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# Sustainable Electronics and Electrical Equipment for China and the World

## A commodity chain sustainability analysis of key Chinese EEE product chains

Martin Eugster, Duan Huabo, Li Jinhui, Oshani Perera, Jason Potts, Wanhua Yang

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Federal Department of Economic Affairs FDEA
**State Secretariat for Economic Affairs SECO**

June 2008

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## Executive Summary

China's importance as both a supplier and consumer of electronic goods and equipment (or e-products) has grown at an unprecedented pace over the course of the past decade. Since its entry into the World Trade Organization (WTO) in 2001, China's e-product manufacturing sector has entirely reoriented itself from an industry driven primarily by domestic markets, to a fundamentally export-driven sector and the world's most important supplier of many, if not most, major e-products on the market today.

The e-product sector now accounts for 10.2 per cent of the country's total industrial output value and 6.3 per cent of national industrial profits. While the rapid transition towards global market leadership in the e-product sector has produced significant economic benefits at both the national and community levels, it has also placed increasing pressures on the local and global environments.

Perhaps not surprisingly, the single most important environmental impact arising from e-products are those impacts associated with energy use. Both the manufacturing and use phases of e-products are highly energy intensive. The growth of e-products can, therefore, be directly linked to growing demands for energy globally and corresponding growth in air pollution and greenhouse gas production. At a more local level, the manufacture, recycling and disposal of e-products presents serious threats to personal and community safety through the heavy metals and chemicals used in processing and production.

China's special role as the world's leading destination for foreign e-waste, combined with its vast system of informal e-waste recycling and disposal, presents both an environmental challenge and opportunity. The current absence of information and management infrastructure related to the e-waste sector within China gives rise to serious pollution problems. At the same time, the efficiency of China's informal collection of e-products places it in a strong position to reap significant benefits through e-waste recycling with the adoption of the appropriate management techniques.

Based on our analysis of the social and environmental impacts of e-products, both within China and abroad, three basic areas for improvement can be identified that provide a baseline set of objectives for any policy action aimed at attaining improved sustainability across the sector:

1. Improved management and handling during e-product manufacture;
2. Improved management and handling during e-waste collection, dismantling and disposal;
3. Improved design for the reduction of energy and resource use (both during production and use phases) and the maximization of recyclability (eco-design).

The main challenge facing Chinese (and international) policy-makers in this context is the

identification of effective mechanisms for stimulating the efficient adoption of such improvements without jeopardizing the economic growth needed to maintain economic development. Building on the existing policy framework and related private initiatives both nationally and internationally, this report proposes policy action along two complementary trajectories: the reinforcement of regulatory measures and the expansion of market-based measures.

**Regulatory reinforcement**

As essential mechanisms for creating a common baseline for business activity within China, regulatory measures provide the foundation for all other activity. As such, it is critical that regulatory measures receive the institutional and resource support for effective implementation. Towards this end, this report proposes a number of recommendations:

**Recommendation 1: National sustainable e-product growth strategy**

The Chinese government should launch a National Sustainable E-Product Growth Strategy explicitly aimed at stimulating "green" economic growth in the e-product sector through investment and innovation for sustainable e-product design and production practices.

> ***Recommendation 1.1:*** *Fortify national eco-design legislation:* The Chinese government should improve the consistency, and strengthen the implementation infrastructure, of its existing e-product eco-design legislation using the EU *Directive Establishing a Framework for the setting of Eco-design Requirements for Energy-using Products (EuP)* as a possible model. The government should also establish detailed guidelines and targets for its existing eco-design legislation. A comprehensive review of existing legislation should form the basis of further legislative efforts.
>
> ***Recommendation 1.2:*** *Fiscal support for eco-design and eco-production*: The Chinese government should provide preferential tax rates to products that comply with internationally recognized eco-design standards. Industry coalitions and associations within the Special Export Zones should be given targeted support to stimulate sustainable e-product design and production.
>
> ***Recommendation 1.3:*** *Investment support for eco-design:* The Chinese government should establish a fund dedicate to eco-design research and development. The Chinese government should establish and sponsor a "national institute" for eco-design.
>
> ***Recommendation 1.4:*** *Building the market for eco-design products:* The Chinese government should strengthen the implementation of the Chinese energy label by expanding product coverage and by linking requirements to the international Energy Star labelling system
>
> ***Recommendation 1.5:*** *Building the market for preferable production practices*: The Chinese

government should expand and strengthen the implementation of its Procurement of Environmentally Labelled Products Policy by setting and monitoring mandatory percentage-based targets for sustainable e-product procurement.

***Recommendation 2: National e-waste strategy***

The Chinese government should implement a comprehensive National Strategy for the Responsible Collection and Treatment of E-Waste based on increased transparency and coherence across existing e-waste management legislation and programs as well as the drafting of new legislation to fill existing e-waste management gaps.

***Recommendation 2.1:*** The Chinese government should facilitate and support the set-up of a legal framework for e-waste management and define the role of all stakeholders, in particular the role of the e-product manufacturers, importers, distributors and consumers, and of e-waste collectors, dismantlers and recyclers.

***Recommendation 2.2:*** The Chinese government should facilitate the establishment of a secure financing scheme for managing and maintaining a sound and safe end-of-life system for e-waste.

***Recommendation 2.3:*** *E-waste treatment quality assurance scheme:* The Chinese government should implement a comprehensive e-waste treatment quality assurance scheme. The scheme should consist of a licensing and auditing system that builds on international e-waste collection and treatment standards. Licensing under the scheme should be made dependent upon regular reporting as well as a demonstration of safe and sustainable handling and treatment practices. Employment of low skilled workers in the currently informal, but highly efficient, e-waste collection scheme should be maintained as much as possible.

***Recommendation 2.4:*** *Improve clarity and impact of existing e-waste import rules:* The Chinese government should establish a set of national guidelines for the identification of e-waste imports. This should be complemented with additional technical assistance resources for customs officials in the implementation of China's official ban on e-waste imports. The Chinese government should also revise its existing rules for related (non-prohibited) e-waste and e-waste fractions imports to take better account of actual product make-up and toxicity levels.

***Recommendation 2.5:*** *Building an information base for improved management of e-waste:* The Chinese government should implement a national system for gathering and compiling data on the quantities and sources of domestic and imported (both legal and illegal) e-waste.

***Recommendation 3: International action plan for sustainable e-waste management:***
The Chinese government should work with the international community toward the establishment of an International Action Plan for the Responsible Trade and Disposal of E-Waste.

> ***Recommendation 3.1:*** *International dialogue:* The Chinese government, in collaboration with the United Nations Environment Program and the Basel Convention Secretariat, should support a major international conference to launch a global dialogue on an International E-Waste Action Plan with a view to improving compliance rates with the Basel Convention guidelines and obligations.
>
> ***Recommendation 3.2:*** *International e-waste treatment standard:* As a starting point for enabling improved private sector management of e-waste, the Chinese government should work with the international community to establish an international standard for the environmentally sound management of e-waste.
>
> ***Recommendation 3.3:*** *Harmonized implementation of e-product treatment legislation:* The Chinese government should launch an international process aimed at harmonizing the implementation procedures for diverse Waste from Electrical and Electronic Equipment (WEEE) and Restriction of Certain Hazardous Substances (RoHS) regulations in order to reduce Chinese compliance costs and improve overall supply chain efficiency.
>
> ***Recommendation 3.4:*** *Global private sector partnership:* Building on, and working with, existing multi-stakeholder e-waste partnerships, such as The Mobile Phone Partnership Initiative, The Global Knowledge Partnerships in E-waste Recycling, The Global Computer Refurbishment and Recycling Partnership and Solving the E-waste Problem: A Synthetic Approach Initiative, the Chinese government, in collaboration with the United Nations Environment Program, should facilitate a global multi-stakeholder, supply chain-based approach to monitoring and managing trade in e-waste.

Given the depth and breadth of the various policy options open to the Chinese government, as well as the international nature of the responsibilities associated with the responsible management of the e-product chain, it is clear that a comprehensive plan towards sustainable e-product policy should, fundamentally, be built upon a basis of international cooperation and shared responsibility. Therefore, this report, through its analysis and recommendations, aims, more than anything, to provide an objective and constructive foundation for the strengthening of such cooperation.

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**Box 1: Study scope and definitions**

This paper provides an analysis of the sustainability impacts of e-products and e-waste with a view to assessing promising policy options for sustainable development from a Chinese perspective, but with attention to global sustainability. For the purposes of this paper, e-products and e-waste are defined as:

**Electronic products (e-products):** Any manufactured good that uses electricity for its functioning or use.*

**Electronic waste (e-waste):** Any e-product that no longer satisfies the current owner for its original purpose—including all components, sub-assemblies and consumables that are part of the-product at the time of discarding.**

In this study, we focus on the impacts of select products within three core categories of e-products as follows:

**Large household appliances:** Washing machines, refrigerators and air conditioners

**Information technology and communications equipment:** Personal computers, laptops and mobile phones

**Consumer goods:** Cathode ray televisions, LCD televisions

Our analysis is based on a detailed life cycle analysis of personal computers, which is used as a basis for extrapolation to other product sectors.

*OECD (2001)
** EU WEEE Directive (EU, 2002a) and SINHA (2004)

## 1.0 Introduction

In 2006, the total sales revenue for the e-products in China was US$640 billion. During the same year trade in e-products reached US$652 billion in 2006, accounting for 37 per cent of China's total foreign trade volume. E-product production and trade forms a core of China's development strategy. Increasingly, as China becomes the leading supplier of a growing list of e-products, Chinese production and trade is also finding its way into the sustainable development policies and strategies of China's trading partners.

Growing pressures on the global environment combined with the unique challenges associated with e-waste management have given rise to a growing body of e-product legislation that is destined to have significant impacts on Chinese production and trade. At the same time, China's own growing e-product market, combined with its rapid expansion of production capacity over the past decade, is presenting unprecedented social and environmental challenges at the local and national levels. Chinese policy makers have responded to the call of the market, and local sustainability challenges—however, the national and international implementation infrastructure remains weak and largely inefficient to date.

The purpose of this study is to provide an overview of the principal sustainability challenges faced by global e-product chains of critical importance to the Chinese economy with a view to identifying priority areas and strategies for improving the sustainability of the global e-product sector. The study draws from the Global Commodity Chain Sustainability Analysis methodology developed by IISD, which provides a framework for developing policy recommendations in the context of global supply chains and international markets.

The basic elements of the GCCSA consist of an analysis of market structure and trends, an analysis of the social and environmental impacts along the global supply chain, an analysis of global supply chain structure and governance and, finally, policy recommendations. The GCCSA effectively links life cycle and related sustainability impact analysis to supply chain decision-making structures and public policy.

One of the driving motivations behind this report, and the GCCSA more generally, is a recognition of the need to adopt strategies of shared responsibility along global product chains with supply chain actors and policy-makers, from China and abroad, working side-by-side in the development of policies and markets for sustainable production and consumption at the global level. Our analysis of the e-product chain confirms this observation and concludes by outlining a series of strategic policy options for building more sustainable global e-product chains. We begin, however, with an overview of the basic structure of the e-product supply chain.

## 2.0 Supply Chain Framework

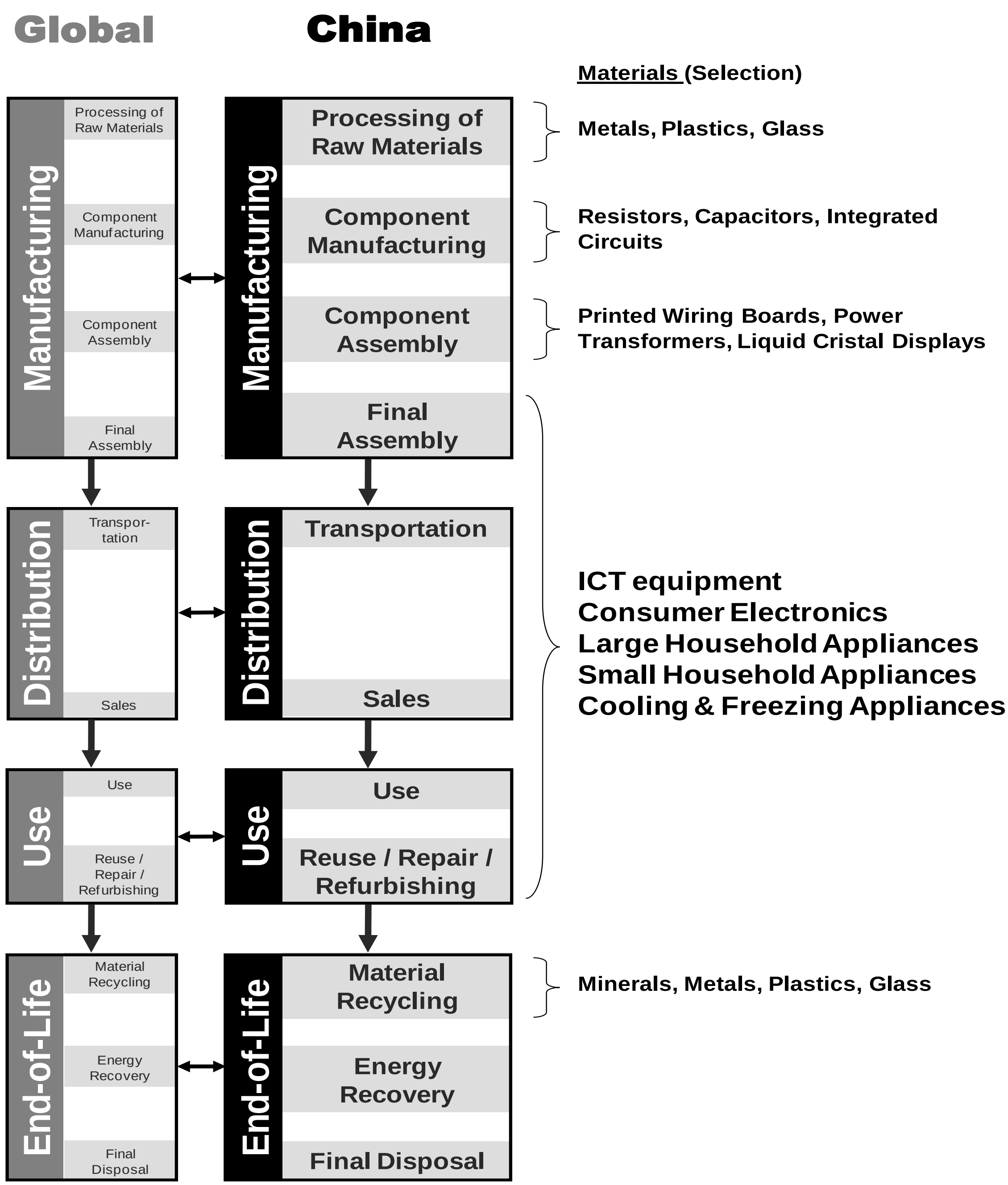
The electrical and electronic product (EEE) industry is one of the largest, fastest growing, most dynamic and most complex sectors in today's global economy. For the purposes of our analysis, it is useful to consider the e-product chain in terms of four distinct phases: manufacturing, distribution (trade), consumption (use) and end-of-life (including recycling and disposal) (see Figure 1).[1] At each stage of the supply chain, trade in the raw material, component, product and service markets between Chinese "domestic" supply chains and global supply chains is represented by a double arrow.

The manufacturing phase consists of four main processes: processing of raw materials, component manufacturing, component assembly and final assembly. The distribution phase consists of trade and distribution in products both within China and across the global market (e.g., imports and exports, as well as in-country distribution). The arrow between global "Distribution" and China's "Distribution" phases indicates imports and exports of e-products respectively. The use phase is divided into use and reuse of e-products and consists of the activities related to the actual operation of e-product over the course of its life. Finally, the end-of-life phase is split into a direct waste stream and a reverse supply chain of e-waste where secondary raw materials are produced for

[1] The boundaries of the supply chain for this analysis are drawn at the manufacturing level. Supply chain activities associated with the extraction of raw materials, or the manufacture of primary materials are therefore not considered within the supply chain analysis. The impacts of such processes are, however, included within the life cycle analysis of the e-product chain (See Section 0 below).

eventual reintegration in production supply chains. The end-of-life phase consists principally of waste collection, dismantling, material recycling, energy recovery and final disposal.

**Figure 1:** A generic analytical framework for e-product chains



# 3.0 Market Trends

Both the global electronics industry and China's role in that industry are growing at a rapid pace. In 2006 the total sales revenue for the e-product sector in China was US$640 billion—up 23.7 per cent from 2005. Trade in e-products reached US$652 billion in 2006, accounting for 37 per cent of China's total foreign trade volume. Of this, exports alone were valued at US$364 billion—a 37.6 per cent increase over 2005.[2] A closer look at the market trends for key e-products suggests that China's role in the global e-product supply chain is growing faster than market growth itself, which suggests a growing consolidation of production capacity and responsibility within China. Market trends also reveal that while growth is large across all sectors, the largest growth potential over the medium- to long-term is related to newer hi-tech markets.

## 3.1 Market trends for key e-products

### *3.1.1 Large household appliances*

The large household appliance market is characterized by a number of older, better established e-product firms[3] originally oriented towards production for China's domestic market. The growth of the refrigerator market between 1990 and 2006 provides an example of the growth pattern for large household appliances more generally. Between 1990 and 1999, refrigerator production grew from 4.6 million units to 12.1 million units—or 18 per cent per annum—effectively the same rate of growth of domestic consumption. With the opening of markets for export in 2001, refrigerator production jumped to 36 per cent per annum growth.

Similar patterns can be observed for air conditioners and washing machines—with air conditioners showing the most dramatic growth in export-oriented production (from 25 per cent of total production in 2001 to 56 per cent of total production in 2006). Total annual production of air conditioners was 58 million units in 2006, making it the most important product in terms of units produced within the large household appliance market. Not surprisingly, the annual growth in production of air conditioners over the past five years (69 per cent) also leads among large household appliances. Overall, the air conditioner market is the most dynamic, both in terms of trade and production growth, within the large household appliance market.

The top three destinations for Chinese exports of large household appliances across the board are the U. S., Japan and Europe. In the refrigerator market, the U. S., Japan and EU markets account for more than 40 per cent of Chinese exports. In the air conditioner market, Japan and the U. S. alone account for 45 per cent of total exports.

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[2] See Hong Kong Trade and Development Council at http://electronics.tdctrade.com/content.aspx?data=electronics_content_en&contentid=850788&w_sid=194&w_pid=695&w_nid=10422&w_cid=850788&w_idt=1900-01-01&w_oid=180&w_jid

[3] For example, Haier, Xinfei, Meiling, Midea.

**Figure 2a:** Annual production growth in China of key household appliances

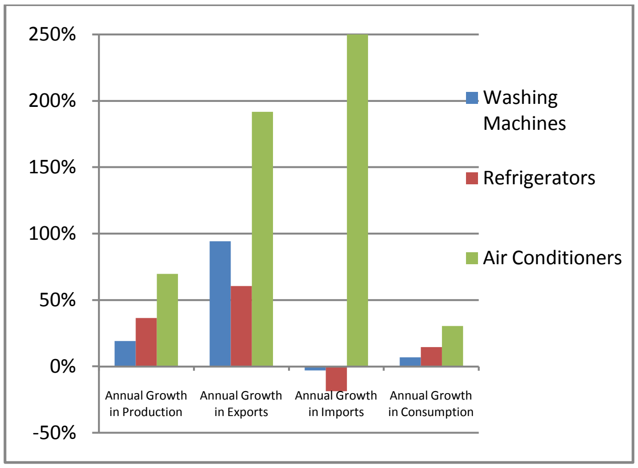



**Figure 2b:** Exports as a percentage of production (2001 and 2006)

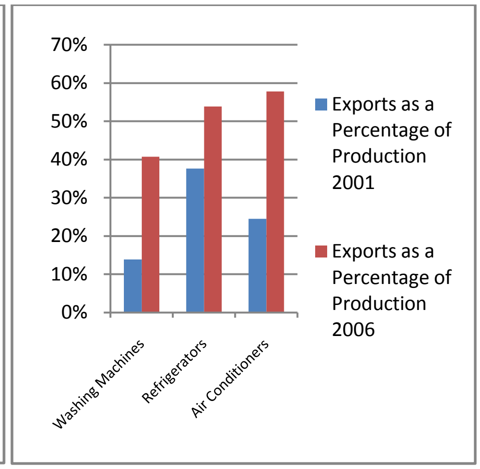
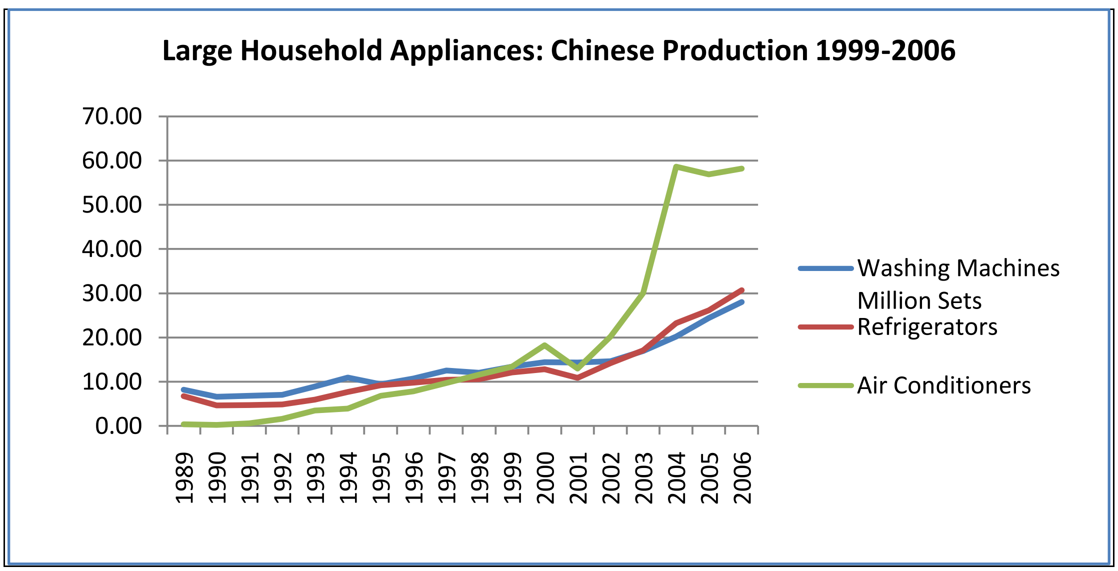



**Figure 2c:** Annual growth figures for large household appliances and exports as a percentage of production (2001–2006)




### 3.1.2 *Consumer goods: Televisions*

The television market is clearly segmented into markets for "new technology Liquid Crystal Display (LCD) screens" and "old technology Cathode Ray Tube (CRT) screens." Since CRT televisions are available at lower prices than their LCD counterparts, CRT production tends to be driven by lower income economies. Indeed, China itself, which consumed 54.5 million CRT televisions in 2006 (up 85 per cent from 2001), accounts for the lion's share of global market growth in CRT television production and sales. Between 2001 and 2006, Chinese production of CRT televisions grew from 42 million units to 84 million units—or, approximately 48 per cent of total global consumption. Over the same period, Chinese consumption of CRT televisions grew from 30 million units to 54 million units. In stark contrast to other products in the e-product market, the amount of production destined for Chinese consumption remained stable at approximately 65 per cent between 2001 and 2006. Overall, the growth of the LCD display market over the past several years has stunted growth in the CRT television market—a trend which will lead to the eventual phasing out of CRT televisions over the course of the next 10–15 years.

In developed-country markets, LCD televisions have effectively replaced CRT televisions as the product of choice. Although Chinese production of LCD televisions is currently considerably less than that of CRT televisions (18 million units in 2006), growth rates in Chinese production suggest that this will not be the case for long. In 2006, approximately 80 per cent of total LCD production was destined for export markets with the U. S., Japan and EU, accounting for more than 90 per cent of total LCD exports. Over the next decade, however, it is expected that Chinese consumption will take a far larger share of Chinese production, as Chinese consumers become more affluent and CRT technology is phased out altogether.

