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E-WASTE IN CHINA: A COUNTRY REPORT

Authors:
Feng Wang (UNU-ISP SCYCLE)
Ruediger Kuehr (UNU-ISP SCYCLE)
Daniel Ahlquist (UNU-ISP SCYCLE)
Jinhui Li (Tsinghua University)

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Table of contents

Abbreviation

BAN	Basel Action Network
BCRC	Basel Convention Regional Centre
EEE	Electrical and Electronic Equipment
EHS	Environment, Health and Safety
EoL	End of Life
GAC	General Administration of Customs (People's Republic of China)
GDP	Gross Domestic Product
LCA	Life Cycle Analysis
MEP	Ministry of Environmental Protection (People's Republic of China)
MIIT	Ministry of Industry and Information Technology (People's Republic of China)
MOC	Ministry of Commerce (People's Republic of China)
MOF	Ministry of Finance (People's Republic of China)
MU	Million Units/Pieces (of appliances)
NDRC	National Development and Reform Commission (People's Republic of China)
NGO	Non-governmental Organization
OEM	Original Equipment Manufacturer
PWB	Printed Wiring Board
RMB	Renminbi (Official currency of China)
StEP	Solving the e-waste Problem Initiative
UNEP	United Nations Environment Programme
UNU	United Nations University
USD	US dollar (Official currency of the United States)
US EPA	Environmental Protection Agency (United States)
WEEE	Waste Electrical and Electronic Equipment

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Executive summary

As one of the world's largest exporters of electrical and electronic equipment (EEE) and importers of waste electrical and electronic equipment (e-waste) worldwide, China plays a key role in the social, economic, environmental and material life cycle of much of the world's electrical and electronic equipment. As a result of increased Chinese and worldwide consumption and turnover of EEE, China is now facing serious e-waste problems from both growing domestic generation and foreign imports. This report presents a comprehensive review of the extant e-waste problems, e-waste flows, the state of the informal and formal e-waste collection and recycling sectors, legislative progress and various stakeholders related to e-waste issues in China. Information and data sources include published national statistics, reports, research papers, project documents and expert interviews.

This report has been developed under the framework grant-agreement on e-waste cooperation between the United States Environmental Protection Agency (US EPA) and the Solving the E-waste Problem (StEP) Initiative hosted by the United Nations University (UNU). The goal of this report is to enable better understanding of the e-waste system in China, including actors, projects, policies and other factors, and to facilitate further discussion, project initiation and communication among organizations working on e-waste in China.

Chapter 2 of this report provides an overview of the quantities of major EEE put on the Chinese market and the estimated accumulation of EEE in households over time, as well as the amount of e-waste generated in China and the transboundary flows of e-waste into China. Between 1995 and 2011, the sales of the five major types of home appliances increased exponentially. In 2011 alone, 56.6 million televisions, 58.1 million refrigerators, 53.0 million washing machines, 94.8 million air conditioners and 73.9 million computers were sold in the formal market of China, along with 250 million mobile phones. Also in 2011, an estimated 1.2 million tonnes of televisions, 0.44 million tonnes of refrigerators, 0.32 million tonnes of washing machines, 0.99 million tonnes of air conditioners and 0.67 million tonnes of computers were discarded. Collectively, these five types of discarded products amounted to 3.62 million tonnes of waste in 2011. In addition to the increasing volumes of e-waste generated domestically, China is also the recipient of transboundary shipments of e-waste. The exact volumes of these import streams are difficult to quantify; however, multiple loopholes through which these transboundary e-waste flows enter China have been identified and will be discussed in this chapter.

Chapters 3 and 4 present a brief evaluation for the e-waste collection and recycling systems in China, with separate overviews of the informal and formal sectors. As of 2007, it was estimated that around 0.44 million people were engaged in informal e-waste collection, and around 0.25 million people were engaged in informal e-waste recycling. Informal recycling focuses on extracting re-use and scrap values from e-waste without environmental protection measures, emissions controls or measures to protect the health and safety of workers. Consequently, such activities have caused serious damage to local environments and the health of workers in locations such as Guiyu in Guangdong Province and Taizhou in Zhejiang Province. In contrast to the large volumes of e-waste processed in the informal sector, formal collection and recycling in China are so far limited in size and capacity. However, thanks to the "Home Appliance Old for New Rebate Program" that ran from 2009-2011 and national e-waste legislation enacted since 2011, the formal sector has shown significant growth. As a result, around 61 million major home appliances were collected and treated by the formal sector in 2011. However, the recycling capacity of the informal sector and the amount of illegally imported and treated e-waste are still not clear due to data scarcity.

Chapter 5 summarizes legislative developments related to e-waste management in China, including five key domestic policies concerning the ban on transboundary shipments of e-waste into China, principles of domestic e-waste management, restrictions on the use of hazardous materials in electronic products, licensing of formal recyclers and treatment standards, and the establishment of a national e-waste collection system and recycling infrastructure. Since 2011, China's legislative focus has been the national e-waste legislation titled "Regulations on the Administration of Recycling and Treatment of

Waste Electrical and Electronic Equipment", which attempts to formalize e-waste recycling in China by creating formal e-waste collection channels, issuing treatment licenses and providing subsidies to the formal sector. The analysis of the policy framework implies that explicit policy targets and strong enforcement on the part of local governments are essential to achieving these defined administrative objectives.

