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# GREEN ICT: A STRATEGY FOR SUSTAINABLE DEVELOPMENT OF CHINA'S ELECTRONIC INFORMATION INDUSTRY

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**ABSTRACT**

Under the national strategy of "let informatization drive industrialization, and let industrialization promote informatization", China's electronic information industry (also referred to as the ICT industry) has achieved continuous and dramatic development during the last three decades. It has now become one of the most essential pillar industries for China's national economy. However, severe pollution issues and environmental challenges emerge at different stages throughout the lifecycle of ICT products (e.g. desktop PCs, laptops, monitors, and TVs), from their design, development, and manufacturing to use and to disposal. Evidence shows that much effort has been put to increase industrial profit margin, improve indigenous innovation, and overcome the negative effects of the 2008 financial crisis on China's electronic information industry. Nevertheless, environmental issues have traditionally received less attention from industrial manufacturers and users of ICT products (e.g. CEOs, managers and employees of companies, and individual citizens). China is still in its infant stage in building up a green ICT industry. This paper discusses and highlights the importance and impacts of current environmental challenges faced by the electronic information industry. Subsequently, it proposes the implementation of Green ICT as a key strategy to ensure environment friendly use of ICT equipments, as well as to maintain sustainable development of China's ICT industry in the long term.

## 1. INTRODUCTION

Ever since China's reform and opening up started in the late 1970s, Information Technologies (IT) and Information and Communication Technologies (ICT) have been perceived by the Central Government as "an important driving force for the economic and social development" in the country[1]. Moreover, in the Sixteenth Central Committee of the Chinese Communist Party (CCP) in 2002, the government launched the national strategy of "let informatization drive industrialization, and let industrialization promote informatization"[2]. This national strategy reinforces the importance and critical role of IT towards achieving industrialization and modernisation in China.

The electronic information industry, or also known as the ICT industry, primarily consists of two fundamental sectors, namely the manufacturing industry for designing and producing ICT products and accessories (e.g. desktop PCs, laptops, tablet PCs, DVD-ROM drives, monitors, printers, scanners, mobile phones, and TVs), and the software industry that includes the design, development, implementation and maintenance services of computer software and information systems. As the backbone for the development of informatization and building an information society in China, the electronic information industry is considered by the State Council as "a strategic, fundamental and pioneering pillar industry of the national economy"[1].

With substantial political and financial support from the government, China's electronic information industry has achieved rapid and continuous development during the last 30 years. Especially since entering the 21st century, its manufacturing output value increased from RMB 755 billion in 2000 to RMB 4456

[1] "Planning on Adjusting and Revitalising the Electronic Information Industry", General Office of the State Council, available at: http://www.lawinfochina.com/display.aspx?lib=law&id=7420&CGid=. [22 May 2011]
[2] "China's Informatization Development During the 10th Five Year Plan", General Office of the State Council, available at: http://www.china.com.cn/chinese/PI-c/1254081.htm [18 May 2011]

billion in 2009, which accounts for more than 8% of the total of the national manufacturing industry[3]. On the other hand, sales of the software industry has also increased dramatically, from RMB 76 billion in 2001 to RMB 1336.4 billion in 2010, which represents an average annual growth of 38%[4].

However, this apparent success of the sector and the increasing use of ICT-related products in the society raised significant environmental issues that can threaten long-term development of the electronic information industry. In particular, the production of ICT products are in fact very energy intensive (e.g. it is estimated that producing a desktop computer with a 17-inch CRT monitor will consume 6400 megajoules of total energy and 260kg of fossil fuels)[5]. On the other hand, the use of many ICT products will not just consume electricity but more importantly will also lead to carbon dioxide ($CO_2$) emissions, e.g. the use of every desktop PC can lead to 0.1 tonne of $CO_2$ emissions per year[6] (Please note that, electricity is generated using fossil fuels, and thus there is a $CO_2$ emissions issue in using ICT products. If renewable sources are used, e.g., solar or wind power, ICT equipment can be used without $CO_2$ emissions). Considering that China manufactures thousands of millions of ICT-related products each year, the associated environmental impacts and pollution problems are particularly striking. Moreover, when this enormous amount of ICT products come to the end of their lifecycle, the disposal of these products leads to further environmental challenges.

When much attention has been paid to increase industrial profit margin, improve indigenous innovation, and mitigate the negative effects of the 2008 financial crisis on China's ICT industry, the above environmental issues have not received sufficient considerations from industrial manufacturers and users of ICT products (e.g. CEOs, managers and employees of companies, and individual citizens). This paper thus provides an analysis and discussion on current environmental challenges faced by China's electronic information industry. It aims to make Chinese policy makers, industrial manufacturers, and commercial and home users become more aware of crucial environmental problems emerged as a result of the production and increasing use of ICT products in the Information Age[7].

The paper is structured as follows. The next section provides a brief history on the development of informatization in China, followed by a review of the government's development plans for the ICT industry as well as an overview of the *status quo* of this industry. Subsequently, the paper discusses a set of environmental issues raised during the manufacturing, use and disposal of ICT products. It then proposes the use of Green ICT as a possible solution and strategy to handle these environmental challenges. Finally, the paper reviews successful Green ICT experience in the West, together with a discussion of potential difficulties and barriers for implementing Green ICT in China, with conclusions and recommendations given.

## 2. DEVELOPMENT OF INFORMATIZATION IN CHINA

The history of China's informatization development can be traced back to the 1970s, when the country called for using computers in supporting government administrative activities[8]. In 1980s, a number of information systems development projects were launched and completed in twelve key sectors of the national economy, such as civil aviation, banking, electricity supply, national postal service, and railway[8]. The building of China's national information highway was started in 1993, when the government launched the Golden Bridge Project. This national project aims to form a nationwide network, which links together all discrete and diverse networks across the country and thus serves as the backbone of China's national

[3] "China Statistical Yearbook" in 2001 and 2010, National Statistical Bureau, available at: http://www.stats.gov.cn/english/statisticaldata/yearlydata/ [19 April 2011]

[4] "Status Quo of China's Software Industry in 2010", Ministry of Information Industry, available at: http://www.cobsq.com/Html/xxjs/201104/1325.html [26 April 2011]

[5] Williams, E. "Energy Intensity of Computer Manufacturing: Hybird Assessment Combin9ing Process and Economic Input-Output Methods". *Environmental Science & Technology*, 38 (2004): 6166-6174. Available at: http://www.scribd.com/doc/4183/Energy-Intensity-of-Computer-Manufacturing [10 April 2011]

[6] "What is Green Computing", *RK Incoporation*, available at: http://kanthinc.com/green/gtech2.html [09 April 2011]

[7] The Information Age (or also commonly known as the Information Era or Digital Age), refers to the phenomenon that with the use of IT, individuals in the 21st century can transfer information more easily and freely, and can get instant access to knowledge that would have been difficult or even impossible to locate before.