**Figure 3a:** Annual production growth in China of key television categories

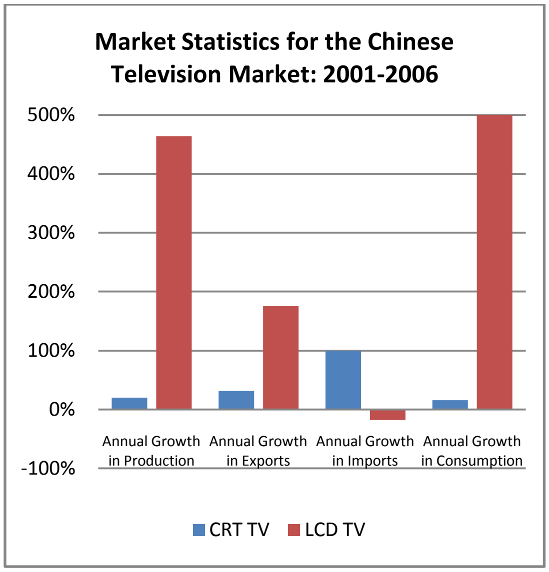



**Figure 3b:** Exports as a percentage of production (2001 and 2006)

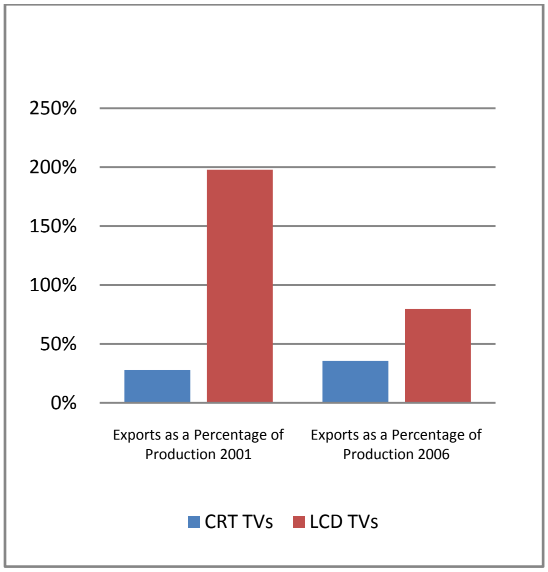
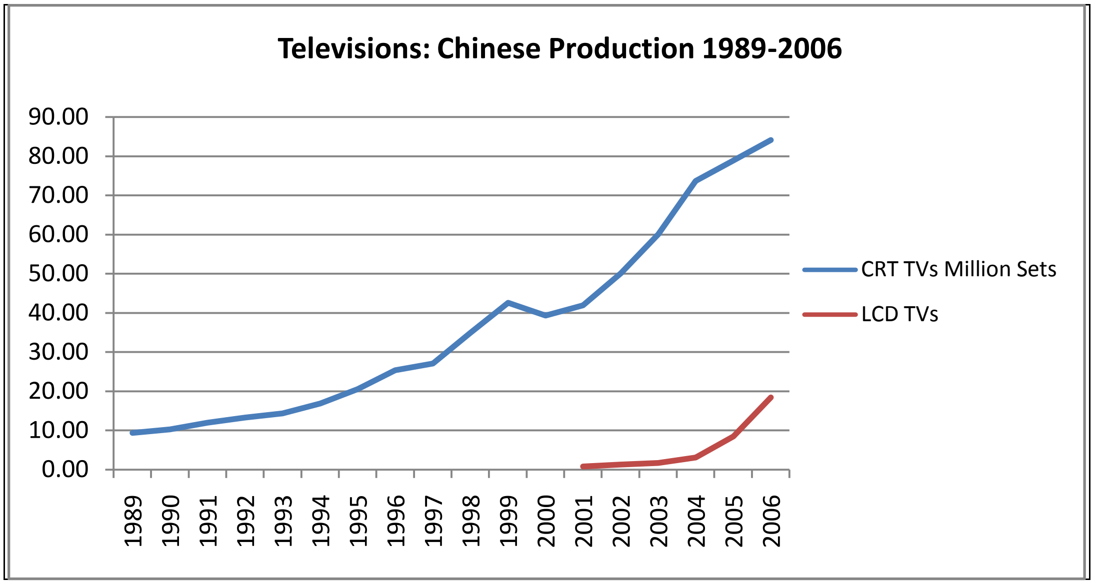


**Figure 3c:** Annual growth figures for televisions and exports as a percentage of production (2001–2006)




### *3.1.3 Information and communications technology: Personal computers and mobile phones*

As with other e-products, China is a world leader in the production of ICT products. Between 2001 and 2006, the production of desktop personal computers (PCs) had grown from 8 million units to 47 million units, while the production of mobile phones had grown from 75 million units to 340 million units. In both segments of the ICT market, domestic consumption, which itself grew by 450 per cent and 160 per cent for personal computers and mobile phones respectively, over the same period, was a major driver in Chinese production. In 2006, domestic consumption accounted for 83 per cent of total Chinese production.

The segmentation of the PC market into "low" and "hi" tech markets with an emphasis on domestic and export markets, respectively, is similar to the segmentation found in television markets. Growth in the notebook market has skyrocketed over the past five years from less than 100,000 units in 2001 to 55 million units in 2006. As of 2006, more than 90 per cent of all notebook PCs produced in China were for export markets. The main export destinations for Chinese notebook PCs are the U. S., EU[4] and Japan, which account for 36 per cent, 34 per cent and 20 per cent, of exports respectively.

It is estimated that PC penetration in Chinese markets is currently about 15.8 units per 1,000 households, a figure that pales in comparison to the 200–350 units per 1,000 households in OECD countries, suggesting massive growth potential in the domestic PC market over the coming decade.[5]

[4] France and Germany are the main European destinations for Chinese notebook PCs.
[5] www.nationmaster.com

**Figure 4a:** Annual production growth in China of key ICT categories

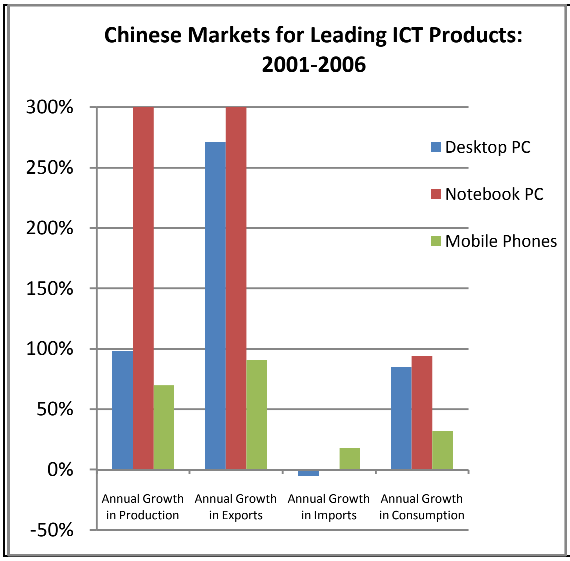
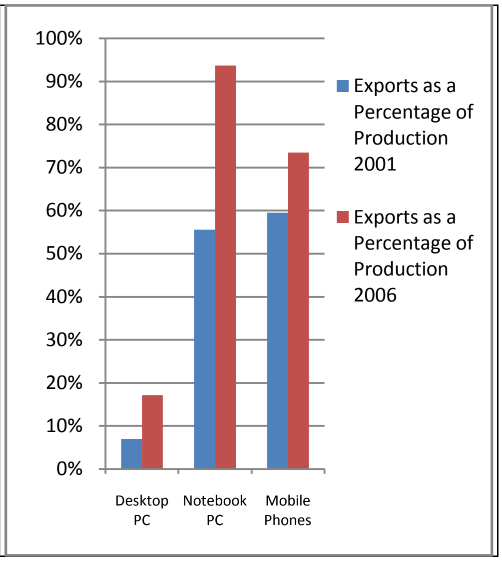



**Figure 4b:** Exports as a percentage of production (2001 and 2006)



**Box 2: The structure of China's changing notebook industry**

A large percentage of notebook PCs shipped out of mainland China are manufactured by companies based in Taiwan. According to Taiwan's Market Intelligence Center (MIC), the island's notebook PC suppliers will account for 70 per cent of total global production in 2007.

Relocation of production to China has enabled these Taiwanese companies to reduce Free on Board (FOB) prices due to lower labour costs and the lower costs of components such as AC adapters. It has also given Taiwanese manufacturers a foothold on the fast-growing domestic Chinese market for notebook PCs. Most companies are clustered in Suzhou and Wujiang in Jiangsu province; Shenzhen and Zhongshan in Guangdong province; and in Shanghai. Some production lines remain in Taiwan and these handle high-end models or pilot runs of new releases. R&D centres and marketing offices are also maintained in Taiwan.

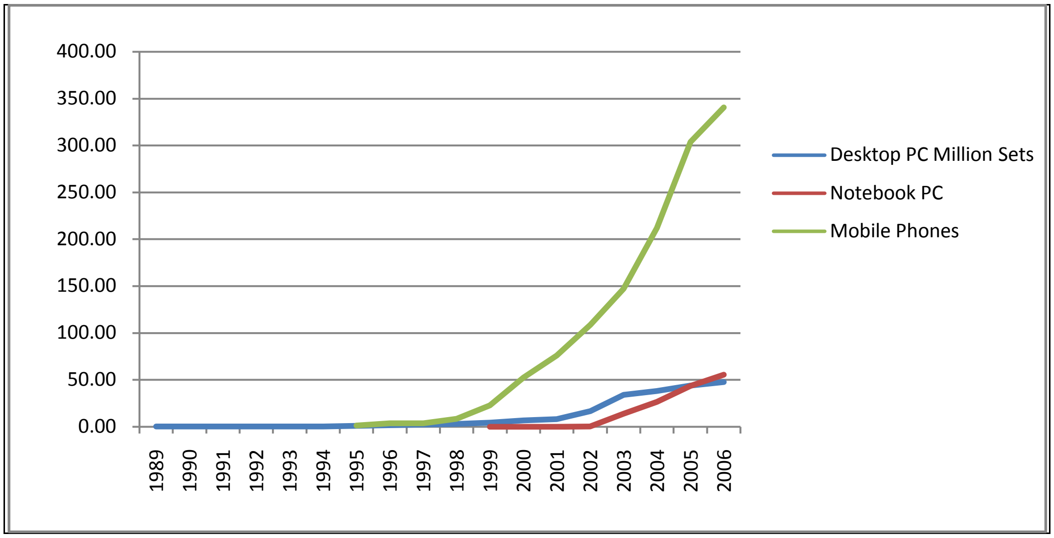
On the other hand, mainland China-based suppliers, who mostly have manufacturing backgrounds in desktop PCs and consumer electronics, sell primarily to the domestic market. While a large majority of these companies work with Taiwanese partners on notebook manufacture, a growing number of Chinese companies are establishing R&D centres to develop the necessary expertise, and are looking to break into international markets across 2007 and 2008.

Notebook PC suppliers in Taiwan are either:

- pure contract manufacturers (without company retail presence) of the world's leading notebook PC brands such as Sony, Toshiba, Hewlett-Packard (HP), Fujitsu-Siemens and Dell, and large retail chains such as Carrefour and Wal-Mart;
- contract manufacturers with their own retail brands; or
- big-brand, non-manufacturing companies.

Taiwan's notebook PC-makers rely heavily on orders from the world's top ten vendors. Orders from other companies are relatively small. The two top pure contract manufacturers, Quanta and Compal, account for nearly two thirds of production, with the remainder divided among half a dozen other large makers.

**Figure 4c:** Annual growth figures for ICT products and exports as a percentage of production (2001-2006)




### 3.1.4 *General market trends*

China's role in the global e-product market has been growing at an astronomical pace. Over the past decade, China has shifted from producing e-products solely for the domestic market to a production system that is not only fundamentally *export-driven*, but where it is also the single most important producer worldwide. China is now the world's largest manufacturer and sourcing point for PCs, televisions, mobile phones, refrigerators and air conditioners. As a general rule, the following basic patterns are observed in Chinese e-product chains:

- Prior to 2001, virtually all e-product production in China was directed principally towards domestic consumption. Growth rates in exports of all e-products since this time have been significant—typically well over 50 per cent per annum and frequently over 100 per cent per annum;
- For large household appliances and newer hi-tech e-product categories, export markets are driving growth in Chinese production. The fact that the rate of growth in production (and exports) in these segments on the whole far exceeds the global growth rates for these sectors suggests that production of these major e-products is rapidly being consolidated within China;
- For a specific set of older technologies with more mature markets (such as desktop PCs and CRT televisions), domestic consumption remains the principal driver of production growth. With the exception of desktop PCs, the rate of growth for Chinese production in more mature markets ranges between 15 per cent and 50 per cent per annum. The rate of production growth for newer "hi-tech" products (notebook PCs, LCD televisions etc.) ranges between 67 per cent and 2800 per cent per annum;
- The principal markets for Chinese e-products are the U. S., Europe and Japan. Typically these three destinations account for 50 per cent or more of total exports.

**Table 1:** Average life span for select e-products

| Product Category | Product Type | Lifespan (years) |
|---|---|---|
| ICT | Desktop PC | 6 |
| | Notebook PC | 5 |
| | Mobile Phone | 3 |
| | CRT Monitor | 6 |
| | LCD Monitor | 6 |
| Televisions | CRT Television | 10 |
| | LCD Television | 5 |
| | PDP Television | 5 |
| Household Appliances | Washing Machine | 12 |
| | Refrigerator | 13 |
| | Air Conditioner | 11 |

To the extent that the e-product market itself is largely driven by technological innovation (e.g., higher tech products that are export-driven in the Chinese context), the Chinese e-product market can appropriately be described as "export-driven." Notwithstanding this basic characteristic, the growing affluence of Chinese consumers, combined with the size of the Chinese consumer market and low e-product penetration levels more generally, suggest that the domestic market will become an increasingly important driver over time—for both new and mature markets alike.

## 3.2 Market trends for e-waste production and trade

For the purposes of our research, e-waste is defined as any e-product that is no longer usable for its original purpose. As such, the generation of e-waste in any given region is directly correlated to regional consumption levels. E-waste has the potential to feed into either the "waste stream" or into the production stream of new products through recycling and reuse. The "market" for e-waste recycling and reuse depends upon the nature of the materials in the e-product, the regulatory framework and the recycling/disposal capacity of any given region.

China has already established itself as a world leader in terms of the volumes of e-waste it processes for recycling and re-use in the supply chain. However, the actual volumes of e-waste either generated by, or coming into, China from foreign markets, is relatively undocumented due to the largely informal character of the supply chains that trade e-waste. Notwithstanding the general absence of robust data, it is possible to estimate e-waste levels based on key variables contributing to overall e-waste levels.

The total physical volume of e-waste generated by any given product is a function of: consumption, product lifespan and per-unit material volume. Overall, increasing rates of technological development are driving higher levels of consumption through the development of new e-product markets and reductions in the lifespan of all e-products.

Below we consider the main sources and trends in e-waste generation at the domestic and international levels respectively.

### 3.2.1 Structure of the e-waste reverse supply chain

The main stages of the waste portion of the supply chain consist of: 1. collection; 2. dismantling; 3. material recovery; and 4. waste disposal. The manner and location under which these stages are carried out depends largely upon whether or not the process forms a part of the formal or informal supply chain. The informal e-waste supply chain is particularly important in China due to a combination of the fact that there is a general absence of strong regulatory and material infrastructure for formalizing the e-waste supply chain and the fact that the import and treatment of e-waste often fails to comply with domestic regulations (thereby creating incentives for operation outside of the formal market).

China is a world leader in terms of its collection, dismantling and material recovery capacity—which is one of the reasons why it is also the most popular destination for global e-waste exports from other countries. According to Liu, Tanaka et al. (2006), currently the majority of e-waste in China is processed (dismantled) in backyards or small workshops. The most prominent regions with small-scale, unlicensed processes are located in the southern Guangdong Province and in Zhejiang Province in eastern China. In many of the small-scale processing workshops in Guiyu it is thought that imported wastes probably account for the major part of the material processed.

### 3.2.2 Domestic e-waste

Chinese consumption of e-products is growing faster than global rates due to rapidly growing affluence

**Box 3: Distribution of activities across the formal and informal e-waste sectors**

**Collection:** Although a number of new collection facilities have recently been established in some of the larger urban centres, most e-waste collection in China is currently conducted through the informal sector. In the informal sector it is estimated that there are approximately 2000 companies involved in collection and trade, 500 companies involved in e-waste collection and recycling and 8000 household workshops involved in e-waste collection and recycling. It is estimated that the collection phase employs 5 million people in China.

**Dismantling:** E-waste dismantling, like collection, is lead by the informal sector in China. Although there are no specific numbers on dismantling workshops, it is estimated that a considerable amount of dismantling occurs in household workshops, with entire communities being dedicated to e-waste dismantling in some cases.

**Material Recovery:** Material recovery, by contrast, is conducted principally by the formal sector. There are at least 509 government-approved centres for carrying out material extraction on e-waste. There are another 100 enterprises involved in extracting materials from waste delivered directly from e-manufacturers.

**Waste:** The waste stage is both formal and informal—as a general rule, waste produced in the informal activities are disposed of informally, while that generated in formal enterprises is disposed of through formal enterprises.

Source: Duan and Eugster (2007)

within the nation which, in turn, is generating a high growth rate for e-waste. In terms of material volumes, CRT televisions and large household appliances are, and will remain for the foreseeable future, the leading sources of e-waste coming from the domestic market.

**Household appliances (washing machines, refrigerators and air conditioners)**

The contribution of household appliances in terms of material waste is particularly important due to the large per-unit volumes of products within the category. Growth in the per-unit consumption of large household appliances ranged between 7 per cent and 30 per cent per unit per annum, depending on the product, between 2001 and 2006. Based on the average weights for air conditioners, refrigerators and washing machines (46, 57 and 27 kg, respectively), large household appliances accounted for about 900,000 tonnes, or approximately 50 per cent of all e-waste generated within China in 2006. By 2015, the total volume of e-waste generated by these three household appliances is expected to rise to 2.3 million tonnes, and will account for approximately 40 per cent of domestic e-waste.

**Consumer products (televisions)**

Due to both the dominance of CRT televisions in the Chinese market as well as the higher material content (as compared with LCD televisions), CRT televisions will remain the dominant source of e-waste from the television market for the foreseeable future. The material volume of e-waste generated by CRT televisions in 2006 was 610,000 tonnes (or 35 per cent of total domestic e-waste), a number that is expected to grow to 1.6 million tonnes by 2015 (or 29 per cent of total domestic e-waste). As such, CRT televisions are, and will continue to be, the *single* most important source of e-waste (in terms of volume) generated within China.

**Information and communication technologies (mobile phones and PCs)**

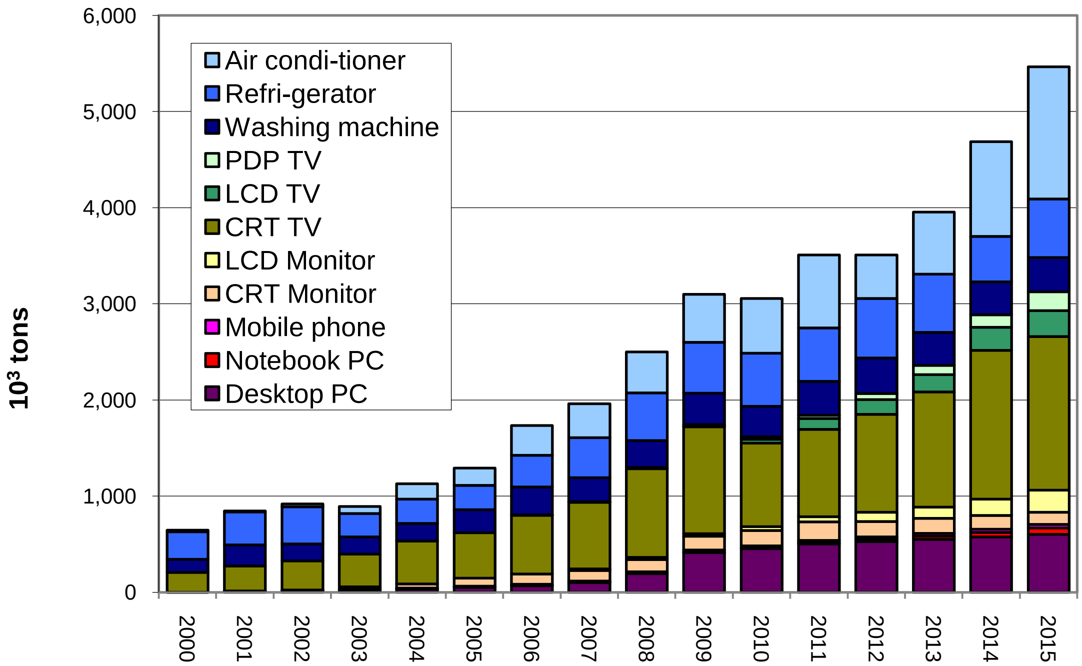
With approximately 300 million cell phone users, China is the world's largest consumer of mobile phones. The number of cell phones purchased in 2006 was 119 million— almost twice that purchased in 2001. The rate of growth combined with the short lifespan of cell phones (2–3 years), suggests a high rate of growth in e-waste generation for mobile phones in the short-term future. Estimates suggest that e-waste from phones generated in China alone were 8.8 million units in 2001, 43 million units in 2006 and 115 million units by 2010. The small material size of mobile phones renders them a minor contributor to overall e-waste volumes.

Similarly, notebook PCs, with consumption at less than 20 million units per annum over the next decade are expected to remain a modest contributor to e-waste from the ICT sector (and e-products more generally). The desktop PC, on the other hand, is currently experiencing rapid growth with expectations of a quadrupling of total e-waste generated (rising from 10 million units in 2006 to 42 million units in 2010). In 2006 PC, systems (including their monitors) generated an estimated 170,000 tonnes (or 10 per cent) of domestic e-waste. By 2015, that number is expected to rise to

720,000 tonnes, or approximately 13 per cent of total domestic e-waste in China.

### Consolidated trends for domestic e-waste

**Figure 5:** Estimates for domestically-generated e-waste: China 2000–2015




Overall, domestic e-waste is on a rapid growth path. In 2006, conservative estimates put total domestic e-waste for our select categories at 100 million units or 1.7 million tonnes or 1.3 kg of e-waste per capita. This number is expected to rise to about 400 million units by 2015 or 5.4 million tonnes.[6] The main contributors to domestic e-waste, in terms of volume currently are, and will continue to be, CRT televisions and large household appliances with desktop PCs taking a significant role contributing more than 10 per cent of total domestic e-waste from 2009 onwards.

[6] Note that estimates by other authors are largely in agreement with our figures. Li, Tian et al. (2006) estimates that by the year 2010 in China the number of obsolescent items among the four largest household appliances and personal computers will be as follows: colour TV sets, more than 58 million units; refrigerators, more than 9 million units; washing machines, more than 11 million units; air conditioners, more than 12 million units; and personal computers, 70 million units. (Li, Tian et al., 2006). According to Liu, Tanaka et al. (2006), in 2010 the number of obsolescent items will increase to 56 million TV sets, 12 million refrigerators, 13 million washing machines, six million air conditioners and 20 million personal computers.

### 3.2.3 *Illegally imported e-waste*

Official Chinese policy qualifies e-waste as one of the substances controlled by the Basel Convention, which in turn implies the need for special measures on the control of trans-boundary movements and disposal. Following this characterization, the Chinese government issued a ban on the importation of e-waste in 2001 under its *Foreign Trade Law,* a move that was subsequently followed by the implementation of further regulations and restrictions on the transport and trade of e-waste.[7]

Notwithstanding the existence of the regulatory ban, substantial and growing amounts of e-waste continue to enter the country illegally. In the same way that increases in domestic consumption of e-products is driving growing levels of domestic e-waste, growing demand for e-products in developed countries, combined with increasingly strict rules on the disposal of such goods internationally, is driving increased e-waste imports in China.

The precise quantities of e-waste imported into China remain entirely uncertain. The Basel Action Network estimates that 70 per cent of the 20 to 50 million tonnes produced globally end up in China (e.g., 14 million to 35 million tonnes annually). Greenpeace estimates that the total e-waste imports going to China increased from just under a million tonnes in 1990 to 17.5 million tonnes in 2000.[8] The Basel Convention Regional Centre for the Asia Pacific estimates that approximately 33 million tonnes of illegal e-waste were imported into the Asian region in 2004—with a majority of that finding its way into China. Drawing from quantities of e-waste actually found at facilities in the major dismantling centres, the numbers would appear to be considerably lower. For example, on-site inspections of housing cases in collection and dismantling centres suggests that the majority of e-waste entering China is coming from the U. S., which might signal lower (than "70 per cent") rates coming from Europe. Moreover, Tshingua University, drawing from data from the Beijing Zhongse Institute of Secondary Metals estimates total illegal imports of e-waste to be around 1.5 million tonnes per annum.

**Box 4: Global e-waste growth: The driver behind Chinese e-waste imports**

UNEP estimates that between 20 and 50 million tonnes of e-waste are generated annually around the world. According to data from the EU WEEE Forum, the system operators in different European countries collected in 2005, on average, 3.4 kg e-waste per capita (Forum 2007) or three times that estimated for China. The EU estimates that e-waste is growing at a rate three times faster than other municipal waste within its borders. Although the majority of e-waste generated in developed countries is disposed of in landfills, a growing portion of it is exported to countries with e-waste recycling capacity. China is, by far, the largest recipient of foreign e-waste.

*Source: UN Warning on Global e-Waste 'Mountain,' BBC News, November 2006,* http://news.bbc.co.uk/go/pr/fr/-/2/hi/technology/6187358.stm

[7] Note also that on July 3, 2002, the Ministry of Commerce (MOFCOM), the Administration of Customs and the State Environmental Protection Administration (SEPA) jointly issued the Notice No. 25/2002 on Waste Lists. The list covers 21 types of wastes including e-waste like LHAs, ICTs and CE, which are banned to import and to be used as secondary raw materials.

[8] www.green-web.org/zt/e-waste/record.htm.

Regardless of the actual amounts of imported e-waste coming into China from foreign markets, two conclusions remain undisputed:

1. That illegal e-waste imports account for a major part of, if not the majority of, Chinese e-waste being treated in the major dismantling centres found along the Pearl and Yangtze river deltas.
2. That these illegal wastes are a major source of highly toxic chemicals giving rise to dangerous living and working conditions in the Chinese dismantling districts.

In Sections 4 and 5 below we consider the social and environmental impacts of these waste products in more detail. [9]

**Figure 6:** Global e-waste trade routes


*Source: Silicon Valley Toxic Coalition, 2007*

[9] The Beijing Zhongse Institute of Secondary Metals (Zhongse, 2002) estimated that the amount of e-waste imported in the Yangtze River Delta accounts for over 700,000 tons in 2001. Tshingua University, using similar techniques, has calculated the total imported e-waste in the Pearl River Delta, another well known destination for e-waste imports, at no less than 700,000 tons in 2006. Similar reports emerged in the neighbouring harbour regions of the Bohai Sea Bay area, including Tianjin harbors and Shandong, where it is estimated roughly 10 per cent of the total e-waste imports (or 150,000 tonnes) arrive (BCRC 2005).

