influenced their products, since it would not be in their best interest to do so.

Although, there is limited evidence to corroborate that the demands from public purchasing have influenced manufacturer's environmental performance, an interesting piece of anecdotal evidence was provided by Statskontoret to suggest otherwise. In the PC Procurement 1998, Compaq was unable to meet the mandatory requirements of the tendering document. They were however, able to meet the requirements for PC 2000, which had not changed from PC Procurement 1998.

When questioned regarding whether the environmental performance of the computers that are sold in Sweden deviates from that of the computers sold in other parts of the world on account of the requirements in PC Procurement 2000, again, 69% of stationary and 73% of the OEMs reported that they did not. However, some OEMs note that Sweden sets the environmental standards in many other markets.[109]

Other evidence to suggest that public procurement of ICT products in Sweden is influencing product development is from comments made by ICT companies noted in the report. One of the OEMs commented that the environmental requirements "communicate clearly that the environment is a priority area". "This is important since customer's demands are a major driving force for environmental improvements today."[110] A possible reason why OEMs claim that PC Procurement 2000 has not influenced product development could be the fact that previous PC Procurements already have influenced them. Since 1998 new legislative and policy initiatives have emerged that are in line with the demands of public procurers in Sweden, which are now considered to be the main drivers influencing product development today.

Representatives from Statskontoret were asked how the requirements are developed and if outside parties provide input to the process. Statskontoret has a staff function that is responsible for environmental requirement development. Unfortunately, this position is currently vacant so it was not possible to conduct an interview. However, Statskontoret has regular dialogue with relevant government agencies such as KemI and the Swedish EPA, as well as eco-labelling organisations such as the Nordic Swan and TCO.

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[108] Statskontoret (2001) Evaluation of PC Procurement 2000: Effects of environmental requirements on the operations of suppliers, 2001-03-06. p. 3

[109] Statskontoret (2001) Evaluation of PC Procurement 2000: Effects of environmental requirements on the operations of suppliers, 2001-03-06. p. 8

[110] Statskontoret (2001) Evaluation of PC Procurement 2000: Effects of environmental requirements on the operations of suppliers, 2001-03-06. p. 13

5.5 End-of-Life Treatment

5.5.1 Background

Representatives from two facilities were interviewed to determine what product environmental information is required to optimise their operations. The facilities differed both in geographic location and business structure. Multis Limited, headquartered in Galway, Ireland, specialises in the remanufacturing of retired computer systems for second use markets. Multis has a pan-European contract with Compaq to supply their authorised customer base with branded second use product. Retired or damaged products from leasing arrangements in the business sector and OEM overstock are the primary sources of equipment handled by Multis. No end-of-life ICT equipment from the residential sector is accepted or managed.

Stena Technoworld (ST) in Bräkne-Hoby was established in 1992 and is a recycler of end-of-life electronic equipment. It has two plants in Sweden, Bräkne-Hoby and Solleftea, and one sales office in Stockholm. It is operating also in Denmark with a sales office and, in a joint operation with Stena Miljö A/S, operates in Norway with one plant in Oslo. Both commercial business-to-business and residential sources of ICT products are managed. Approximately 60% of products handled are ICT, with the remaining 40% consisting of electric appliances (brown goods). Roughly 80% of the ICT products handled are from the business-to-business sector.

5.5.2 Interesting findings

The amount of information that each facility received from OEMs differed considerably. Multis' requires technical information concerning product configuration in order to facilitate refurbishing of Compaq's products. The company needs to have access to Compaq's testing protocols to ensure that products meet the applicable standards for reuse. Compaq when required provides all assembly, material, and technical data, including CAD data.

Provision of product information differs considerably in the case of ST. The company claims that manufacturers do not supply information to the company in any active way. Although, the company has had contact with manufacturer-recycler databases set up in Germany (IDIR) it has found the information to be of limited value. When considering the information that is available in catalogues concerning components containing PCB, mercury and cadmium, ST has found that this information is neither consistent nor reliable. Its approach has been more of a 'learn by doing' situation where information is gathered by testing or through Internet searches. Very little dialogue with manufacturers exists today, although the company has participated in pilot projects on a national and EU level.

However, ST states that it needs more information from OEMs concerning materials contained in products. According to ST's experience the ideal format for the information would be a combination of electronic file format and physical marking of components containing hazardous components. ST currently uses bar code technology to identify batch processing, which could be easily adapted for use with products. However, hard copy lists or manuals are considered unsuitable for use by dismantlers. Time taken to look up information would jeopardise the profitability of the operation. IT Företagen's eco-declarations are not used to evaluate product disassembly or create teardown strategies.

Representatives at ST made an interesting observation in relation to product design for disassembly efforts within the ICT sector. The general pressure on industry to produce better, faster, smaller, lighter products in shorter cycles has created the need to design and assemble products modularly with less fastening devices. This naturally facilitates the opportunities for upgradeability and ease of disassembly.

An important development was mentioned by Eamonn Reay of Multis, which should stimulate the demand for used components in ICT products. Used components that meet a determined standard can now legally be incorporated into new products. Thirty percent of components by weight can originate from used products providing that they met a certain standard.[111] Both organisations report that the reuse of components in retired ICT products, especially from leasing arrangements, is bound to increase in the future. This is especially true for companies that begin to take control of their products from a closed loop perspective, that proactively recovery the products at end-of-life. Asset recovery departments in IBM, Nortel Networks, Xerox, Compaq, and Ericsson provide examples of this activity. The relative value of the products most likely plays a role in this phenomenon as well.

However, there are still many barriers to the uptake of this practise including the following example found within newly created the Swedish take-back system. Component reuse from products that are collected through the municipal collection system or old-for-new at retail has been set to predetermined levels in an agreement between the OEMs and the participating dismantlers. Unofficial lists provided by manufacturers have been circulating among recyclers concerning components that should not be reused. Manufacturers claim that there are liability issues when components are reassembled into new products. Whether this is a valid argument is out of the scope of this thesis, but sheds light on the limitations towards reuse vs. strictly material recovery. More research is required to understand the inherent trade-offs associated between component reuse vs. material recycling.

Market demand for used parts fluctuates quite extensively in the case of ST. The company has built up a customer network for spare parts, (IC, optical devices, disk drives, etc.) however, no formal market exists today. When demand is low, shredding and subsequent material recovery predominates. If demand for parts increases to the point where it is economically preferable over shredding (when transportation is factored in), then disassembly of components as far down to the PWB level can be achieved.

ST is a participating recycler in the newly created EL Kretsen, the consortium set up to manage the producer responsibility requirements in Sweden. Under the system, similar ICT product families like computers, printers, copiers, etc. have a predetermined price per kilogram. When asked if it would be possible to be able to differentiate the fee for products that are easier to disassemble, have more precious metals, and less hazardous materials. The answer provided was “theoretically, yes, practically no”. With the current system brand products are commingled together, making the administration considerably complicated. However, if manufacturers were to transport their products to the facility in bulk batches then it would be quite feasibly to differentiate the costs for varying products. Therefore, in the current system, manufacturers have no incentive to design their products differently for products in the municipal sector. However, for business-to-business collection take-back programs financed by the manufacturer the economic differentiated fee structures are more feasible, therefore likely to influence design considerations. This point was illustrated in the case of Ericsson presented above in *section 5.2.2.*

Although Multis is a successful business concept, representatives from the company report that within ICT sector companies, the level of applied and planned initiatives to support product reuse and or remanufacturing is appallingly weak.[112] Most ICT companies continue to operate according to the traditional business models that drive obsolescence.

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[111] Reay, E. (2001, July 19) Telephone Interview.

[112] Reay, E. (2001, July 19) Telephone Interview.

6. Analysis and Discussion: Current Demand vs. Supply of Environmental Information

Sections 3 and 4 of this thesis have provided a comprehensive background of selected determinants of environmental product information flow and concrete examples found in the relevant literature, respectively. This has illustrated that information flow in the product chain is not one directional, but in fact it flows back and forth along the chain influencing decisions made by actors that ultimately affect the environmental performance of products. *Section 5* has attempted to describe the situation in reality, by describing various actor experiences with environmental product information flow. This has provided valuable insight into how information flow affects the environmental performance of products and where there are information gaps.