[8] Chen, X. "The Ideas and Practices of Promoting E-government in China" (paper presented at the Asia E-government Forum, 2007), available at: http://unpan1.un.org/intradoc/groups/public/documents/apcity/unpan039695.pdf

information infrastructure. As a result of the Golden Bridge Project, China built up a modern information network that covers more than 2000 cities in the country and links to all major international networks in the world by the early 2000s[9].

Associated with the development of this national information network, the number of Net Citizens (i.e. users of the Internet) in China has grown up year by year (Figure 1). According to the official data provided by the China Internet Network Information Center[10], in October 1997, China only had 0.62 million of Net Citizens, and only 0.3 million of PCs could be used to get access to the Internet. However, by the end of 2005, the number of Net Citizens and the number of PCs with Internet access grew to 111 million and 49.5 million respectively. By July 2010, the number of Net Citizens reached 420 million, which accounted for 31.8% of the Chinese population. In addition, Chinese Net Citizens are no longer just using traditional desktop PCs to get access to the Internet. A larger number of them are in fact also using their wireless laptops (36.8%) and mobile phones (65.9%) to browse the Web. With this popularisation rate of Internet usage, China has now become the largest Internet-using country in the world – well ahead of the US.


**Fig. 1.** Net citizen scale and popularisation rate in China
*Source:* China Internet Network Information Center, 2010

Apart from the above achievements, the results of informatization development in Chinese companies are also very remarkable. In particular, all Chinese large-size firms nowadays have computer facilities and company websites. For small and medium-sized enterprises (SMEs), 94.8% of them have been equipped with PCs, and 43% have built their own company webpages, by the end of 2010. Moreover, and according to CCW Research[11], IT investments of China's manufacturing sector reached RMB 24.5 billion in 2004, of which 61% were put on hardware and IT infrastructure building and 39% were spent on information systems development and IT services outsourcing. A more recent survey report of CCW Research[12] shows that IT investments of the manufacturing sector increased to RMB 52.9 billion in 2010.

Overall, such rapid development of informatization in China results in a very high national demand for ICT products in both organisational and individual levels. In order to meet this increasing national demand of ICT equipment, as well as to accelerate the progress of national informatization and industrialization, the Chinese government has provided very substantial support in developing the domestic ICT industry.

## 3. A BRIEF REVIEW OF GOVERNMENT SUPPORT TO THE ELECTRONIC INFORMATION SECTOR

Ever since the 1980s, the government has formulated and implemented a wide range of industrial programs and policies in supporting and promoting the development of the ICT industry, although only a few

[9] China Economic Yearbook Editing Committee. *China economic yearbook* (Beijing: China Economic Yearbook Press Office, 2004).
[10] "Statistical Reports on the Internet Development in China", China Internet Network Information Center, available at: http://www.cnnic.net.cn/en/index/0O/02/index.htm [23 March 2011]
[11] Zuo, W. "Informatization of Manufacturing Sector Became Increasingly Prevalent in 2005" (in Chinese), 2005, available at: http://www.people.com.cn/GB/paper 53/13867/1238567.html [18 May 2011]
[12] "IT Investments of the Manufacturing Sector Reached RMB 52.9 billion in 2010 ", CCW Research, available at: http://www.donews.com/it/201102/371478.shtm [20 May 2011]

can be named here. As one of the significant examples, the National High-Tech Research and Development Program (also known as the 863 Program)[13], which was launched in March 1986, specifically highlighted the electronic information industry as one of China's prioritised development sectors. Moreover, in the various Five-Year Development Plans[14], China has continuously placed the ICT industry at the top of the national development agenda.

Most of these policies/programs call for special government funds to be assigned and used to support indigenous research and development (R&D) of core technologies and products in the electronic information industry[15]. In particular, a major fund operated by the Chinese government in this sector is the 'Development Fund for the Electronics and Information Industry' (or also known as the IT Fund), which was established in 1986. From 1986 to 2010, the IT Fund supported a total of 3,909 R&D projects with RMB 8.02 billion[16].

Moreover, in relation to the above government development programs, there is a list of tax benefits and incentives available to China's ICT companies, including income tax exemption and reduction, VAT rebate and exemption, and preferential tariff treatment. For example, China's software companies can enjoy a full income tax exemption for the first two years after they start to make profits, followed by a 50% tax reduction for the next three years. It is clear that all these tax incentives can help to increase profit margin of ICT companies in China.

In 2008, the global economic crisis hit hard on the international market and China's national economy. As a result of this financial crisis, in the second half of 2008, China's export growth rate of ICT products slowed down considerably. Sales income of many subsectors in the electronic information industry showed a significant decrease and even a negative growth rate. Many leading domestic companies in the sector also reported operational and financial difficulties. In response to these severe challenges, in April 2009, the State Council released a new Revitalising Plan for the Electronic Information Industry 2009-2011. This revitalising plan provides a set of development guidelines in seven key areas, namely increasing national demand of electronic information products, increasing state investment and policy support, improving investment environment, supporting mergers and acquisitions, exploring further the international market, and enhancing indigenous innovation[17].

As a result of these political and financial supports from the government, China's electronic information industry have achieved very dramatic and remarkable development in the last three decades, as further discussed in the next section.

## 4. THE STATUS QUO OF CHINA'S ELECTRONIC INFORMATION INDUSTRY

As introduced earlier, China's electronic information industry contains two essential components, namely the manufacturing sector of ICT products and the software industry.

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[13] "China's National High-Tech Research and Development Program, also known as the 863 Program, emerged in 1986 as a response to the growing technological and innovation gap between China and the West […] The main objectives of the 863 Program are to fund technological research and innovation in areas of strategic importance to the nation's economic and social development", quoted from Thornley, B., Wood, D., Grace, K. and Sullivant, S. "Impact Investing: A Framework for Policy Design and Analysis", 2011, available at: http://www.pacificcommunityventures.org/insight/impactinvesting/report/13-High_Tech_R&D_Program.pdf .