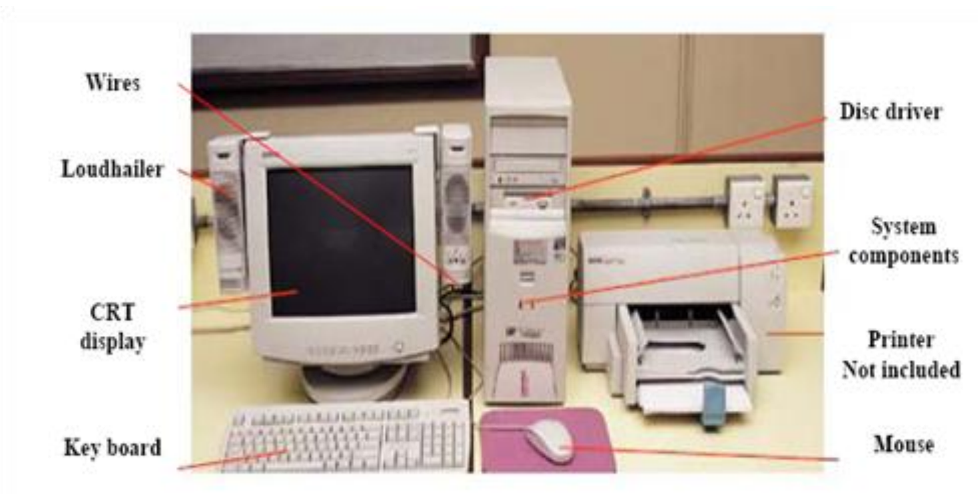
# 4.0 Environmental Life Cycle Assessment of Select Chinese E-Product Chains

The following section provides an overview of the results of a life cycle assessment (LCA) for key e-products from the large household appliance, consumer electronic and information and communications technologies segments of the e-product market. The results of the LCA are based on a detailed life cycle assessment for PC systems originating in China, which combines primary data from Chinese factories and data in the Eco-invent database and provides analysis through "Eco-indicator 99" LCA software. [10]

## 4.1 Summary of PC life cycle analysis

The functional unit of our LCA of the PC is the complete lifespan[11] of one desktop personal computer system as shown in Figure 7.

**Figure 7:** Functional unit of life cycle analysis—Desktop PC with CRT monitor, printer not included




The environmental impact throughout the life of a PC is directly related to the specific context of the supply chain of which the PC is a part. For the purposes of our analysis we assumed production in China—starting with the extraction of the raw materials (metals, raw oil, natural gas, etc.) but with distribution across China, the EU and the U. S., in proportions consistent with current trade data.

[10] Due to resource limitations on the scope of study, the methodology adopted for the life cycle analysis was to conduct a detailed life cycle analysis of the personal computers as a basis for extrapolating LCA results for a select range of other e-products. The complexity of the PC system (containing both integrated circuitry and display screens) renders it a particularly rich basis for generating LCA results for other e-products. All LCA analysis is conducted using primary data gathered from Chinese factories and existing data in the inventory database Ecoinvent (v.1.3).

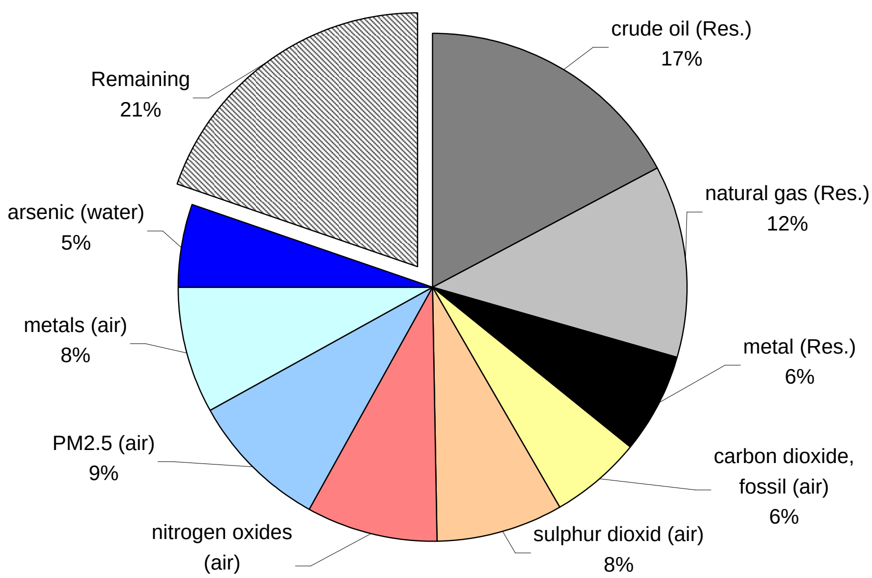
[11] For the purposes of our research we assumed the lifespan of an average PC to be six years.

Since the distribution, use and end-of-life context varies significantly among the three major markets for Chinese PCs, it is helpful to consider these supply chains separately at each stage of the PC's life cycle.

#### *4.1.1 Production impacts*

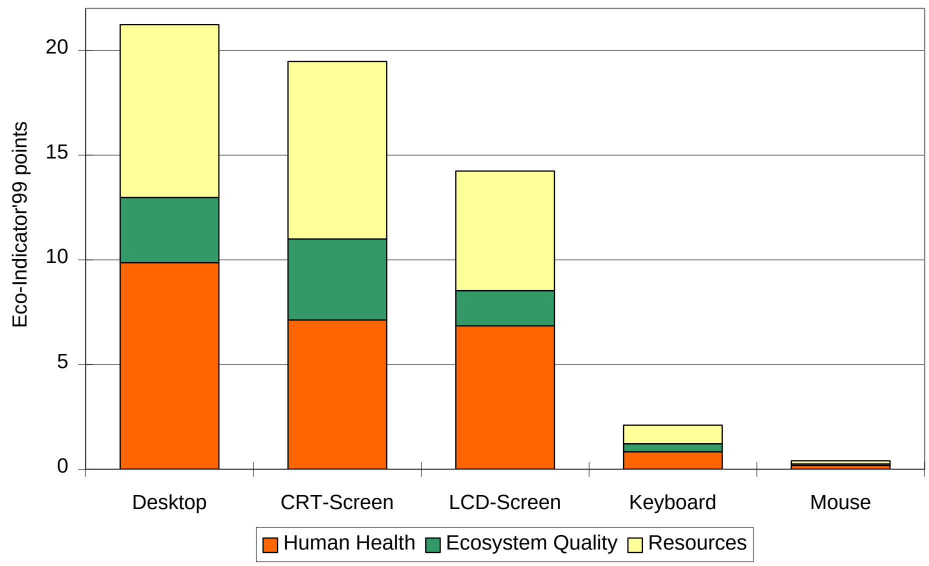
The total environmental impact of the manufacture of a PC produces a score of 40 Eco-indicator 99 points, making this one of the most important phases for environmental impact in the PC supply chain. The production impacts of the PC are a function of the total set of processes and components that go into the manufacture of the PC system as a whole. Given the complexity of the PC system, it is not surprising to find environmental impacts arising from a variety of sources and processes. Figure 8 below provides a graphic depiction of the principal sources of environmental impact of the PC system on a resource-by-resource basis. Based on this breakdown—approximately 53 per cent of the PC's total environmental impact at the production stage can be attributed to the burning and use of fossil fuels (crude oil, natural gas, carbon dioxide, sulphur dioxide and nitrogen oxides) while another 20 per cent can be attributed to the processing and use of metals.

**Figure 8:** Manufacturing phase: the most important exchanges with nature (resource extraction/emissions to air, water, soil) contributing to the overall environmental impact of this specific life stage.




Considering the PC system as a whole, the computer and the monitor (whether CRT or LCD) account, by far, for the major impacts of the system (see Figure 9). These two components result in more than 10 times the impact of the keyboard and mouse combined.

**Figure 9:** Environmental loads of the different parts of a desktop PC system. The production of one computer is compared with the production efforts of a 17-inch CRT screen, a 17-inch LCD screen, a keyboard and an optical mouse.




In the case of the computer, over 50 per cent of the environmental impact is associated with the manufacture of the motherboard. The high environmental impact of the motherboard, in turn is due to its intense use of integrated circuits. ***Integrated circuitry is the single most important source of negative environmental impact in the production of PCs***.

The principal sources of environmental impact arising from integrated circuits are:

- **heat energy** used (here produced by heavy fuel oil);
- waste generation caused by **wafer production** process; and
- use of **gold** (precious metal)—and corresponding environmental impacts associated with mining and processing (e.g., energy use and sulphidic tailings).

In the case of the display unit, the second most important source of environmental impact arising from PC production, the principal sources of impact are:

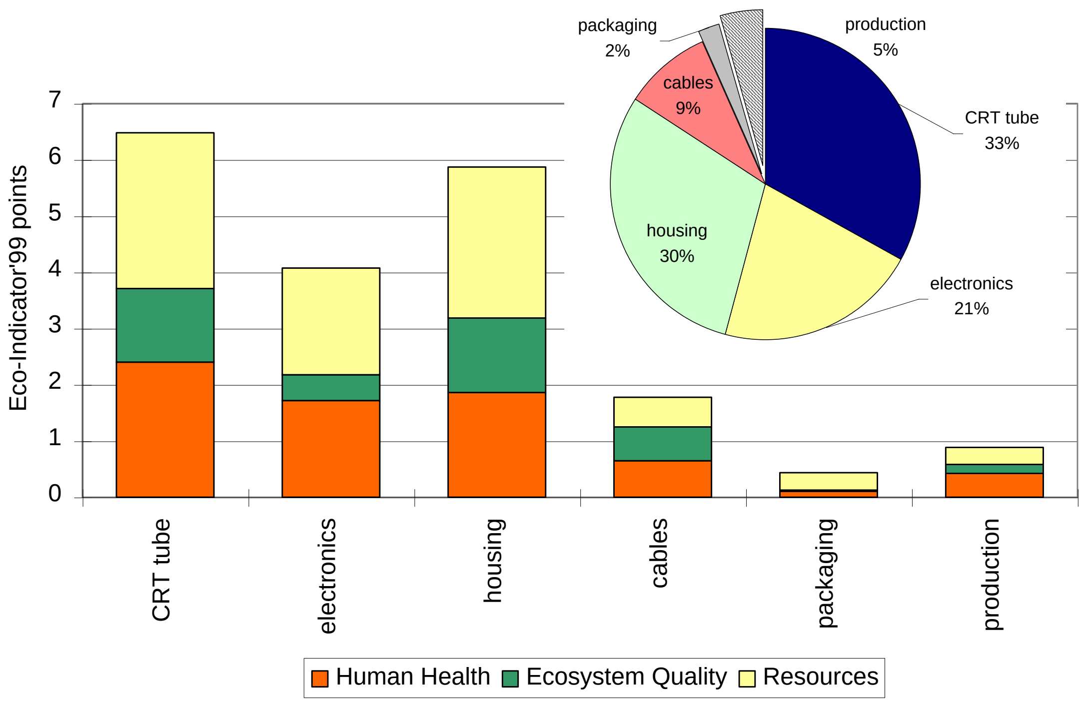
***For CRT screens*** (see Figure 10 below)***:***

- construction of the CRT tube due to high chromium and glass content as well as electronic circuitry;
- printed wiring board construction; and
- housing.

*For LCD screens:*

- construction of the LCD module due to high use of electricity, chromium use in circuitry;
- backlight due to production of poly(methyl methacrylate) sheets and electricity usage;
- integrated circuits (energy, wafers and gold); and
- printed wiring board construction.

**Figure 10:** Environmental loads of the different pieces within a 17-inch CRT screen.

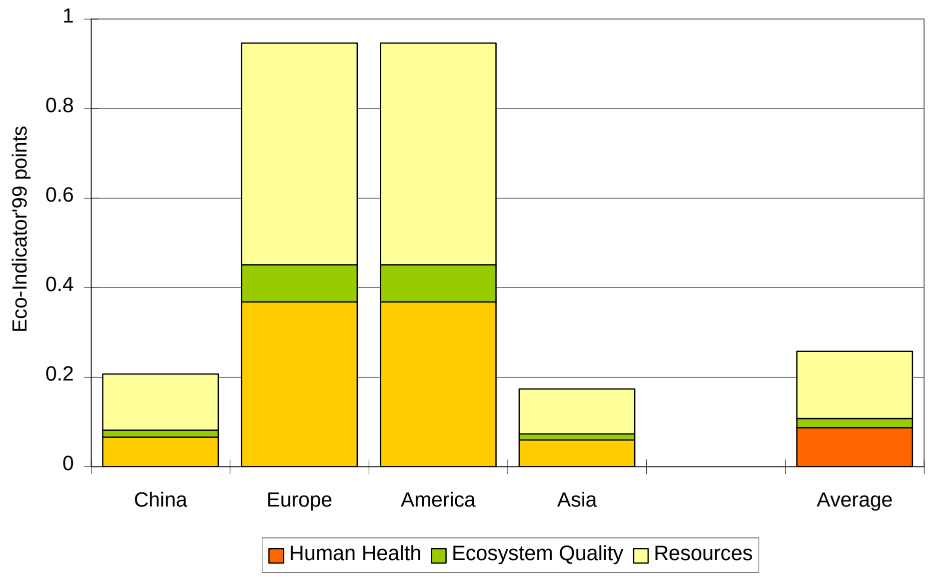



### 4.1.2 Distribution impacts

The principal distribution destinations for Chinese made PCs are China, the EU and the U. S. Based on a rough assumption that approximately 50 per cent of total PC production is consumed within China, with the remaining 50 per cent being consumed between the U. S. and EU equally, we derived Eco-indicator 99 scores between 0.2 and 1 (see Figure 11). The environmental impact from the distribution phase is entirely related to the burning and use of fossil fuels for transportation. Not surprisingly, the environmental impacts for PCs distributed to the U. S. and the EU are almost five times that of PCs consumed within China.[12] However, compared to the indicator scores for manufacturing (more than 40), the distribution impacts are almost negligible.

[12] An average distance of 21,300 km of shipment by boat, 1200 km by train and 200 km by road was assumed for distribution to the U.S. and EU.

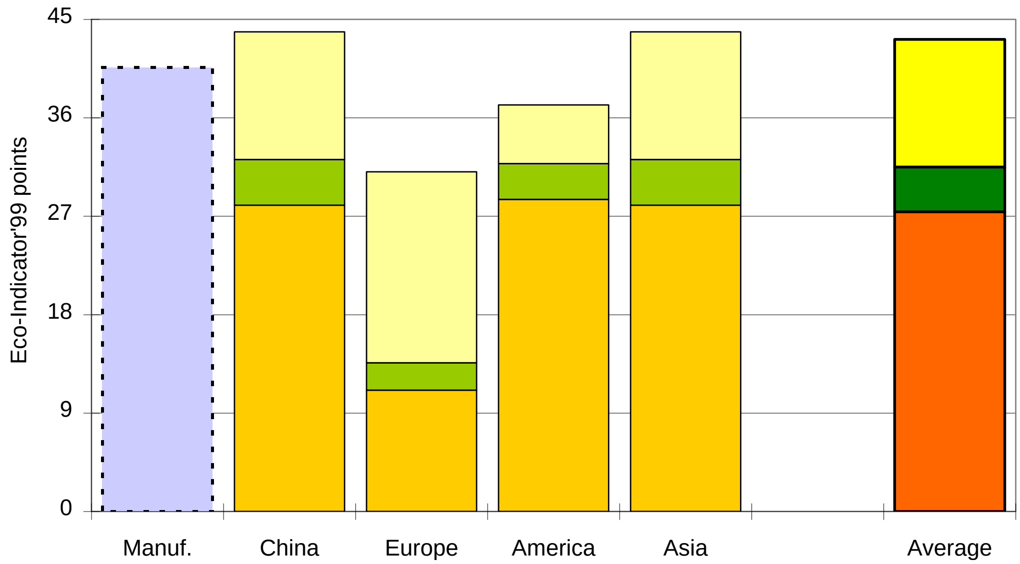
**Figure 11:** Environmental impact (in Eco-Indicator 99 points) of the distribution of one desktop PC system produced in China to the four major markets as well as global average value, based on the current export rates.




### *4.1.3 Use impacts*

As with the distribution phase, the principal environmental impacts through the use phase are linked to energy used during the operation of the PC. Beyond any specific design features that any given PC might have, the degree of energy used will depend upon the type of use, office or home, to which the PC is subject. Whereas office-use implies full-time active operation, home-use implies limited running time. Based on average consumption data, the spread among office, home and home/office shared use was assumed to be 12.95 per cent, 35.24 per cent and 51.81, respectively. Transposing this general framework to the three main markets for Chinese PCs, we obtained Eco-indicator 99 results of 31 for the EU, 37 for the U. S. and 44 for China (see Figure 12). The variances in "use impact" are due strictly to differences in the energy mixes in the respective regions. That China's energy production systems are more heavily dependent upon fossil fuels thus displays the most important environmental impact during the use phase, which actually ranks *higher* than the impacts arising from the manufacturing phase in the case of China.

**Figure 12:** Environmental impact (in Eco-indicator 99 points) of the use phase—results for the use of one desktop PC system produced in China in the four major markets as well as global average value, based on the current export rates. For comparison reason, the total load during the manufacturing phase of a desktop PC system is shown on the left side (row "Manuf.").




### 4.1.4 *Environmental impacts of the end-of-life phase*

The principal environmental impacts associated with PC recycling are as follows:

Negative Impact

- chemical use and release in dismantling and extraction
- heavy metal release during recovery or landfill (lead, chromium, mercury and cadmium)
- energy use for collection and transportation
- disposal of non-recyclable materials

Positive Impact

- precious metal recovery (gold)
- energy savings

The actual quantities of these elements that find their way back into the environment depends upon whether or not the products are sent to a landfill or recycled and, if recycled, what processes are used. In the best-case scenario, products are

**Box 5: Improved recycling techniques as a tool for reduced environmental impact**

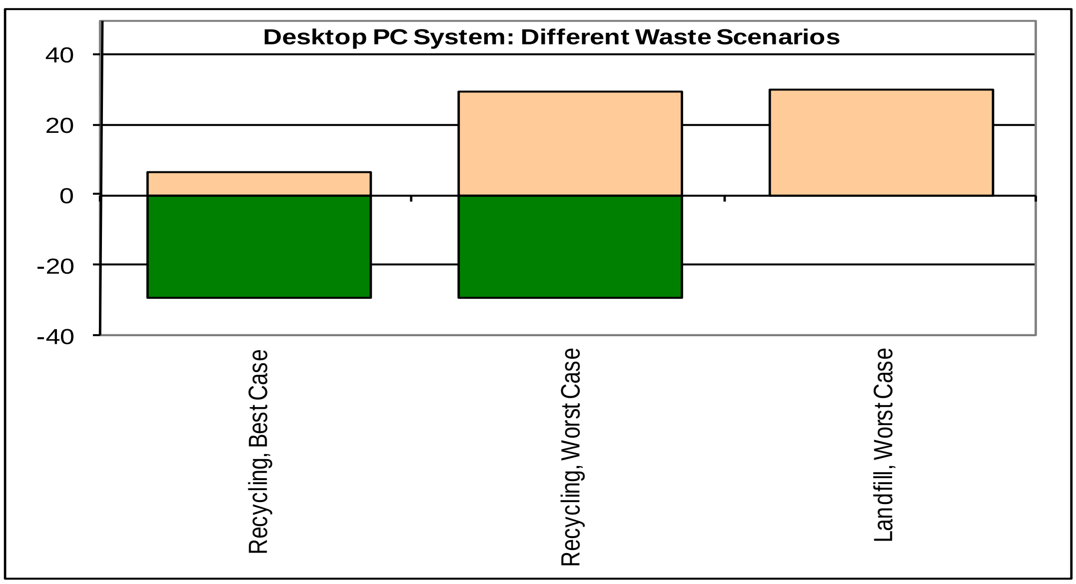
In a state-of-the-art gold recovery process from printed wiring boards (PWBs), around 90 per cent of the potential quantity can be recovered. Rochat et al. (2007) investigated gold recovery processes of PWBs in informal workshops in India and estimated a recovery rate of only about 40 per cent. Similar rates of recovery can be expected from informal workshops found in China. Improvements in the recuperation process have the potential to lead to significant gains in the environmental performance of the e-product supply chain.

recycled using state-of-the-art techniques that minimize the release of toxins into the environment. In the worst-case recycling scenario, the products are recycled but without special mechanisms for protecting the environment. In the worst-case scenario, without recycling, the e-waste is simply returned to the environment through landfills.

Although data on volumes of e-waste treated in one manner or another are not available, each of the different scenarios roughly maps onto the three major consumer markets for Chinese PCS. The EU has a high percentage of e-waste recycling using state-of-the-art facilities. China has a high percentage of recycling, but using processes that take little care for workers or the environment. The U. S., on the other hand, has lower levels of recycling resulting in a high transfer of e-waste to landfills.

Figure 13 below illustrates a variance of 60 Eco-indicator 99 points between the environmental impacts of PCs that are recycled under state-of-the-art conditions and those that are disposed of by landfill.

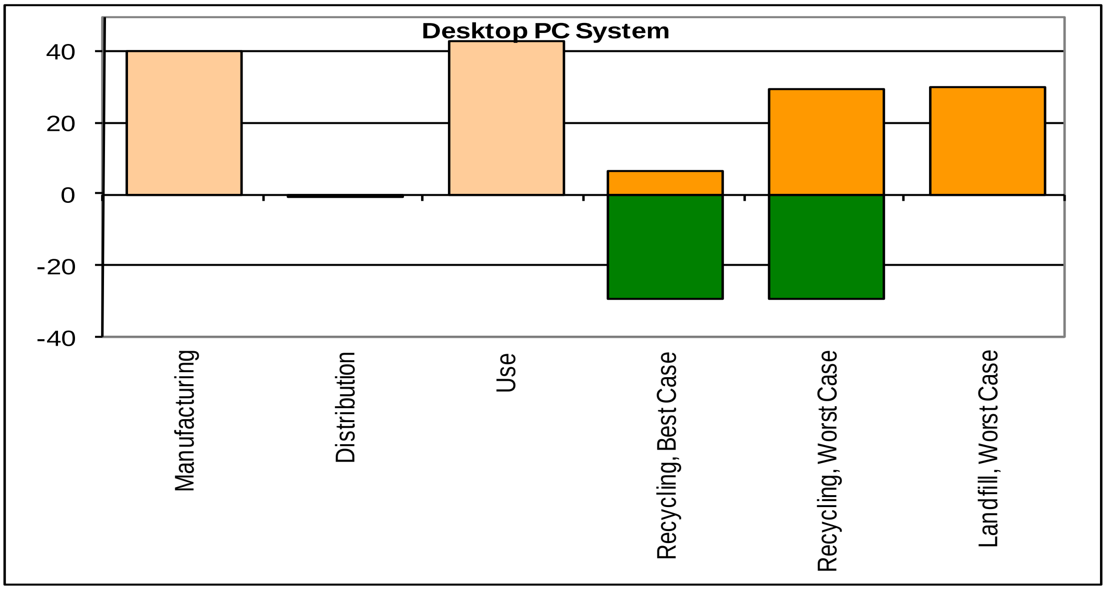
**Figure 13:** Desktop environmental impacts: The impacts of the end-of-life stage of the PC vary significantly depending upon whether or not recycling is applied. The green bars represent "positive" environmental impacts from recycling, while the orange bars represent the "negative" environmental impacts from the release of metals and chemicals into the environment.




### 4.1.5 *Overall assessment of PC impacts*

In Figure 14, the main impacts of PCs along the supply chain are summarized. Comparing the impacts along the supply chain, the manufacturing and the use phases stand out as having the most important environmental impacts. The main source of the impacts throughout these two phases is energy use. The distribution phase, regardless of whether the PC is consumed in China or abroad, remains insignificant. Finally, the impacts of the end-of-life stage vary significantly depending upon the process applied. Although the total impact from the "worst-case scenario" in the end-of-life phase is less than that of the manufacturing and use phases, the potential for reducing the overall impact of PCs is greatest at this stage and therefore warrants special attention.

**Figure 14:** PC environmental impacts: Environmental impacts in terms of Eco-indicator 99 points over the life cycle of the PC.




The geographical distribution of environment impacts at different stages of the PC supply chain is shown in Figure 15.

**Figure 15:** Component manufacturers (supplier for passive components) in mainland China and Taiwan (Source: Global Sources)

We have already seen that the principal impacts from PCs arise in the production and use phases of the PC life cycle. We have also seen that integrated circuits account for the vast majority of the impacts caused by PC production. Combining this result with the input source of PC components (see Table 2 below), we find that the most important environmental impacts of PC production occur *outside* of China since 95 per cent of integrated circuits used in Chinese PCs are produced abroad. High levels of environmental impacts do, however, occur in China during the production of CRT and LCD displays, of printed wiring boards and in PC use and disposal. Moreover, the potential of generating the promised environmental benefits associated with recycling are dependent upon the development of the relevant infrastructure within the Chinese context.

**Table 2:** Geographical distribution of a desktop PC system produced in China (excluding end-of-life imports)

| Lifespan | | | China | Abroad |
|---|---|---|---|---|
| **Manufacturing** | **CRT display** | 50% | 80% | 20% |
| | **LCD display** | 50% | 95% | 5% |
| | **PWB** | | 40% | 60% |
| | **IC** | | 5% | 95% |
| | **others** | | 90% | 10% |
| | **PC assembly** | | 100% | 0 |
| **Use stage** | | | 90% | 10% |
| **End-of-life** | | | 90% | 10% |

### *4.1.6 The impact and significance of illegally imported e-waste*

Notwithstanding the international prohibition of trade in toxic e-waste and a corresponding ban on the import of e-waste into China, between 1.5 and 33 million tonnes of illegally imported e-waste are imported into China each year. Given the fact that imported e-waste is illegal in the first place, the treatment, dismantling and recovery process, operating within the black market, also remains largely unregulated. Table 3 provides a short list of the types of chemicals released during the dismantling process.