Although the following section discusses the demand and supply of environmental product information flow, actor by actor, this does not suggest that it happens in isolation. Although each actor plays a different role in the product, they are all inherently connected to it and decisions made in one part of the chain can severely impact other parts. Collectively, they determine the environmental performance of the ICT product, with some actors having more significance than others.

6.1 Manufacturing Supply Chain - Manufacturers and their Suppliers

Manufacturers and their suppliers hold a pivotal role in determining and generating absolute product environmental data and passing that information downstream to other actors. Throughout this thesis it has been stressed that the product development phase influences the environmental performance of the ICT products most significantly. The product development stage, is however, influenced by many factors that are characteristic of other actors in the product chain. Three key determinants have been identified including, legislation, consumer demand and corporate environmental strategy that shape the product development strategy with respect to environmental performance. Of course there are other variables that influence environmental improvement such as available technology and cost factors that have not been adequately addressed in this thesis.

However, when considering how environmental product information flow affects the environmental improvement criteria proposed in this thesis, manufacturers and their suppliers are extremely influential. This is illustrated below.

6.1.1 Material Composition and Materials of concern

To address the issue of materials of concern it has been shown that OEMs have developed supplier questionnaires to determine what materials are present in supplied parts. At Ericsson and numerous other OEMs, banned and restricted material lists have been developed to guide designers and suppliers as to what materials to avoid. Information demand for material disclosure has been so intense that Industry Associations on three continents have or are in the process of developing material declarations standards that can be used by OEMs and their supply base. This will drastically improve the flow of material data within the supply chain so that it can be collated within OEM databases. Suppliers can develop declarations in advance for one (or possibly three) standard formats, avoiding duplicative efforts. There is an inherent cost reduction also associated with collection and supply of data by OEMs and their suppliers when standard formats are used. Significant reductions in time spent on answering independent surveys from OEMs or customers will cut staff resources substantially. Standard questionnaire formats will help to alleviate the current gaps in information farthest upstream in the product chain to suppliers of chemical substances and materials. The use of IT tools that are integrated with other Enterprise Resource Planning (ERP) and e-business software tools will facilitate these efforts even further.

When considering what an efficient level of material information flow (what materials to consider) in the manufacturing chain might be, the following variables should be taken into account. As has been identified by all three Industry Associations, there are many reasons cited for the need of material information ranging from customer demand, end-of-life considerations, and current and future legislation which have influenced the decision on what materials to include in the declarations. Unfortunately, only the EIA initiative was available to be reviewed during the course of this research as both the Japanese and European initiatives had not been completed. However, from conversations with a member on the EICTA initiative it was determined that material declarations should account for at least 99% of materials by weight of the declared part or component, suggesting a very complete disclosure of materials.

The EIA initiative is quite comprehensive, however the list of materials to be declared does not include *all probable materials and chemical substances* that are present in ICT products. Considering the fact that it represents current US industry consensus on what materials are banned and restricted in markets around the world, and what customers are interested in knowing, this approach seems reasonable. However when taking into account the likelihood of increased attention on materials and chemical substances (evaluation of the toxicological properties of metals and 'existing' chemical products in the EU and other parts of the world, and future material content disclosure in Sweden) it would seem appropriate from a cost efficiency standpoint to include all possible substances and materials from the onset. Experience has shown that often materials are at first thought to pose no impact to the environment but have subsequently been identified as problematic. To prepare for any situation that may arise, complete disclosure is the safest measure (excluding dopants used in semi-conductor manufacturing). According to companies that have experience with material declarations, the added cost for complete disclosure is minimal when considering the level of detail already required.

6.1.2 Use of LCA & the availability of LCI data

The use of LCA in the ICT sector as a whole has been relatively limited. However, at Ericsson it was found that its use is quite extensive within the environmental support function. LCA has been used to determine environmental aspects as part of an ISO 14 001 EMS, and to measure continuous environmental improvement. It has been used to communicate environmental performance to customers and other stakeholders as well as to provide a quantitative comparison of older and newer products, systems and services. LCA is also used as a support or decision tool for considering the environmental implications and trade offs between various end-of-life treatment options and DfE activities.[113]

More often in the ICT sector the use of LCA has been focused on assessment of existing products, with the results subsequently shaping eco-design programs strategies and guidelines. It is rarely, if at all, used during the "live" product development process, even at Ericsson. Due to the extremely short product development cycles, designers have had very little time to focus effort on LCA procedures. IBM, for example, claims that to use full LCA methodologies is not appropriate for the complex products it produces. The shear number of materials of construction, components and assembly manufacturing processes would require the collection of extensive inventory data, making the process both costly and time consuming. IBM however, uses a less rigorous assessment methodology consisting of Design for Environment (DfE) checklists and technical review by environmental experts. This primarily includes focus on product design to reduce, eliminate or substitute hazardous materials, incorporating design elements that improve the products use phase (including energy efficiency, duplex printing, noise reduction, or which facilitate end-of-life disassembly and recycling (e.g. fewer fastening units, elimination of painted plastics).

[113] Weidman & Lundberg, Life-cycle Assessment of Ericsson third generation systems, p, 141

LCI Data Availability

Current availability of life cycle inventory data varies depending on which part of the product chain that is analysed. LCI data concerning the manufacturing and assembly of ICT components is scarce, while data on raw material extraction, refinement and transportation of metals and polymers is available in databases and LCA reports.[114] OEMs that are in control of the final assembly of the product generally have good environmental data concerning their activities as well. LCI end-of-life scenario data is usually over simplified often accounting for only two end-of-life strategies: recycle or disposal through landfill or incineration. The acquired data sets do not include end-of-life strategies such as reuse, service or remanufacture as possible treatment options at end-of-life.[115]

By gathering data directly from actors in the product chain, a representation of reality is obtained. While this approach for gathering LCI data is the most preferable, it is time consuming and consequently the most expensive component of an LCA study.

The use and encouragement of life cycle inventory (LCI) and life cycle assessment (LCA) should be considered in light of the current drawbacks that are associated with this methodology, namely data availability and quality, cost of conducting an LCI and or LCA, and the subjectivity of the process. Even if quality data existed for the variety of materials, processes, transportation profiles, and end-of-life scenarios, the appropriateness of using a full LCA for each product development process is questionable from a both an economic feasibility and environmental improvement perspective. Due to the extremely short product development times, a full LCA would probably not be suitable for the time frame involved.

As was illustrated in previous chapters of this thesis, acquiring information concerning the materials incorporated in ICT finished products has been shown to be an extremely difficult task. Many actors upstream in the supply chain, namely complex component manufacturers, have limited knowledge or are unwilling to share this level of detailed information with their customers. Considering the fact that life cycle inventory data are really an extension of the material content of the product, illustrates the difficulties that are faced when developing an LCI database for the ICT sector.[116]

6.1.3 Product Sales & Marketing Functions

Despite OEMs efforts to improve the environmental performance of ICT products, there is little evidence that manufacturers are promoting these efforts to private customers at the point of purchase. Retailers in Sweden have little or no information provided to them by OEMs, concerning the environmental attributes of the products they sell. On the other hand many of the OEMs (13) that have prepared IT Företagen eco-declarations, post them on their websites with direct links from IT Företagen's site. The fact that these declarations are available to the public illustrates that these companies see value in the information. Ericsson's ECMA TR/70 declarations have been posted on the website for all mobile phone models marketed. The demand for this information is limited however, with few registered hits with interest primarily coming from the media.[117] However, many OEMs have produced elaborate environmental reports that provide environmental product information concerning their products.

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[114] Erixon, Maria. (1999). Practical Strategies for Acquiring Life Cycle Inventory Data in the Electronics Industry. Report 1999:3. p. 12

[115] Rose, Catherine M., Stevels, Ab. (2001). Metrics for End-of-Life Strategies (ELSEIM). In 2001 IEEE International Symposium on Electronics and the Environment ISEE-2001. (101)

[116] Erixon, Maria. (1999). Practical Strategies for Acquiring Life Cycle Inventory Data in the Electronics Industry. Report 1999:3. p. 6

[117] Schmidt, M. (2001, July 24) Telephone Interview

In *section 4.2.1* it was noted that the marketing function is involved from the onset in the product development process acting concurrently with other functions. When considering that eco-design or DfE initiatives within ICT companies is becoming more common, it would be expected that the marketing function would want to market the results to gain competitive advantage. However, this has not been the general case to date. No explanation has been provided for this, however it is expected that industry view the added value not to be significant.