[14] China's Five-Year Plans are a series of economic development indicators. Each plan sets the blueprint, strategies and targets for national economic development for a period of 5 years. China is currently implementing its 12th Five-Year Plan for 2011-2015.

[15] Stewart, T.P. "China's Industrial Subsidies Study: High Technology", 2007, available at: http://www.uscc.gov/researchpapers/2008/TLAG%20Study%20-%20China's%20Industrial%20Subsidies%20High%20 Technology.pdf [12 April 2011]

[16] "The IT Fund led to Remarkable Results in Developing the Electronic Information Industry During the 11th Five-Year Plan", *China Electronic News*, available at: http://news.cena.com.cn/important/2011-06-24/130887472557733.shtml [14 May 2011]

[17] "Planning on Adjusting and Revitalising the Electronic Information Industry", General Office of the State Council, available at: http://www.lawinfochina.com/law/displayModeTwo.asp?id=7420&keyword [12 March 2011]

As the world's leading manufacturer and assembler of ICT products, in 2009 China produced 182.2 million units of desktop PCs, 619 million units of mobile phones, 99 million units of TVs, and 41.4 billion units of integrated circuits, which respectively accounted for 60.9%, 49.9%, 48.3% and 12.9% of the total of the world[18]. Exports of ICT products grew from US$ 55.1 billion in 2000 to US$ 591.2 billion in 2010, accounting for 37.5% of China's total exports. A number of domestic ICT manufacturing companies, led by Huawei, Konka, TCL and ZTE, have become increasingly well known in the international market. Furthermore, the industrial output value of this manufacturing sector increased rapidly from RMB 583.1 billion in 1999 to RMB 4456.3 billion in 2009, which represents an average annual growth rate of 22.5% (Figure 2).

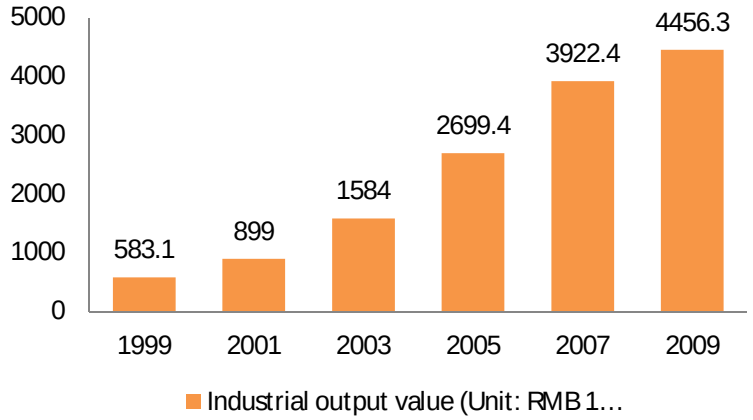


**Fig. 2.** 1999~2009 industrial output value for the manufacturing sector of electronic information products
*Source*: China Statistical Yearbook in various years

Moreover, in 2009 the ICT manufacturing sector contributed to 8.1% of the total industrial output of the national industry. As clearly shown in Table 1, this represents the highest contribution to the national industrial output value, comparing with the other pillar manufacturing sectors in China in the same year. This rapid development of the ICT manufacturing sector has also created a significant number of job opportunities in China. For instance, the number of employees of this sector reached 6.64 million in 2009, which accounted for 7.5% of the total of the national industry (Table 1).

**Table 1.** Comparison of the top 8 manufacturing sectors in China in 2009 (*Source*: China Statistical Yearbook, 2009)

| *Manufacturing sector* | *Industrial output (RMB 1 billion)* | *% of the total of the national industry* | *No. of Employees (million)* | *% of the total of the national industry* |
|---|---|---|---|---|
| ICT product manufacturing | 4,456.3 | 8.1 | 6.64 | 7.5 |
| Ferrous metals smelting and manufacturing | 4,263.6 | 7.8 | 3.23 | 3.7 |
| Transport equipment manufacturing | 4,173.0 | 7.6 | 4.98 | 5.6 |
| Chemical material and chemical product manufacturing | 3,690.9 | 6.7 | 4.40 | 5.0 |
| Electrical machinery and equipment manufacturing | 3,375.8 | 6.2 | 5.35 | 6.1 |
| General purpose machinery manufacturing | 2,736.2 | 5.0 | 4.87 | 5.5 |
| Non-metallic mineral product manufacturing | 2,484.4 | 4.5 | 5.09 | 5.8 |
| Textile manufacturing | 2,297.1 | 4.2 | 6.17 | 7.0 |
| *Total of the top 8 manufacturing sectors* | *27,477.3* | *50.1* | *40.73* | *46.1* |

[18] "Bluebook of Informatization: Analysis and Forecast on China's Informatization", available at: http://www.gov.cn/jrzg/2010-08/19/content_1683939.htm [23 May 2011]

On the other hand, the software industry as an emerging sector has also been playing an increasingly important and strategic role to the national economy. Sales of China's software industry increased dramatically from RMB 59.3 billion in 2000 to RMB 583.4 billion in 2007, which showed an annual growth rate of over 30%. This sales figure also accounted for 8.7% of the world's total in 2007, and made China become the fourth largest IT market in the world[19]. In 2010, the sales revenue of the software industry reached RMB 1330 billion, which represented 18% of the total sales of China's ICT industry. The number of employees engaged in the software industry also increased significantly from 300,000 in 2000 to 2 million in 2010[20].

Overall, given these high contributions to the national economy, China's electronic information industry is widely perceived as the No. 1 pillar industry of the country[21]. However, such high-speed growth of the ICT industry and the increasing use of ICT products in the Chinese society have also led to a set of crucial environmental issues. Although the central government is aware of these ICT-related polluting problems and are attempting to deal with them, the results are still to be seen. Moreover, given the size and the fluid situation of the country, these environmental challenges are actually very difficult to handle.