**Table 3:** Toxic Chemicals Released in e-waste Dismantling and Recovery

| Chemical | Environmental/Health Impact |
|---|---|
| **Lead** | Found in glass panels, solder and printed circuit boards—causes damage to endocrine system, blood system, kidney and reproductive systems in humans. |
| **Cadmium** | Found in semiconductor chips and infrared devices—causes irreversible damage to kidneys. |
| **Mercury** | Found in batteries, flat panels, printed circuit boards, switches, thermostats etc. —causes damage to the brain and kidneys and is easily transmitted through the food chain. |
| **Hexavalent Chromium** | Used as a decorative hardener in some e-products—causes DNA damage to exposed cells. |
| **Brominated Flame Retardants** | Used in plastics to reduce fire hazard, BFRs have been shown to be mutagenic in the past. Newer formulations have been shown to have negative impacts on animals.[13] |
| **Barium** | Used in CRT screens to reduce radiation exposure—can cause heart, liver and spleen damage in humans. |
| **Beryllium** | Used in printed circuit boards for its conductive properties—is classified as a carcinogen and has been linked to lung cancer when Beryllium dust is inhaled. |
| **Tonors** | Used in printer cartridges—he dust is a class 2 b carcinogen that can cause lung irritation and damage if inhaled. |
| **Phosphor** | Used in CRT screens—classified as highly toxic to humans. |
| **Plastics** | Found in the housings of most e-products—can release dioxins and other hazardous materials when burned. |

[13] Linda S. Birnbaum and Daniele F. Staskal *Brominated Flame Retardants: Cause for Concern?* http://www.ehponline.org/members/2003/6559/6559.html

In fact, a vast majority of the e-waste dismantling within China occurs within household workshops which, quite literally, see the U. S. and European toxic waste entering the very living rooms of Chinese e-waste workers. Informal dismantling and recovery procedures constitute the majority of dismantling operations in China and typically consist of:

- Manual extraction with the use of hands and hammers (used for CRTs): produces exposure to phosphors, lead and mercury
- Open burning (used to extract metals from wiring): produces dioxins
- Acid stripping (heavy metal extraction from chips): produces chlorine and dioxide gases
- De-soldering (printed circuit boards): produces toxic lead fumes

Throughout the process, the majority of the estimated 700,000 workers involved in the collection, dismantling and material recovery sectors do not wear protective equipment during the process (Duan and Eugster, 2007).

**Figure 16:** Unprotected dismantler cracking the yoke of a CRT screen.[14]

**Box 6: To import or not to import?**

Although both national and international law prohibits the trade of toxic e-waste into China, the illegal import of e-waste clearly represents a major source of negative social and environmental impact within China arising from the global e-product sector. While the negative impacts associated with dismantling and recovery in China are largely attributable to traded e-waste products, the *source* of the impact is not the *trade* of e-products per se, but rather the inappropriate treatment of e-products that are dismantled within China. Moreover, while the negative impacts felt by China arise during the recycling process, recycling itself produces significant social and environmental benefits to the planet as a whole.

Under current conditions, the Chinese role as "global recycler" is leading to a net "environmental loss" for China, and a net "environmental gain" for the rest of the planet. The principal cause for this disparity is due to not to the trade in such products per se, but rather the improper treatment of such products once they arrive in China. In order to deal with the social and environmental problems associated with e-waste treatment in China, there is a need to forcefully *monitor* the trade in such products, while simultaneously strictly enforcing safe handling standards over the treatment process. If importing e-waste to China can provide safe jobs and communities while diverting e-waste from landfills elsewhere in the world, net global environmental gains can be realized through the Chinese e-waste treatment industry.

[14] Source: Basel Action Network., *Exporting harm: The hi-tech trashing of Asia* (2002)

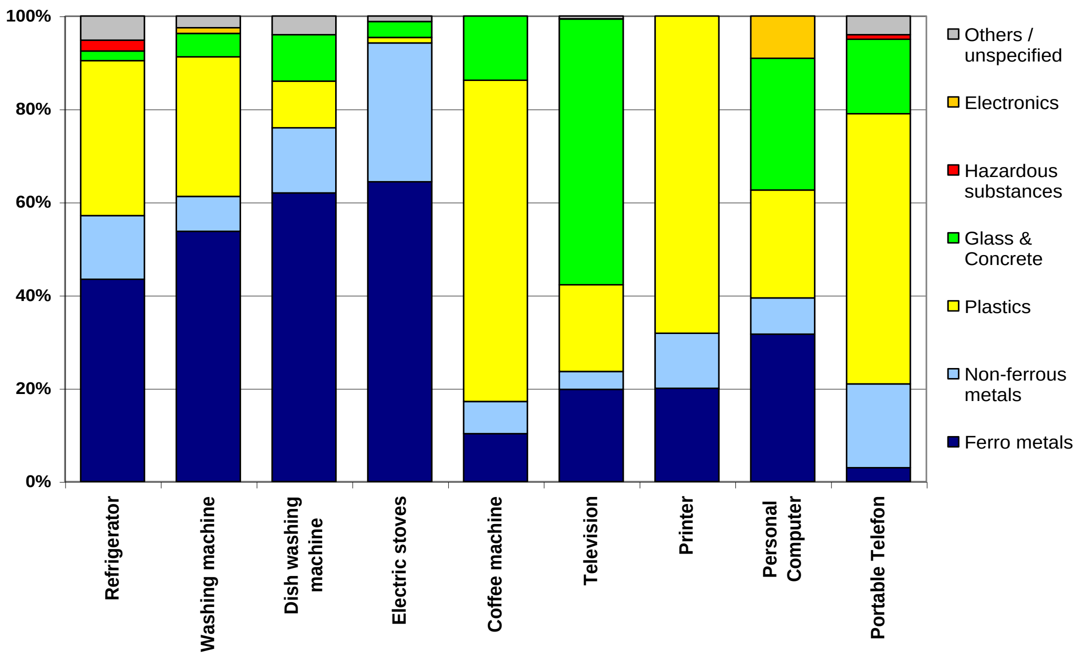
The combination of highly toxic materials found within e-products and the highly unregulated character of e-waste treatment renders the import of e-waste a serious environmental and health hazard for the dismantling workers and their communities. The fact that e-waste enters without records or monitoring makes it difficult to quantify the full nature of this impact, however it is clear that the environmental impacts, from a strictly Chinese perspective, are highly damaging and need to be addressed.

## 4.2 Application of life cycle analysis to select e-products

### 4.2.1 *Key characteristics of select e-products produced in China*

Although each e-product is unique, both across and within major categories, broad similarities exist between different products. More specifically, the resources and inputs that make up individual e-products are largely the same, albeit in different quantities and distributions. Figure 17 provides a snapshot of the relative amounts of key inputs that go into producing major e-products produced in China.

**Figure 17:** The very different composition of various electronic and electric devices (source: Hischier et al., 2004)




Based on an analysis of the different material compositions, and average energy demands of different e-products, a simplified life cycle analysis (LCA) for other major e-products reveals similar patterns to that found for the desktop PC. Figure 18 provides a graphic representation of the results of this analysis. For all the products analyzed, the manufacturing and use phases of the e-product chain exhibit the largest environmental impacts, with the distribution phase exhibiting negligible levels of impact and the end-of-life stage representing varying levels of impact depending on techniques used during end-of-life treatment. The principal impacts of the different products tested can be summarized as follows:

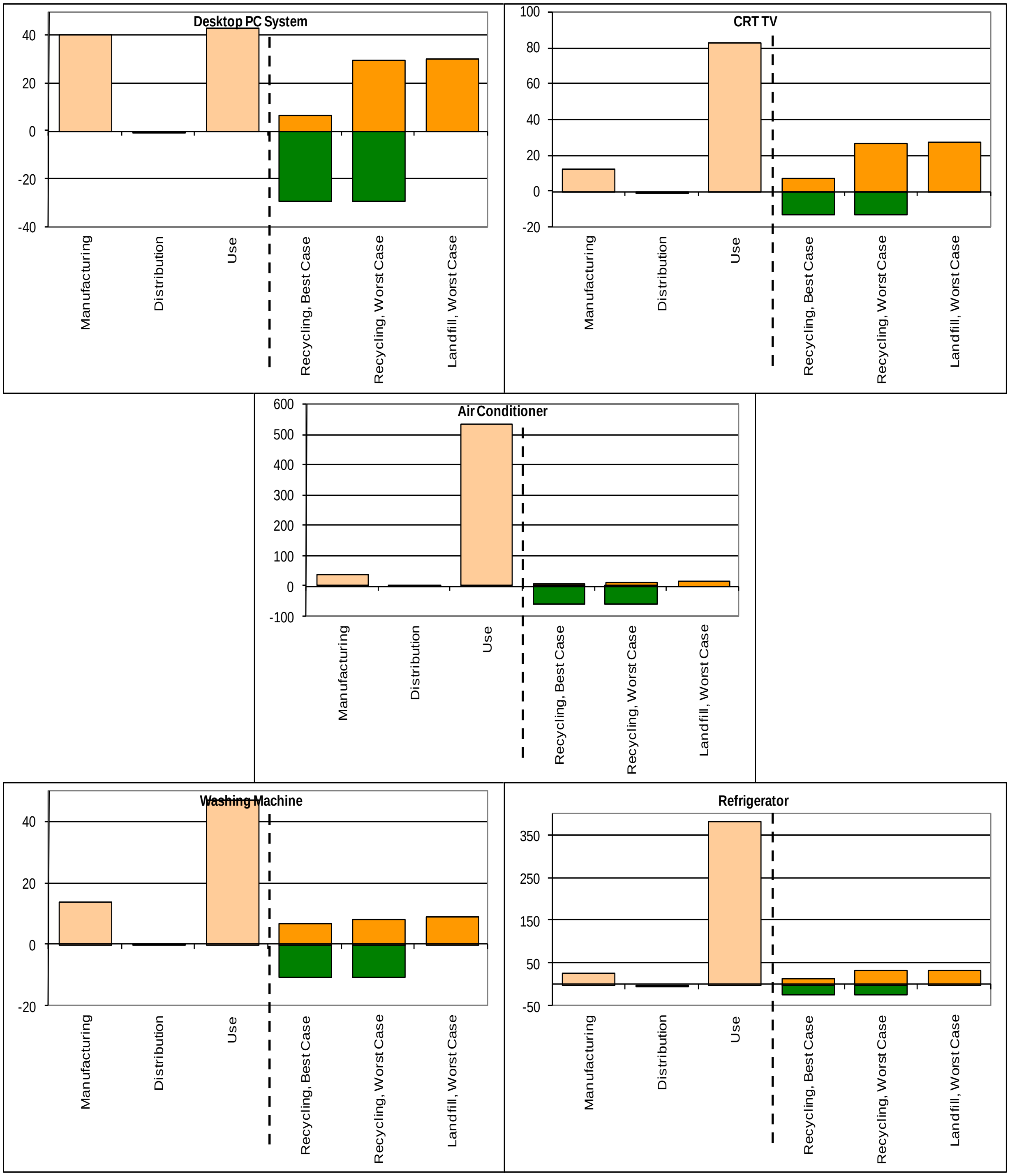
*CRT television:* Large amounts of glass and plastic, as well as chromium in the production of the cathode ray tube, account for the main production impacts—but these are nevertheless about half that associated with the PC. Use impacts are due entirely to electricity usage and are more than three times that of the PC. The disposal of CRT televisions poses serious threats to the environment through potential heavy metal release—a problem analogous to PC disposal where the PC system includes a CRT screen.

*Refrigerator:* Large amounts of plastic, steel and copper in the construction of refrigerators lead to slightly higher environmental impacts than those associated with PCs. The larger volume of refrigerators leads to a higher environmental impact arising from distribution than found with PCs, but this impact remains relatively insignificant, even in the context of international trade. By far the most important environmental impact of refrigerators is in the use phase which, through energy use, is 15 times that associated with PCs. Copper and chlorofluorocarbon (CFC) disposal present the potential of both environmental damage and conservation during the end-of-life phase, depending on the treatment system used.

*Air conditioner:* Large amounts of steel, copper and aluminum used in the production of air conditioners gives them the most environmentally intensive/damaging production process (40 per cent more than the PC). The use phase, however, is by far the most important source of environmental impact both within the air conditioner life cycle and across e-products more generally—registering an impact 21 times that found in PCs. Similarly, the presence of CFCs and copper in air conditioner refrigerators has the potential to render disposal either highly damaging to the environment or highly beneficial. Under the right conditions, the recycling of copper piping from air conditioners can significantly reduce the negative impacts associated with the production process.

*Washing machine:* The washing machine has a relatively low material load, and therefore, a lower impact at the production stage than all of the other e-products observed. The use phase, although lower than refrigerators and air conditioners, is still greater than that of the PC. Similarly, due to the lower material inputs, the end-of-life phase has a more limited capacity to generate an environmental benefit than other electronic devices.

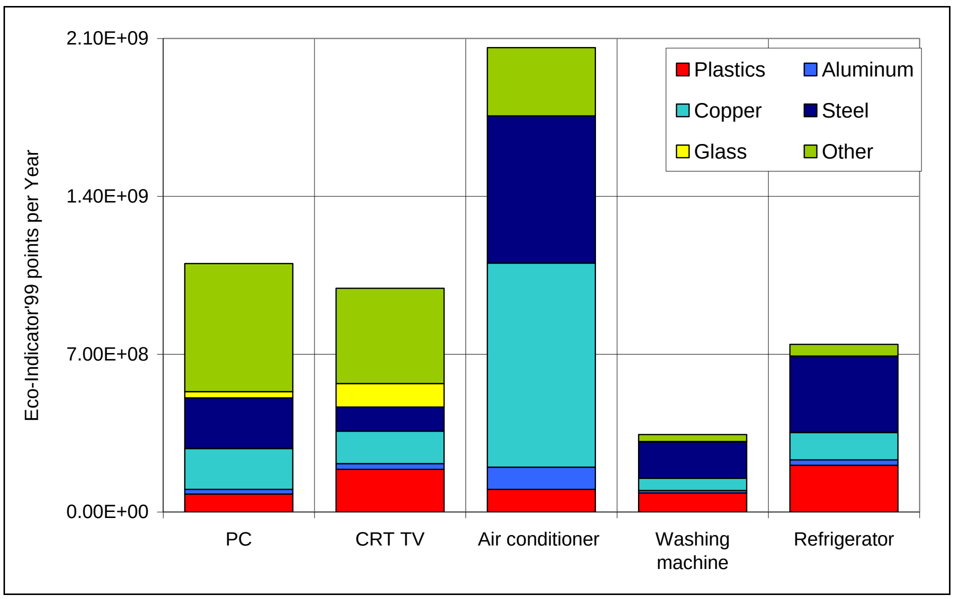
**Figure 18:** Per-device Eco-indicator 99 analysis for different e-products over the four main stages of the e-product supply chain—with different scenarios for disposal.



In terms of "per-device" environmental impacts, air conditioners and refrigerators clearly have the most important negative impacts. Although their per-device impacts at the manufacturing stage are similar to those of other e-products, their impacts at the use stage dwarf those of any other e-products due to their constant operation and high power requirements.

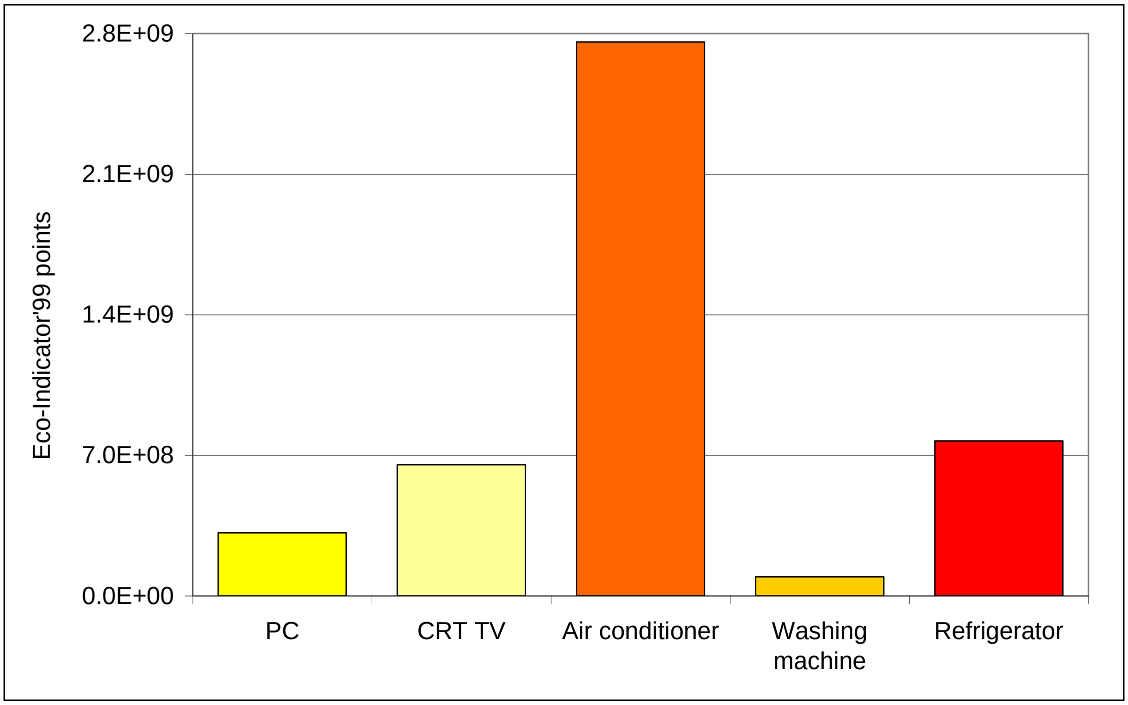
The *total* environmental impact from each product area, based on 2005 production data, varies considerably from the per-device impacts due to variances in individual production and use levels (Figure 19). Globally, the production impacts of the air conditioner are more significantly than all other e-products due to the high production volumes (56.9 million units in 2005). PCs and CRT televisions are second and third in total importance respectively.

**Figure 19:** Environmental loads of the annual Chinese production of refrigerators, washing machines, air conditioners, CRT TVs and personal computers (simplified calculation, based standard LCA data from Ecoinvent).




Although the per-unit usage of electricity for refrigerators is significantly higher than CRT televisions (due to their continuous operation), actual impacts due to Chinese refrigerator use (26.2 MWh) are comparable to those of other e-products with only slightly lower total use-based impacts (CRT TV 18.2 MWh/ PC 17.9 MWh). At the use phase ***globally***, air conditioners are responsible for the single most important environmental impact (using 97.4 MWh per annum)—far outstripping all other e-products analyzed (see Figure 20).

**Figure 20:** Annual environmental impacts of refrigerators, washing machines, air conditioners, CRT TVs and desktop personal computers produced in China due to electricity consumption in use phase on a global level (results are for the total amount of devices produced in China in 2005).




## 4.3 General conclusions

China plays a key role in the international e-product market as one of the most important producers and consumers of electronic goods. In 2006, China produced 75 per cent of the global output of notebook PCs, 39 per cent of the global output of PCs and 48 per cent of the global output of CRT televisions (NBSC, 2006; Display, 2007). Around 11 per cent of the PCs, 90 per cent of the notebook PCs, 79 per cent of the mobile phones and 51 per cent of the CRT TVs produced in China are exported. The export volume of washing machines accounts for 33 per cent, refrigerators amount to 52 per cent and air conditioners amount to 42 per cent of total production in China. Added to this, is China's significant production of unfinished electronic components, which form the primary inputs to many e-products produced abroad. Although China imports a significant portion of electronic components from other manufacturers in the Asian region, particularly hi-tech components such as Integrated Circuits and LCD modules, it imports very little in the way of finished e-products.

The LCA study of the desktop PC system here shows that the manufacturing and use phases generate very high environmental impacts, while the end-of-life phase can produce either a significant environmental burden or benefit depending upon the processes used.[15] The same pattern applies to other key e-products, with the notable exception that the use and waste phases have particularly important environmental impacts in the case of air conditioners and refrigerators. In terms of overall environmental impact, air conditioners display the highest negative overall impacts at both the production and use stages and, as such, represent a key product to target in a Chinese strategy. At the manufacturing level, PCs, CRT televisions and refrigerators all display important environmental impacts at the production and use phases. The production process associated with integrated circuits and printed wiring boards represents a significant portion of the environmental impacts at the production level across all e-products. Energy use is the main environmental impact at the use phase.

Environmental impacts at the end-of-life phase under current practices are thought to be significant under current practices. These impacts are already highly concentrated in specialized industrial hubs in the Guangdong and Zhejiang Provinces but promise to become far more important as total domestic and imported e-waste continues to grow in volume. While the enforcement of existing trade bans on illegal imports would offer an immediate solution to the current "import" of dangerous working conditions from the U. S. and Europe in the form of toxic e-product imports, long term solutions must be grounded on sound domestic treatment of e-waste. Fortunately, the existence of current technologies provides a substantial potential for reducing the impact of e-products at the end-of-life stage and the possibility of rendering this stage a "net benefit" if managed appropriately. The recycling of air conditioners offers the greatest possible benefits due to high copper levels.

In order to facilitate China's transfer to a high efficiency and safe location for e-waste recycling and disposal, the international community, including stakeholders along the supply chain, will need to adopt transparent and cooperative approaches to monitoring and evaluating the trade and treatment of e-waste.

## 5.0 Social Impacts of Major Chinese E-product Chains

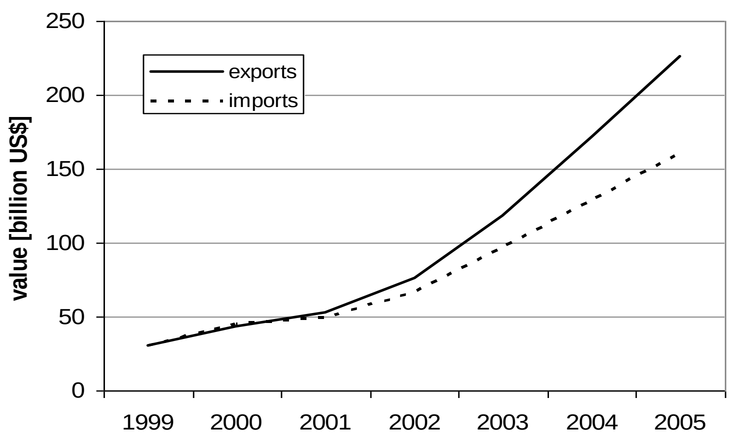
The environmental impacts of e-products provide one key variable for consideration in the development of sustainable e-product communities, markets and supply chains. The promotion of truly sustainable development, however, rests on the ability to dovetail improved environmental performance efforts with sound social and economic impacts. The following section summarizes the results of our literature review on the observed social and economic impacts associated with the e-product sector in China and serves as a basis for building a balanced approach to policy recommendations.

[15] These findings are in line with those found in similar studies. See for example: Tekawa et al. (1997), Seungdo, Taeyeon et al. (2001), Hikwama (2005) and Choi, Shin et al. (2006).

## 5.1 National economy

The recent and rapid growth of the e-product sector within China has played a central role in the overall growth and performance of the Chinese economy over the past decade. The manufacturing of e-products alone makes up 10.2 per cent of the country's industrial output value and 6.3 per cent of overall industrial profits at the national level (NBSC, 2006). In addition to being a major source of foreign direct investment, the e-product sector is responsible, since 2001, for a substantial portion of China's trade surplus. In 2005, the Chinese electronics industry generated a trade surplus of US$65.5 billion or 64.2 per cent of the country's total surplus (WTO, 2006).[16]

**Figure 21:** Export and import values of office and telecom equipment




[A] Includes electronic data processing devices, integrated circuits and electronic components.

*Source: WTO, 2002-2006*

### *5.1.1 Contribution to national budget*

The electronics industry is highly subsidized in China. In order to attract investments, combinations of land subsidies, loan subsidies, discounts on utilities and logistical support, and preferential tax treatments are routinely granted by the national and provincial administrations (PwC, 2004; AA, 2005). For this reason the tax revenues from the electronics industry are much lower than from other Chinese industries (see Table 4).

[16] The e-product sector's contribution to China's trade surplus is a result of China's role in product assembly and manufacture. China remains reliant on foreign imports for hi-tech components such as integrated circuits and LCD modules (WTO, 2006; PwC, 2007).

**Table 4: Taxes and other charges paid in 2004 in percentage of the total industry profits**

| | |
|---|---|
| Manufacture of communication equipment, computers and other electronic equipment | 3.2% |
| Manufacture of textile wearing apparel, footwear and caps | 15.3% |
| Manufacture of plastics | 16.1% |
| Manufacture of textiles | 19.5% |
| Recycling and disposal of waste | 20.6% |
| Manufacture of transport equipment | 26.7% |

Source: NBSC, 2006

### 5.1.2 *Contribution to national employment*

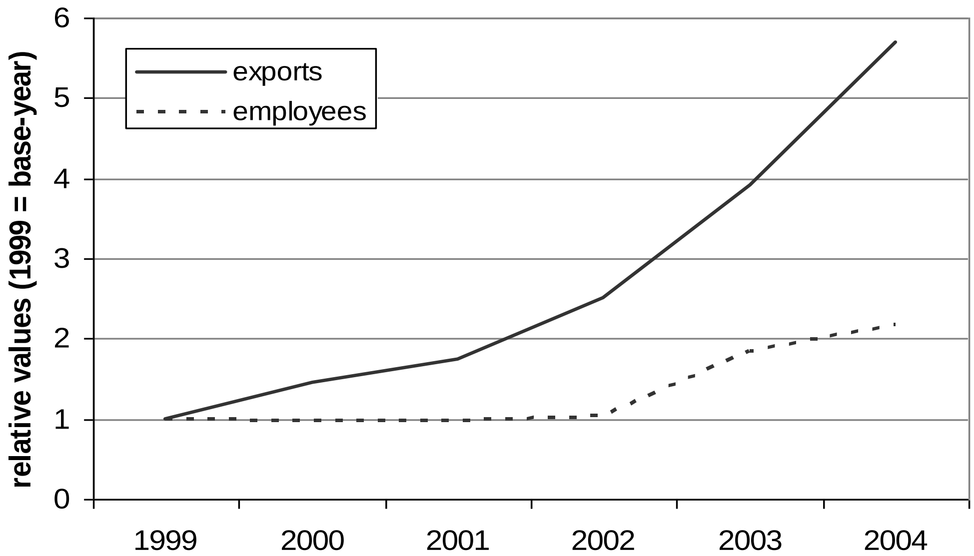
Since 2003, the electronics industry in China has contributed to a constant increase in employment. Depending on the data source, between 2.27 and 6.3 million people are employed in the electronics industry in China (NBSC, 2006; ILO, 2007).[17] In any case, the electronics industry is currently among the top three most important Chinese manufacturing industries from an employment creation perspective (NBSC, 2006).[18] Nevertheless, the growth of jobs is significantly lower than the total electronics industry growth rate. While electronics exports grew by a factor of 5.7 between 1999 and 2004, according to ILO—data show the number of employees grew by a factor of 2.2 (see Figure 22). This is mainly due to increasing mechanization, which is not only driven by technological innovation, but also by the ongoing product miniaturization.[19] This trend of increasing mechanization is very likely to continue in the coming years, which bears considerable risks for employment creation.