6.2 Retailers and Wholesalers

Given the limited current demand for environmental product information from private consumers today, it is not surprising that retailers have not promoted the environmental attributes of the products they sell. Outlined in the 'essential requirements' of the EEE Working Paper, is the requirement for manufacturers to provide information to consumers on the significant environmental characteristics and performance when products are placed on the market to allow the consumer to compare the aspects of the products. Although not explicitly referring to the responsibility of retailers, it should be assumed that retailers have an important role to play. Often the producer does not control how ICT products are marketed in retail stores, in particular how product information is presented to the customer. This falls within the roles and responsibilities of the retailer sector, especially for individual consumers.

Given that the limited level of environmental product information flow identified in the retail sector in Sweden, suggests that currently there is very little understanding of the environmental impacts associated with ICT products. Producers seem to be unmotivated to actively promote the environmental characteristics of their products through eco-labels other than the *de facto* labels of TCO and Energy Star. Even though Type II declarations such as the IT Företagen and ECMA are commonly produced and supported by manufacturers and their representatives, they are rarely promoted to the individual consumer. It is not surprising that this is the case when considering that it is not in the interest of the manufacturer to draw attention to environmental issues of their products when no such attention exists. In fact, evidence suggests that consumers think otherwise and assume that the ICT sector is relatively 'environmentally friendly'.[118] Even the most environmentally benign products on the market today have problems associated with resource consumption (material and energy) and obsolescence issues that still need to be considered.

On the other hand, all retailers interviewed commented that consumers have reacted positively towards mandatory labelling of energy consumption for white goods. Often better energy rating products are more expensive than lower performing models. However with the labelling, sales staff can point to the energy savings over the lifetime of the product to justify the added expense. It was noted that consumers are well aware of the price of a kilowatt-hour and therefore take account of energy consumption when purchasing these products.

Whether or not mandatory energy labelling of certain ICT products is a suitable option is out of the scope of this thesis. However, considering that energy consumption during the use phase has been identified as the most significant environmental impact of ICT products, this policy tool should be further investigated. Considering that the US EPA Energy Star is the de facto voluntary standard in the ICT industry, the added value of mandatory energy labelling comes into question.

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[118] Johansson, D. (2000). The influence of Eco-labelling on Producers of Personal Computers: The potential for eco-labelling as part of an IPP approach for reducing chemical risks related to PCs in Sweden. Lund: IIIEE Communications 2000:03. p. 73.

6.3 Public and Private Consumers

Eco-labels or declarations are the interfaces that provide consumers environmental product information. They also create the need for OEMs to document product attributes, which implies gathering of information throughout the manufacturing supply chain. Type I or 'seal of approval' labels communicate to consumers that the products are environmentally preferable over other similar products. *Table 6-1* below compares the Type I., II, and III labels on a number of key criteria. This has been adapted from a paper presented by Hermann et al. (2001), which presents the European IT Industry's position concerning the use of eco-labels for IT products.

Table 6-1: Comparison of ISO Type I, II, III, eco-labels on a number of key criteria

Aspect	ISO Type I	ISO Type II	ISO Type III
Time to market	Long	Short	Very long
Suitable for	Consumer Products	Complex Products	Materials and simple products
Cost for Producers	Medium	Medium	High
Must meet all criteria for use	Yes	No	No
Based on LCA	EU Flower for PC criteria is based on LCA Most others – No	No (Parts can be included)	Yes according to ISO 14040
Allows comparison of same product types	Yes (high)	Yes (low)	No, only if product standards are established
Can be demanded according to EU public procurement directives	Criteria can be demanded but label itself cannot	Yes, if enough bidders can supply comparable documents	Criteria can be demanded but the label itself cannot
Independent quality control	Yes	Yes (IT Företagen Eco-declaration)	Yes

Source: Adapted from Hermann, F., Urbach, H-P., Wendschlag, H.. (2001)

There are some interesting points to consider from this assessment when evaluating the use of eco-labels to communicate environmental product information to consumers. With the proliferation of eco-labelling schemes that have established criteria for product groups within the IT sector, OEM manufacturers have voiced their concern at their appropriateness. Due to the fact that most manufacturers market their products worldwide, it is somewhat understandable that they have difficulties with geographic variations in eco-label criteria, as they design new products to meet this demand.

According to some OEMs, considering the time critical processes of an international product release, variations in eco-labelling criteria become problematic to manage. The following paragraph outlines the essence of the IT Industry's position on the use of eco-labels.

In 1999 EICTA, with support from European national IT Industry Associations, updated its original position paper that outlined the industry's general concern with the proliferation of eco-labels. With regard to the ISO classification standards, EICTA had the following comments. Type I "seal of approval" labels are not appropriate for ICT sector because of the high cost, time involved to apply and are barriers to trade. EICTA claims that global producers of ICT products currently have approximately 20 labels to consider; therefore this approach is not feasible. However, further investigation of Type 1 eco-labelling programs that have ICT product groups, shows that there are currently 7 programs for Computers, 7 programs for Copiers, and 6 programs for Printers, drastically lower than reported by EICTA. In any event the association promotes the use of Type II labels and recommends either the IT Företagen and/or the ECMA TR/70 declarations. For Type III labels, EICTA claims that it is too early in the development process, far too expensive (considering that a full LCA according to ISO 14 025 is required) and therefore not appropriate for complex products.

EICTA asserts that industry accepts their environmental responsibility to identify all major parameters and how to measure them, which has been realised with the development of the IT Företagen and the ECMA TR/70 declarations. To be able to support labels efficiently industry, not surprisingly, likes to see a criteria harmonisation applied worldwide with a mutual recognition and cross wise acceptance of all labels.[119] For these reasons, EICTA notes that environmental declarations of the ECMA TR/70 and the IT Företagen have proven to be the most efficient tool to satisfy consumer demand for environmental information without sacrificing time to market. In terms of legality issues concerning the EU Public Procurement, governments can demand the declarations, as they are considered non-discriminatory when enough suppliers can provide them.

Similarly, there has also been criticism concerning the use of Type I eco-labels through binding requirements in public procurement or other mechanisms. Critics claim that these labels create barriers to innovation because they are based on existing products. Since it is not possible to anticipate how new products will develop, there needs to be more flexibility in the assessment of the environmental quality of products. According to the EU Committee (a US based trade organisation representing US interests in Europe), "eco-labels try to offer a simplification to make complex information available to the average consumers, but this simplification has huge drawbacks for business with fast evolving technologies where they can prevent step changes and stifle innovation. They definitely are not suited to guide e.g. important government purchase decisions".[120]

In a study conducted on behalf of European Commission, harmonisation of product criteria for 'Type I eco-label schemes was a key recommendation put forth to facilitate their use by producers both directly and indirectly.[121] In addition the study found that Type I labels are less suited for products with market life cycle spans shorter than two years. The study specifically states that "Type I labels are generally not suitable for fast moving consumer goods and products with a short market life span, e.g. electronics, particularly if new products are significantly different in terms of composition and/or manufacture. This is due to both the length of criteria development and the application process, which in some cases can be longer than the products' market lifetime."[122]

Effort to harmonise criteria among the various Type I eco-labelling programs has been coordinated by the Global Eco-labelling Network (GEN). For example, there has been harmonisation of the criteria for photocopiers in the Swan Label and the Japanese Eco Mark. There has also been an attempt to harmonise the criteria for computer equipment with the circulation of a draft document entitled *Common criteria requirements for computer equipment* to all GEN members for review and comments.[123]

Despite Industry's general disdain for Type I labels there has been significant penetration in some markets, particularly in Sweden (TCO) with 1200 VDUs registered and in Germany (Blue Angel) with 200 ICT products carrying the label. This raises conflicting messages on the part of industry. It is clear that the market value of acquiring the label is recognised for some markets where customer demand is high. The question of why European ICT OEMs seem view the environment as a issue to

[119] Hermann, F., Urbach, H-P., Wendschlag, H.. (2001) Eco-labelling and Information Technology (IT) Industry. In 2001 IEEE International Symposium on Electronics and the Environment. ISEE-2001. p. 3

[120] EU Committee. (2001). Position Paper on Integrated Product Policy (IPP) Ideas and comments on the Commission's Green Paper. [Online]. Available: http://www.eucommittee.be/Pages/fspop.htm

[121] Allison, C., Carter, A. (2000). Study on the Different Types of Environmental Labelling: Proposal for an Environmental Labelling Strategy. Brussels: European Commission, DG Environment. p. VIII

[122] Allison, C., Carter, A. (2000). Study on the Different Types of Environmental Labelling: Proposal for an Environmental Labelling Strategy. p. 45

[123] Global Eco-labelling Network. (2001). [Online]. Available: http://www.gen.gr.jp/activities.html [2001, August 1]

be addressed collectively rather than a competitively through eco-labelling cannot be answered within the scope of this thesis. Perhaps since industry competition is so intense on other fronts, OEMs have agreed that environmental considerations should be managed from a sector-wide perspective.