# 5. GREEN CHALLENGES OF THE ELECTRONIC INFORMATION INDUSTRY

It is widely recognised that the use of ICT tools can help to address environmental problems by improving production efficiency, reducing unnecessary production waste, and enhancing production control. However, environmental issues caused by the increasing use of ICT products have not been well reported. This section highlights the current level of China's CO2 emissions, and then provides a critical discussion on how the manufacturing, use and disposal of ICT products can increase CO2 emissions in China.

## 5.1 China's Increasing $CO_2$ Emissions and Government Commitment

Official statistics provided by the Netherlands Environmental Assessment Agency showed that, in 2005 China's $CO_2$ emissions were 2% lower than the emissions of the US[22]. However, in 2006 the $CO_2$ emissions of China have surpassed those of the US by 8%. China has since then become the world's largest $CO_2$ emitting country. Since 2006, China's $CO_2$ emissions have kept going up rapidly. Further statistics provided by the U.S. Energy Information Administration show that, the $CO_2$ emissions of China reached 7,711 million tonnes in 2009, which were larger than the total of US, India and Canada, and were up by 171% since the year 2000[23].

Faced with severe environmental threats, China has recently taken significant steps to reduce polluting emissions. In particular, in 2007 China released its first national strategy on climate change, namely China's National Climate Change Program[24]. This plan, in conjunction with China's 11th and 12th Five-Year Plan, aims to reduce the country's $CO_2$ emissions substantially by improving energy efficiency, upgrading energy-

[19] "China's Software Industry Reached RMB 583.4 billion", Ministry of Industry and Information Technology, available at: http://www.ce.cn/cysc/tech/07ityj/guonei/200806/12/t20080612_15807641.shtml [12 April 2011]

[20] "China's Software Industry Strives to Reach RMB 3000 billion in Sales by 2015", *Xinhua News*, available at: http://www.xinhua08.com/news/cyjj/201103/t20110322_404359.html [17 May 2011]

[21] Gou, Z. "Innovation in China's Electronic Information Industry", *China Communications*, 2006, available at: http://unpan1.un.org/intradoc/groups/public/documents/APCITY/UNPAN027039.pdf [08 May 2011]

[22] "China now no.1 in $CO_2$ emissions, USA in second position", Netherlands Environmental Assessment Agency, 2007, available at: http://www.pbl.nl/en/dossiers/Climatechange/moreinfo/Chinanowno1inCO2emissionsUSAinsecondposition [26 May 2011]

[23] "World carbon dioxide emissions data by country: China speeds ahead of the rest", *Guardian*, available at: http://www.guardian.co.uk/news/datablog/2011/jan/31/world-carbon-dioxide-emissions-country-data-co2# [12 March 2011]

[24] Leggett, J.A., Logan, J. and Mackey, A. "China's Greenhouse Gas Emissions and Mitigation Policies", CRS Report for Congress, 2008, available at: http://www.fas.org/sgp/crs/row/RL34659.pdf [12 July 2011]

saving technologies, and expanding low-carbon energy supply[25]. China's committed target is to reduce its $CO_2$ emissions per unit of GDP by 40 to 45 percent below 2005 levels, by 2020[26].

## 5.2 An Industrial Dilemma: Will ICT Reduce or Increase $CO_2$ Emissions?

Under the above environmental threats, it is widely perceived that ICT is one of the most important tools for China to achieve its committed targets of reducing $CO_2$ emissions and building a low-carbon society. In fact, the adoption of ICT technologies (e.g. computerized information systems) has significantly transformed the legacy systems of China's manufacturing companies. Such ICT-enabled transformation has resulted in better production control and monitoring, more efficient resource management, better transportation and logistic management, less energy waste, and less polluting emissions across the whole industry of the country[25]. It was estimated that, for every kilowatt-hour (kWh) of electricity devoted to ICT, an average of 10 kWhs of electricity are saved in the overall economy[27].

However, although ICT does have the potential to save energy by making other processes more energy efficient, rebound effects may counteract this positive outcome[28]. Rebound effects are empirically known to work against energy/resource usage efficiency in energy economies. One of the most crucial rebound effects related to ICT is that, the increasing use of ICT products at work and at home has led to significant increase in carbon footprint of the ICT sector. Gartner (a very well-known international IT consulting firm) estimates that the global ICT industry is responsible for 2% of the world's $CO_2$ emissions – a figure equivalent to the aviation industry[29]. In China, it was estimated that $CO_2$ emissions of the domestic ICT industry accounted for 2.4% of the country's total in 2007[30]. It is also estimated that by 2020, the ICT industry will produce 415 million tones of $CO_2$ emissions, which represent 3.0%-3.3% of China's total emissions. This increasing amount of $CO_2$ emissions of the ICT industry in the world in general, and in China in particular, is attributed to a wide range of pollution issues that can occur during manufacturing, transporting, using and disposing ICT products[31].

Specifically, and as also discussed earlier, the production of many ICT products and related components are very resource- and energy-intensive. For example, a study of the United Nations University found that, the manufacturing process of a desktop PC with 17 inch monitor requires the use of 1.8 tons of total materials and natural resources, including 240 kilograms of fossil fuels, 22 kilograms of chemicals, and 1,500 kilograms of water (this amount of resources is equivalent to those required to produce a mid-size vehicle)[32].

Moreover, a report from the European Commission identified that the average amount of electricity consumed by a laptop is about 97.34kWh per year[33]. This amount of power consumption can result in 38.94kg of $CO_2$ emissions[23]. The total $CO_2$ emission of a desktop PC with a 17-inch monitor was even

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[25] Gao, D. "Green ICT and Green Industrial Development in China", 2011, available at: http://www.itu.int/ITU-D/asp/CMS/Events/2011/ITU-MIIT/S2.1.pdf [15 March 2011]

[26] "Reducing Transport Greenhouse Gas Emissions: Trends & Data 2010", OECD and International Transport Forum, available at: http://www.internationaltransportforum.org/Pub/pdf/10GHGTrends.pdf [30 May 2011]

[27] "Green IT: The Best Practices Collection 2010", Green IT Promotion Council, available at: http://greenit-bestpractice.jp/common/pdf/bp2010_en.pdf [23 June 2011]

[28] Hilty, L. M., Köhler, A., Von Schéele, F., Zah, R. and Ruddy, T. "Rebound Effects of Progress in Information Technology". *Poiesis & Praxis: International Journal of Technology Assessment and Ethics of Science*, 4 (2006): 19-38