[17] The differences can partly be explained by the fact that the National Bureau of Statistics uses the definition, "manufacturing of communication equipment, computers and other electronic equipments," while the ILO also includes employees in electrical product manufacturing. Nevertheless, inconsistencies within the China Statistical Yearbook (two diverging figures: 2.269 million [p. 135] and 4.3548 million [p.507] cannot be explained likewise.

[18] Manufacturing of textiles: 2,716,000; Manufacturing of transport equipment: 2,295,000 jobs; Manufacturing of communication equipment, computers and other electronic equipment: 2,269,000 jobs.

[19] PCB-mounting is a prominent example thereof: While electronic boards and cards were mounted manually only a few years ago, the increasing integration density in most product groups can only be achieved using automatic assembly machines.

**Figure 22:** Exports and employment in the Chinese e-product industry




*Source: WTO, 2004-2006; ILO, 2007*

## 5.2 Working conditions

### *5.2.1 Safe and healthy working conditions*

The main health problems reported in the electronics industry worldwide arise primarily from the handling of toxic materials and the prolonged exposure to vapours. Most incidents reported are linked to the semiconductor industry, where several surveys yielded increased rates of cancer as well as elevated rates of spontaneous abortion among female workers (LaDou, 2006). Although there are no studies on the Chinese semiconductor industry available yet, it seems very plausible that its employees are exposed to similar risks. This is partly due to the fact, that about 20 per cent of the semiconductor industry in China used equipment imported from OECD-countries, and therefore cannot benefit from the latest health and safety standards (PwC, 2004, 2007; LaDou, 2006). Furthermore, PricewaterhouseCoopers (2004) raised the concern that domestically owned semiconductor companies in China will likely spend less to protect workers' health in order to compensate the cost advantages of international operating firms that—due to the latest technologies—can produce more efficiently.

Beyond the obvious challenges facing the semiconductor industry, there is also considerable evidence that similar problems arise in less prominent production processes such as the manufacturing of printed circuit boards, batteries, plastic parts, cases and cables in China (CAFOD, 2003; Schipper and de Haan, 2005; Frost, 2006a; SACOM, 2006). Although it is difficult to match the use of specific substances with diseases that might develop years after exposure, some cases of lead and cadmium poisoning have been directly linked to e-product manufacture (Leong and Pandita, 2006; Frost, 2006a). In response to the risks that certain substances pose to health and environment, the European RoHS-directive and the Chinese regulation on Management Methods on Control of Pollution from Electronic Information Products (China RoHS) widely ban cadmium, lead, mercury, hexavalent chromium and the flame retardants PBB and PBDE in the manufacture of electronic products. Although there is no information on the impacts of regulation as of yet, it is clear that these impacts will be closely related to the degree of enforcement infrastructure that is available to support their implementation.

In addition to chemical exposure, there are several other health and safety risks reported for electronic manufacturing in China. These include injuries from machinery handling, factory fires, ergonomic detractions from monotonous line-work, and eye strain caused by the handling of small parts and visual quality inspections (CAFOD, 2003; Schipper and de Haan, 2005; Leong and Pandita, 2006; Xinhua News Agency, 2007). Generally, it is not clear whether these types of risks are significantly higher or lower than in other manufacturing industries in China. In terms of identifying enterprises most at risk, some experts argue that small- and medium-sized companies are generally more vulnerable to the violation of health and safety standards than big entities (Liu, 2005).

The Chinese WEEE-recycling industry is also widely associated with significant health and safety risks for workers involved in this sector (Pucket and Smith, 2002; Brigden et al., 2005; Terazono et al., 2006). These risks stem principally from improper techniques during the recovery of raw materials, like the open burning of wires and the chemical treatment of PCBs and electronic parts during the material recovery of used e-waste. As a general rule, only minimal precautionary measures are applied to protect workers' health within the informal Chinese WEEE-recycling industry. Widmer et al. (2007) conclude that about 20 per cent of employees are exposed to extreme health-threatening working environments. Among the occupational effects that have already been reported are skin disease, stomach, respiratory tract and other organ failure (Hicks et al., 2005; Terazono et al., 2006).

There is evidence to suggest that workers involved in the dismantling of e-waste could avoid major health risks through the use of readily available low-tech and low-cost precautionary measures such as basic inhalation protection against dust.[20] Nevertheless, many actors in the Chinese WEEE-recycling industry either are not aware of existing health risks or have only limited knowledge about basic protection measures (Widmer et al., 2005) and may therefore be exposed to risks that would be easy to mitigate.

[20] This view is supported by a study on WEEE-collection and disassembly structures in Beijing, which found out that these processes (as practised in Beijing) do not expose workers to major health risks (Eugster and Fu, 2004).

### 5.2.2 *Remuneration*

Growth in the e-product sector, notwithstanding trends towards increased mechanization, represents a major source of new opportunities for employment. The continued growth in the Chinese economy more generally has also lead ongoing increases in national and regional minimum wages. Current minimum wage rates in major e-product export zones (e.g. Guangdon and Guangshou) range from RMB690 to RMB810. The overall growth in wages can be largely attributed to the ongoing growth of the e-product sector within China. Nevertheless, there are reports on systematic violations of these thresholds in some production sites (CAFOD, 2003; Schipper and de Haan, 2005; SACOM, 2006; Leong and Pandita, 2006): While in some cases workers can only achieve the minimum wages doing overtime, other companies are reported to deduct a substantial portion of the salary for housing and catering. Furthermore, there are cases where overtime is not compensated at a premium rate and where employees are made financially liable for quality-losses or misconduct. According to SACOM (2006) these deductions can account for more than 50 per cent of the basic salary.

Although labour in the e-product sector is dominated by low wage positions, there is a growing range of higher-level employment opportunities within the sector as well. Overall, the total mean wage rate for the e-product sector is 28 per cent higher than that for the manufacturing sector in China[21] (NBSC, 2006).

### 5.2.3 *Working hours*

Electronic equipment assembly in China is usually organized in two daily shifts of eight hours. During peak seasons, each shift can be extended to 11 hours, so that—with the exception of routine breaks—production can be maintained virtually non-stop (Manhart and Grießhammer, 2006). Several surveys documented excessive working hours (Schipper and de Haan, 2005; Torres, 2005; Wilde and de Haan, 2006; SACOM, 2006). Nevertheless there is also evidence that this is not the case for all factories (SACOM, 2006).

### 5.2.4 *Human and labour rights*

There are no significant reports on abuses of basic human rights through practices such as forced labour, child labour or worker discrimination. Freedom of association, although technically permitted, has not given rise to any significant labour union presence.

## 5.3 Community impacts

### 5.3.1 *Safe and healthy living*

Community-level impacts on the environment related to the e-product sector arise principally through the manufacture and end-of-life phases of the supply chain. At the manufacturing stage,

[21] While the average wages in "Manufacturing of Communication Equipment, Computer and other Electronic Equipment" are at RMB20,299 per year, the figure is RMB15,757 for all manufacturing industries.

emissions of copper, selenium, mercury, fluoranthene and nickel in the production of electronic parts are likely to be the most problematic. The production of printed circuit board material also results in oil emissions, which have been observed to pollute soil and water. An analysis of the-wastewater of two printed circuit board manufacturing sites carried contaminations of bromated flame retardants, one phosphorus-based flame retardant, benzophenone, diphenylethanone, a thioxanthen-9-one derivative, phthalate esters, alkyl benzenes, aliphatic hydrocarbons, sterols derivatives and high concentrations of copper, nickel, lead, tin and zinc. Furthermore, high copper and tin concentrations, as well as several flame retardants, were found in soil samples near the sewers. Since a large portion of industrial sites in China are situated between agricultural lands, it is likely that some of these contaminants do enter the human food chain.

The *assembly* of electronic devices, on the other hand, is largely free of toxic emissions (Choi et al; 2006). These assumptions are supported by analytic measures on soil and wastewater samples collected around production facilities in China (Bridgen et al, 2007).

At the disposal/recovery stage of the e-product supply chain, the dismantling stage presents the greatest threats to community well-being. Studies on environmental and health impacts of WEEE-recycling in Guiyu, one of the main Chinese WEEE-recycling clusters where a large portion of the recovery of copper, lead and precious metals is carried out, reveal high levels of heavy metals and organic contaminants in samples of dust, soil, river sediment, surface water and ground water (Puckett et al., 2002; Brigden et al., 2005; Huo et al., 2007). Furthermore, severe air-pollution from the incineration of waste is reported (Sun Yat-sen University and Greenpeace, 2003). Generally, there is strong evidence that environmental pollution affects not only the health of employees of the WEEE-recycling industry, but also the health of the local population not directly engaged in the sector: A recent study on blood-lead levels of children yielded significantly higher values for children living in *Guiyu* than for children living in a nearby settlement with no WEEE-recycling industry (Huo et al., 2007).

The fact that residual waste is almost entirely disposed of in uncontrolled landfill sites gives rise to further serious health risks for local communities. According to Terazono et al. (2006), WEEE discarded in this manner is a major source of heavy metal contamination in soils and groundwater. Since many recycling and disposal sites are located close to agricultural land, it is likely that some of these contaminants also enter the human food chain. In addition to the direct effects on human health and the environment presented by the e-product sector, the fact that many of the pollutants are persistent in nature suggests that many of the impacts may not be observable until in future generations.

### 5.3.2 Social and economic opportunities

The large number of new industrial estates—including electronics manufacturing facilities—on the east coast of China has led to substantial economic growth and rapidly rising per-capita income in the locality. In the course of a rapid technological learning process, this economic growth has also been a springboard for the creation of high-quality jobs. The high demand for low-skilled labourers has opened up employment opportunities for migrant workers from other parts of the country.[22]

While the quality of these jobs may be questionable in some cases, these employment opportunities offer an important alternative to agricultural work or rural unemployment. Ping and Shaohua (2005) assert that money transfers from migrant workers to their home regions also spread positive social and economic benefits to those regions.[23] Moreover, it has also been reported that many migrant workers return home with savings that enable them to found their own small businesses and achieve a moderate level of social advancement.

## 5.4 International social impacts

At a broad level, China's rapid growth in production and trade has been built on its ability to combine a low-wage labour force with overall labour efficiency. Through its own efficiencies, China has brought lower priced electronic goods to the world, which can be interpreted as a "net welfare gain" to the global community. Notwithstanding this important positive impact of Chinese productivity on the international community, the rapid demand for natural resources has led Chinese firms to all corners of the world, generating increased pressures on foreign environments and natural resource reserves. Part of this growth has also driven Chinese firms into increasingly unstable political environments, which, in turn, have lead some to suggested linkages between the perpetuation of internal strife in some countries and the growth of the Chinese e-product sector.[24]

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22 In Guangdong province—a major centre of the Chinese electronics industry—migrant workers account for 65 per cent of the labour force in manufacturing (Hess, 2007).

23 According to Ping and Shaohua (2005), cash transfers from migrant workers to their regions of origin are primarily used to meet regular housekeeping expenses, for children's education, house building and improving agricultural production.

24 In 2001 the global electronics industry was accused of indirectly financing the war in the Democratic Republic of Congo, due to the sector's high demand for tantalum (Hayes and Burge, 2003). While the market for the metal stabilized after 2001, the general problem has persisted: Various metals used in electronic components are supplied from regions which are rife with political instability. Some of these raw materials—including tantalum and to a lesser extent palladium—are used primarily in the electronics industry, so that social, political and environmental impacts of the related supply chains can be attributed more or less directly to the industry. Since China holds an increasing share of the global electronics production, it is likely that the Chinese electronics industry will sooner or later be linked to such conflicts.

## 5.5 Summary of the social impacts of the e-product supply chain

The most important social impact of the e-product chain arises from the massive positive contribution the sector provides to the national and local economies within China. The e-product sector is one of the top drivers of the Chinese economy and is one of the principal sources of China's positive trade balance. The rapid growth of the sector places both policy-makers and firms in a positive position to improve those areas where negative social impacts have been most readily observed within the sector. By far, the most important impacts are those related to the health and safety of workers and communities related to the *production* and *material recovery* processes associated with e-products. These two stages of the supply chain, therefore, represent key stages for supply chain and policy intervention/support. Moreover, given that the sources of negative social and environmental impacts are largely the same (e.g., pollution), a particularly strong case exists for focusing such intervention and support towards pollution reduction, whether through improved management, monitoring or design.

**Box 7: Main players along the e-product supply chain**

***Original equipment manufacturers:*** Original equipment manufacturers (OEMs), also known as Brand Manufacturers, are fundamentally responsible for developing the product concept and market. Although OEMs, can take on a wide range of production and distribution tasks, there is a general trend towards outsourcing those tasks that are less directly linked to these specific objectives.

***Contract manufacturers:*** Contract manufacturers (CMs), also known as electronic manufacturing service providers, are responsible for the production of e-products according to specifications determined by OEMs. CMs may undertake the manufacturing themselves or subcontract the manufacturing to outside third parties. CMs are increasingly taking on additional tasks related to product servicing and take-back. There is a trend towards consolidation of CMs in the e-product sector.

***Original design manufacturers:*** Original design manufactures (ODMs) are responsible for production and basic product design. ODMs are desirable for OEMs as they give OEMs the freedom to focus on market and product development, but also pose a threat as they have the potential to enter into OEM markets directly as well.

***Sub-contractors and component manufacturers:*** Both ODMs and CMs, in order to meet increasing demands, depend heavily upon subcontractors for carrying out the manufacturing of products and components. SMEs operative in the e-product sector in China are more likely to operate as sub-contractors and component manufacturers.

***Material suppliers:*** Material suppliers are responsible for sourcing the basic raw materials that make up e-products. Depending upon the material, a considerable amount of processing may be involved before actually moving raw materials to e-product manufacturers.

***Value-added distributors and retailers:*** Value-added distributors and retailers (VDRs) are responsible for product distribution and marketing to consumers. Ensuring speed to market and timely inventory management are particularly important tasks facing retailers within the context of highly dynamic e-product markets. Retailers are increasingly involved in product recycling and take-back schemes, but less involved with configuration and installation than in the past. The retail sector is moving towards greater consolidation.

# 6.0 International Supply Chain Structure and Governance

Promoting or managing changes along the e-product supply chain implies an ability to influence the way actors along the supply chain plan and carry out their business decisions. An overview and understanding of the supply chain structure, and corresponding inter-firm relationships, therefore provides a critical foundation for developing effective public policy. Below, we consider the market drivers in the e-product sector, the supply chain structure and overall global supply chain governance with a view to locating responsibility and opportunity for improving e-product sustainability along the supply chain.

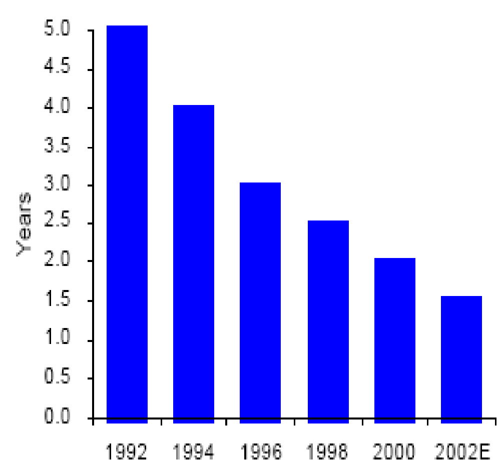
## 6.1 E-product market context

The main determinants of competitiveness in global e-product markets are also highly influential in determining supply chain relationships and structure within the sector. Competitiveness in e-product chains effectively revolves around three basic themes: innovation, price and organizational flexibility.

As a general rule, e-product firms have relied upon innovation as the single most important basis for building and maintaining market share. Rapid growth on the technological frontier has created a horizon of open opportunity that fundamentally drives the sector. And while innovation has always been a defining element of competitiveness in e-product markets, the importance of innovation as a determinant continues to grow—again as a reflection of the growth in technological possibilities. As such, the ability to open and develop markets is closely linked with a firm's ability to invest in the necessary research and development activities.

***The leadership of brand manufacturers (also known as original equipment manufacturers) located outside of China in sectoral R&D investment establishes them as de facto "leaders" in international e-product supply chains.***

**Figure 23:** Average life of PC, 1992-2002E




Source: Dataquest, Interviews, SemiConductor Magazine(March 2000)

Although price-based competition is less important within the e-product sector than many other, more mature, product sectors, all other things being equal, price remains a key component in determining market share. Indeed, China's recent, and rapid, growth as a supplier of e-products to the global marketplace can largely be attributed to its ability to combine technical sophistication with low production costs. The increasing technical complexity associated with e-products has led to a growing need for fixed investments at the level of production, which has, in turn, increased the need to leverage economies of scale through the consolidation of production-based firms, both within the Chinese context and elsewhere. ***This consolidation among e-product producers is generating an increasingly powerful challenge to brand manufacturer leadership in the supply chain.***

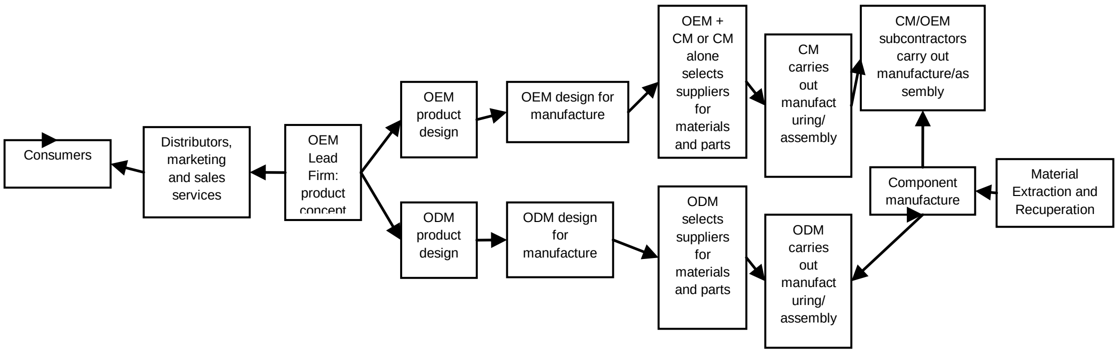
As the pace of innovation grows through increased competition, the shelf life and predictability of new electronics products is in continual decline, giving rise to a need for increasingly flexible and responsive production systems. On the one hand, the decreasing shelf life of electronics products makes it essential for production systems to be able to switch from one production line to another at regular, recurring and decreasing intervals. On the other hand, the cross-fertilization of technologies is leading to more frequent "trajectory-disrupting innovations" that have the potential to bring about a complete reorganization of markets.[25] Since short and changing product cycles imply a rapid depreciation of installations, equipment and R&D, only those production systems that are highly adaptable and able to get the right product, at the right time, to the largest segment of the market, can survive. ***In order to meet these conditions, e-product firms are driven, on the one hand, towards outsourcing as a means of distributing risk and responsibility, and, on the other hand, towards closer coordination with other supply chain actors.***

## 6.2 E-product supply chain structure and inter-firm relationships

The electronics industry covers an increasingly large range of products, some of which are homogeneous (appliances and white goods), others of which are highly differentiated (e.g., ICT equipment). This inherent diversity points towards different supply chain structures. As a general rule, supply chains for homogeneous products—display more stable and permanent commercial relationships, while differentiated product supply chains display more dynamic and increasingly complex commercial relationships. ***However, there is a general trend across e-products towards increased differentiation based on innovation, which is generating more dynamic and complex relationships across all e-product sectors.***

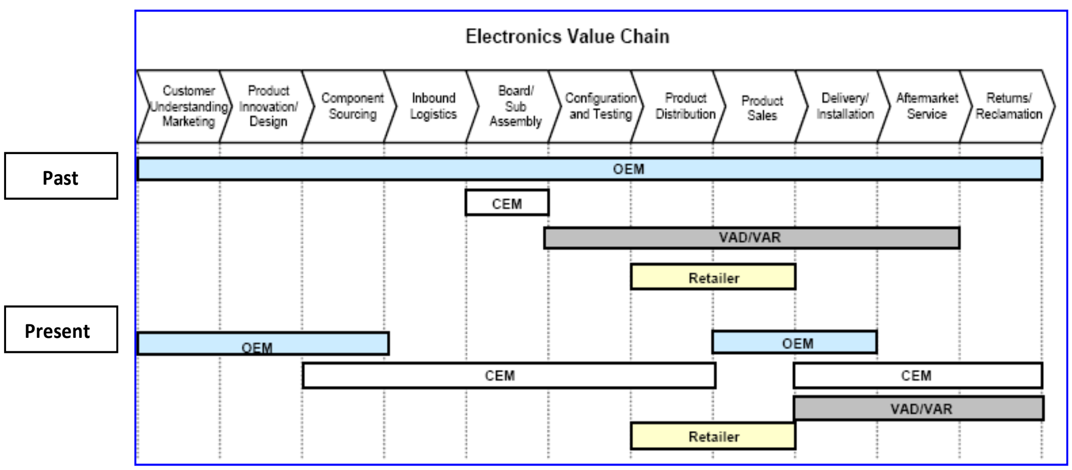
[25] These forces are particularly evident in the ICT sector, where computers are now being used as televisions, stereo systems and phones through VoIP, while mobile telephones are being used for e-mail, web navigation, music playback and photography.

**Figure 24:** E-product supply chain




Responding to market pressures, there is a general trend for original equipment manufacturers (OEMs) to outsource more of their activities toward Contract Manufacturers (CMs) and/or original design manufacturers (ODMs). Today, leading CMs and ODMs offer services throughout the entire product life cycle, from product development to after-sales service and end-of-life support. By involving CMs in processes related to new product introduction, CMs are able to develop the appropriate manufacturing and delivery systems for the product, while also being better equipped to service OEM needs (i.e. the lead firms' time-to-market, time-to-volume, or time-to-cost needs) (Handfield et al., 2002). ***The growing range and complexity of tasks being allocated to CMs is pushing the sector towards consolidating outsourced activities at a particularly fast rate, making CMs important global players in their own right.***

**Figure 25:** Changing roles in the e-product value chain




Adapted from Boos-Allen Consultants "Logistics Endgame: Industry Study Findings" (2001)

The trend towards outsourcing in the e-product sector is complemented by a trend towards enhanced coordination. Although much coordination remains bilateral between OEMs and other concerned players along the supply chain, there is a growing use of multi-firm platforms and partnerships, which are increasingly being used to establish production strategies and norms. The following five types of coalitions and networks are linked to specific activities along the supply chain, and play a role of particular importance in the electronics sector:

1) ***Supplier networks,*** which include subcontracting and a variety of other contracts such as consignment assembly, original equipment manufacturing (OEM), original design manufacturing (ODM), contract manufacturing and turnkey production;[26]
2) ***Producer networks,*** which include co-production arrangements that enable competing producers to pool their production capacities, financial capabilities and human resources in order to broaden their product portfolios and geographical coverage;[27]
3) ***Customer networks,*** which include forward linkages with distributors, marketing channels, retail outlets, value-added re-sellers, end users and services for the collection of end-of-life equipment;[28]
4) ***Standards coalitions,*** which set baseline criteria and boundaries for the production and use of electronics products. Increasingly, these are addressing social and environmental issues;[29] and
5) ***Technology coalitions,*** which facilitate the exchange and joint development of product design and production technology. Technology coalitions may undertake patent swapping,

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[26] For example: The EICC group consists of 26 of the largest, global electronics equipment manufacturers (OEM) and their first-tier original design manufacturers (ODM) and equipment manufacturers (EM). This grouping concentrates on improving working conditions and environmental stewardship throughout the electronics supply chain. This group supports a common "Code of Conduct" for electronics companies—the Electronics Industry Code of Conduct (EICC). The Code covers expectations for performance across a range of issues including labour, health and safety, environmental practices, ethics and management systems. The EICC group is coordinated by Business for Social Responsibility, based in the U. S.

[27] For example: The Electronic Industries Alliance (EIA), the Japan Green Procurement Survey Standardization Initiative (JGPSSI), and JEDEC have jointly published the Joint Industry Guide (JIG) for Material Composition Declaration of Electronic Products. (Producers are required to complete and maintain material composition of all electric and electronic products due to legal and market requirements. The industry is also required to gather information about the composition of products and subparts that are purchased from suppliers for incorporation into final products. This affects the entire supply chain worldwide.)

[28] For example: The Consumer Electronics Retailers Coalition (CERC) is a grouping of electronic, specialty and general retailers and retail associations. It publishes and lobbies on market perspectives and policy issues facing the consumer electronic retail industry and their customers. CERC has a unique and expert perspective on consumer electronics from the retail sector's point of view.

[29] For example: The mission of the WEEE Forum is to facilitate collective take-back systems for discarded electrical and electronic equipment throughout Europe. Its membership includes companies, government organizations and NGOs working on electric and electronic take back, recycling and recovery. The forum also provides a forum for the sharing of good practice in dealing with end-of-life e-products and WEEE related training to EU member states. The WEEE Forum enables stakeholders to debate on emerging issues, to define common positions, and to make expert and constructive contributions to the general debate on the management of WEEE. It provides technical assistance to different stakeholders, including legislators.

cross licensing and the sharing of R&D. Under such arrangements, knowledge typically flows to and from the lead firm and its value chain. The entire network is therefore required to work with a fairly broad array of technological and business capabilities and to generate new products and production systems.[30]

The growing use of coalitions and networks in supply chain decision-making and planning provides an alternate and potentially more effective target-point for policy influence and implementation.