However, when considering the appropriateness of the ECMA TR/70 and IT Företagen's eco-declaration for stimulating private consumers to purchase environmentally improved products, it is uncertain if the format can be considered efficient. Given that they are currently, unavailable to consumers at the point of retail in Sweden, raises some further questions. Is this a question of a lack of demand on the part of the consumer (which was found to be true in Sweden) or a lack of supply by OEMs and retailers? And even if demand increases, will average consumers be able to comprehend and distinguish environmentally preferable products by reviewing the eco-declarations? These questions have not been able to be answered in the course of this research. On the other hand, given the continued interest from public and corporate procurers to 'green' purchasing decisions, the use of these formats is considered more appropriate. Within the Commission, it has been illustrated that there is an increased effort to provide training and guidance to procures to incorporate environmental considerations in purchasing decisions. Part of this training could assist purchasers to be able to identify environmentally preferable ICT products from IT Företagen's eco-declaration and ECMA TR/70 declarations.

6.4 End-of-life Facilities

There are a number of interesting findings that influence the management of ICT products at their end of life, which are independent of, but related to, the flow of product information to end-of-life facilities. This primarily concerns how take-back programs are funded and the feedback loop to the design function of the OEM they provide. For example it was discussed that within the Swedish take-back system all producers pay the same fee per kilogram of ICT products that they put on the market. This shared financing does not provide an incentive for OEMs to design products for cheaper end-of-life disposal when the savings will be shared among all competitors. OEMs will continue to focus more on reducing raw material costs and design without consideration on the impact of end-of-life costs.

Conversely, it was shown that when the manufacturer controls the end-of-life costs directly (as with the case of Ericsson's business-to-business take-back program) material choice and product configuration is considered important drivers for a profitable system. The demand for product information throughout the supply chain increases, as manufacturers need to know pertinent information that negatively affects the end-of-life costs. Similarly, this was found in the case of Multis. Compaq shares all relevant product information with the company needed to refurbish the product for second use marketed under license with Compaq. However, the prerequisite for the increased information flow is the decision of Compaq to market used products.

On the other hand independent recyclers such as Stena-Technoworld have no active communication with manufacturers concerning hazardous materials, reusable, or valuable parts. When considering that most often the recyclers that manage ICT products operate independently of OEMs, the requirement for information dissemination contained in both the WEEE Directive and the EEE Working Paper appears to be justified. However, higher levels of cooperation between manufacturers and treatment facilities appear to be necessary if product reuse is to gain a foothold.

6.5 Public Authorities – KemI's Perspective

From the perspective of the Swedish Chemicals Inspectorate, both a demand for and supply of environmental product information is part of its roles and responsibilities in the ICT product chain. A prerequisite for identifying and reducing chemical risks from products is the knowledge of the hazardous materials found within them. Without this knowledge it is difficult to identify chemical risks to human health and the environment, which ICT products may cause during their lifetime.[124] In order to reduce the risks associated with products, information on chemicals contained in products must follow the product through the entire chain from raw material suppliers to end-of-life treatment facilities. With this in mind it is understandable that KemI is interested in the development of environmental product information systems that collect data throughout the manufacturing supply chain and make it available to other actors in the product chain.

KemI plays an active role in the Swedish Chemical Committee, and has provided instrumental input for the recommendations put forth. In fact, it is the organisation most concerned with the work in pursuing the Committee's proposals. The Swedish Chemicals Inspectorate observance list of hazardous substances and chemical products provides guidance to many organisations with regard to their chemical use and choices. According to the Chemicals Committee the list is widely used by both authorities and companies in their chemicals oversight, in public procurement and in various projects and surveys at the local, regional and national level.[125] There have recently been suggestions to revise and improve the list, to make it user-friendlier, with reference to industry sector specific applications. There exists an opportunity to work directly with other initiatives such as C4E guidance documents on the use of hazardous substances in ICT products, both at the European and international levels to stimulate the debate in line with Swedish policy.

[124] Johansson, D., Young, A., Simon, Antonia (2000) Reducing the Use of Hazardous Substances in Personal Computers: Drivers and Barriers for Attaining a Less Toxic Environment. KEMI Report No. 2/00. Swedish National Chemicals Inspectorate. p. 16.

[125] SOU 2000:53 Non-toxic, pg. 227

7. Main Findings and Conclusions

7.1 Considerations for Efficient Levels of Environmental Product Information

The aim of this research stated in *Section 1.2* was to determine how the flow of environmental product information along the ICT product chain influences the environmental performance of finished products from a total life-cycle perspective. This research has outlined many of the possible flows of environmental product information in the entire product chain and how this information influences the environmental performance of products. This wide scope has been intentional in order to highlight the complexities involved in determining how the environmental performance of products is improved. The approach has provided a platform for which to provide insight on what an efficient (balance between economic, social and environmental) level of data flow along the product chain could include.

What has become evident through the investigation of product environmental information flow and the linkage to product environmental improvements is that although information is important for product improvement, it is not the driver for the change. From the findings in this research, it would appear that it is the key legislative, policy, (WEEE, RoHS, IPP, EEE, etc.) and market drivers (public & corporate purchasing) that are influencing product design and subsequently product improvement more directly than the actual flow of environmental product information. However, this is not to say that prescriptive formulas are the answer to promote the flow of product information in the ICT product chain, rather legislative drivers are necessary to set the framework for which market forces can operate in the most efficient way. These key drivers however, stimulate environmental product information flow, which in turn leads to more informed choices by all actors in the product chain, necessary to reduce the environmental impacts of products.

Demand for environmental product information, particularly material contents of ICT products marketed by OEMs, has prompted manufacturers to develop material declaration questionnaires to gather the appropriate data in the supply chain. The proliferation of different survey formats has driven Industry Associations in Europe, Japan, and the US to standardise information requests in order to improve the efficiency of data flow. Manufacturers claim that the need for material disclosure is driven by a combination of factors, including customer demand for information (public and corporate purchasing), to assess legal conformity to legislation (WEEE, RoHS), to manage risks and anticipate how future legislation will influence current supplier base, as well as to maximise end-of-life value. However, there are present barriers to information disclosure associated with corporate secrecies that will need to be addressed in order to facilitate information flow from farthest upstream with chemical and substance suppliers.

When discussing the link between environmental product information flow and environmental improvements from an OEM perspective, it has been illustrated that determining an efficient amount of information is dependent on the company's environmental strategy and the level of responsibility it assumes for the lifecycle of the product. For example, it was found that at Ericsson the level of information required is motivated not only by legislative requirements to market products worldwide, but also reflects the company's strategy to manage chemical risks and maximise end-of-life value. Complete material declarations (99% by weight) of purchased components are requested from suppliers down to the smallest component level. This implies that complete disclosure of product material and chemical content is necessary to meet the company goals to improve the environmental performance of its products.

Interestingly, Ericsson's ban on the use of beryllium oxide (BeO) was motivated by the fact that at the end-of-life stage the cost to remove and dispose of components containing this substance negatively effects the economics of the recycling process. Since Ericsson independently finances its business-to-business take-back system the decision to eliminate BeO directly affects the profitability of this value added service. This example provides a concrete reason why it is important that end-of-life take-back schemes financed by producers are designed in such a way that directly motivates them to consider the entire lifecycle costs of material selection.

Dependent on the success of the three material declaration systems, the amount of product information concerning materials in finished ICT products will be substantial. This will provide OEMs numerous options concerning how this information is used within the organisation and also communicated to other actors in the product chain, including government authorities. If proven successful, additional product information could be requested from suppliers, to include data on the input and output of energy, materials, emissions and waste materials. The challenge is to determine what is the most appropriate way communicate this information to other actors in the product chain that will lead to environmental improvements.