[29] Gartner "Gartner Estimates ICT Industry Accounts for 2 Percent of Global $CO_2$ Emissions", *Gartner Press Release*, 2007, available at: http://www.gartner.com/it/page.jsp?id=503867 [16 March 2011]

[30] Zadek, S., Forstater, M., Yu, K. and Kornik, J. "ICT and Low Carbon Development in China", Report for Digital Energy Solutions Campaign (DESC), 2011, available at: http://www.zadek.net/wp-content/uploads/2011/05/DESC-paper_ICT_Low-Carbon-Development-in-China_01052011.pdf [09 July 2011]

[31] James, P. and Hopkinson, L. "Sustainable ICT in Further and Higher Education: A Report for the Joint Information Services Committee (JISC)", 2009, available at: http://www.jisc.ac.uk/media/documents/publications/ rptgreenictv1.pdf [15 July 2011]

[32] Hoang, A., Tseng, W., Viswanathan, S. and Evans, H. "Life Cycle Assessment of a Laptop Computer and its Contribution to Greenhouse Gas Emissions" (paper presented at the 8th World Congress of Chemical Engineering, Quebec, Canada, 23-27 August 2009).

[33] "Personal Computers (Desktops and Laptops) and Computer Monitors", European Commission, available at: http://extra.ivf.se/ecocomputer/downloads/EuP%20Lot%203%20Task%201-7,%20draft%20report.pdf [21 April 2011].

estimated to be 0.1 tonne per year[34]. Given the fact that China manufactured 182.2 million units of desktop PCs and 150 million units of laptops in 2009, the amount of $CO_2$ emissions during the production and use of these ICT products would be enormous.

Furthermore, with increasing consumer demands for new functionality, the lifecycle of ICT products has nowadays become much shorter. When these ICT products come to the end of their lifecycle, their disposal and recycle are also fraught with problems and difficulties. In particular, it is common knowledge that ICT products in fact contain a various set of harmful and toxic substances (such as lead and mercury). Therefore, the recycling process of these products will be very complicated and energy-intensive. More importantly, rather than being properly collected and recycled, many ICT products may very often just be dumped in landfills, e.g. 92% of obsolete laptops ended up in landfills and only 8% got recycled in the US[35]. Worse of all, most discarded and toxic electronic waste (e-waste) from developed countries has been shipped overseas to Asian developing countries, e.g. China and India. It is estimated that 70% of e-waste in the world has been illegally imported to China every year[36]. Plus 2.3 million tonnes of e-waste generated domestically[37], China has been facing very significant environmental threats.

# 6. GREEN ICT: STRATEGY FOR A SUSTAINABLE ICT LIFE CYCLE

It is clear from the above discussion that, when ICT is a key tool to be used to reduce carbon footprint, the ICT industry itself is also a significant source of polluting emissions. Therefore, building an environment-friendly ICT industry is not just imperative for sustainable development of this sector, but is also of crucial importance to meet goals of energy saving and environment improvement of the overall economy in the long term. Consequently, 'Green ICT' emerges in recent years as a holistic strategy to achieve these objectives.

## 6.1 Main features of Green ICT

Green ICT is a strategy that can be implemented across the entire lifecycle of ICT products, from design and development, to use, and to disposal of ICT equipment. It aims to achieve green and sustainable use of ICT in the information society, and thus helps reduce the 2% of global $CO_2$ emissions generated by the electronic information industry. As a fairly new concept emerged in the West, it is hard to find a universally accepted definition of Green ICT. In order to capture the rich meaning and all essential aspects of this term, by considering the definition given by Murugesan[38] and Elliot[39], this paper defines Green ICT as:

> The strategy and practice for designing, producing, using and disposing ICT products and related components and accessories, in an efficient and environmental-friendly manner, to minimise harmful effects and achieve sustainable use of ICT in the long term.

When coming into actual practice and implementation, Green ICT covers a wide range of collaborative activities, which can be divided into the following four main categories:

- *Green design of ICT*. In terms of green design, ICT technologists, designers and developers should explore innovative designs and technologies for maximising energy efficiency and minimizing

[34] "What is Green Computing", *RK Incoporation*, available at: http://kanthinc.com/green/gtech2.html [02 July 2011]
[35] Matthews, S.H. and Matthews, D.H. "Information Technology Products and the Environment", in *Computers and the Environment: Understanding and Managing their Impacts*, eds. Kuehr, R. and Williams, E. (Kluwer Academic Publishers: Dordrecht, Netherlands, 2003).
[36] "70% of Electronic Waste in the World has been dumped in China", *Xinhua News*, available at: http://news.xinhuanet.com/fortune/2006-12/04/content_5429353.htm [15 October 2010]
[37] "UNEP: China will be the Main Source of E-waste", *ChinaTechNews*, available at: http://www.chinatechnews.com/2010/02/25/11623-unep-china-will-be-the-main-source-of-e-waste-this-year [28 June 2011]
[38] Murugesan, S. "Harnessing Green IT: Principles and Practices", *IEEE IT Professional*, 10 (2008): 24-33.
[39] Elliot, S. "Environmentally Sustainable ICT: A Critical Topic for IS Research?" (paper presented at the 11th Pacific Asia Conference on Information Systems, Auckland, New Zealand , 4-6 July 2007).

environmental impact of ICT products. One of such examples is 'Energy Star' qualifying computers. The Energy Star program was released by the United States Environmental Protection Agency (EPA) in 1992 and was then revised in 2006. According to the revised requirements of the program, all Energy-Star qualifying PCs are designed to be 65% more power efficient than conventional ones.

- *Green production of ICT*. In terms of green production, ICT manufacturers should attempt to reduce the use of harmful substances in ICT products by investigating new alternative materials or solutions. Moreover, current production and transportation models adopted by ICT manufacturers may be reviewed, evaluated and improved in order to reduce power consumption and carbon footprint during these processes.
- *Green use of ICT*. Modern ICT-intensive organizations (especially large and medium-sized companies across all industries, banks, universities, government institutions, and hospitals) should develop and implement a set of internal policies and initiatives to enable energy-saving and environmental-friendly use of ICT. Some basic Green ICT activities being adopted by leading global companies (e.g. Microsoft, Google, HP, GE, Toyota and Fujitsu) include:
  - setting double-sided printing as the default for all office printers (to save unnecessary paper waste);
  - encouraging video conferencing meetings across geographical locations (to reduce travel cost and related carbon footprint);
  - purchasing and using 'Energy Star' qualifying PCs and monitors (to reduce energy cost);
  - switching off building (and thus PC) power after office hour (to reduce power consumption);
  - outsourcing databases, servers, and IT applications to third-party IT firms in a cloud computing environment[40] (to reduce the number of in-house servers required and simplify the internal IT infrastructure).