Chapter 6 introduces two national pilot projects that sought possible solutions to the problem of formalizing e-waste treatment systems in China. The "National Pilot on e-waste Collection and Recycling", a project developed by the National Development and Reform Commission, was conducted from 2003-2006 and focused on constructing recycling plants in four target regions. The project demonstrated that recycling facilities face significant challenges in their ability to operate regularly and efficiently without a proper collection system in place to ensure a constant supply of waste to the facilities. In order to address this issue, the "Home Appliance Old for New Rebate Program", which ran from June 2009 to December 2011, achieved notable success by providing consumers with economic incentives to turn in their household e-waste to formal collectors, who then sold the collected e-waste to designated recyclers for environmentally-responsible processing. In this program, both designated collectors and recyclers received government subsidies. Finally, this chapter briefly highlights key international collaborations, projects and agencies that provide insight and guidance for efforts to address e-waste issues in China.

Chapter 7 provides a system map of the relevant stakeholders in e-waste management in China. The central government is in the pivotal position to regulate, manage and coordinate the collection, treatment and disposal of e-waste, while local governments are responsible for implementation. Producers provide important financial support to the formal management of the system by paying the treatment fees stipulated in the national e-waste legislation. While formal collectors and recyclers are still limited in size and remain heavily dependent on government supports and subsidies, the scope and influence of informal collectors, refurbishers and backyard recyclers is still considerable. Consumers are accustomed to selling their obsolete equipment to the informal sector and tend to use formal channels only when offered greater economic benefit. Scientific research plays an important role in the process of problem definition, impact assessment and decision making, with policymakers frequently drawing on academic scholarship in order to make informed policy decisions. Finally, cooperation from foreign governments and international organizations helps to bring state-of-the-art treatment technologies, best management practices and effective policies to China.

Chapter 8 concludes this report by identifying key research gaps and proposing a list of key steps in the effort to address China's e-waste challenges, including: 1) conducting research on the routes, trading mechanisms and quantities of transboundary flows of e-waste into China; 2) gathering data on, and developing a more accurate portrait of, e-waste flows within China, including a clearer pictures of the volume of EEE put on the market, the amount of e-waste collected and treated by the formal and informal sectors, and the scale of the market for refurbished and second-hand equipment; 3) developing a systematic assessment of the current state of e-waste treatment levels and industrial development in China, as well as approaches to improve the health and environmental conditions in the informal sector; and, 4) facilitating the transfer of best technologies and practices related to critical processes and waste streams in order to substantially upgrade and improve e-waste treatment in China.

1. Background

1.1. Goal of the study

Technological innovation, intense marketing strategies and increasing consumer demand have lead to a rapid turnover of electrical and electronic equipment (EEE) globally. As a result, large amounts of waste electrical and electronic equipment (e-waste) are generated worldwide. The high volume of e-waste streams and the hazardous substances contained therein pose serious challenges for the treatment and final disposal of e-waste.

As one of the biggest electronics manufacturing countries and emerging economies in the world, China is facing serious e-waste problems resulting from both growing domestic generation and foreign imports. China produces, consumes and exports huge amounts of EEE. In 2009, the production of major home appliances (e.g. televisions, refrigerators, washing machines, air conditioners and computers) was close to 500 million units, and the quantity of export was 240 million units, nearly 50 per cent of total production [1]. Meanwhile, China's annual domestic generation of e-waste continues to rise, with an estimated 50 million units of EEE (televisions, refrigerators, washing machines, air conditioners and computers) becoming e-waste in 2010, alone, marking a 20 per cent increase in the amount of e-waste generated annually within China [1].

Informal recycling of e-waste in China has caused severe damage to local environments and the health of unprotected workers. Because of the environmental and social concerns surrounding improper recycling of e-waste, the Chinese government has promoted relevant policies to restrict import and improper treatment of e-waste, and has established domestic collection and recycling systems in order to promote environmentally-sound treatment. Because informal and formal treatment of e-waste will continue to co-exist for the foreseeable future, it is useful to assess the present state of affairs regarding the structure, flows and management of this complex system. This overview will provide insights on how to improve the system to make it more sustainable.

In 2010, the US EPA and China Ministry of Environmental Protection (MEP), recognizing their respective countries' key roles in addressing the e-waste problem, agreed to collaborate on the management of used and end-of-life electronics as a shared environmental priority.

In an effort to benefit from global expertise and knowledge related to e-waste, the US EPA and the United Nations University (UNU), in its role as host of the StEP (Solving the E-Waste Problem) Initiative, agreed to cooperate in advancing effective management of used and end-of-life electronics in the US EPA's priority partner countries and regions. One aspect of the agreement was to convene a stakeholder dialogue in China in cooperation with MEP. The purpose of this dialogue was to shed light on e-waste management in China, to identify the roles and responsibilities of different government agencies, industry and technical institutions, and other stakeholders, and to facilitate cooperation between and among stakeholders. The meeting was designed to enable participants to share their ongoing activities related to e-waste, as well as their priorities and future goals, in order to enhance communication and avoid duplication. On 16 and 17 July 2012, the "Stakeholder Workshop & StEP Open Meeting in China" was successfully held in Beijing.

This report was prepared in advance of the stakeholder meeting by UNU and Tsinghua University to present a comprehensive review about the e-waste problems, policy, industrial development and management status, and main stakeholders in China based on existing literature and documents. It provided background information and helped to facilitate discussion at the meeting. Information and data sources referenced by this document include published national statistics, reports, research papers, project documents and expert interviews. In addition, key information presented and discussed during the meeting has also been incorporated into this document.