Clearly, end-of-life treatment facilities operated independently of OEMs require more information than they are now receiving concerning the location of hazardous materials in components and products. Information flow mandated in the WEEE Directive requires producers to provide, as far as it is needed by treatment facilities, appropriate information to identify the different electrical and electronic equipment components and materials, and the location of dangerous substances and preparations in products. Interfaces need to be developed that allow for this information to be communicated to recyclers in an efficient manner. Standardised reporting formats described in *section 4.4.3* such as the disassembly bill of materials (DBOM) are necessary to facilitate improved environmental performance and cost effectiveness of end-of-life disposal.

Higher levels of remanufacturing and reuse will most likely require shifts in the business model used by most ICT companies today. Throughout this thesis examples have been provided that show there are successful reuse and remanufacturing strategies employed by OEMs. In these cases, the level of information exchange is very high with treatment facilities partnering with OEMs to deliver the service. However, these examples are limited for a number of reasons and include such factors as extreme competition to develop and bring to market products faster, cheaper, lighter, and better than competitors. These trends not only drive increased resource consumption but also drive built in obsolescence. Financial responsibility schemes that have been set up so far do not seem to provide any real incentives for design for reuse or remanufacturing within OEMs. This is because, in systems where producers pay uniform recycling fees there is no financial feedback mechanism for products designed for less costs at end-of-life. Since the reduced end-of-life costs are shared among all producers of the similar product group, the savings are also shared. The exception is individual programs set up by manufacturers.

What has been less obvious to determine is what an efficient level of environmental product information might entail concerning private consumers. When considering the environmental improvement criteria presented in this thesis, all the labels and declarations reviewed address these issues to similar extents .The discussion concerning the appropriateness of eco-labels and eco-declarations showed that industry clearly favours the Type II declarations of either ECMA or IT Företagen formats to communicate environmental information to consumers. Although industry favours Type II declarations, they have rarely been promoted or marketed to consumers at retail stores in Sweden. At the same time it was found that private customers rarely, if ever ask for environmental information concerning ICT products.

Arguments put forth by the ICT industry against the use of Type I eco-labels are somewhat valid given the short development times in which products are brought to market. However, the options for a suitable alternative to stimulate demand for environmentally improved ICT products in the private consumer market are uncertain. Can private consumers absorb the information provided in the

ECMA TR/70 or IT Företagen declaration? The answer has not been determined in this research, but some indication may be provided when considering the limited use at the point of retail so far.

Given the role that public and corporate procurement seems to be playing by pulling markets towards more environmentally adapted products, it appears OEMs are influenced and have responded by setting up information systems (discussed above) to collect the requested data. Industry response suggests that further environmental requirements to be compared on, could be an important driver for product improvement. Therefore, the eco-declarations of IT Företagen could be adapted to reflect the current advances in substitutes for lead free soldering, for example. Although the ban in 2006 seems to be moving forward, OEMs may respond more quickly if competition exists. Other technologies that offer significant environmental gains could also be promoted in the declaration systems. In general, by including the current best practises within the declarations awareness is created that can stimulate demand for improved products.

7.2 Standardisation of Environmental Product Data

Throughout this thesis, it has become clear that due to the international structure of the ICT industry in terms of both manufacturing and market placement, international standards where appropriate are necessary to facilitate the flow of environmental product information.

Concern over the proliferation of Type I eco-labels with different environmental criteria has been expressed by industry as being an unworkable option considering the structure of the market. Harmonising of eco-labelling criteria between programs for ICT product groups may alleviate some of this concern. The work of the Global Eco-labelling Network to harmonise criteria between programs should be supported as a means to address the issue. Similarly, the European Commission has found that the need for harmonisation of Type I labelling is necessary to facilitate their use by producers both directly and indirectly.

Standardisation of material declaration questionnaires provides an example of the importance of having uniform inquiries between manufacturers and their supply-chains. Without standardised formats the process becomes not only time consuming but also extremely expensive and has characteristically poor reporting results. This situation has prompted Industry Associations to normalize the formats in an attempt to alleviate these concerns.

The recent release of the technical specification for documenting LCA data – ISO 14048, is an important step in the promotion of standardised and transparent LCI data in the ICT sector. It creates a platform on which LCI data can be exchanged on an international level appropriate for the ICT sectors composition. Initiatives by the European Commission to develop LCI databases, should promote the use of the technical specification early in the development stages.

Concerning the issue of the use of hazardous chemicals and substances in ICT products standardisation and harmonisation also plays an important role. The Swedish Committee on New Guidelines on Chemicals Policy in their report "Non-hazardous products - Proposal for implementation of new guidelines for public policy" note that due to the international trade aspect, the stipulated guidelines cannot be implemented solely via measures on a national level, but that measures must be adopted primarily on an international level, to begin with at the EU level. Harmonisation has in fact already started. The European Community together with its trading partners is committed to developing a global system for managing chemicals.[126] Work is underway with the candidate countries for accession to the EU, in the framework of the OECD and at a global level in the framework of the United Nations.

[126] Commission Proposal COM (2001) 88 final. White Paper: Strategy for a future Chemicals Policy. p.28

These efforts should substantially improve the flow of environmental product data along the ICT product chain necessary to improve the environmental performance, given the international structure of both the production chain and that of the worldwide marketing channels.

7.3 EEE Working Paper – Are the essential requirements really essential?

Section 3.1.4 provides a background and outlines the 'essential requirements' of the EEE Working Paper for a directive on the impact on the environment of electrical and electronic equipment. This 'New Approach' directive, like all New Approach directives, will require a standardisation body (in this case CENELEC) to develop technical standards that must be adhered to by designers of EEE products to be placed on the European Community Market. Given the findings concerning environmental product information flow, there are a number of positive suggestions as well as uncertainties concerning the current proposed 'essential requirements' listed in the working paper.

In Annex II, the essential requirements are laid down in three sections A) General Provisions, B) Requirements for the design of EEE and C) Requirements for information and labelling concerning the environmental design aspects of electrical and electronic equipment.

Within the General Provisions paragraph there is explicit reference that manufacturers of EEE shall perform an assessment of the environmental impact of a product throughout its lifecycle. What is still unclear is if in fact a LCA is required to meet this obligation. Although the Enterprise Directorate has repeatedly stated that the EEE directive does not require a LCA, it is unsure what other methods would be appropriate to meet this obligation especially considering the definition of life cycle assessment given. The definition of 'life cycle assessment" in Article 2 is stated as "a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and associated environmental impacts directly attributable to the use of a product throughout its life cycle. In addition, stated within the CENELEC's proposal for a "Standardisation Structure in Support of EEE" document is the use of ISO for identifying environmental aspects.[127]

Further evidence of the use of life cycle assessment is with reference to Annex II B). It is stated here that manufacturers are required to identify and estimate the magnitude of environmental inputs and outputs with electrical and electronic equipment during all life cycle phases. Again, it seems that LCI is the only workable option that will allow an accurate estimation of inputs and outputs of all materials and energy used to manufacture products.

Given the difficulty expressed in gathering data on materials found within the supply chain of Ericsson, the requirement in the EEE directive seems far-reaching. This is in light of the fact that not only all of the materials within the product need to be accounted for, but also as the requirement states, for all life cycle phases, consumption of raw materials and energy and emissions to air, water or soil must be estimated. In addition the expected generation of waste and the anticipated pollution from noise, vibration, radiation, and electromagnetic fields, and the possibilities for reuse, recycling and recovery of materials must also be generated. Given the lack of standardised LCI data available for many of the life cycle phases there will be considerable data availability problems with this approach. Although there is a requirement in the working paper for all component manufacturers to supply the "necessary information" that manufacturers require to comply with the directive, in reality it will be very difficult to enforce this requirement. This is in light of the geographical makeup of component suppliers in the ICT sector. This demand will most likely come from OEM pressure rather than legislation that is unenforceable in the country of origin. Even if all actors have the applicable data, problems with allocation to specific materials, components and assemblies may be

[127] CENELEC. (2001). Standardisation Structure in Support of EEE: CLC (SG) 857. European Committee for Electrotechnical Standardisation. p. 2

extremely challenging. Confidentiality issues will need to be addressed for which IT applications can assist.