  In fact, many of these practices (e.g. using double-sided printing, switching PC off when it is not in use, purchasing energy-star computers) can be implemented by not just organizations but also individual home users, in order to reduce ICT energy consumption in the whole society.
- *Green disposal of ICT*. Agreements can be established between ICT manufacturers and ICT-intensive organizations to ensure proper collection and return of obsolete ICT products for recycling. Manufacturers and distributors of ICT products may also establish certain reward schemes (e.g. offering cashback or giving discount for the next purchase) to encourage consumers to trade in any unused ICT equipment. These green disposal activities conducted by ICT manufacturers should then be acknowledged and supported by the government.

It is evident that, this wide range of Green ICT activities is concerned with a variety of stakeholders in different areas (e.g. government policy makers, ICT technologists and manufacturers, user organizations, and individual citizens). Also given the diverse causes of ICT carbon footprint, it is clear that no single endeavour will be sufficient in making a substantial effect towards improving ICT energy consumption. Therefore, in order to enable environment-friendly use of ICT, a combined and nationwide effort is required, including government support and instructions, industry-wide collaboration and cooperation, inter-disciplinary research, and extensive social awareness[41].

## 6.2 Benefits of Green ICT

The immediate benefit of implementing Green ICT is to reduce environmental impact and polluting emissions of the ICT industry. Apart from this, a holistic Green ICT strategy can in fact offer a very attractive and meaningful list of benefits at both national and organizational levels.

[40] Cloud computing refers to an emerging and innovative model for enabling convenient and on-demand access to a pool of shared computing resources (e.g., databases, servers, IT applications and services) through the Internet.

[41] Yousif, M. "Keynote: Towards Green ICT" (paper presented at the European Research Consortium for Informatics and Mathematics (ERCIM) News, 2009), available at: http://perso.ens-lyon.fr/laurent.lefevre/Documents/ERCIM_79.pdf [02 July 2011]

At the national level, successful implementation of a nationwide Green ICT strategy can substantially reduce $CO_2$ emissions, energy consumption and resource waste of the whole country. This can directly help top polluting countries, leading by China, USA and India, to achieve their committed targets of $CO_2$ reduction by 2020, as well as to improve their international images.

At the organizational level, ICT-incentive organizations can significantly reduce energy and IT cost by adopting proper Green ICT practices. For instance, it was estimated that Higher Education (HE) Institutions in the UK have a total of 1,468,000 computers, 246,000 printers, and 238,000 servers[30]. These ICT equipment are typically used for less than 40 hours a week, but are often left on for all days (i.e. 24 hours * 7 days = 168 hours per week). Consequently, the UK HE sector has to pay for an unnecessary huge ICT electricity bill of at least £116 million per year. By more intelligent use of ICT (e.g. turning off PCs, photocopiers and printers when they are not in use), it is expected that the UK HE sector can make more efficient use of their IT infrastructure and save up to 75% of its electricity cost annually. The lifetime of the hardware may also be potentially enhanced, and thus reducing IT cost of purchasing new hardware.

Other than direct cost savings, Green ICT can also offer a set of intangible benefits to organizations. In particular, the adoption of Green ICT to reduce $CO_2$ emissions will enable organizations to better fulfil their social responsibilities, as well as to improve corporate image and reputation. Employees, especially those in the west, will often show higher loyalty and satisfaction to work in an organization that has clear social and environmental commitments[42]. Moreover, being an environmentally-aware organization can also have a very positive marketing effect in increasing customer loyalty and attracting new customers.

Table 7.2 provides a summary of the key Green ICT benefits discussed above.

**Table 2.** Benefits of adopting Green ICT

| |
|---|
| *To the whole nation and society:*<br>• Lower $CO_2$ emissions;<br>• Reduce energy and resource consumption;<br>• Help to achieve national commitment of $CO_2$ reduction;<br>• Improve international image. |
| *To ICT-incentive organizations:*<br>• Reduce energy cost;<br>• More efficient use of IT infrastructure;<br>• Enhance lifetime of hardware;<br>• Fulfil corporate social responsibility;<br>• Improve corporate image and reputation;<br>• Increase employee satisfaction and loyalty;<br>• Better marketing. |

## 6.3 Green ICT programs in the US and Europe

Given the increasing international concern of ICT carbon footprint, Western countries, leading by the US and European countries, have been working closely in recent years to establish and implement a holistic set of Green ICT plans and programs which cover the entire lifecycle (i.e. design, production, use, and disposal) of ICT products.

As one of the most significant examples, the US government established and released the Energy Star program as a means to promote energy-efficient design of office ICT equipment (e.g. PCs, monitors, printers, fax machines, photocopiers, and scanners)[43]. In 2001, the European Union (EU), partnered with the US

[42] "White paper Green ICT: The Greening of Business", available at: http://www.ictliteracy.info/rf.pdf/T-SystemsWhite Paper_Green-ICT.pdf [15 August 2012]

[43] "History of energy star", *US Environmental Protection Agency*, available at: http://www.energystar.gov/index.cfm?c=about.ab_history [17 March 2012]

government, launched the EU version of Energy Star program[44]. Since then, office equipment that are specifically designed to meet the predefined energy-efficient criteria of the program, will receive the Energy-Star label in the US and European market. ICT-incentive organizations in these countries are encouraged by the government to purchase Energy-Star qualifying equipment.

In terms of production, the EU launched the Restriction of Hazardous Substances (RoHS) directive in 2003. This directive restricts the amount of use of six hazardous materials (i.e. lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, polybrominated diphenyl ether) in the production of various types of electronic and electrical products. By using the RoHS directive as a guide, all EU member states have adopted their own implementation policies and laws to restrict and control the use of toxic substances in the manufacturing of ICT equipment. On the other hand, although the USA does not currently have a federal law regulating the use of hazardous substances in ICT products, individual states have been attempting to implement their own laws related to this issue. For instance, the Electronic Waste Recycling Act (EWRA) adopted by California is generally referred to as the California RoHS.