This report contains six chapters, including the introduction. Chapter 2 summarizes the scope of the e-waste problem in China by estimating the volumes of e-waste generated domestically and imported from other countries. Chapter 3 and 4 give an overview of the current state of collection and recycling systems in both the informal and formal sectors. Chapter 5 and 6 cover legislative developments, existing pilot projects and scientific research related to e-waste issues in China. Chapter 7 discusses and maps relevant stakeholders and their respective roles in China's e-waste system. Based on the analysis and observations in this report, Chapter 8 highlights key gaps in the literature and outlines the most urgent or essential topics for future research and development.

1.2. Country profile

The People's Republic of China (hereafter referred to as China) was established in 1949. The country's land area is approximately 9.6 million square kilometres. Based on an April 2011 national census, China's population stands at 1.37 billion – 19 per cent of the world's population – and is experiencing an annual growth rate of 0.57 per cent. While 50.32 per cent of the national population lives in rural areas, the ratio of urban residents has shown continuous growth of 13.46 per cent compared to the 2000 level [2].

Figure 1: Map of China's administrative districts

1 Map source: http://www.nationsonline.org/ ; According to the administrative districts set by the People's Republic of China, Taiwan is part of the Chinese territory.

According to the administrative division of the Chinese government, there are 23 provinces, five autonomous regions, four municipalities that are directly administrated by the central government and two special administrative regions (Hong Kong and Macau) (Figure 1). Subordinate to these primary administrative levels are smaller administrative units such as districts, prefecture-level cities, county-level cities, towns and villages etc.

In 2011, China's Gross Domestic Product (GDP) was valued at 7.298 trillion USD, making China the world's second largest economy, behind only the US. China's GDP per capita of 5,413 USD ranked 90th in the world [3]. Manufacturing is an important sector of the national economy, accounting for one-third of the country's economic output in 2009. Production of electrical and electronic equipment for both domestic and overseas markets is an indispensable part of China's manufacturing industry (12 per cent in 2009).

In 2009, the total output value of the eletrical and electronics manufacturing industry in China was 74.33 billiion RMB (11.15 billion USD) and the sales value was 70.43 billion RMB (10.56 billion USD), an increase of 85 per cent and 80 per cent, respectively, from 2005 levels. The delivery value of EEE export in 2009 was 20.08 billion RMB (3 billion USD), an increase of 33 per cent from the 2005 level. In 2008, China had 28.6 per cent share of the global EEE export market. Chinese exports of small household appliances accounted for 60 per cent of the global market, with the shares for microwave ovens, air conditioners, refrigerators and washing machines standing at 72 per cent, 54 per cent, 27 per cent and 21 per cent, respectively [4].

China has abundant mine resources, including 171 types of mines and some of the world's largest reserves of coal, iron, copper, aluminium, antimony, magnesium, tin, lead, zinc and mercury. Furthermore, China's reserves of rare earth metals are larger than the sum of all the reserves in other countries combined. This abundance of essential natural resources makes China well-positioned for the production of EEE.

The following table summarizes the key facts about China [5].

Table 1: Key facts & figures about China

ITEM	DESCRIPTION
Capitl city	Beijing
Government	Single-party state, Communist Party
Administrative divisions	23 provinces, 5 autonomous regions, 4 municipalities (Beijing, Tianjin, Shanghai, Chongqing), and 2 special administrative regions (Hong Kong and Macau)
Official language	Modern Standard Mandarin (Putonghua)
Total area	9.64 million km[2]
Population	1.37 billion (2011 census) Annual growth rate: 0.57% Men: 51.2%, Women: 48.7%; Urban population: 49.9%, Rural population: 50.1%
Population density	139.6 people/km[2] (2011)
Ethic make-up	91.5% Han Chinese, 8.5% ethnic minorities (55 recognised groups)
Official currency	Renminbi (abbrievated as RMB) 1 RMB = 0.15 US Dollars (as of Nov. 2011)
GDP nominal (2011)	7.298 trillion USD (2nd in the world)
GDP per capita (2011)	5,413 USD (90th in the world)
Emissions (2010)	COD (Chemical oxygen demand): 12.4 million tonnes SO2 : 2.18 million tonnes Industrial dust: 4.49 million tonnes Industral solid waste: 4.98 million tonnes
Municiple waste (2011)	130.89 million tonnes treated (Landfill: 76.9%; Incineration: 19.9%; Other: 3.3%)
Investment in treating industrial pollution (2011)	44.4 billion RMB Investment ratio: Waste water 35.5%; Waste gas: 47.6%; Solid waste: 7.1%; Noise: 0.5%; Other: 9.3%