## 6.3 China's role in the global e-product chain

Consolidation in e-product supply chains has lead to a growing delegation of management authority and responsibility to contract manufacturers (CMs) and original design manufacturers (ODMs) based in China. Table 5 shows that the highest ranked CMs and ODMs (in terms of market share) have located the majority of their facilities in China. Although grounded in low-cost, mass production of well-established products, China's growth is now also being lead by inroads into the provision of additional services to ODMs, such as consumer services. The growth of CM and ODM presence in China re-emphasizes the importance of China's importance in global e-product chains more generally.

**Table 5: CM and ODM manufacturing locations (including subsidiaries) in Asia, 2005**

| Company (rank*) | Singapore | Malaysia | Indonesia | India | Japan | China | Taiwan |
|---|---|---|---|---|---|---|---|
| **Flextronics** | 1+HQ | 5 | 0 | 2 | 1 | 12 | 1 |
| **Foxconn/Hon Hai** | 0 | 2 | 0 | 1 | 1 | 9 | 5+HQ |
| **Samina-SCI** | 0 | 1 | 1 | 0 | 3 | 5 | 0 |
| **Solectron** | 1 | 3 | 0 | 1 | 3 | 9 | 0 |
| **Celestica** | 1 | 3 | 0 | 1 | 2 | 6 | 0 |
| **Venture** | 6+HQ | 4 | 1 | 0 | 0 | 4 | |
| **Jabil Circuits** | 1 | 1 | 0 | 3 | 1 | 5 | 1 |
| **BenQ** | 0 | 0 | 0 | 0 | 0 | 2+HQ | 1 |
| **Inventec** | 0 | 0 | 0 | 1 | 1 | 5 | 1+HQ |
| **Benchmark Electronics** | 2 | 0 | 0 | 0 | 0 | 2 | 0 |

[30] For example: The Internet Security Alliance (ISAlliance), founded in 2002, is a collaboration between the Electronic Industries Alliance and Carnegie Mellon University. It goal is to help businesses develop effective solutions to information security issues and security issues, and minimize the potential for regulation. These issues include outsourcing, rising compliance costs, expanding regulation of the Internet and identity theft over the Internet.

Corresponding to China's ability to attract and stimulate CM and ODM capacity, it has had to rapidly develop its core manufacturing base to supply the new mega-CMs. This trend is also apparent from the number of electronic information companies operating in China. In 2005, the number of electronic information companies in China jumped from 7,500 in 2001 to 67,000, including approximately 56,000 manufacturing companies. The number of employees engaged in the industry grew from 3.01 million in 2001 7.61 million in 2005 (out of whom 5.51 million are employed in the manufacturing industry). In terms of investment, the Fujistsu Research Institute reports that electronic parts-related investment accounted for 55 per cent of total investment in the Chinese, electronic information industry (both export and domestic). Indeed, the promotion of the electronic parts industry was one part of the national government's industrial policy to raise the ratio of value added in the electronic information industry.

Even without considering future growth, China is already the world leader in the production of PCs, televisions, mobile phones, refrigerators and air conditioners.

**Box 10: Company Perspectives**

*"Our OEM customers call the shots. At the end of the day, they will brand and sell our work. We design, but we design for others, we only share IPR and licensing agreements. We are not in the driving seat—our customers are."* **(Direct Communication Quanta Computers, May 2007)**

*OEMs, ODMs and CMs together provide a monumental force of leadership and authority towards manufacturers and subcontractors. Indeed, "it is not unusual for lead firms, CM and ODMs' to exert great pressure on their suppliers to adopt the newest technology to streamline quality control and facilitate tracking"* — **(Direct Communication, Tim Sturgeon, MIT, June 2007).**

**Box 8: Consolidation among Chinese manufacturers**

Many factors are driving consolidation among Chinese e-product manufacturers. On the one hand, rapid growth in local minimum wages is driving a trend toward automation among factories—a trend that raises the level of the fixed investments required for participation in the sector and that puts SMEs at increased risk. The corresponding growth of strict international requirements linked to production and design is similarly requiring new investments and designs often beyond the reach of SMEs, with weaker communications and networking bases. China's niche is large-scale, mass production where competition is based on high-volume economies of scale.

## 6.4 Governance of the global e-product chain

As already noted, the innovation-oriented nature of the e-product market has led to the development of highly complex and organized supply chains that are increasingly relying on outsourcing for product delivery. Each of these trends has direct impacts on the way in which the global e-product chain is governed, which, in turn, has implications for policy development for sustainable development at the global level.

The single most important factor affecting the governance structure of e-product chains is the innovation-based nature of competition.

Innovation leads the market and, as a result, also plays a natural role in leading the supply chain. Those firms that are capable of, and responsible for, product design and marketing, form the foundation and overall leadership of the chain. Profits sit where value is added which is directly linked to innovation, and, to date, this has rested primarily in the hands of OEMs. Electronics Design News reports that over 93 per cent of annual electronic patent applications in North America and the EU are made by OEMs.[31] Moreover, notwithstanding the fact that OEMs are increasingly seeking to expand the range and depth of their outsourcing, outsourcing is typically performed with a view to strengthening OEM capacity (and hold) on the core competencies of design and market development.

The high level of investment required to lead research and development to successful product launch has led to a natural consolidation within the OEM sector, a factor that reinforces the logistical authority that OEMs have over the supply chain due to their control of the design process. The top ten global OEMs account for more than 50 per cent of global market share.[32] At the same time, as the complexity and costs associated with pure manufacturing activities also grow, there has been a corresponding growth in consolidation at the level of CMs and ODMs as well. Consolidation among manufacturers has led to increased decision-making authority across the supply chain. This changing role is perhaps best evidenced by the growing participation of CMs and ODMs in the early stages of product design and in post-delivery service provision. While CMs and ODMs are becoming more interactive partners with OEMs, they are also gaining unilateral authority over their own manufacturing supply chains. Whereas preferred supplier lists were determined by OEMs in the past, increasingly, CMs and ODMs are providing and managing their own supplier lists without OEM intervention.[33]

**Box 9: China's Role —View from the Field**

*"An example I like to use is the cell phone. There are two pieces of it. You have the handset and the infrastructure. Handsets lend themselves to China. They are small, and built in large volumes. You put them in crates and fly them where they need to be. However, cellular base stations are more complex. They have more critical intellectual property (IP) issues related to them and you're not going to put them on a plane. You have put them on a big container and then on a ship to your customers. In this case it makes sense to have them built closer to the end customer,"* (Direct communication, Celestica, June 2007)

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[31] Electronics Design News, Daily Bulletin, 13 March 2007

[32] Electronics Supply and Manufacturing, November, 2006.

[33] "A few years ago, especially in new products, we used to rely on the supplies specified by the OEMs. But now, we have increasing influence over the preferred supplier list and who we ultimately pick for the job. Of course, all depends on how technically complicated the product is. But on average, we have at least 5 to 8 times more control over supplier spend than maybe 10 years ago." (Direct communication, Celestica, June 2007).

## 6.5 E-waste supply chain structure

The manner in which e-waste chains are governed depends fundamentally on whether they managed as part of the "formal" or "informal" economy. As noted above, the vast majority of e-waste currently flows through informal supply chains, which represent significant threats to workers and the environment. However, the nascent and rapid development of more formal e-waste supply chains represents a valuable opportunity for overcoming many of the sustainability challenges facing the processing and recuperation of e-waste.

### 6.5.1 *Formal e-waste supply chains*

Formal e-waste recycling supply chains are still in their infancy. In many respects, the first formal e-waste chains chain can be traced back to the implementation of European and Japanese extended producer responsibility legislation in 1998. Since then, the strengthening of Extended Producer Responsibility (EPR) and related requirements through EU Directives, WEEE and RoHS, and similar legislation in Japan, China, Taiwan, South Korea and several states in the U. S., has fuelled the rapid development of the formal e-waste sector over the past several years. At the same time, the requirements associated with these laws have also raised a significant number of challenges for companies and countries implicated in e-waste chains for ensuring operationally and financially viable e-waste collection and recuperation.

The concept behind EPR is that the lead firm—the original equipment manufacturer—takes the financial responsibility for the disposal of their end-of-life and obsolete stocks. The rationale is that this will provide greater incentives for original equipment manufacturers to design more environmentally-suitable products that can be cost-effectively recycled. Producer take-back also mandates that consumers are able to take back their e-waste free of charge and that e-waste is recycled in controlled conditions that minimize environmental harm and ensure health and safety for workers.

Because the development of the formal sector is largely driven by legislation directed at the production side of the supply chain, it seeks to leverage the leadership of OEMs, CMs and retailers in the development of a more transparent supply chain. Not surprisingly, under this context, these players tend to play a leadership role in the development and management of formal e-waste chains.

### 6.5.2 *Informal e-waste supply chains*

If the e-product supply chain is defined by its high degree of structure, coordination and organization, the informal e-waste supply chain is defined by the absence of these qualities. In the informal sector, free market prices determine the flow and destination of e-waste, which is typically collected by waste management companies and traded on the open market. With municipalities traditionally responsible for municipal waste collection and disposal in both China and the major consuming countries (e.g., EU and U. S.), and the recent shift of municipalities to using commercial companies for these tasks a fairly new phenomenon, adequate control mechanisms are yet to be developed to track waste from collection to recycling points.[34]

Indeed, at present, informal e-waste supply chains remain more or less "unmanaged" with each actor along the supply chain retaining close to full decision-making authority for the activities they perform. The lack of coordination along the chain clearly operates as a major obstacle to the implementation of improved practice on a systemic basis. Moreover, although legislation and related initiatives have been formally implemented both in China and internationally to restrict the uncontrolled flow of e-wastes, to date, a lack of coordination both in enforcement and along the supply chain has prevented effective implementation on a broad scale.

End-of-life and obsolete products are typically collected at take-back centres and transported to recovery facilities where e-waste components are then separated. The e-waste is then sold to scrap brokers, who specialize in the trade of electronic wastes. Alternatively, e-waste brokers can also ship the e-waste as non-sorted products. The largest market of non-working equipment is for the circuit boards that contain metals such as silver, gold, palladium and platinum.[35]

Research conducted by the Basel Action Network and the Silicon Valley Toxic Coalition indicates that when e-wastes arrive in China, they are again graded and sold off in the domestic market. It has also been reported that there are a growing number of Chinese recyclers who openly solicit foreign companies for business.[36]

### 6.5.3 E-waste governance

The governance of the e-waste supply chain, operates in stark contrast to the e-product supply chain. Although recycling and recuperation can be a technically demanding activity, the degree of investment made towards R&D and innovation has been minimal in comparison to the production of e-products. Moreover, the fact that e-waste has only recently been treated or recognized as a "product of value" has prevented the development of highly structured global e-waste supply chains comparable to those found on the production side of the e-product supply chain. As a result, global e-waste supply chains have "sprung into being" largely in the absence of proportionately organized governance at the global level.

***The fact that much e-waste transportation and collection may actually be illegal and that guidelines for good practice in e-waste management are not yet formally recognized at the international level could be regarded as encouraging e-waste suppliers and handlers in the***

[34] Global Waste Management Market Assessment 2007, www.marketresearch .com
[35] Direct communication, Basel Convention
[36] The EU Recycling Platform claims to be received at least one letter of solicitation from Chinese e-waste dealers per week.

***maintenance of informal supply chain arrangements.*** Regardless, to the extent that much of the trade of e-waste is in fact illegal, clear and credible statistics on the levels and impacts of such trade are hard to gather—something that stands as a critical and immediate challenge to the effective governance of e-waste supply chains.

The e-waste supply, being less directly driven by innovation and "just-in-time" product development, is generally faced with far lower organizational demands than the e-product supply chain. As a result, the supply chain has remained largely insular with firms along the chain retaining responsibility and decision-making authority over the tasks that they undertake. As a general rule, trade is managed by traders and "waste management" firms, while recuperation is managed by recycling facilities at sites of recuperation (typically in China itself). Increasingly, there is a trend towards collective initiatives for managing recycling by leveraging the authority and infrastructure of those active on the production side of the supply chain. As a part of these collective initiatives, retailers, OEMs and CMs are becoming involved individually or jointly in the take-back of e-products for recycling.

Notwithstanding the trend towards outsourcing by OEMs, as leaders in the productive chain, they retain an undeniable ability to manage the e-waste chain through both their post-sale services and their decision-making authority in production. At the same time, any basis for a coherent system of sustainable e-waste management will inevitably require the full participation and leadership of Chinese-based CMs and ODMs as well. Moreover, given the potential for competitive distortions through the sort of sector-wide coordination which will be required, it is also apparent that government decision makers must play an increasingly important role in providing leadership and a level playing field to ensure rapid adoption of good practices in the e-waste management.

## 6.6 Implications for managing sustainability in the e-product sector

In terms of sustainable development, the existence of "globally organized" value chains implies that no one company, not even a lead firm, can expect to improve sector or supply chain sustainability performance through individual action. ***However, the continued prominence and authority of lead firms in determining baseline quality criteria for products does suggest that they will continue to play a critical role in leveraging change among other actors in the supply chain.***

Whether change is leveraged through the leadership of lead firms, inter-firm networks, national or international policy, the complexity of e-product supply chains makes the integration of the views and experiences of multiple actors a prerequisite to effective policy. Purely top-down structures are unlikely to succeed in the e-product sector. Furthermore, the complexity and highly dynamic nature of the e-product sector suggests that one-size-fits-all approaches are also unlikely to be successful. "Learning by doing" can therefore be expected to be a key building block for the development of appropriately specialized implementation mechanisms. The existence of a variety of supply chain coalitions and corresponding governance infrastructure, on the other hand, points towards potential leverage points for building systemic change towards sustainable development. Transparency, measurement and enforcement, however, will be critical to ensure that more decentralized and specialized approaches contribute appropriately and meaningfully to national and international sustainability objectives.

At the same time, the growing global dominance of China as the principal source of e-products affirms the importance of China as a major player in the determination of the social and environmental impacts of the electronics industry. This dominance suggests the importance of having proactive policy intervention/guidance from Chinese public and private stakeholders. Although it is clear that the breadth of the challenge will require interventions from both the public and private sectors, high public ownership rates of private firms in the Chinese context points towards a unique capacity of the Chinese public sector to support proactive changes, not only through more traditional public policy measures but through the direct development and influence of private sector decision making as well. In this respect, China is particularly well-placed to leverage the potential of public/private supply chain initiatives aimed at improving the sustainable development impacts of the e-product chain.

The highly underdeveloped nature of governance structures associated with the e-waste chain, although a source of considerable social and environmental risk at present, can also be regarded as a major opportunity for improving the sustainability performance of these chains. Clear identification of good practice combined with more formal governance, transparency and traceability requirements provide an obvious and necessary stepping stone to ensuring more responsible behaviour along global e- waste chains.

| Table 6: 20 Largest Global Original Equipment Manufacturers (OEM), 2005 | | | | |
|---|---|---|---|---|
| **2005 Global Revenue Rank** | **Company** | **2005 Revenues ($US million)** | **HQ** | **Primary markets** |
| 1 | IBM | 91, 134 | U. S. | Diversified |
| 2 | HP | 86, 696 | U. S. | Computer, computer peripherals |
| 3 | Sony | 66,912 | Japan | Computer, electronics, audio/video |
| 4 | Samsung | 57.721 | Korea | Computer, computer peripherals communications, audio/video, appliances |
| 5 | Dell | 55,908 | U. S. | Computer, computer peripherals |
| 6 | Toshiba | 54,264 | Japan | Computer, computer peripherals machinery, instruments |
| 7 | Nec | 45,298 | Japan | Computer, computer peripherals communications |
| 8 | Fujitsu Siemens | 44,284 | Japan | Computer, computer peripherals communications |
| 9 | Nokia | 40,465 | Finland | Communications |
| 10 | Motorola | 36,843 | U. S. | Communications |
| 11 | Phillips | 35,972 | Netherlands | computer peripherals, communications appliances |
| 12 | Cannon | 31,843 | Japan | Photography, graphics, compute peripherals, audio/video |
| 13 | Mitsubishi Electric | 31 712 | Japan | Computer, communications, machinery appliances |
| 14 | Cisco | 24,810 | | Communications, networking |
| 15 | LG Electronics | 23,879 | Korea | Communications, computer peripherals audio/video |
| 16 | Sharp | 23,615 | Japan | Computer, computer peripherals audio/video, appliances |
| 17 | Ericsson | 19,100 | Sweden | Communications |
| 18 | Ricoh | 16,867 | Japan | Computer, computer peripherals machinery |
| 19 | Alcatel | 15, 577 | France | Communications |
| 20 | Thales | 15,186 | France | Aerospace |
| Source: Electronic Design Strategy | | | | |

# 7.0 National and International E-Product Policy

## 7.1 Chinese policy

### *7.1.1 E-products related economic policy*

To provide for continued growth and foreign direct investment, China continues to provide incentives to sustain its global competition and is working towards meeting its core WTO targets on market liberalization. These developments include:

- the ability for foreign firms to invest in China not only as equity joint ventures and contractual (cooperative) joint ventures, but also as wholly foreign-owned enterprises. (A majority of investment is however encouraged in the form of joint ventures.);
- the designation of five special economic zones (SEZs) in 14 coastal cities;
- a series of "zones" connecting the SEZs that provide a lowered (average) import tariff of 9.4 per cent for industrial goods, and a value-added tax of 17 per cent on all export items;
- export credits from the People's Bank of China to Chinese enterprises selling electronic equipment on the global market;
- foreign currency export credits are extended to buyers of Chinese-made and completed electronic equipment valued at US$1million per transaction;
- preferential treatment to Sino-foreign joint ventures that are export oriented and working on technologically advanced products that include electronics. For example, electronics vendors that export 70 per cent or more in product value may reduce their income tax value by half at the end of the relevant tax reduction period; and
- local enterprises are exempt from import duties on raw materials provided by overseas supplies to meet export contracts or for use in manufacturing exports.

It is noteworthy that each SEZ or industrial park has the ability to establish its unique mix of industries that qualify for special tax incentives. At the time of writing, electronic products that qualified for incentives included photo-electronic materials, semi-conductors, software, mainframe and mini-computers, personal computers with 32 bits or higher CPUs (top-end products), 900MHz cellular mobile communication equipment, fibre optic communication equipment, components for satellite communications and commercial satellites, mercury-free batteries, digital high-definition TV, DVD recorders and disc players and digital microwave communication systems.

It is also noteworthy that China discourages investment in technologies that are considered to be well-established in its domestic market. For example, no foreign investment is allowed for products such as radio-cassette players, satellite and analogue televisions and compatible equipment, video cameras, magnetic heads, fax machines, radio and TV broadcasting systems, personal computers under 16 bits and microwave relay communications equipment below 140mbps.

These incentives demonstrate China's ambition to compete as a cutting-edge hub of electronics innovation in years to come. The electronics industry in China is predicted to grow at 17 per cent per annum,[37] and given the global growth and innovation which is synonymous with this industry, China's position in the electronics sector is only beginning.

But trade barriers do remain in several sectors on the Chinese economy, although some of them can be expected to be gradually dismantled after the markets for services in China are opened to foreign

[37] China Ministry of Information Industry, 2007, http://en.ce.cn

investment in 2008. For example, foreign retailers need to set up outlets that are in compliance with a range of local planning requirements and these remain largely vague and discretionary. Foreign investors are not allowed to invest in telecommunications services and the construction of related infrastructure, postal services, and in radio and TV broadcasting. In several sectors, including telecommunications, the regulatory framework is still to be made independent from government bodies. China also administers a complex system of non-tariff trade barriers that include quotas on imports and import licences, under which 350 line items are reserved for State Owned Enterprises (SOE).

China's trade, investment and regulatory systems have also been characterized by a lack of transparency and inconsistent enforcement. This is mainly due to a complicated and often conflicting system of national, regional and local administrative regulations on foreign investment. Foreign investors in China face obstacles such as the inadequate protection of intellectual property, limited availability of foreign exchange, lack of legal and contractual tradition especially in resolving disputes, barriers to market access, unequal treatment compared to domestic companies and the highly personalized nature of conducting businesses in general (Pecht, 2007).

Notwithstanding these challenges, China is now a powerful global player in the world economic and sustainable development arena.

### 7.1.2 Environmental and e-product policy in China

China has enacted a comprehensive body of environmental laws, regulations, standards, technical guidance and norms related to e-product production. In the area of e-project pollution control, the Chinese government has also actively adopted a range of softer policy measures aimed at e-product production, consumption, trade as well as disposal and reuse.

Several general environmental laws are applicable to e-product regulation. Among them the most important ones are:

- General Environmental Law (1980) ─ Sets forth rules related to implementation of the "pollution prevention" principle and the "polluter pays" principle;
- *The Clean Production Promotion Law (2002)* ─ Deals with producer responsibility, encouragement of eco-design and the life cycle approach, phase-out of obsolete production processes and products, promotion of eco-labels and technology innovation; and
- The Solid Waste Pollution Control Law (amended in 2004) ─ Addresses the 3Rs (reduction, recycling and reuse), producer/retailer/importers/consumer responsibility for prevention and control of pollution caused by solid wastes.

In addition to its general framework of environmental legislation, China has been proactively developing specific e-product legislation to address a number of the social and environmental challenges associated with growing production, consumption and trade in the sector. The following table provides a summary overview of the key elements of the main e-product regulations currently in existence in China.

| Table 7: Specific Chinese policy on e-products | |
|---|---|
| Laws/regulations | Major contents |
| The Circular on Strengthening Environmental Management of WEEE Equipment (2003) | Strengthens control of pollution caused by WEEE (focusing on EEE with voltage of less than 1000Vac or 1500Vdc) |
| The Administrative Measures on the Control of Pollution Caused by Electronic Information Products (2006) | Restriction of toxic and hazardous substances of EIP; producer and importers to meet the requirements (eco-design, labelling & certification) set in the regulation |
| The Technical Policy on Pollution Prevention and Control of Waste Electrical and Electronic Products (2006) | Overall guiding principles; polluter pays principle, the principle of reduction, reuse and minimization of e-wastes; eco-design; and shared responsibility of producers, retailers and consumers. |
| The Regulations on the Management of Waste Electrical Household Appliances Collection and Treatment (to be adopted) | Producer extended responsibility: eco-design, information and disposal responsibilities; retailers and consumers responsibility: collection obligations. |
| | |
| The Requirements for Concentration Limits for Certain Hazardous Substances in EIP (2006) | Setting concentration limits for regulated hazardous substances in EIP |
| The Marking (Labelling) for the Control of Pollution caused by Electronic Information Products (2006) | Setting up labelling standards/requirements |
| The Testing Methods for Hazardous Substances in EIP(2006) | Testing methods for EIP |
| General Principle for Environmental Use Terms for EIP (2006) | Explanations of Environmental Use Term |
| Explanation of Electronic Information Product Classification (2006) | A guiding document specifying EI products |

Policy measures such as the Chinese Environmental Label and the green government procurement policy have also been implemented to help stimulate more sustainable consumption of e-products. Chinese policy has proactively promoted eco-design, taking into account the environmental impacts of a product's entire life cycle.

| **Table 8: China's consumption-related e-product policy** | |
|---|---|
| Regulations/Rules | Major Contents |
| China Environmental Label (since 1993) | The environmental label is awarded to products that meet certain green criteria |
| Government Procurement of Energy Efficiency Products (2004) | Central and local governments prioritize purchasing energy-efficient products, including air conditioners, refrigerators, bulbs, TV, computers, printers and copiers |
| Government Procurement of Environmentally-Labelled Products ( 2006) | Central and local governments prioritize purchasing environmentally labelled products, including printers, copiers, fax machines, colour TVs, etc. |

The development of the Chinese national legislative framework for the management of e-waste is simultaneously a top-down and a bottom-up approach. The process has been launched by the national authorities at two levels. First, at a national level, drafting key components of the legislative framework and, second, at the local level, in the form of pilot e-waste management schemes in Beijing, Qingdao, Tianjin and Zhejiang Provinces.[38]

Reducing, minimizing, recycling and reusing e-wastes are also recognized as core objectives of Chinese policy. However, the laws and regulations adopted in this area remain very general at this point in time and need to be supported by more detailed provisions to ensure effectiveness. Moreover, the recycling and treatment of electronic wastes (mainly mobile phones and other electronic information products) are not covered by the impending waste electrical household appliance law soon to be adopted. Given the fact that China's domestic electronic waste streams continue to grow rapidly as both population and consumption increase, there is a growing need to explicitly address the collection and treatment of electronic wastes as well.

***Although China has passed several laws and regulations on waste imports, the problem of e-waste imports from foreign countries, mainly through illegal trade, remains a serious concern. Lack of effective enforcement and monitoring mechanisms associated with the formal ban on foreign e-waste imports, as well as exemptions for "recyclable-wastes," which are poorly defined, allows significant quantities of foreign e-waste to enter the country through illegal channels.*** Other logistic problems also create challenges for the effective regulation

[38] The Swiss program Global Knowledge Partnerships in E-waste Recycling facilitates and supports the drafting process of key components of the legislative framework and the implementation of the pilot e-waste management schemes in Qingdao and Tianjin.

of e-waste trade. For example, according to the custom and quarantine inspection rules, quarantine inspection officials at the border do not have the authority to inspect the goods before custom inspection; while-waste import laws require a quarantine inspection to take place before custom clearance. Even where smuggling of e-waste products is identified, Chinese criminal law is ambiguous about the punishments for waste smuggling, reducing the effectiveness of the law as a deterrent on illegal trade.

***While there are many opportunities for policy development and improvement within the Chinese context, the very fact that e-waste imports are sourced internationally points towards a clear opportunity, and need, for enhanced cooperation from international trading partners in the development and implementation of measures for enforcing the trade ban.***

### *7.1.3 National voluntary initiatives*

China faces the compound issues of both e-waste imports from developing countries as well as the volumes generated from its rapidly expanding domestic electronics sectors. The industry itself appears to have been the first to realize the risks and opportunities in this area; the ten top global OEMs all report establishing internal e-waste collection and treatment mechanisms in their operations in China.