As a complement to the RoHS directive, the EU also released the Waste Electrical and Electronic Equipment (WEEE) directive in 2003[45]. The WEEE directive enforces responsibilities for the disposal of obsolete electrical and electronic equipment on manufacturers. As a result, all ICT manufacturers in the EU are imposed to establish appropriate procedures and targets for collecting, recycling and/or reusing e-waste in an environmental-friendly manner. In the US, despite a current lack of federal law on recycling e-waste, some individual states (e.g. California) have established state-wide programs that impose manufacturers to take actions to gather and recycle disposed ICT and electronic equipment.

Apart from these directives and programs being applied to manufacturers, many EU member countries have also started implementing regulations that aim at improving energy efficiency and cutting emissions in ICT-incentive organizations in recent years. For instance, the UK government introduced the Carbon Reduction Commitment (CRC) Energy Efficiency Scheme in 2008[46]. This mandatory scheme involves all large public and private sector organizations (including all government departments, universities, hospitals, banks, supermarkets, and large manufacturing companies), which currently contribute to 10% of UK's emissions. All participants of the scheme are required to report to the government their annual energy usage and emissions, as well as to buy allowance for their $CO_2$ emissions each year (CRC allowance is planned to be sold at a fixed price of £12 per tonne of $CO_2$, from 2012). In other words, the less energy that the organization consumes, the less energy bill and less CRC allowance that the organization needs to pay. By adopting these procedures, the CRC scheme aims to encourage organizations to develop and implement energy management strategies (such as internal Green ICT strategies) to achieve better utilization of energy and thus reduce emissions and cost.

## 6.4 Green ICT in China

After reviewing the key Green ICT programs in the US and EU, this section highlights some of the recent Green ICT initiatives introduced by China, and more importantly provides a critical discussion on potential difficulties for implementing Green ICT in the Chinese context.

### 6.4.1 Chinese government's Green ICT initiatives

As one of the most prevalent topics in the world, Green ICT has attracted increasing attention of the Chinese government. By collaborating with Western partners and taking into account successful practices adopted in the West, the Chinese central government has established a set of Green ICT measures and programs in recent years.

In particular, China's Ministry of Environmental Protection (MEP) has been collaborating with the US Environmental Protection Agency (EPA) on a number of projects that help China to improve energy

[44] "Introducing EU energy star", available at: http://www.eu-energystar.org/en/index.html [29 June 2011]

[45] More information about the EU RoHS and WEEE directives is available at: http://ec.europa.eu/environment/waste/rohs_eee/index_en.htm [08 April 2012]

[46] "What is the CRC energy efficiency scheme?", *Department of Energy and Climate Change*, available at: http://www.decc.gov.uk/en/content/cms/emissions/crc_efficiency/crc_efficiency.aspx [29 February 2012]

efficiency. By learning EPA's experience on the Energy Star program, China set up a list of domestic energy-efficient standards for labelling 10 key categories of ICT products, including PCs, monitors, TVs, office copiers, and fax machines[47].

Moreover, in 2006 China released a national regulation to control the use of toxic materials in ICT equipment, namely the Administration on the Control of Pollution Caused by Electronic Information Products (also commonly called as the China RoHS)[48]. The China RoHS, which was actually put into effect in 2007, has similar functions to the EU RoHS, but also differs from the EU directive in certain aspects (e.g. the EU RoHS covers eight broad categories of products including ICT equipment, but the China RoHS focuses specifically on electronic information products[49]). This regulation is enforced to be followed by all ICT manufacturers, importers and distributors that play in the Chinese market.

In addition, the China WEEE (officially known as the Regulations on the Recycling and Treatment of Waste Electrical and Electronic Equipment), which was initially drafted in 2004 and finally revised in 2009, also started taking effect on 1st Jan 2011[50]. The China WEEE, which is a complement to the China RoHS, sets out responsibilities on various parties (e.g. ICT manufacturers, distributers, and importers) in relation to the import, recycling and disposal of waste ICT equipment.

Overall, it is clear that China's recent green effort has covered the design, manufacture and disposal phases of ICT equipment. Nevertheless, there is currently limited nation-wide regulation that aims to promote energy-efficient use of office equipment in China's ICT-incentive organizations. Although China has implemented a green public procurement program in 2004 to require all public sector organisations to purchase certified energy-efficient products, no similar regulations have been introduced to private sector organisations. Furthermore, the implementation of this green public procurement program has also been fraught with problems and challenges[51]. As mentioned earlier, large public and private sector organizations, who are heavy ICT users and energy consumers, contribute to 10% of $CO_2$ emissions in the UK. Although no similar statistics was found in China, it can be argued that given the size and number of large organizations in the country, $CO_2$ emissions of these organizations would be very high. As a result, there will be an essential need for China to introduce more schemes and regulations (e.g. a similar scheme to the UK CRC Energy Efficiency Scheme, as discussed above) to control and reduce energy consumption and polluting emissions of these ICT-incentive organizations in both the public and private sector.

### 6.4.2 Difficulties for Green ICT implementation in China

Despite substantial government effort towards improving ICT-related environmental problems, the above Green ICT programs may actually not be easily implemented in China, owing to a number of barriers existed in the current national context. This section provides a critical discussion on some of the key barriers that can affect Green ICT implementation in China, with recommendations given.

*Poor enforcement of laws and regulations*

China is rich in laws, but the implementation of these laws is not always easy. It is often criticized that double standards exist in the enforcement of some laws in China, and that over/under-enforcement is not uncommon in the country[52]. The existence of these problems can certainly threaten the effective implementation of the China RoHS and WEEE regulations. For example, it has been frequently reported that although the China RoHS has been implemented for more than four years, many domestic ICT manufacturers still have not followed the regulation to specify (in product packages) the amount of toxic substances being used in their products. Due to a lack of awareness of the regulation and inefficient monitoring of local

[47] "Cooperative activities in China", *Environmental Protection Agency (EPA)*, available at: http://www.epa.gov/international/regions/Asia/china/chinaprogs.html [12 May 2011]

[48] More information about the China RoHS is available at: http://www.chinarohs.com/ [19 June 2011]

[49] "Differences between EU and China RoHS", available at: http://www.newark.thinkhost.com/brands/promos/China_vs_EU_RoHS.pdf [23 March 2010]

[50] More information about the China WEEE is available at: http://ewasteguide.info/china-approves-e-was [16 June 2011]

[51] Qiao, Y. and Wang, C. "Issues and challenges in implementing China's green public procurement program". *Journal of Environmental Protection*, 2 (2011): 1034-1045.