[2] The data only covered mainland China, excluding Hong Kong, Macau and Taiwan

2. Sources and volumes of e-waste in China

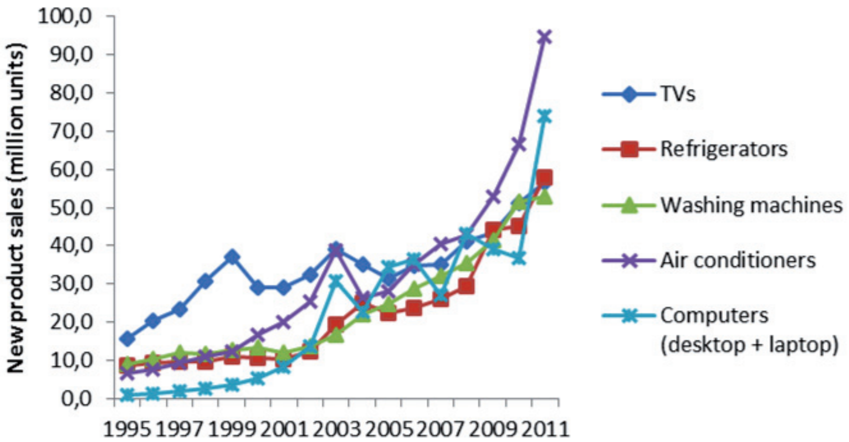
Sources of e-waste in China include both imports and domestic generation. The importing of e-waste was formally banned by the government in 2000. However, administratively invisible flows of e-waste are still thought to be finding their way into the country to meet the constant demand for cheap second-hand products and raw materials for re-manufacturing [6, 7]. Meanwhile, domestic generation of e-waste has risen rapidly as a result of technological and economic development. This section gives an overview of EEE being put on the Chinese market, EEE stocks in Chinese households, quantity of domestic e-waste and the transboundary import of e-waste into China.

2.1. Products put on the domestic market

A great variety of electrical and electronic products has been put on the domestic market in China. However, due to data availability, this report focuses only on the quantities of the major home appliances, including televisions, refrigerators, washing machines, air conditioners and computers (desktop and laptop). Figure 2 shows the historical sales data for these five products in the Chinese market. Annual sales data for these appliances are calculated by adding the total numbers of appliances manufactured domestically and the total number of appliances imported, and then subtracting the total number of domestically-produced appliances that were exported. The manufacturing data are derived from the China National Statistics Yearbooks 1996-2011 [5], while the international trade data are obtained from the United Nations Comtrade database by tracking the corresponding Harmonized System Codes for international goods shipments [8].

Between 1995 and 2011, the sales of all five types of appliances increased exponentially in China, due to such factors as increasing market demand and product availability, rising incomes and technological innovation. The sales of televisions have increased by a factor of four, reaching 56.6 million units in 2011. The sales of refrigerators and washing machines grew by an average rate of 12 per cent annually, with 58.1 and 53.0 million units, respectively, sold in 2011. The sales of air conditioners grew ten-fold, reaching 94.8 million units in 2011. Finally, computer sales grew by an average rate of 37 per cent, with sales reaching 73.9 million units in 2011. Applying the same calculation methods, the results indicate that more mobile phones were sold than any other major electrical or electronic product, with 0.25 billion units sold in 2011.

Figure 2: Sales of five major home appliances in China (1995-2011)



Although the sales data are not complete for all product types, it is generally recognized that televisions, refrigerators, washing machines, air conditioners, computers and mobile phones are the most popular products in the Chinese domestic market. As sales of these products rise, so do the stocks of such equipment accumulating in households.

Table 2 presents the penetration rates of home appliances and electronics into urban households. An estimated 690.8 million people lived in urban households in 2011, with the average urban household containing 2.87 members [5]. The 2011 data shows that the average urban household possessed 2.05 mobile phones, 1.35 colour TVs, 1.22 air conditioners, and nearly one washing machine (0.97 per household) and refrigerator (0.97 per household). Possession of most appliances increased steadily between 1990 and 2011. The products that showed the most pronounced rise in possession among urban households were mobile phones (27 per cent annual growth rate), computers (24 per cent) and video cameras/camcorders (22 per cent). The only appliance to show a decline since 2005 is the land line telephone, which can be attributed to the growth in ownership of personal mobile phones.

Table 2: Possession of home appliances and electronic equipment per urban household in China

APPLIANCE	1990	1995	2000	2005	2009	2010	2011	ANNUAL GROWTH RATE
Mobile phone	-	-	0.20	1.37	1.81	1.89	2.05	27%
Colour TV	0.59	0.90	1.17	1.35	1.36	1.37	1.35	1%
Refrigerator	0.42	0.66	0.80	0.91	0.95	0.97	0.97	2%
Washing machine	0.78	0.89	0.91	0.96	0.96	0.97	0.97	1%
Air conditioner	0.00	0.08	0.31	0.81	1.07	1.12	1.22	15%
Computer (desktop & laptop)	-	-	0.10	0.42	0.66	0.71	0.82	24%
Telephone (land line)	-	-	-	0.94	0.82	0.81	0.70	-3%
Camera	0.19	0.31	0.38	0.47	0.42	0.44	0.44	1%
Microwave oven	-	-	0.18	0.48	0.57	0.59	0.61	13%
Stereo set	0.00	0.11	0.22	0.29	0.28	0.28	0.24	1%
Video camera	-	-	0.01	0.04	0.08	0.08	0.09	22%

The penetration rates of various home appliances and electronics in rural households showed a similar rising trend, though rural households possessed fewer appliances in total than urban households. In 2011, China's total rural population was 656.6 million, with the average rural household containing 3.9 members. The five most commonly possessed appliances among rural households were mobile phones, colour TVs, telephones, washing machines and refrigerators. Only mobile phones and colour TVs were found at a rate of more than one unit per household, which indicates that there is still room for growth in the sales of most appliances in rural markets. Historically, the fastest-growing household stocks of electrical and electronic equipment have been mobile phones (45 per cent annual rise in household stocks), computers (44 per cent) and air conditioners (33 per cent) [5].