One of the first voluntary collective partnerships in China was an initiative launched by Sony, HP, Electrolux and Brant to collectively establish an inter-firm platform for materials purchasing, transportation and recycling of the e-wastes. Soon thereafter, in 2005, Motorola, Nokia and China Mobile initiated the *Green Box Program*, a collective take-back scheme for used mobile phones in 10 cities in China. This scheme has now been expanded to 36 cities and 11 other OEMs including Lenovo, Siemens, Panasonic, Sony Ericsson and LG.

The first multi-stakeholder platform for e-waste treatment in China was initiated in 2006, by the China WEEE Recycling Union in collaboration with China Home Electrical Appliance Research Institute, the China Chamber of Commerce for Import and Export of Machinery and Electronic Products, China Resale Goods Trade Association and China Electronics Scientific and Technical Development Company of China Electronics Group. The platform is facilitated by the China WEEE Recycling Union and Hellmann Group in Germany.[39]

## 7.2 E-product policy in major foreign markets

The EU, Japan, and the U. S. account for about two thirds of China's electronics exports.[40] All of the major markets, as well as other markets for Chinese electronic goods, have adopted regulatory measures to control pollution from such products.

[39] EU Asia Eco-Design Project, June 2007

[40] The largest share of Chinese EEE exports is the U.S., 31.2 per cent, then EU, 22.2 per cent, and Japan, 13 per cent.

### 7.2.1 EU policy

The EU has the most stringent laws on e-wastes, which require mandatory take-back mechanisms while also restricting the use of hazardous substances in electronics products for sale in the respective markets. The two pillars of EU legislation are the Directive on Waste from Electrical & Electronic Equipment (WEEE)[41] and Directive on the Restriction on of Certain Hazardous Substances (RoHS).[42] The WEEE legislation requires e-manufacturers to provide take-back schemes for the products sold in the EU market, while the RoHS restricts the use of six hazardous substances. Because these policies apply across the board to products sold in the EU market, they are expected to have major impacts on Chinese producers.

Other important pieces of EU e-product legislation include:

- The Directive on Registration, Evaluation and Authorization of Chemicals (REACH),[43] which requires companies to provide detailed information on specific substances imported into the e-market; and
- Directive Establishing a Framework for the setting of Eco-design Requirements for Energy-using Products (EuP) in 2005, establishing a common framework for the promotion of eco-design within the EU.

The growth, stringency and multiplicity of EU legislation and policy represent a key challenge for Chinese production.

### 7.2.2 Japanese policy

Japanese policy on e-products and e-waste, like the EU, sets mandatory requirements for the take-back of select e-products, while also limiting the use of selected hazardous substances. The principal laws applicable to imported e-products are:

- *The Law for the Promotion and Effective Utilization of Resources (LPEUR),* which promotes recycling and reuse, while also establishing systems for research and testing on recycling technologies;
- *The Ordinance of the Ministry to Require Design for Environment (DfE)*, which establishes a system for assessing the design characteristics of select e-products;[44]
- *Laws for promoting specific waste recycling* Japan's *Home Appliances Recycling Law (HARL),* which requires producers and importers to take back and recycle used air conditioners, televisions, electric refrigerators and washing machines, as well as freezers; and

[41] Directive 2002/96/EC of the European Parliament and the Council of 27 January 2003 on Waste from Electrical & Electronic Equipment.
[42] Directive 2002/95/EC of the European Parliament and the Council of 27 January 2003 on the Restriction on of Certain Hazardous Substances, and was last amended 28 April 2006.
[43] Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH).
[44] See the website of the Ministry of Economy, Trade and Industry at http://www.meti.go.jp/policy/recycle/main/3r_policy/policy/pdf/j-moss_english.pdf

- *The Green Purchasing Law (GPL) and The Law Concerning the Promotion of Procurement of Eco-friendly Goods and Services by the State and Other Entities,* which requires government agencies to promote environmentally-friendly products and services in their purchasing requirements.

### *7.2.3 North American policy*

Although both Canada and the U. S. have relatively weak E-product legislation at the federal level, provincial and state regulations (cf. California) can be as, or more demanding, than their European counterparts. As a general rule, however, North American governments have opted, to date, for voluntary approaches in the curtailing of pollution from electronics goods with the Environmental Protection Agency (EPA)'s Environmentally Preferable Purchasing (EPP) Guidelines and Energy Star Program leading the way in the U. S. and the Electronic Product Stewardship Canada initiative leading the way in Canada. The Canadian Council of Ministers of the Environment (CCME) has also endorsed the National Principles for Electronics Product Stewardship to help encourage and facilitate provincial and territorial programs.[45]

While larger joint ventures and domestic enterprises in China are relatively well equipped to comply with WEEE and RoHS, small and medium-sized enterprises (SMEs) at the bottom of the supply chain, which account for approximately 30 per cent of Chinese supply, are facing serious challenges that could threaten the continued existence of many.

The biggest challenge for Chinese exporters of electronic products arises for the considerable diversity of the legal and administrative requirements associated with e-products. Within the EU alone, each of the 25 member states has different transpositions and interpretations of the relevant EU directives; some of the specific national rules are reportedly unavailable to Chinese exporters due to language problems. Also some countries allow for an "advanced recycling fee," while others do not. The current and growing complexity of the legal regime related to e-products is giving rise to increasing costs and delays for producers outside EU. This creates competition differences between producers.

It should be noted that the EU environmental legislation on WEEE does not stop at its WEEE, RoHS and REACH directives. The EU policy trend is moving towards integrated product policy (IPP), which calls for eco-design. In order to maintain longer-term market access to the EU, manufacturers will likely need to keep in mind the environmental impacts of the product's entire life cycle, energy efficiency and recyclability and reusability of materials used in the design of products. By providing for such requirements early in the design stages, opportunities for economic growth can be preserved, while simultaneously minimizing environmental impacts from production, consumption and disposal.

45 See above.

## 7.3 International policy initiatives

### *7.3.1 Multilateral Environmental Agreements (MEAs)*

Several MEAs are relevant to WEEE, including the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal, the Montreal Protocol on Substances that Deplete the Ozone Layer, Stockholm Convention on POPS and the Rotterdam Convention.

The Basel Convention came into force in 1992, and regulates the trans-boundary movements of hazardous and other wastes, and obliges its parties to ensure such wastes are managed and disposed of in an environmentally sound manner (ESM). To this end, parties are expected to minimize the quantities that are moved across borders, to treat and dispose of wastes as close as possible to their place of generation, and to prevent or minimize the generation of wastes at source.

Some hazardous substances contained in WEEE such as lead, cadmium, mercury and PBB are listed in Annex I as waste streams subject to the Convention. Annex VIII, List A also specifies that certain electrical and electronic wastes are hazardous substances under Article 1, paragraph 1 (a) of the Convention,[46] with an exception being specified in Annex IX List B.[47] Therefore, certain electrical and electronic wastes are covered by the Basel Convention.

The Montreal Protocol, adopted in September 1987, came into force in January 1989, and was designed to phase out substances that deplete the ozone layer, including a number of CFCs (CFC 11, 12, 113, 114, and 115) and several Halons (1211, 1301, 2402). The relevance of the Montreal Protocol to WEEE is marginal, as it only relates to the control of CFCs, often used as refrigerants in refrigerators, freezers and air conditioners.

### *7.3.2 Market-based initiatives*

Given the intrinsically international and highly complex nature of e-product supply chains, governance systems that build on existing supply chain and market relations have a particular merit with the e-product sector. Below is a brief list of some of the major private sector "policy"-oriented forms of collaboration.

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[46] Annex VIII, List A (A1180): "Waste electrical and electronic assemblies or scrap containing components such as accumulators and other batteries included mercury-switches, glass from cathode-ray tubes and other activated glass and PCB-capacitors, or contaminated with Annex I constituents (e.g., cadmium, mercury, lead, polychlorinated biphenyl) to an extent that they possess any of the characteristics contained in Annex III"

[47] Annex IX, List B (B1110) excludes A1180 substances from the coverage of the Convention as long as they are destined for direct reuse, and not for recycling or final disposal, or have been removed to an extent that they do not possess any of the characteristics contained in Annex III.

The Mobile Phone Partnership Initiative (MPPI) was established under the Basel Convention in December of 2002 during COP 6, as a public-private partnership for the environmentally sound management of used and end-of-life mobile phones to the benefit of the partners and the environment. Initially, 12 manufacturers including LG, Matsushita, Mitsubishi, Electric, Motorola, NEC, Nokia, Philips, Samsung, Siemens and Sony Ericsson, signed a declaration entering into sustainable partnership. The objectives of the partnership are to:

- achieve better product stewardship;
- influence consumer behaviour towards more environmentally friendly actions;
- promote the best disposal/recycling/refurbishing options;
- mobilize political and institutional support for environmentally sound management; and
- create an initiative that could be replicated to build new public/private partnerships for the environmentally sound management of hazardous and other waste streams.

Since the initiation of the partnership, five guidelines have been completed that address the refurbishment of used mobile phones, recovery and recycling of end-of-life mobile phones, raising awareness on design considerations of mobile phones, and on the collection and transboundary movement of used mobile phones.[48]

The Global Knowledge Partnerships in E-waste Recycling was launched in 2003 by the Swiss State Secretariat for Economic Affairs (SECO), and is implemented by the Swiss Materials Science and Technology Research Institute (EMPA) in China, India, South-Africa, Colombia and Peru. The overall goal of the program is the improvement of living conditions for the affected local population based on better managed e-waste streams, resource protection, reduced health risks and a better economic situation. The two main objectives are:

- Capacity building: Improving the e-waste situation in the selected countries by supporting initiatives by the responsible industries and governmental bodies towards targeted and critical improvements of existing e-waste systems, resulting in more sustainable recycling systems that remain at the same time financially viable. In line with the national e-waste strategies, the program concentrates on actual implementation activities aiming to improve recycling processes and the specific framework of the recycling sector; and
- Knowledge management: Exchanging expertise between countries and replicating the successful improvement of e-waste management systems to other developing and transitioning countries through open access to and exchange of knowledge. This will be based upon a global knowledge platform using the extended eWasteGuide (ewasteguide.info).

Global Computer Refurbishment and Recycling Partnership (e2e) was proposed by the Secretariat of the Basal Convention with an aim to increase the reuse and recycling of used personal computers and to encourage the diversion of such end-of-life computing equipment being recycled or reused. Focusing on the environmentally sound management of used and end-of-life personal computers,

[48] The parties to the Basel Convention have, on many occasions, lauded the work of this first public-private partnership within the framework of the Basel Convention and consider its work to be a priority.

the partnership was set up with a target of recycling and reusing 80 per cent of end-of-life computing equipment by 2020. The mandate of the partnership includes:

- to develop standards/guidance on the environmentally sound refurbishment and recycling of used and end-of-life personal computers;
- to facilitate capacity building in developing countries and countries with economies in transition via Basel Convention Regional Centres (BCRCs);
- to review different successful collection/take-back schemes and transboundary movement issues;
- to document what is being done by individual companies and by other international organizations with regard to green design; and
- to raise awareness of the environmentally sound management of end-of-life personal computers through fact sheets, and other training material, and through involvement of Basel Convention Regional Centres.

Solving the E-waste Problem: A Synthetic Approach (StEP) is an initiative of several UN organizations with an aim to solve the global e-waste problem. Together with prominent members from industry, governments, international organizations, NGOs and the science sector actively participating in StEP, it initiates and facilitates approaches towards the sustainable handling of e-waste. The main objectives of StEP are:

- Optimizing the life cycle of electric and electronic equipment by 1) improving supply chains; 2) closing material loops; and 3) reducing contamination;
- Increasing utilization of resources and reuse of equipment;
- Exercising concern about disparities such as the digital divide between the industrializing and industrialized countries; and
- Increasing public, scientific and business knowledge.

Five task forces are set up targeting policy and legislation, redesign, reuse, recycle and capacity building. Participants of StEP include UN University, United Nations Conference on Trade and Development (UNCTAD), United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), SECO, EMPA, U. S. EPA, GTZ, MIT, University of Melbourne and many private companies.

The WEEE-Forum is an open, non-profit association of voluntary industry-driven collective e-waste take-back systems, taking care of individual producers' responsibilities in Europe. It was founded in April 2002 by operational collective systems in Europe.

European Recycling Platform (ERP), initially founded by Braun, Electrolux, Hewlett Packard and Sony, works to provide an integrated platform for take-back and end-of-life treatment for e-waste categories covered by the EU Directive WEEE. The ERP now has 933 member companies, works across 29 countries and offers services along business-to-business and business-to-consumer waste streams.

# 8.0 Policy Analysis and Recommendations

## 8.1 Context summary

The growth of the e-product sector within China over the past decade has played a significant role in the growth of Chinese GDP, employment and overall national well-being over the past decade. As such, the e-product sector offers a critical springboard to the long term economic sustainability of the country. Closely linked with the current economic success of the e-product sector, however, is a rapid increase in the importance of the negative social and environmental impacts associated with rapid growth in the sector.

The principal social and environmental challenges facing the e-product sector *within China* are associated with the production, use and disposal/recycling of e-products. Globally, the main sustainability challenges arise at the use and end-of-life stages of the supply chain.

The main *environmental impacts* of the stages can be summarized, respectively, as follows:

- Production:
  - Non renewable resource use and depletion
  - Energy use for resource extraction and manufacture
  - Heavy metal and chemical pollution during manufacture
- Use:
  - Energy use during product use
- End-of-life:
  - Heavy metal and chemical pollution during dismantling
  - Heavy metal and chemical pollution arising from improper disposal

The main *negative social impacts* arising from the e-product sector are closely linked to the environmental impacts and arise at the production and end-of-life phases of the supply chain:

- Production
  - worker health and safety due to poor chemical management during component manufacture
  - community health and safety due to poor chemical management during component manufacture
- End-of-life
  - worker health and safety due to poor chemical management during dismantling, recovery and disposal
  - community health and safety due to poor chemical management during dismantling, recovery and disposal

With respect to variances in the distribution of impacts across different geographic locations of the international supply chain, it is clear that the largest total environmental and negative social impacts from products *produced* in China are found within China itself. Elevated impacts at the manufacturing, use and end-of-life phases combined with the size of the domestic market leads to this result. Nevertheless, it is worth noting that the use phases of e-products represent the stage with the single most important environmental impact. As such, with 50 per cent or more of e-products going to foreign destinations (and rapid increases in export levels annually), foreign impacts are also significant, and increasing.

It is also important to note that even though a majority of the social and environmental impacts occur within China, the responsibility for these impacts is largely borne by the international community in the following ways: as the principal consumer of Chinese e-products, as home to the majority of OEMs responsible for the design and marketing of e-Products and as the source of significant amounts of e-waste redirected to China at the end-of-life stage of the product cycle. Given this context, it will be critical that the Chinese government work hand-in-hand with the international community in addressing China's sustainability challenges in the sector.

Although there are a wide range of options available for the Chinese government in its efforts to ensure that the growing e-product sector contributes in the most positive manner possible to national and global well being, the Chinese government needs to focus its leadership on creating change where the greatest impact can be generated for the lowest cost. Fundamentally, the basic criterion of "cost-efficiency" suggests an overarching preference for initiatives that: 1. leverage existing initiatives and investment, and 2. establish a foundation for the integration of best practice *within the market structure*. Based on these two broad parameters, we recommend the Chinese Government focus its efforts in the e-product sector in the form of a three-pronged strategy consisting of the establishment of:

1. A National Sustainable E-Product Growth Strategy
2. A National E-waste Strategy
3. An International Action Plan on the Responsible Trade and Disposal of E-Waste.

## Recommendations

***Recommendation 1: National Sustainable E-Product Growth Strategy.* The Chinese government should launch a "National Sustainable E-Product Growth Strategy" explicitly aimed at stimulating "green" economic growth in the e-product sector through investment and innovation for sustainable e-product design and production practices.**

The Chinese government has adopted an explicit strategy for developing the e-product export economy. One component of this strategy has been in the form of attractive tax benefits for companies involved in e-product and component manufacture. The spectacular growth of China's role at this stage of the e-product chain over the past decade is a testament to the impact that combined fiscal support and market demand can have in the reorientation of the Chinese economy. The orientation of fiscal incentives towards verifiable "good practice" at the production stages of the supply chain could help China strengthen its role in the international market by transitioning China from its current position as global leader in e-product production to one as the global leader of *green* e-product production. The following sub-recommendations outline the core elements of a "National Sustainable E-Products Growth Strategy":

> ***Recommendation 1.1:*** *Fortify national eco-design legislation:* The Chinese government should improve the consistency, and strengthen the implementation infrastructure, of its existing e-product eco-design legislation. The government should also establish detailed guidelines and targets for its existing eco-design legislation. A comprehensive review of existing legislation should form the basis of further legislative efforts.
>
> Existing Chinese e-product policy and legislation, at this point, remains very general and typically is not accompanied by effective implementation systems and resources. Since 2002 the Chinese government has explicitly referred to the need for "eco-design" in a variety of laws including the Clean Production Promotion Law (2002), The Administrative Measures on the Control of Pollution Caused by Electronic Information Products (2006) and The Technical Policy on Pollution Prevention and Control of Waste Electrical and Electronic Products (2006), but without providing any systemic guidance for enabling the application of this principle across the e-product sector. The establishment of a clearer infrastructure, including the establishment of a "national institute for eco-design," could help leverage existing legislation towards more substantive results.
>
> ***Recommendation 1.2:*** *Fiscal support for eco-design and eco-production:* The Chinese government should provide preferential tax rates to products that comply with internationally recognized eco-design standards. Industry coalitions and associations within the Special Export Zones should be given targeted support to stimulate sustainable e-product design and production.

At present, the combined taxes and charges on e-products at the national level is estimated to be approximately 3.2 per cent, as compared with tax rates of between 15 per cent and 25 per cent for other industrial goods produced in China. By directing the preferential fiscal treatment in the e-product sector toward design and practice that is recognized and verified as environmentally preferable (e.g., consistent with standards for best practice), the Chinese government can help ensure that new investments and innovations lead to the growth of a green e-product sector.

***Recommendation 1.3:*** *Investment support for eco-design:* The Chinese government should establish a fund dedicated to eco-design research and development. The Chinese government should establish and sponsor a "national institute" for eco-design.

In addition to generalized fiscal incentives, China should establish a publicly funded national institute for eco-design as a means to providing a consistent knowledge base for innovation and competitiveness in eco-design. In order to stimulate sector-wide innovation for eco-design, the Chinese government should also establish an eco-design research fund accessible to the private sector under specific conditions.

***Recommendation 1.4:*** *Building the market for eco-design products:* The Chinese government should strengthen the implementation of the Chinese Energy Label by expanding product coverage and by linking requirements to international Energy Star labelling system

Significant environmental impacts are associated with the use phase of e-products. The establishment of the Chinese Energy Label in 2005 offers consumers and policy-makers the ability to selectively promote energy efficiency through their purchases, and therefore provides a direct mechanism for linking the market with public policy objectives. However, at present, the Energy Label only applies to a select group of white appliances and is not recognized by the public on a broad scale. As such, there is considerable need for broadening the scope of coverage of the label and overall publicity of the label. Additionally, in the interests of efficiency and building markets internationally as well, efforts should be made to establish mutual recognition/harmonization between the China Energy Label program and the international Energy Star Program.

***Recommendation 1.5:*** *Building the market for preferable production practices:* The Chinese government should expand and strengthen the implementation of its Procurement of Environmentally Labelled Products Policy by setting and monitoring mandatory percentage-based targets for sustainable e-product procurement.

The Chinese government is the single largest consumer of e-products within China and, as such, has a direct role to play in stimulating market recognition and growth towards environmentally sound production practices. The current policy requires that priority be given to environmentally labelled products but there is no system for obliging or ensuring the policy objectives are met. The government should, to the extent possible, make eco-design and energy efficiency *requirements* in public purchases of e-products wherever possible. As a complement to a system of obligatory eco-purchasing requirements, a comprehensive system for monitoring the volumes of eco-labelled products (including e-products) purchased by the government should be established.

***Recommendation 2: National e-waste strategy.*** **The Chinese government should implement a comprehensive National Strategy for the Responsible Collection and Treatment of E-Waste based on increased transparency and coherence across existing e-waste management legislation and programs as well as the drafting of new legislation to fill existing e-waste management gaps.**

The Chinese government has recently taken on a wide range of measures to regulate and limit the impacts associated with growing e-waste generated within the country and e-waste imported from abroad. Currently, regulatory development in the management of e-waste is left to individual departments based on their respective mandates and functions without adherence to any coherent plan or strategic agenda.[49] Moreover, there is an acute lack of robust, up-to-date information on the levels of domestic and imported e-waste at the national level. The resulting patchwork of legislation has led to incomplete e-product coverage in key waste regulations[50] and inconsistent definitions and principles for pollution control across regulations.[51] In order to improve efficiency and generate the economies of scale necessary for substantive action at the national level, the government should

[49] Environmental management of e-waste in China is currently regulated by, among others, the NDRC, the Ministry of Science and Technology, the Ministry of Information Industry, MOFCOM, SEPA, the General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) and the General Administration of Customs (GAC)

[50] *The Administrative Measures on the Control of Pollution Caused by Electronic Information Products*, for example, only covers electronic information products, leaving a wide range of electrical products outside of its scope. Similarly, the imminent *Regulation on the Management of Waste Electrical Household Appliances Collection and Treatment,* currently being formulated by NDRC only covers collection and treatment of select waste electrical products.

[51] For example, *The Technical Policy on Pollution Prevention and Control of Waste Electrical and Electronic Products* adopted by SEPA in 2006 specifies a principle of "Polluter Pays" (meaning both producers and users pay), whereas the pending *Regulation on the Management of Waste Electrical Household Appliances Collection and Treatment* specifies the principle of "Producer's Responsibility," holding only "producers" responsible for waste electrical household appliances.

adopt a common, interdepartmental strategy and implementation plan for the management of e-waste. The following sub-recommendations outline specific elements related to the implementation of National E-Waste Strategy.

**Recommendation 2.1:** *Fortify the existing e-waste legal framework:* The Chinese government should facilitate and support the set-up of a legal framework for e-waste management and define the role of all stakeholders, in particular the role of the e-product manufacturers, importers, distributors and consumers, and of e-waste collectors, dismantlers and recyclers.

The Chinese government has developed a growing body of legislation to deal with the growing e-waste management problem facing the country. Because e-waste legislation is being developed and managed by different branches of government, causing inconsistency and lack of clarity about its application to different stakeholders, there is a deep need to review and consolidate existing legislative frameworks for managing responsible e-waste management.

**Recommendation 2.2:** *E-waste finance scheme:* The Chinese government should facilitate the establishment of a secure financing scheme for managing and maintaining a sound and safe end-of-life system for e-waste.

The Green Box Program, originally established by the mobile phone industry in 2005, has grown from an original implementation based in 10 cities to implementation in 36 cities at present. The rapid growth of the initiative demonstrates the potential of industry-led activities in the e-product sector more generally, but particularly of promoting responsible e-waste collection and treatment at the national level. At the same time, the Green Box Program faces significant constraints on its further growth due to the absence of the appropriate incentives for the private sector and consumers in participation. The Chinese government should explore the development of explicit financial incentives to stimulate responsible private sector and consumer e-waste management.

**Recommendation 2.3:** *E-waste treatment quality assurance scheme:* The Chinese government should implement a comprehensive e-waste treatment quality assurance scheme. The scheme should be consist of a licensing and auditing system that builds on international e-waste collection and treatment standards. Licensing under the scheme should be made dependent upon regular reporting as well as a demonstration of sustainable handling and treatment practices. Employment of low skilled workers in the currently informal, but highly efficient, e-waste collection scheme should be maintained as much as possible.

Currently, China has a highly developed e-product collection and dismantling system that has developed as part of the informal economy. E-products are currently gathered by individual waste collectors who then transport the goods to one or another waste collection and dismantling centre. Although this system provides a relatively efficient means for the collection and treatment of e-waste, at present, it is entirely unmonitored and, as such, operates as a vast source of illegal processing activity. Establishing a licensing system for collectors and dismantlers could allow the government to leverage the existing private infrastructure for waste collection towards more effective monitoring and enforcement without jeopardizing the efficiency of the sector or the well-being of those who depend upon it for their livelihoods.

***Recommendation 2.4:*** *Improve clarity and impact of existing e-waste import rules:* The Chinese government should establish a set of national guidelines for the identification of e-waste imports. This should be complemented with additional technical assistance resources for customs officials in the implementation of China's official ban on e-waste imports. The Chinese government should also revise its existing rules for related (non-prohibited) e-waste and e-waste fractions imports to take better account of actual product make-up and toxicity levels.

At present, Chinese law prohibits the importation of e-waste, however the definition of e-waste is drawn along broad boundaries which do not actually allow for the most positive environmental outcomes. For example, while the importation of CRT glass from CRT monitors could, if performed in responsible manner, enable significant reductions in the impacts of CRT televisions by reducing the need for new materials, it is currently prohibited under Chinese law. At the same time, the importation of plastic housings containing brominated flame retardants (sourced from e-products) would not qualify as "e-waste" and therefore are permitted to enter China notwithstanding the known health hazards associated with flame retardants. A more targeted set of rules and guidelines could help customs officials, traders and waste management authorities implement more efficient recycling of e-products at the global level while simultaneously limiting the dangers of particularly dangerous e-waste fractions. As a starting point, the government should establish a set of national guidelines for the identification e-waste imports. This should be complemented with additional technical assistance resources for customs officials in the implementation of the ban as well as a review of the implementation rules associated with the ban.[52]

***Recommendation 2.5:*** *Building an information base for improved management of e-waste:* The Chinese government should implement a national system for gathering and compiling data on the quantities and sources of domestic and imported (both legal and illegal) e-waste.

[52] According to custom and quarantine inspection rules, quarantine inspection officials at the border do not have the authority to inspect the goods before custom inspection; while-waste import laws require a quarantine inspection to take place before custom clearance. This inconsistency can prevent proper inspection prior to entry. Additionally, Chinese criminal law is ambiguous with respect to the specific punishment for waste smuggling.