[52] Pigott, C. *China in the world economy: the domestic policy challenges*. (Paris: OECD Publishing, 2002), p. 378-380.

government, many Chinese supermarkets and retailers nowadays are still selling ICT equipment and components that have not met the RoHS requirements.

This clearly indicates that related government departments (e.g. the Ministry of Environmental Protection, and the Ministry of Industry and Information Technology) must take further actions and procedures to improve enforcement of the China RoHS and WEEE regulations. There is also a need to make Chinese consumers become more aware of these Green ICT directives. By doing so, it is hope that consumers will refuse to purchase ICT equipment that do not satisfy the necessary requirements and also dispose waste ICT products in appropriate ways (e.g. return them to original manufacturers).

*Insufficient investment of ICT manufacturers on environmental-friendly technologies and processes*

In order to meet the standards and requirements of the China RoHS and WEEE, domestic ICT manufacturers need to adopt new technologies and processes to minimise the use of toxic materials in manufacturing as well as to ensure proper recycling and disposal of waste products. However, given the very hard market conditions after the 2008 global financial crisis, many Chinese ICT manufacturers (especially for those with a smaller business size) are actually struggling for survival and thus will not be ready to invest further resources in the development of new production technologies and business processes.

Therefore, when improving enforcement of the China RoHS and WEEE regulations, it is also essential for the Chinese government to provide sufficient support to help domestic ICT companies to meet the required standards. For instance, more funding schemes can be launched to support industrial projects that aim to develop new green technologies. It will also be beneficial for Chinese ICT market leaders, partnered with their counterparts in the West, to share their green production and recycling experience with smaller players in the industry. This type of industry-wide collaborate activities should be supported, and probably even initiated and organized, by the government.

*Unbalanced economic development*

It is widely acknowledged that China's industrialization and economic development manifest significant inequality between different cities and regions. Citizens in less developed and rural areas are living in relatively poor financial conditions, and thus will inevitably have less awareness of environment protection. This issue is particularly apparent in China's northwest regions (e.g. Xinjiang, Qinghai, and Ningxia) and some of the southeast regions (e.g. Guiyu in Guangdong, and Taizhou in Zhejiang), in which the majority of the people are peasants and are living in very discrete geographical areas. These local economic features make collection, disposal and recycle of ICT equipment become extremely difficult. In fact, also owing to a lack of effective legal control and monitoring, China's northwest regions have now become the country's largest base of toxic e- waste. Worse of all, due to a lack of proper recycling technologies and inefficient transportation, a huge amount of e-waste in these regions will just be dumped into landfill, which can significantly damage the local environment in the long term.

In order to improve this situation, the Chinese government should establish a set of new stimulation schemes (e.g. offering cashback or launching a trade-in program) to encourage citizens and peasants in less developed and rural areas to return their obsolete ICT products properly. It will also be beneficial for the government to invest new ICT recycling centers in the northwest regions, in order to address difficulties related to technology and local transportations.

*Lack of social awareness and interest in environment protection*

China's continuous national economic reform has significantly changed the society and business market of the country. Probably the most important change is the very serious competition factor introduced in the whole Chinese economy. Under the ever competitive national environment, individuals and organizations in contemporary China are increasingly driven by short-term and immediate economic benefits. Moreover, they may also not be fully aware of the negative impact associated with current environmental threats faced by the country. Consequently, some Chinese citizens and managers may not be interested in cooperating with the government on environment protection. This can present significant barriers and resistance in implementing Green ICT projects in Chinese firms.

Therefore, more advertisements (e.g. on newspapers and TV) need to be done to make the Chinese society become more aware of environmental impacts caused by the increasing use of ICT and people's responsibilities towards improving the current situation.

*Lack of Green ICT awareness in organizations*

Further to a lack of social awareness and interest on environmental issues, it was also identified that as a very recent concept, Green ICT has not been widely known by the Chinese society. In particular, according to a survey conducted by CIO Insight China in 2008[53], 65% of Chinese Chief Information Officers (CIOs) have not heard about Green ICT. Among the remainder 35% of Chinese CIOs, 25% stated that their organisations have not yet planned for any Green ICT projects. Interestingly, the survey also found that 48% of these Chinese CIOs have not received any information about Green ICT from their IT system and service providers. This finding clearly indicates a need for IT vendors to make a better effort in promoting Green ICT to Chinese companies. Moreover, the Chinese government should also establish further industrial schemes, by considering experience in the West (e.g. the UK CRC Energy Efficiency Scheme), to encourage large public and private sector organizations to develop proper Green ICT plans to improve their energy efficiency and reduce polluting emissions.

# 7. CONCLUDING REMARKS

China's electronic information industry is one of the most important pillar industries to the national economy. In fact, it does not just play a strategic and fundamental role in driving the country's industrialization and modernisation development, but is also of crucial importance to enable China to build an energy-saving and environment friendly society. Nonetheless, the rapid development of this industry and the increasing use of ICT products have also raised significant environmental concerns and threats to the Chinese economy. Faced with these environmental challenges, this paper proposed the use of Green ICT as a strategy to reduce pollution and carbon footprint during design, production, use and disposal of ICT products. However, although the government has made an essential effort to establish a set of Green ICT regulations, the actual implementation of these programs is still fraught with problems and difficulties. Moreover, current awareness of Green ICT in the Chinese society is still low. Given the fact that ICT-related pollution has many sources, no single effort will be sufficient in making an actual effect in improving the situation. In order to achieve sustainable and more environmental friendly use of ICT, there is a strong need for more substantial collaboration and cooperation between government policy makers, ICT manufacturers, ICT technologists, academic researchers, and Chinese CEOs and managers. To conclude, China has made an important first step, but still has a long way to go, towards developing a Green ICT industry.

[53] "Green ICT: Difficult to Implement", *CIO Insight China*, available at: http://www.cioinsight.com.cn/html/dy/2008/06/449.html [08 May 2011]