If existing LCI data is to be used, agreement will be required by all OEMs that the data is acceptable to avoid future controversies over data accountability. This process could take extended periods of time. It is true that international standardisation of data collection techniques such as ISO 14048 will aid in the process, however the time taken to collect relevant data will prove to be too slow for the product development process. This has been highlighted in the current research with major OEMs now claiming to use the results of LCA to develop guides and checklists to aid the design process that is not part of the active design process. It is unclear in the working paper if the requirement for estimating the ecological profile (the result of the impact assessment) is needed for each product designed or product family designed or if it is a “one-off” requirement.

Although the Commission in its IPP green paper has noted that it has the intention to build data inventories and provide simple tools that allow for a fast check of the environmental impacts of the product, this general lack of information will need to be addressed. Will these tools use predetermined data in LCI databases? Will the Commission manage and coordinate such databases? How will the data that are generated from the requirements be fed into existing or future databases? What about privacy issues? It is clear that the Commission needs a strategy for the road ahead, before far-reaching requirements are placed on businesses, especially small and medium sized firms.

From the ecological impact manufacturers must apply principles that are meant to improve the environmental performance of products. According to CENELEC, the use of existing guidelines will be used such as the IEC Guide 109 - Environmental Aspects – inclusion in electro-technical product standards and the forthcoming ISO 14062 - Environmental Management: Guidelines to integrating environmental aspects into product development. Here it is clear that the use of guidelines and checklists are the most appropriate tools for the product development stages. From the existing work in the IEC and ISO, this should be easily attainable. Also, ECMA has developed a preliminary draft design standard that they are promoting to the Commission.[128] It is clear that there is momentum building concerning guidelines and checklists that can meet the demands of the requirement.

Regarding paragraph C) -requirements for information and labelling concerning the design aspects of EEE – some important considerations are noted. It is somewhat unclear what is meant by the fact that manufacturers shall ensure information concerning the environmental design aspects are passed on to the manufacturing process. Most certainly these requirements are already included in manufacturing specification briefs, for example, what materials to use, energy power specification, size and weight. On the other hand designers may be able influence manufacturers to incorporate other pollution prevention initiatives listed in paragraph B).

However, there is great potential to meet the requirement to encourage the dissemination of environmental product information to consumers concerning the significant environmental characteristics of the product when it is placed on the market. Discussed previously, the use of ECMA TR/70 or IT Företagen eco declarations are supported by industry and could provide a suitable format for this purpose. These formats could also support the requirement on providing consumers on how to install, use and maintain the product in order to minimise its impact and ensure optimal life expectancy, including general take-back information. Since voluntary disclosure of this information at retail outlets is currently minimal, this requirement may stimulate demand for environmental product information by consumers. However, whether or not consumers can absorb and compare the information provided in the declarations to actually choose products that are more environmentally adapted has not been determined.

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[128] ECMA. (2001). *Environmental design considerations for electronic products – preliminary draft May 2001, Draft Standard ECMA-999*. Switzerland: Standardizing Information and Communication Systems (ECMA).

Finally there are information requirements for manufacturers to provide information to treatment facilities concerning disassembly, recycling of disposal at end-of-life. This requirement is important and has been identified as a major gap in environmental product information flow. Recyclers need more information concerning at minimum the location of components containing substances of concern and materials or substances that interfere with the recycling processes. However, this requirement is already part of the WEEE Directive informative requirements and therefore the need for duplication is questioned. Standard formats are needed and development should involve dialogue between recyclers and manufacturers on the most appropriate format. This is to ensure that efforts that have been undertaken by designers to facilitate end-of-life management are communicated to facilities so that the efforts are not in vain, such as material marking and component identification. Within this thesis an example of a standard coding system was highlighted. Future work needs to focus on the appropriate format of information exchange for the purposes of end-of-life treatment.

Bibliography

Allison, C., Carter, A. (2000). Study on the Different Types of Environmental Labelling: Proposal for an Environmental Labelling Strategy. Brussels: European Commission, DG Environment.

Atlantic Consulting, IPU. (1998). LCA Report: EU Ecolabel for Personal Computers. Environment Directorate: European Commission.

Baynes, A. et al. (2001) Environmental technologies and their business drivers. In M. Charter & U. Tischner, *Sustainable Solution: Developing Products and Services for the Future* (340-348). Sheffield: Greenleaf Publishing.

Bergendahl Carl-Gunnar. (2000). Electronics Goes Halogen-free: International Driving Forces and the Availability and Potential of Halogen-free Alternatives. In 2000 IEEE International Symposium on Electronics and the Environment. ISEE-2000.

Bowman, Heather (Heatherb@eia.org) . 2001, August 9). Re: Electronic Industry Alliance (2000) Material Declaration Guide. E-mail to Chris van Rossem (Christopher-van.Rossem.002@student.lu.se)

Brezet, Han., Rocha, Cristina. (2001). Towards a model for product-oriented environmental management systems. In M. Charter & U. Tischner, *Sustainable Solution: Developing Products and Services for the Future* (243-262). Sheffield: Greenleaf Publishing.

Brinkley, A., Mann, T. (1997). Documenting Product Environmental Attributes. In 1997 IEEE International Symposium on Electronics and the Environment. (52-56)

Bromine Science and Environment Forum (2000.) An introduction to Brominated Flame Retardants. [Online]. Available: www.bsef.com [2001 July 14]

CENELEC. (2001). Standardization Structure in Support of EEE: CLC (SG) 857. European Committee for Electrotechnical Standardization.

CEFIC et al. (2000). Guidance Document on the Appliance of Substances under Special Attention in Electric & Electronic – Products. Version 02. CEFIC, EACEM, EECA, EICTA, EUROMETAUX.

Commission Interpretative Communication COM(2001) 274 final. Commission Interpretative Communication on the Community law applicable to public procurement and the possibilities for integrating environmental considerations.

Commission Proposal COM (2000) 347 provisional. Proposal for a Directive Of the European Parliament and Council on Waste Electrical and Electronic Equipment.

Commission Proposal COM (2001) 88 final. White Paper: Strategy for a future Chemicals Policy. p. 11

Commission of the European Communities. (2000). *Green Paper on the Contribution of Product –Related Environmental Policy to Sustainable Development: A Strategy for an Integrated Product Policy Approach in the European Union*. Com (2000), Brussels.

Commission of the European Communities. (1998). Efficiency and Accountability in European Standardization under the New Approach". (COM 1998) 291 final. Brussels.

Commission of the European Communities. (2001) Working Paper for a Directive on the impact on the environment of electrical and electronic equipment (EEE). Version 1.0, February 2001 http://europa.eu.int/comm/enterprise/electr_equipment/eee/workdoc.pdf [2001, May 21]

CPM, Competence Center for Environmental Assessment of Products and Material Systems (2001). [Online]. Available: http://www.glObalSPINE.com [2001, July 10]

Das, S., Naik, S. (2001). The DBOM Standard: A specification for efficient product data transfer between manufacturers and demanufacturers. In 2001 IEEE International Symposium on Electronics and the Environment. ISEE-2001. (241)

DG Enterprise Press Release. (2001). *Commission launches a new approach to free movement of green electrical goods.* [On-line] -Available http://europa.eu.int/rapid/start/cgi/guesten.ksh?p_action.gettxt=gt&doc=IP/01/313|0|RAPID&lg=EN [20 April, 2001]

DG Enterprise. (2000). Shaping standards for Enterprise Europe: Fifteen years of the 'new approach'. Enterprise Europe No. 1 (newsletter)

Ends Data Services. (2001). *Commission proposes EMAS role in electronics eco-design Directive*. The Ends Report, Issue No. 314, March 2001

ENDS Environment Daily. (2000. Sweden to give product policy major push, January 12, 2000. [On-line] – Available: http://www.ends.co.uk [2001, January 252525].

ENDS Environment Daily. (2000). *EU electroscrap directive finally proposed.* Ends Data Services. [2000, June 13]

ENDS Environment Daily. (2001). *Second EU green electrogoods draft released.* ENDS Data Service. [2001, 02/10/01

Environment Canada. (1998). Understanding the Environmental Aspects of Electronic Products: A Life Cycle Assessment Case Study of a Business Telephone. Ottawa: Environment Canada.

Erixon, Maria. (1999). *Practical Strategies for Acquiring Life Cycle Inventory Data in the Electronics Industry. Report 1999:3.* Göteborg: Chalmers, Göteborg University.

Ernst & Young Consultants. (2000). *Developing the Foundation for Integrated Public Policy in the EU.* DG Environment, European Commission, Brussels.