The most basic challenge facing regulatory officials and policy makers in the development and implementation of sound e-waste policy is the absence of sound data on the quantities and sources of e-waste. A starting point for the implementation of a more harmonized approach to e-waste management at the national level should be through established through a common database for gathering information on e-waste generation and distribution. In order to enable the collection of such information, it will likely be necessary to establish basic control points on the informal e-waste sector (see Recommendation 2.3 above).

***Recommendation 3: International action plan for sustainable e-waste management.* The Chinese government should work with the international community toward the establishment of an International Action Plan for the Responsible Trade and Disposal of E-Waste.**

The Basel Convention on the Control of the Trans-boundary Movement of Hazardous Waste and their Disposal was adopted in 1989 with a view to preventing economically motivated hazardous waste dumping from richer to poorer countries. The Convention, which currently has 169 signatories, prohibits cross-boundary trade in hazardous wastes, including toxic e-waste. Notwithstanding this general prohibition, an estimated 1.5 to 33 million tonnes of e-waste are imported to China annually through the illegal black market without any formal monitoring or management practices in place. Part of the challenge facing more robust management of the e-waste trade and disposal at the international level revolves around the need for clearer rules on what constitutes "environmentally sound management" of e-waste at all stages of the reverse supply chain. Another challenge relates to the incomplete coverage of the Basel Convention itself (e.g., not all countries are signatories and the role of companies in its implementation is often unclear). The ongoing illegal trade in hazardous e-waste represents a serious threat to the health of not only Chinese workers and communities but the global community more generally. The Chinese government should promote the establishment of a clear, standards-based framework for the sustainable management and monitoring of e-waste trade and disposal by leading the establishment of an international action plan. The following sub-recommendations outline core elements in the development of such an action plan.

***Recommendation 3.1*:** *International dialogue:* The Chinese government, in collaboration with the United Nations Environment Programme and the Basel Convention Secretariat, should support a major international conference to launch an international dialogue on an International E-waste Action Plan with a view to improving compliance rates with the Basel Convention guidelines and obligations.

Notwithstanding the existence of a ban on the trade of hazardous e-wastes both within

China and across the 169 ratifying members of the Basel Convention more generally, a significant amount of e-waste continues to be imported into China for treatment. Although much the trade is due to loopholes in different legal systems (e.g., the U. S. is not a signatory to the Basel Convention; some e-waste products enter China under a different name), a large degree of the trade is performed illegally through bribes and corruption. The continued survival of the illegal trade in e-waste relies on poor international cooperation at the implementation stages of their respective e-waste regulations and policies. In order to eliminate the presence of illegal e-waste trade, the Chinese government should join forces with the United Nations Environment Programme and the Basel Convention Secretariat to sponsor a high profile international conference for developing joint strategies for improved management of e-waste trade.

***Recommendation 3.2***: *International E-waste Treatment Standard: As* a starting point for enabling improved private sector management of e-waste, the Chinese Government should work with the international community in the establishment of an international standard for the environmentally sound management of e-waste.

At the sixth and eighth meetings of the Conference of the Parties of the Basel Convention, the importance of environmentally sound management (ESM) of the end-of-life e-products was recognized. It was also acknowledged at those meetings that no common definitions currently exist for implementing a transition to ESM at the international level.[53] By establishing clear, objective ground rules for ESM through a standards-building process linked to the Basel Convention, Chinese authorities could secure a common reference point for their own efforts towards the implementation of improved e-waste management while also generating efficiencies with respect to market requirements related to e-waste management. Given China's prominence in the treatment of e-waste at present, the Chinese government has both the potential and the responsibility to lead such discussions to establish an international ESM standard for e-waste.

***Recommendation 3.3:*** *Harmonized implementation of e-product treatment legislation:* The Chinese government should launch an international process aimed at harmonizing the implementation procedures for diverse Waste from Electrical and Electronic Equipment (WEEE) and Restriction of Certain Hazardous Substances (RoHS) regulations in order to reduce Chinese compliance costs and improve overall supply chain efficiency.

[53] At present, the principle mechanism under the Convention is embodied within the Basel Ban Amendment, adopted in 1995, which prohibits all exports of hazardous wastes from Parties that are member states of the EU, OECD and Liechtenstein to all other Parties to the Convention. A voluntary certification system could allow for a more precise, facility-by-facility identification of suitable destinations for e-waste shipments.

All of the major markets, as well as other markets for Chinese electronic goods, have adopted regulatory measures to control pollution from such products. The EU and Japan have the most stringent laws on WEEE, which require mandatory take-back mechanisms while also restricting the use of hazardous substances in electronics products for sale in the respective markets. Although both Canada and the United States have relatively weak e-product legislation at the federal level, provincial and state regulations (cf. California) can be as demanding as (or more demanding than) their European counterparts. The considerably diverse regulatory regimes in EU, Japan, the Unites States, Canada and other markets and their different legal and administrative requirements have created great challenges for Chinese suppliers and inefficiencies in international supply chains.[54]

Given that the vast majority of e-product regulations seek to achieve the same basic objectives, there is no reason, in principle, why different regimes cannot establish systems of mutual recognition for compliance with one or another alternate standard. In order to facilitate this process, the Chinese government should lead an international dialogue aimed at identifying ways in which the implementation and conformity assessment processes across different national regimes can be harmonized and simplified.

***Recommendation 3.4***: *Global private sector partnership:* Building on, and working with, existing multi-stakeholder e-waste partnerships, such as The Mobile Phone Partnership Initiative, The Global Knowledge Partnerships in E-waste Recycling, The Global Computer Refurbishment and Recycling Partnership; and, The Solving the E-waste Problem: A Synthetic Approach Initiative, the Chinese government, in collaboration with the United Nations Environment Programme, should facilitate a global multi-stakeholder, supply chain-based approach to monitoring and managing trade in e-waste.

The complexity of the e-products and their supply chains necessitates close cooperation along supply chains for effective integration within the highly dynamic production processes. At the same time, inter-firm cooperation on issues related to sustainable development can help spread the research and related investment burdens across the sector as a whole. Moreover, as brands become increasingly linked to supply chain practices, there is a growing awareness and concern among OEMs and other players about the final social and environmental consequences of their products.

As such, multi-stakeholder and multi-firm processes represent a key asset and strategy for leveraging supply chain actors efficiently towards improved practices. Currently a number of such processes exist including: The Mobile Phone Partnership Initiative, The Global Knowledge Partnerships in E-waste Recycling, The Global Computer Refurbishment and

[54] Currently there are 25 different transpositions and interpretations of the key EU directives alone.

Recycling Partnership and The Solving the E-waste Problem: A Synthetic Approach Initiative. Currently, these initiatives remain entirely voluntary and lack appropriate *economic incentives* to create significant infrastructural change. The Chinese government should, in collaboration with existing multi-stakeholder partnerships, establish a new international partnership among private sector actors aimed at preventing the illegal trade of e-waste into China. The partnership should also inform the development of standards for the responsible trade and treatment of e-waste (see recommendation 3.2 above).

## References


Auswärtiges Amt (AA). (2005, May 31). *Bericht des Generalkonsulats Kanton vom 31.05.2005 zur Sonderwirtschaftszone Shenzhen.* Report of the Consulate General of the Federal Republic of Germany in Guangzhou on the Shenzhen Special Economic Zone.

Alpermann, B. (2004). Dimensionen sozialer Probleme in der VR China – regionale und sektorale Facetten. In Kupfer, K. (Ed.): *"Sprengstoff China?" Dimensionen sozialer Herausforderungen in der Volksrepublik.* Essen: Schriftenreihe des Asienhauses, No. 17.

BCRC (2005). *Investigation on E-waste import and soundly environmental management in China.* Beijing, Regional Center for Basel Convention: BCRC.

Bridgen, K., Labunska, I., Santillo, D. and Allsopp, M. (2005). *Recycling of electronic waste in China and India: Workplace and environmental contamination.* Amsterdam: Greenpeace International.

Bridgen, K., Labunska, I., Santillo, D. and Walters, A. (2007). *Cutting edge contamination: A study of environmental pollution during the manufacturing of electronic products.* Amsterdam: Greenpeace International.

Catholic Fund for Overseas Development (CAFOD). (2003). *Clean up your computer: Working conditions in the electronic sector.* London: CAFOD.

Chan, A. (2006, October 12). *Made in China: Wal-Mart unions.* Retrieved March 21, 2007 from YaleGlobal: http://yaleglobal.yale.edu/display.article?id=8283.

Center, N. I. (2005). *Month Report for Traffic and Transportation in China.*

Cheung, D. and Welford, R. (2005). Is child labour on the increase in China? *CSR Asia Weekly, 1*(45).

China Labour Bulletin. (2005, April 22). More than 10,000 striking workers at Japanese-invested Wal-Mart supplier firm in Shenzhen demand right to set up their own trade union. *China Labour Action Express, 55.* Retrieved October 28, 2008 from: www.china-labour.org.hk/en/node/8499.

China Labour Bulletin. (2006, May 30). *Survey report on child labour in China.* Retrieved June 1, 2006 from: www.china-labour.org.hk/public/contents/article?revision%5fid=38181&item%5fid=38180.

China Post. (2007). *Union set up in Foxconn plant in southern China.* Retrieved march 21, 2007 from: www.chinapost.com.tw/news/archives/business/200713/99059.htm.

Choi, B.-C., H.-S. Shin, H.-S., Lee, S.-Y. and Hur, T. (2006). Life cycle assessment of a personal computer and its effective recycling rate. *International Journal of Life Cycle Assessment, 11*(2), 122–128.

Cody, E. (2005, August 10). China grows more wary over rash of protests. *Washington Post*.

Custom, C. (2005). *Trade Statistics of P.R. China 2005*. Beijing.

Custom, C. (2006). *Trade Statistics of P.R. China 2006*. Beijing.

Deng, W. J., Louie, P. K. K. et al. (2006). Atmospheric levels and cytotoxicity of PAHs and heavy metals in TSP and PM2.5 at an electronic waste recycling site in southeast China. *Atmospheric Environment, 40*(36), 6945–6955.

Display. (2007). *Display search*. Retrieved August 2, 2007 from: www.displaysearch.com.

Duan, H. and Eugster, M. (2007). *Employment analysis of WEEE recycling and disposal in China*. Internal working paper of EMPA. St. Gallen: EMPA.

Materials Science and Technology Research Institute (EMPA). (2007). *E-Waste Guide*. Retrieved October 28, 2008 from: http://ewasteguide.info.

Eugster, M. and Fu, H. (2004). *E-waste assessment in P.R. China: A case study in Beijing*. Swiss e-Waste Programme. St. Gallen: EMPA - Materials Science and Technology.

Foreign Investment Advisory Service (FIAS). (2007). *Corporate social responsibility in China's information and communications technology (ICT) sector*. UNEP.

Forum. (2007). *WEEE Forum*. Retrieved July 30, 2007 from: www.weee-forum.org.

Frost, S. (2005). China view: A roundup of stories making the Chinese press last week. *CSR Asia Weekly*, *1*(20).

Frost, S. (2006a, March 30). Gold Peak, cadmium and "grey babies." Retrieved May 18, 2006 from: www.csr-asia.com/index.php?p=6098.

Frost, S. (2006b). China view: A roundup of stories making the Chinese press last week. *CSR Asia Weekly*, *2*(17).

Frost, S. (2006c): Is land acquisition a supply chain issue? *CSR-Asia Weekly, 2*(13).

Goedkoop, M. and Spriensma, R. (2000). *Eco-indicator 99: A damage orientated method for life cycle impact assessment*. Methodology Report. Amersfoort: PRé Consultants.

Grießhammer, R., Buchert, M., Gensch, C.-O., Hochfeld, C., Manhart, A. and Rüdenauer, I. (2007). *PROSA – Product Sustainability Assessment*. Freiburg: PROSA.

GWMR (2005). *Waste electrical and electronic equipment (WEEE): Innovating novel recovery and recycling technologies in Japan.* G. W. M. Report.

Handfield, R. B., Ragatz, G. L., Petersen, K. J. and Monczka, R. M. (2002). Involving suppliers in new product development. *California Management Review, 42*(1), 59–82.

Hayes, K. and Burge, R. (2003). *Coltan mining in the Democratic Republic of Congo: How tantalum-using industries can commit to the reconstruction of the DRC.* Cambridge: Flora & Fauna International.

He, W., Li, G. et al. (2006). WEEE recovery strategies next term and the WEEE treatment status in China. *Journal of Hazardous Materials, 136*(3), 502–512.

Hess, W. (2007). Critical Eye on Guangdong: China's powerhouse shows its soft underbelly. Retrieved March 29, 2007 from China Business Review: www.chinabusinessreview.com/public/0703/criticaleye.html.

Hicks, C., Dietmar, R. and Eugster, M. (2005). The recycling and disposal of electrical and electronic waste in China: Legislative and market responses. *Environmental Impact Assessment Review, 25*(5), 459–471.

Hikwama, B. P. (2005). *Life cycle assessment of a personal computer.* Faculty of Engineering and Surveying. Southern Queensland: University of Southern Queensland.

Hischier, R., Wäger, P. et al. (2005). Does WEEE recycling make sense from an environmental perspective? The environmental impacts of the Swiss take-back and recycling systems for waste electrical and electronic equipment (WEEE). *Environmental Impact Assessment Review, 25*, 525–539.

Huang, P., Zhang, X. et al. (2006). Survey and analysis of public environmental awareness and performance in Ningbo, China: A case study on household electrical and electronic equipment. *Journal of Cleaner Production, 14*(18), 1635–1643.

Huo, X., Peng, L., Xu, X., Zheng, L., Qiu, B., Qi, Z., Zhang, B., Han, D. and Piao, Z. (2007). Elevated blood lead levels of children in Guiyu, an electronic waste recycling town in China. *Environmental Health Perspectives, 115*(7). Retrieved October 28, 2008 from: http://www.ehponline.org/members/2007/9697/9697.html.

IDC. (2007). *IDC market intelligence.* Retrieved August 2, 2007 from: www.idc.com.

International Labour Organization (ILO). (2007). *The production of electronic components for the ICT industries: Changing labour force requirements in a global economy.* Report prepared for discussion at the Tripartite Meeting on the Production of Electronic Components for the ICT industries: Changing Labour Force Requirements in a Global Economy. Geneva.

Jinhui, L., Baoguo, T., Tongzhou, L., Hao, L., Xuefeng, W. and Shun'ichi, H. (2006). Status quo of e-waste management in mainland China. *Journal of Material Cycles and Waste Management, 8,* 13–20.

LaDou, J. (2006). Occupational health in the semiconductor industry. In Smith, T., Sonnenfeld, D. A. and Pellow, D. N. (Eds.), *Challenging the Chip: Labour rights and environmental justice in the global electronics industry* (pp. 31–42). Philadelphia: Temple University Press.

Leong, A. and Pandita, S. (2006). "Made in China": Electronic workers in the world's fastest growing economy. In Smith, T., Sonnenfeld, D. A., Pellow, D. N. (Eds.). *Challenging the Chip. Labour rights and environmental justice in the global electronics industry* (pp. 55–69). Philadelphia: Temple University Press.

Leung, A., Wei Cai, Z. et al. (2006). Environmental contamination from electronic waste recycling at Guiyu, Southeast China. *Journal of Material Cycles and Waste Management, 8*, 21–33.

Leung, A. O. W., Luksemburg, W. J. et al. (2007). Spatial distribution of polybrominated diphenyl ethers and polychlorinated dibenzo-p-dioxins and dibenzofurans in Soil and Combusted Residue at Guiyu, an Electronic Waste Recycling Site in Southeast China. *Environmental Science and Technology, 41*(8), 2730–2737.

Li, J., Tian, B. et al. (2006). Status quo of e-waste management in mainland China. *Journal of Material Cycles and Waste Management, 8*, 13–20

Liu, C. (2005). Occupational diseases in China: The hidden blight. *CSR Asia Weekly, 1*(20).

Luo, Q., Cai, Z. W. et al. (2007). Polybrominated diphenyl ethers in fish and sediment from river polluted by electronic waste. *Science of The Total Environment, 383*(1–3), 115–127.

Liu, X., Tanaka, M. et al. (2006). Electrical and electronic waste management in China: Progress and the barriers to overcome. *Waste Management Research, 24*(1), 92–101.

Luo, Q., Wong, M. et al. (2007). Determination of polybrominated diphenyl ethers in freshwater fishes from a river polluted by e-wastes. *Talanta, 72*(5), 1644–1649.

Maass, H. (2006, August 15). Neue Stimmen in den Billig-Fabriken. *Badische Zeitung.*

Manhart, A. and Grießhammer, R. (2006). Social impacts of the production of notebook PCs: Contribution to the development of a Product Sustainability Assessment (PROSA). Freiburg.

Maskus, K. E., Dougherty, S. M. and Mertha, A. (2005). Intellectual property rights and economic development in China. In Fink, C. & Maskus, K. E. (Eds.), *Intellectual property and development: Lessons from recent economic research* (pp.295–332). Washington: IBRD/World Bank.

Messner, D. and Humphrey, J. (2006). Self-serving giants in a multipolar world. *D+C, 5.*

Nationmaster. (2007). Nationmaster.com. Retrieved August 2, 2007 from: www.nationmaster.com.

National Bureau of Statistics of China (NBSC). (2005). *China Statistical Yearbook 2005*. Beijing: NBSC.

National Bureau of Statistics of China (NBSC). (2006). *China Statistical Yearbook 2006*. Beijing: NBSC.

Pecht, M. (2007). *China's electronics industry: The definitive guide for companies and policy makers with interests in China.* Norwich, U. S.: William Andrew Publishing.

Ping, H. and Shaohua, Z. (2005). *Internal migration in China: Linking it to development.* Paper prepared for the Regional Conference on Migration and Development in Asia. Lanzhou, China, 14-16 March 2005.

PRé Consultants. (1999). SIMAPRO 7.0. P. C. Amersfoort, The Netherlands PRé Consultants.

Puckett, J. and Smith, T. (Eds.) (2002). *Exporting harm: The high-tech trashing of Asia.* Basel Action Network & Silicon Valley Toxics Coalition. Seattle.

PricewaterhouseCoopers (PwC). (2004). *China's impact on the semiconductor Industry.* PwC

PricewaterhouseCoopers (PwC). (2007). *China's Impact on the Semiconductor Industry* (2006 update). PwC.

Qifai, H., Qi, W., Lu, D., Beidou, X. and Binyan, Z. (2006). The current situation of solid waste management in China. *Journal of Material Cycles and Management, 8*, 63–69.

Qu, W., Bi, X. et al. (2007). Exposure to polybrominated diphenyl ethers among workers at an electronic waste dismantling region in Guangdong, China. *Environment International, 33*(8), 1029–1034.

Rochat, D., Hagelüken, C., Keller, M. and Widmer, R. (2007). *Optimal recycling for printed wiring boards (PWBs) in India: Recovery of materials and energy for resource efficiency*. Davos, Switzerland: Umicore.

Scharnhorst, W., Hilty L. M. et al. (2006). Life cycle assessment of second generation (2G) and third generation (3G) mobile phone networks. *Environmental International.*

Students and Scholars against Corporate Misbehaviour (SACOM). (2006). *An investigative report on labor conditions of the ICT industry: Making computers in South China.* Hong Kong: SACOM.

Schipper, I. and de Haan, E. (2005). *CSR issues in the ICT hardware manufacturing sector.* SOMO ICT Sector Report. Amsterdam.

Swiss Foundation for Waste Management (SENS). (2007). Annual Report 2006. Zurich, Switzerland: SENS.

SEPA (1999). *Environmental management—Life cycle assessment—Principles and framework*. S. E. P. o. Administration. GB/T 24042-1999.

SEPA (2000). *Environmental management—Life cycle assessment—Goal and scope definition and inventory analysis*. S. E. P. o. Administration. GB/T 24042-2000.

SEPA (2002). *Environmental management—Life cycle assessment—Life cycle impact assessment*. S. E. P. o. Administration. GB/T 24042-2000.

SEPA (2003). *Environmental management—Life cycle assessment—Interpretation*. S. E. P. o. Administration. GB/T 24042-2003.

Seungdo, K., Taeyeon, H. and Overcash M. (2001). Life cycle assessment: Study of color computer monitor. *International Journal of Life Cycle Assessment 6*(1), 35–43.

Steiner, S. (2004). Risk assessment of e-waste burning in Delhi, India. Zurich & St. Gallen, Switzerland: Swiss Federal Institute of Technology (ETH), Materials Science and Technology Research Institute (Empa).

Sun Yat-sen University (Anthropology) and Greenpeace China. (2003). *Anthropological report on electronic waste disposal industry in Guiyu*. Shantou, China.

Süddeutsche Zeitung (SZ). (2007, February 7). China hängt die USA ab. Schon 2008 avanciert das Land zum Export-Weltmeister. *Süddeutsche Zeitung*.

Tekawa, M., Miyamoto, S. et al. (1997). Life cycle assessment: An approach to environmentally friendly PCs. U. S.: IEEE.

Terazono, A., Murakami, S., Aba, N., Inanc, B., Moriguchi, Y., Sakai, S. et al. (2006). Current status and research on E-waste issues in Asia. *Journal of Material Cycles and Waste Management, 8*, 1–12.

Transparency International (TI). (2002). *Transparency International Bribe Payers Index 2002*. Retrieved March 29, 2007 from: www.transparency.org/policy_research/surveys_indices/bpi/bpi_2002/complete_report_bpi_2002.

Tong, X. and Wang, J. (2004). Transnational flows of E-waste and spatial patterns of recycling in China. *Eurasian Geography and Economics, 45*(8), 608–621.

Torres, G. (2005, June 21) *ECS factory tour in Shenzhen, China*. Retrieved October 13, 2005 from Hardware Secrets: www.hardwaresecrets.com/printpage/169.

UBS Global Asset Management. (2005). Arbeitsstandards in China. *SRI Newsletter,* 3.

UNEP Life Cycle Initiative. (2006). *Feasibility study: Integration of social aspects into LCA*. UNEP.

Wang, D., Cai, Z. et al. (2005). Determination of polybrominated diphenyl ethers in soil and sediment from an electronic waste recycling facility. *Chemosphere, 60*, 810–816.

Weidenhamer, J. D. and Clement, M. L. (2007a). Widespread lead contamination of imported low-cost jewelry in the US. *Chemosphere, 67*(5), 961–965.

Weidenhamer, J. D. and Clement, M. L. (2007b). Leaded electronic waste is a possible source material for lead-contaminated jewelry. *Chemosphere, 69*(7), 1111–1115.

Widmer, R., Oswald-Krapf, H., Sinha-Khetriwal, D., Schnellmann, M. and Böni, H. (2005). Global perspective on e-waste. *Environmental Impact Assessment Review, 25*, 436–458.

Widmer, R., Eugster, M. and Streicher-Porte, M. (2007, April 24). *Social impacts of WEEE-recycling in China.* St. Gallen, Switzerland.

Wilde, J. and de Haan, E. (2006). *The high cost of calling: Critical issues in the mobile phone industry.* Amsterdam: SOMO.

Willliams, E. D., Ayres, R. U. and Heller, M. (2002). The 1.7 kilogram microchip: Energy and material use in the production of semiconductor devices. *Environmental Science and Technology, 36*(24), 5504–5510.

Willmann, K. (2006). Der Chemieunfall von Songhua und das Potenzial für soziale Proteste. *China Aktuell, 1*.

Winkelmann, C. (2004). AIDS in China: Eine selbstgemachte Epidemie? In Kupfer, K. (Ed.): *"Sprengstoff in China?" Dimensionen sozialer Herausforderungen in der Volksrepublik. Focus Asien.* Essen: Schriftenreihe des Asienhauses.

Wong, M. H. (2006, June 7). Sources, fates, and environmental and health effects of persistent toxic substances from e-waste recycling in Southeast China. Presentation prepared for the Sino Swiss Scientific Workshop, Dübendorf.

Wong, C. S. C., Duzgoren-Aydin, N. S. et al. (2007). Evidence of excessive releases of metals from primitive e-waste processing in Guiyu, China. *Environmental Pollution, 148*(1), 62–72.

Wong, C. S. C., Wu, S. C. et al. (2007a). Trace metal contamination of sediments in an e-waste processing village in China. *Environmental Pollution, 145*(2), 434–442.

World Trade Organisation (WTO). (2002): *International trade statistics 2002*. Geneva: WTO.

World Trade Organisation (WTO). (2003): *International trade statistics 2003*. Geneva: WTO.

World Trade Organisation (WTO). (2004): *International trade statistics 2004*. Geneva: WTO.

World Trade Organisation (WTO). (2005): *International trade statistics 2005*. Geneva: WTO.

World Trade Organisation (WTO). (2006): *International trade statistics 2006*. Geneva: WTO.

Xianbing, L. and Masaru, T. Y. M. (2006). Electrical and electronic waste management in China: Progress and barriers to overcome. *Waste Management Research, 24*: 92–101.

Xinhua News Agency. (2007, February 12). Eight dead in South China factory fire. Retrieved February 23, 2007 from: www.china.org.cn/english/China/199847.htm .

Yang, P. (2006). Rise of China and the cross-strait relations. *Tamkang Journal of International Affairs, 9*(4), 1–32.

Yoshida, A. (2005). China: The world's largest recyclable waste importer. In Kojima, M. (Ed.), *International Trade of Recyclable Resources in Asia.* Chiba, Japan: IDE-JETRO.

Yu, X. Z., Gao, Y. et al. (2006). Distribution of polycyclic aromatic hydrocarbons in soils at Guiyu area of China, affected by recycling of electronic waste using primitive technologies. *Chemosphere, 65*(9), 1500–1509.

Zhao, G., Xu, Y. et al. (2007). PCBs and OCPs in human milk and selected foods from Luqiao and Pingqiao in Zhejiang, China. *Science of the Total Environment, 378*, 281–292.

Zhao, G., Xu, Y. et al. (2007). Prenatal exposures to persistent organic pollutants as measured in cord blood and meconium from three localities of Zhejiang, China. *Science of the Total Environment, 377*, 179–191.

Zhongse Institute. (2002). *Impact analysis and forecasting on metal recycling in Yangtze River Delta.* Beijing: Beijing Zhongse Institute of Secondary Metals.