Table 3: Possession of home appliances and electronic equipment per rural household in China

APPLIANCE	1990	1995	2000	2005	2009	2010	2011	ANNUAL GROWTH RATE
Mobile Phone	-	-	0.04	0.50	1.15	1.37	1.80	45%
Colour TV	0.05	0.17	0.49	0.84	1.09	1.12	1.15	9%
Washing machine	0.09	0.17	0.29	0.40	0.53	0.57	0.63	8%
Refrigerator	0.01	0.05	0.12	0.20	0.37	0.45	0.63	18%
Air conditioner	-	-	0.01	0.06	0.12	0.16	0.23	33%
Computer (desktop & laptop)	-	-	-	0.02	0.07	0.10	0.18	44%
Telephone (land line)	-	-	0.26	0.58	0.63	0.61	0.43	5%
Camera	0.01	0.01	0.03	0.04	0.05	0.05	0.05	4%
Ventilation hood (for cooking)	0.00	0.01	0.03	0.06	0.10	0.11	0.13	17%
TV (black & white)	0.40	0.64	0.53	0.22	0.08	0.06	0.02	-29%

Both the annual sales figures and the penetration rates of home appliances (as a result of the sales) indicate that the demand for electrical and electronic appliances is rapidly increasing in China. Table 4 shows the total number of home appliances, by category, possessed in China in 2011. As the table shows, Chinese people possess nearly 800 million mobile phones, over 500 million colour TVs, nearly 230 million computers, roughly 340 million washing machines and about the same number of refrigerators.

Table 4: Total household stocks of home appliances and electronics in China in 2011 (In order of magnitude)

APPLIANCE	QUANTITY (MILLION UNITS)
Mobile phone	796.6
Colour TV	519.7
Washing machine	338.9
Refrigerator	338.9
Telephone	240.0
Computer	227.3
Camera	114.7

Eventually, when these products reach the ends of their life cycles, they will become obsolete and pose a significant challenge to China's waste management system. The following section analyzes the volume of domestically-generated e-waste over time.

2.2. Domestic e-waste generation

New electrical and electronic equipment is being produced at ever-greater rates to replace older equipment. When replaced, this older equipment will either be stocked temporarily at home or will become waste. Several publications have estimated the quantity of domestically-generated e-waste based on domestic sales data and waste disposal patterns. Table 5 summarizes estimates made in the e-waste literature of domestic e-waste generation for the year 2011.

As Table 5 illustrates, predictions of e-waste generation vary widely, likely due to variations in the scope, methods and parameters of the studies. The primary differences between these studies lie in their sources of market sales data and the probabilistic distributions of product lifespans. The estimated numbers of discarded refrigerators and washing machines are quite consistent among these studies, with average volumes of 9.8 and 12.7 million units separately in 2011. The estimated quantities of waste TVs ranged from 27.5 to 60.2 million units, with an average of 40 million units. Estimates for the number of waste air conditioners also ranged considerably, from 6.6 to 36.7 million units, with an average of 19.6 million units. Estimates of the number of waste computers generated in 2011 vary the most widely, from 22.7 to 107.9 million units, due to the parameters of their calculi (e.g. whether estimates included both laptops and desktops). The average of the estimates of waste computers generated in 2011 is 66.7 million units. Estimates for the total weight of waste appliances, by category, were made by multiplying the total number of units of waste appliances with their respective unit weights. Based on this calculus, using the average of the above estimates above, it is estimated that 1.2 million tonnes of TV became discarded in 2011, along with 0.44 million tonnes of refrigerators, 0.32 million tonnes of washing machines, 0.99 million tonnes of air conditioners and 0.67 million tonnes of computers. Overall, these five types of waste products added up to 3.62 million tonnes, and indications suggest that this number is growing steadily. Finally, the significant inconsistency between different estimations of e-waste generated suggests the need for more standardized data sources and estimation methods. It is critical to apply uniform estimation methods, reliable data sources and data validation steps to obtain accurate and unbiased results upon which future research, policy and projects can be based.

Table 5: Estimates of domestic e-waste generation in China for 2011 (millions of units discarded)

SOURCE	TVs	REFRIGE-RATORS	WASHING MACHINES	AIR CONDI-TIONERS	COMPUTERS
1. Li et al. (2005, 2006) [9-11]	**32.5**	9.7	12.8	36.7	107.9*
2. Tian (2012) [12]	**27.5**	7.6	12.1	15.4	69.5*
3. Yang et al. (2008) [13]	**60.2**	12.1	13.3	6.6	22.7
Average *(million units)*	***40***	***9.8***	***12.7***	***19.6***	***66.7****
Average weight *(kg/piece)* **Schluep et al.** (2009) [14]; **Yang et al.** (2008) [13]	**30**	45	25	51	15
Total weight *(million tonnes)*	***1.2***	***0.44***	***0.32***	***0.99***	***0.67***

* Includes both desktop and laptop computers

2.3. Transboundary shipments

Apart from the domestic generation of e-waste, a remarkable amount of e-waste is imported into China to meet the demand for second-hand equipment and for secondary resources. China now appears to be the largest e-waste dumping site in the world, receiving shipments from the US, Europe and neighbouring Asian countries, including South Korea and Japan [6, 15-17]. Despite the fact that the Chinese government banned the import of e-waste (for both domestic re-use and recycling) in 2000, large volumes of imported e-waste and second-hand EEE still flow into the country [7, 18].

According to a European Commission study, the total amount of e-waste in EU Member States in 2005 was 10.3 million tonnes[19]. Inspections of 18 European seaports in 2005 found that as much as 47 per cent of all waste destined for export, including e-waste, was illegal [20]. In the UK alone, at least 23,000 tonnes of undeclared or “grey market” electronic waste was illegally shipped to Southeast Asia, India, China and Africa in 2003. In the US, it was estimated in 2002 that 50–80 per cent of the domestic e-waste collected is not recycled domestically, but is shipped to destinations such as China [15]. This activity is legal because the US has not ratified the Basel Convention.