Fava, J. et al. (2001). The Evolution of Design for Environment in Electronics Firms. In 2001 IEEE International Symposium on Electronics and the Environment. 2001.IEEC.

Furuhjelm, Jörgen. (2000*).* Incorporating the end-of-life aspect into product development: Analysis and a systematic approach. Dissertation No.642. Linköping: Department of Mechanical Engineering, Linköping University.

Garcia, Raquel. (2000). *Product Chain Management to Facilitate Design for Recycling of Post Consumer Plastics: Case studies of polyurethane and acrylic use in vehicles.* Lund: IIIEE Communication 2000:2.

Hedermalm, P., Carlsson, P., Palm, V. (1985). Waste from electrical and electronic products: A survey of the contents of materials and hazardous substances in electrical and electronic products. Nordic Council of Ministers. Tema Nord 1995:554.

Heiskanen, E., Kärnä, A., Niva, M., Timonen, P., Munch af Rosenschöld, E., Pripp, L., Thidell, Å. (1998). Environmental Improvements in Product Chains. Nordic Council of Ministers. Tema Nord 1998:546

Hermann, F., Urbach, H-P., Wendschlag, H.. (2001) Eco-labeling and Information Technology (IT) Industry. In 2001 IEEE International Symposium on Electronics and the Environment. ISEE-2001. (1-3)

Hieronymi, K. (2001) Implementing the WEEE Directive. In 2001 IEEE International Symposium on Electronics and the Environment. ISEE-2001. (217-222)

Hunter et al. (2001). Legality of the Draft Directive on the Impact on the Environment of Electrical and Electronic Equipment. [On-line] –Unavailable http://www.ends.co.uk/subscribers/envdaily/docs/eee3.pdf

IVF Industrial Research and Development Corporation. (2001). [Online]. Available: http://extra.ivf.se/dfee/news/ISOstandard.htm [2001, June 23]

Januschkowetz, A., Hendrickson, C,T. (2001). Product and Process Life Cycle Inventories using SAP/R3. In 2001 IEEE International Symposium on Electronics and the Environment. ISEE-2001. (59-65).

Johansson, Ann-Marie. (2200). *Opportunities and Obstacles Faced by SMEs in Adopting Design for Environment.* Lund: IIIEE Masters theses 2000:15.

Johansson, D. (2000). The influence of Eco-labelling on Producers of Personal Computers: The potential for eco-labelling as part of an IPP approach for reducing chemical risks related to PCs in Sweden. Lund: IIIEE Communications 2000:03.

Karlsson, Mårten. Green Concurrent Engineering (1997). Green Concurrent Engineering: Assuring environmental performance in product development. Licentiate thesis. The International Institute for Industrial Environmental Economics, Lund, Sweden.

Kliejn, R. et al. (1999). Electronic Consumer Goods case report. [Online]. Available: http://www.leidenuniv.nl/interfac/cml/chainet/ECG.html [2001, May 27]

Kärna, A. (1999). Managing Environmental Issues from Design to Disposal- A Chain Reaction: Experiences of Product Chain Actors in the Finish electrical and electronics industry. Helsinki: Federation of Electrical and Electronics Industry. p. 108

Mälhammar, G. (1998). Material Declaration Questionnaire. In 1998 IEEE International Symposium on Electronics and the Environment. ISEE-1998. (14-18)

McAloone, T.C. (2000). *Industrial Application of Environmentally Conscious Design.* London: Professional Engineering Publishing Limited.

Miller, G.Tyler. (2000*). Living in the Environment: principles, connections, solutions, eleventh edition.* Pacific Grove: Brooks/Cole Publishing Company

Muller et al. (2000) Product based Environmental Performance Indicators: A methodology for selecting and supporting environmental metrics. In 2000 IEEE International Symposium on Electronics and the Environment. ISEE-2000. 93-98

Murphy, F. Cynthia, Pitts, Gregory. (2001). Survey of Alternatives to Tin-Lead Solder and Brominated Flame Retardants. In 2001 IEEE International Symposium on Electronics and the Environment. ISEE-2001. (309-315).

Ohashi, T. et al. (1999). Ecological Information System: Data exchange system between manufacturers and recyclers. In 2001 IEEE International Symposium on Electronics and the Environment. ISEE-2001. (143-147)

Rose, Catherine M., Stevels, Ab. (2001). Metrics for End-of-Life Strategies (ELSEIM). In 2001 IEEE International Symposium on Electronics and the Environment ISEE-2001. (100-105)

Society for Promotion of Life-cycle Assessment Development (2001). [Online]. Available: http://www.spold.org/whatis.html [2001, August 10]

Smith, D., Berkhout, F., Howes, R., Johnson, E. (1999). *Adoption by Industry of Life Cycle Approaches: Its Implications for Industry Competitiveness and Trade.* London: European Communities.

Socolof, M. et al. (2001). Life-cycle Environmental Impacts of CRT and LCD Desktop Monitors. In 2001 IEEE International Symposium on Electronics and the Environment ISEE-2001. (119-127)

Statistics Sweden (2001). Summary: Use of Heat and Electricity. [Online]. Available: http://www.scb.se/sm/en11sm0101%5Finenglish.asp [2001, September 6].

Tischner, Ursula. (2001). Tools for ecodesign and sustainable product design. In M. Charter & U. Tischner, *Sustainable Solution: Developing Products and Services for the Future* (263-281). Sheffield: Greenleaf Publishing.

Turbini, L. et al. (2000). Examining the Environmental Impact of Lead-free Soldering Alternatives. 2000 IEEE International Symposium on Electronics and the Environment. ISEE-2000. (46-53).

UNEP. (2001). The Life Cycle Initiative: UNEP/SETAC co-operation on best available practice in Life Cycle Assessment (LCA). United Nations Environment Programme, Division of Technology, Industry & Economics Production and Consumption Unit.

WBCSD. (2000). Eco-efficiency: Creating more value with less. [On-line] Available: http://www.wbcsd.org/newscenter/reports/2000/EEcreating.pdf, [2001, August 3]]

Weidman, E., Lundberg, S. (2000). Life cycle Assessment of Ericsson Third Generation Systems. In 2000 IEEE International Symposium on Electronics and the Environment. ISEE-2000.

Abbreviations

BFR	Brominated Flame Retardant
CENELEC	European Committee for Electrotechnical Standardization
CEM	Contract Electronic Manufacturer
CRT	Cathode Ray Tube
DfE	Design for Environment
EACEM	European Association of Consumer Electronic Manufacturers
ECIF	European Chemical Industry Council (CEFIC)
ECMA	Standardizing Information and Communication Systems
EECA	European Electronic Components Association
EEE	Electrical and Electronic Equipment
EIA	Electronic Industry Alliance
EICTA	European Information and Communication Technology Association
EMF	Electromagnetic Fields
EMS	Environmental Management System
EMSs	Electronic Manufacturing Services
EOL	End-of-Life
EPR	Extended Producer Responsibility
EUROMETAUX	European Association of Metals
IC	Integrated Circuit
ICT	Information and Communication Technology
IEC	International Electrotechnical Committee
IPP	Integrated Product Policy
ISO	International Standard Organisation
KEMI	Swedish National Chemicals Inspectorate
LCA	Life Cycle Assessment
LCD	Liquid Crystal Display
LCI	Life Cycle Inventory
MSDS	Material Safety Data Sheet
NGO	Non-Governmental Organisation
OEM	Printed Board Assembly
PC	Personal Computer
PTH	Plated Through Hole
PWB	Printed Wire Board
SME	Small and Medium Enterprises
VDU	Video Display Units
WEEE	Waste Electrical and Electronic Equipment

List of Interviews

June 5, 2001 IVF Carl Gunnar Bergendahl, Technical Area Manager – Environmental Compatibility, Mölndal, Göteborg: personal interview

June 25, 2001 CPM Chalmers Institute of Technology Raul Carlson, Lead Researcher, Göteborg, personal interview

June 28, 2001 Ericsson Radio Systems, Nicole Damen, Camilla von Wachenfeldt, Per Döfnäs, personal interview

June 28, 2001 IT Företagen, Björn Axelsson, personal interview

July 7, 2001 Ericsson AB, Camilla von Wachenfeldt, telephone interview

July 9, 2001 Ericsson AB, Jens Malmodin, telephone interview

July 20, 2001, Multis – Product Sustainment Services, Eamonn Reay, telephone interview

July 23, 2001, Philips Semiconductors, Mr. Leo Klerks, telephone interview

July 24, 2001, Ericsson AB, Ms. Michele Schmidt – Manager Corporate Marketing and Communication – Sustainability & Environment

July 26, 2001, DG Enterprise, Mr. Norbert Anselmann – Deputy Head of Unit- Single Market, regulatory environment, standardisation and the new approach: Mechanical and electrical engineering, radio and telecom terminal equipment industries

August 7, 2001 Camilla von Wachenfeldt: Ericsson AB, telephone interview

August 23, 2001, Per Orsander - Butikschef, ONOFF, Malmö: personal interview

August 23, 2001, Johan Blom - Sff Butikschef, SIBA, Malmö: personal interview

August 27, 2001, Sverker Sjölin – Miljöchef, Stena Technoworld, telephone interview

Aug 27, 2001, Connie van der Capellan - Statskontoret, Stockholm: telephone interview

Aug 27, 2001, Björn Axelsson, IT Företagen, Swedish IT Association, Stockholm: telephone interview

Aug 28, 2001, Ulf Rick, Swedish Chemicals Inspectorate, Solna, Stockholm: telephone interview

Email Correspondence

August 6, 2001, Hiroko Takahashi, takahashi.hiroko125@canon.co.jp Re: Japan Material Declaration Initiative

July 24, 2001, Derek Washington, washington@clara.net Convenor, CENELEC BTWG 85-3,

July 18, 2001, Dr. Georg Niedermeier, Siemens AG Corporate Standardization and Regulation Georg.Niedermeier@mchp.siemens.de

August 9, 2001, Heather Bowman Heatherb@eia.org, Electronics Industry Alliance

Appendix 1: Exemptions from the RoHS Directive

Applications of lead, mercury, cadmium and hexavalent chromium, which are exempt from the RoHS Directive

- Mercury in compact fluorescent lamps not exceeding 5 mg per lamp
- Mercury in straight fluorescent lamps not exceeding 10 mg per lamp
- Mercury in lamps not specifically mentioned in this Annex
- Mercury in laboratory equipment
- Lead as radiation protection
- Lead in glass of cathode ray tubes, light bulbs and fluorescent tubes
- Lead as an alloying element in steel containing up to 0.3% lead by weight, aluminium containing up to 0.4% lead by weight and as a copper alloy containing up to 4% lead by weight
- Lead in electronic ceramic parts
- Cadmium oxide on the surface of selenium photocells
- Cadmium passivation as an anti-corrosion in specific applications
- Cadmium, mercury and lead in hollow cathode lamps for atomic absorption spectroscopy and other instruments to measure heavy metals
- Hexavalent chromium as an anti-corrosion of the carbon steel cooling system in absorption refrigerators.

Appendix 2: EIA Material Declaration Guide

EIA Category A: Controlled Substances

Material Category	Prohibition Type	Industry Uses	Threshold for Disclosure
Asbestos, Asbestos Materials	Product	Not expected	Intentionally added
Ozone Depleting Substances – Class I	Product and Process	Not expected due to industry phase-out, but rare cleaning applications may be found.	Intentionally added
Ozone Depleting Substances – Class II	Product and Process	Not expected, but use of HCFCs as substitute for CFCs in cleaning operations may be found.	Intentionally added
Polychlorinated Biphenyls (PCBs)/ Terphenyls (PCTs)	Product	Not expected, but historically used in transformers, capacitors	Intentionally added
Polybrominated Biphenyls (PBBs) and their ethers/oxides	Product	Not expected. Some PBBOs (PeBDPO) were previously used as a flame retardant in low cost PWBs and capacitors. Decabromobiphenyls may previously have been used in some plastic resins for flame retardancy. OBDPO may be used in ABS and other thermoplastics. DBDPO may be used in HIPS and other thermoplastics. Please note: TBBPA is not a PBB when incorporated in product.	Intentionally added
Certain Ethylene Glycol Ethers	Product and Process	Certain ethylene glycol ethers were traditionally used as solvent in semiconductor manufacture.	Intentionally added

EIA Category B: Restricted Substances

Material Category	Banned Uses	Threshold for Disclosure
Cadmium and its compounds	Dyes, Pigments, paints/enamels Plastic Stabilizer (electric cables) Packaging/Packaging Inks Plastic parts >25 grams	Intentionally added
Chromium (VI) and its compounds	Packaging/Packaging Inks	Intentionally added
Lead and its compounds	Packaging/Packaging Inks Paints	Intentionally added
Mercury and its compounds	All uses except Packaging/Packaging Inks	Intentionally added

EIA Category C: Materials of Interest - Metals and their components

Material Category	Threshold Reporting Level	Industry Uses
Antimony and its compounds	1000 ppm	Solder alloy. Antimony Trioxide as flame retardant synergist in plastic housings (e.g., power chargers) and chip encapsulate. CRT glass. It typically has been used in combination with a brominated flame retardant and PVC.
Arsenic and its compounds	1000 ppm	Arsenic is used as dopant in semiconductor manufacture. Gallium arsenide is used as semiconductor substrate.
Beryllium and its compounds	1000 ppm	Used as alloy with copper for electrical contacts and springs. Substrate for integrated circuits, lightweight housings. Beryllium oxide as insulator.
Cadmium and its compounds	1000 ppm	May be used as surface finish on circuit boards. Silver cadmium oxide electrical contact alloys for relays and switches. Cadmium telluride photovoltaic cells, cadmium sulfide based photocells, Photocells Surface Coating/Plating
Chromium (VI) and its compounds	1000 ppm	Anti-corrosion treatment
Lead and its compounds	1000 ppm	Electrical interconnect (surface finish, solder, leads) Leaded glass (CRTs. Lenses) Plastic Stabilizer Moulding agent in plastic manufacture Counterweights, machined metal parts (transformers)
Mercury and its compounds	Any intentionally added	Lamps (back light for LCD, high intensity discharge lamps) Thermostats
Nickel and its compounds	1000 ppm	Surface finish Anti-corrosion Seed layer for immersion-less gold surface finish Stainless steel components
Magnesium and its compounds (metal or alloy only, not compounds)	1000 ppm	Surface coating Computer casings
Selenium and its compounds	1000 ppm	Used in diodes and light detectors (lead selenide). Historically used as photoelectric coating.
Copper and its materials	1000 ppm	Electrical interconnect
Gold and its materials	1000 ppm	PWB finish, Gold fingers and wires
Palladium and its materials	1000 ppm	PWB surface finish, component lead finish, electroless operations
Silver and its materials	1000 ppm	Surface treatment, conductive epoxies, electrical interconnect, Solder paste

EIA Category C: Material of Interest – Flame Retardants

Material Category	Threshold Reporting Level	Industry Uses
Organophosphorus compounds	1000 ppm in any plastic part > 25 gm	Common flame retardant in thermoplastics (e.g., keyboards, housings)
Tetrabromobisphenol A (TBBA)	1000 ppm in any plastic part > 25 gm	Common flame retardant used in circuit board resins. Some use as an additive type of FR in ABS or other thermoplastics. This listing refers only to the monomeric (unreacted) TBBA. When TBBA is a reactant in epoxy resins or other polymeric materials it is not reportable.
All other organic or inorganic substances used as FR's.	1000 ppm in any plastic part > 25 gm	Other common flame-retardants (halogenated or non-halogenated) used to impart ignition resistance to polymers or other organic substrates. include mineral type, nitrogen-based chemistries, other brominated and non-brominated flame-retardants.

EIA Category C: Materials of Interest – Organic Materials

Material Category	Threshold Reporting Level	Industry Uses
Chloroparaffins	1000 ppm (total product weight) or 1000 ppm in any plastic part > 25 gm	Plasticizer Lubricants
Phthalates	1000 ppm (total product weight) or 1000 ppm in any plastic part > 25 gm	Plasticizer
Azo-Based Materials	1000 ppm	Dyes, plastic colorant
Chlorinated polymers (PolyVinylChloride- PVC)	1000 ppm	Plastic Windows on cell phones Housings Cables Flexible CD jackets

EIA Category C: Materials of Interest – Other Materials

Material Category	Threshold amount	Industry Uses
Radioactive Substances	Intentionally added	Overvoltage device