China banned the import of e-waste on 1 February 2000, when the State Environment Protection Administration (SEPA; later upgraded to the Ministry of Environmental Protection in March 2008) issued the Notification on the Import of the Seventh Category of Solid Wastes (No. 19), which listed e-waste as a material prohibited for import. However, no clear definition of “e-waste” was included in this regulation or any other government document. Previously, on 3 July 2002, the Ministry of Foreign Trade and Economic Cooperation, Customs General Administration and SEPA jointly issued Notice No. 25 “Catalogue of Commodities Forbidden to Import (the fourth and the fifth batch)”, which lists types of goods prohibited from being imported. The list contains 21 types of e-waste banned from being imported, including large household appliances, information and communication technologies, and consumer electronics [21]. In 2008, Notice No. 25 was replaced by the Catalogue of Solid Waste Forbidden to Import in China (Announcement No. 11, 2008) [22], which prohibited the import of waste mechanical and electronic apparatuses (including their parts, components and scraps, unless exempted by other laws). In 2009, Announcement No. 11 (2008) was replaced by Announcement No.36 (2009) on the Adjustment of E-Waste Import Management Catalogue [23], which prohibits the import of waste glass (including waste cathode ray tube (CRT) glass and radioactive waste glass), waste batteries, waste computer equipment and office EEE (printers, copiers, fax machines, typewriters, calculators, computers etc.), waste home appliances (air conditioners, refrigerators and other refrigeration equipment etc.), waste communications equipment (telephones, network communication equipment etc.) and waste electrical and electronic components (printed circuit boards, cathode ray tubes etc.).

In a July 2012 presentation, the Ministry of Environmental Protection (MEP; formerly SEPA) indicated that the illegal import of e-waste is being restrained as a result of these policies and close cooperation between the MEP and customs and quality inspection departments to enhance the effectiveness of both the monitoring of and crackdowns on illegal e-waste imports [24].

Despite of the implementation of these regulations on customs control, e-waste is still entering China through numerous channels. The following routes and means of have been identified in the literature as sources of tranboundary shipments of e-waste into China:

1) Direct shipments to Chinese ports

Due to increasingly strict customs control and the ease of identification, direct shipments of full containers of e-waste into the ports of mainland China are rare nowadays [25]. Scrap dealers and smugglers today tend to use less direct and less visible routes and means.

2) Mixed shipments with bulk steel and copper scraps

A large proportion of waste and second-hand home appliances generated in Japan and South Korea is exported to China along with other types of waste [6, 7, 26, 27]. Several metal recycling companies in Taizhou indicated in interviews that they frequently encounter components and shredded fractions from e-waste that has been blended with other types of waste (such as mixed-metal scrap, cables etc.) in the same container [28]. The ratio of e-waste in such containers tends to be around 10 per cent and is very difficult to separate because of the small and mixed shredded fractions. Furthermore, because the import of mixed-metal scrap for recycling is legal in China, it is quite difficult to determine the point at which a shipment of metal scrap mixed with e-waste is regarded as an illegal import.

3) Transit through Hong Kong

Hong Kong is a Special Administrative Region (SAR) of China. Because China is party to the Basel Convention, the Convention is also applicable to Hong Kong. According to the website of Hong Kong Environmental Protection Department (EPD), the Basel Ban was incorporated in the Waste Disposal Ordinance in April 2006 in the Laws of Hong Kong [29]. EPD is designated as the competent authority under the Convention to enforce the control on import, export and transit of hazardous waste in the Hong Kong SAR. From this perspective, it is regarded as illegal to ship e-waste into Hong Kong without notification.

However, there is a legislative difference between Hong Kong and mainland China. Under the "One Country, Two Systems" policy, China, as party to the Basel Convention, only performs customs control for mainland China. Hong Kong is responsible for implementing separate controls on the tranboundary movement of hazardous wastes. Legislation in mainland China thus does not apply to Hong Kong. As the most significant difference, China totally banned the import of e-waste in 2000, and no exception is allowed to any recycling company or organisation. However, imports of second-hand EEE and e-waste into or through Hong Kong is legal if an import license is obtained in Hong Kong [30]. Furthermore, once equipment has been imported into Hong Kong, it can then shipped to another country, including mainland China, for direct re-use, with no waste import/export permit required from the EPD [31]. This apparent loophole exists due to the legal and administrative difficulty in distinguishing between e-waste and reusable EEE, as well as different policies and control measures between Hong Kong and mainland China.

Hong Kong is a free port and a central hub in the global e-waste trading network. Once second-hand equipment has been imported into Hong Kong, it can be legally re-exported to other countries and regions, as well as into mainland China, for refurbishment and recycling. Hong Kong's border with China's Guangdong Province and the accessibility of Guangdong's inland waterways from the port of Hong Kong make possible the easy transfer of e-waste from Hong Kong into mainland China.

Much of the e-waste that makes its way into China comes from the US, Canada, the EU, Japan and other countries, though it cannot be legally defined as direct export. Based on Japanese export statistics, for example, there is hardly any documented direct export of second-hand equipment from Japan to mainland China [7]. However, there is a remarkable amount of low-value equipment identified as "second-hand" exported to Hong Kong, including 2.84 million second-hand televisions and 1.35 million computer monitors in 2005, and 541,000 second-hand air conditioners in 2006. It is likely that the majority of these second-hand appliances exported from Japan to Hong Kong are subsequently transferred to mainland China.

From 2007 to 2010, 360 illegal containers of hazardous waste were intercepted by Hong Kong customs. Most of the shipments were e-waste from the US, Canada, Japan and EU countries intended for China [32]. In 2010, 25 per cent of all illegal waste shipments from Hong Kong seized by Chinese customs contained e-waste [33]. In the same year, the Hong Kong Environmental Protection Department seized 760 tonnes of e-waste in 38 cases (45 containers), including 18 cases of notebook computer batteries, 19 cases of waste cathode ray tubes (CRT), and 1 case of mixed batteries and waste cathode ray tubes. Twenty-five of the cases came from the United States [32, 34]. Under the global concern of illegal transboundary movement of hazardous e-waste, the EPD has been exercising stringent import/export control on such waste in recent years [32]. On November 15, 2007, the Ministry of Environmental Protection (China) and Hong Kong EPD had signed the Cooperation Arrangement on Control of Waste Movements between the Mainland and HKSAR for combating illegal movements of waste.

4) Transit through Vietnam

Another route through which e-waste and second-hand EEE enter China is via a geographically-circuitous path through Vietnam. E-waste and second-hand EEE, such as discarded CRT televisions and household appliances, exported from the US and Japan enters Vietnam through the international port at Haiphong in northern Vietnam. It is then transported to the Mong Cai border gate, where it crosses the border into Dongxin, China. The e-waste and second-hand EEE is then taken to Guangzhou by truck, where it is rebuilt and then illegally exported back to Vietnam [7]. The smuggling of the rebuilt EEE between Dongxin and Mong Cai is quite simple. The EEE is simply carried over the river in small boats and unloaded at night. Second-hand home appliances smuggled from Dongxin into Mong Cai have been put up for sale in second-hand markets in northern Vietnam, including in Hanoi and Haiphong. Some of the refurbished equipment is also sold in the Chinese market [7].

It is important to note that, like China, the Vietnamese government has also banned the import of e-waste. However, a noteworthy exemption built into this ban allows for the importation of second-hand EEE for the purpose of re-export. This exemption makes it possible for China to legally import, via Vietnam, the e-waste and second-hand EEE from other countries.

The actual quantity of illegal e-waste and second-hand EEE shipped into China is difficult to estimate due to a lack of systematic accounting and first-hand investigation. Some media reports have claimed that the import of e-waste is still a growing problem in China and that the problem is spreading from Guangdong Province to other regions such as Guangxi, Zhejiang, Shanghai, Tianjin, Hunan, Fujian and Shandong. Between 1994-2007, at least 30 illegal shipments of e-waste intended for these provinces were intercepted by Chinese authorities [27].

The Beijing Zhongse Institute of Secondary Metals estimates that the amount of e-waste imported via the Yangtze River Delta in 2001 was over 700,000 tonnes [35]. Applying the same estimation methods to the Pearl River Delta, it is estimated that another 700,000 tonnes of e-waste illegally entered China via the Pearl River Delta in 2001. Other harbour regions, such as the Bohai Sea Bay area, including Tianjin harbours and Shandong, also illegally import e-waste, accounting for roughly 10 per cent (150,000 tonnes) of China's estimated 1.5 million tonnes of e-waste imports in 2001 [34]. Most of the refurbishment and recycling of the illegally-imported e-waste in China is carried out within the informal sector, where the lack of environment, health and safety (EHS) standards and improper handling of hazardous fractions present serious risks to workers and to the environment.

Existing estimations in the literature regarding the total volume of e-waste imported into China are very rough and outdated [6, 15, 30]. Substantial further investigation and analysis is needed to obtain more precise and up-to-date estimations. It is also important to recognize that the issue of transboundary shipments of e-waste is not confined to China. Significant volumes of e-waste are also exported to India, Pakistan, Vietnam, the Philippines, Malaysia, Bangladesh, Nigeria and Ghana, and possibly to Brazil and Mexico [15]. Exacerbating monitoring and enforcement challenges is the fact that the trading landscape is dynamic and the resulting e-waste flows are ever-shifting as they respond to changing market situations, commodity prices, and enforcement of customs controls in both sending and receiving countries.

3. E-waste collection in China

Both the formal and informal sectors participate in the collection of e-waste in China. Because there is relatively little environmental impact associated with the collection of e-waste, the central government has not explicitly banned informal sector involvement in e-waste collection. Most collection activities are carried out in urban areas because of their high population density and large volumes of broken, obsolete and discarded EEE available for collection. E-waste collectors and collection systems currently have very little presence in rural areas because home appliances were only introduced on a broad scale in many rural areas in the recent 10-15 years, so the rate of obsolescence is still low. In the meantime, due to relatively low penetration rate of home appliances and slow replacement for new technologies, it would take time for the equipment in the rural areas to become e-waste in large quantities.

This chapter introduces the collection activities and characteristics of both informal and formal collectors. It also summarizes and discusses the results of a survey of Beijing residents on their e-waste disposal habits and preferences.

3.1. Informal collectors

Informal collectors are often self-employed migrant workers from rural areas who travel door-to-door in urban areas, using cash to purchase a variety of used and waste household items ranging from plastic, paper and metal scraps to household appliances and other electrical and electronic equipment. These informal collectors serve as brokers between consumers and medium-level scrap dealers, refurbishers and recyclers. Once the material has been collected and undergone a simple sorting and classification process, the usable second-hand home appliances and valuable components that have been collected are sold to the local second-hand market. Those items with little or no re-use value are sold to scrap dealers for the value of the remaining material. This informal collection process is sometimes called “cherry picking” because only those appliances with significant re-use and recycling value are collected [16, 36-39].

The informal collection system is effective because individual collectors can efficiently reach almost any household, while urban residents (consumers) are doubly incentivized to sell to collectors because they are able to generate cash from obsolete and waste household items while at the same time saving the time and effort that would have been required to dispose of the items themselves. The effectiveness of the informal collection system increases the rates of re-use and material recycling, thus providing an important environmental benefit by keeping these materials out of the general waste stream and reducing the need for resource extraction.

Table 6 presents the findings of a 2005 market survey of the prices paid to urban residents by informal collectors for waste household appliances and the resale price of those refurbished items in the informal market[39, 40]. As the table illustrates, the prices at which refurbished items are sold in second-hand markets often far exceed the prices paid to consumers for their waste items. Through this trading mechanism, consumers, collectors, refurbishers and even recyclers are benefiting economically.

It is estimated that about 20 million migrant workers are currently engaged in the informal collection and recycling of solid waste. Among the various types of solid waste collected by informal collectors, the collection and recycling of e-waste is particularly labour-intensive. Due to the high labour input it requires, informal e-waste collection provides working opportunities and livelihoods for hundreds of thousands of unskilled and redundant workers from China’s rural areas [39]. Duan and Eugster (2007) estimate that around 440,000 people are involved in informal e-waste collection [41, 42]. However, formulating precise estimates of the numbers of informal e-waste collectors has proven challenging due to the difficulty of separating generalist solid waste collectors from collectors who specialize in e-waste. In most cases, informal e-waste collectors also collect other types of valuable solid waste, such as plastic, metal and paper scraps.

Table 6: Collection price of e-waste and price of second-hand products in the informal market in 2005

	CRT TV (B&W)	CRT TV (colour)	REFRI-GERATOR	WASHING MACHINE	AIR CON-DITIONER	COMPUTER
Price paid to consumers for e-waste (USD/item)	1.6-3.2	7.9-15.7	7.9-23.6	11-15.7	12.6-30	11-47.2
Informal market price of second-hand equipment (USD/item)	6.3-12.6	47.2-62.9	28.3-47.2	31.5-66.1	12.6-126.8	23.6-62.9

3.2. Formal collectors

The boundary between informal and formal collectors is not always clear. In principle, at least, anyone in China can sell or buy e-waste within the country. Nevertheless, formal collectors are generally defined as those collectors who work in a formal, tax-paying business entity and who deliver the collected e-waste to legitimate recyclers for environmentally-sound treatment.

From June 2009 to December 2011, the Chinese government implemented a national “Home Appliance Old for New Rebate Program” (hereafter referred to as the "Old for New Program") in order to stimulate both the buying of new home appliances and the proper recycling of old appliances (more details about this national project are provided in section 5.1.2.). This program first launched as a pilot in nine cities and provinces deemed to be more economically developed than other regions. Only authorized collectors – including home appliance retailers, chain stores, supermarkets, waste collection companies and logistics companies – were allowed to participate in this rebate program, through which they received collection subsidies from the government. These authorized collectors were eligible to take back old appliances from consumers and to issue discount coupons to these consumers in order to reward their participation in the project [43].

Because only authorized (formal) collectors were able to access the inflated profits on offer from the government’s “Old for New Program”, they were able to pay consumers a higher price for their waste appliances, which put them at a significant competitive advantage over informal collectors and increased the formal sector’s collection efficiency. According to a recent industrial report, formal collectors collected 61.29 million home appliances for recycling in 2011, including 51.49 million TVs, 2.23 million refrigerators, 4.72 million washing machines, 0.22 million air conditioners and 2.62 million computers [12]. When the total volume of e-waste collected by the formal sector in 2011 is divided by the total volume of e-waste generated in 2011 (3.62 million tonnes; see Figure 8), the annual collection rate for the formal sector is 64 per cent. Factoring in only the e-waste generated and collected in urban areas, the collection rate for the formal sector rises to nearly 88 per cent.

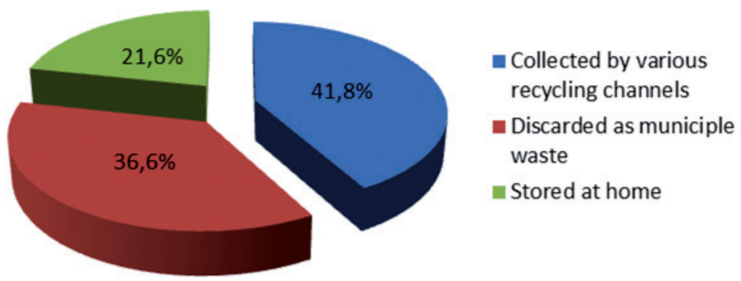
The “Old for New Program”achieved impressive collection rates for home appliances and set an important precedent for future e-waste management plans. However, two limitations must be addressed before this program can applied more broadly on a long-term basis. First, the program’s success and the inflated profits earned by collectors depended in large part on substantial government subsidies. When the program and its subsidies to formal collectors ended in December 2011, the formal sector’s competitive advantage over the informal sector also vanished. Successful long-term e-waste management by the formal sector in China will depend on the ability to replicate the successes of the program through long-term rebate structures. Furthermore, economic development is spreading to rural areas, bringing with it increased standards of living and greater access to household appliances and other electrical and electronic equipment for rural residents. Presently, most rural areas lack collection channels and recycling infrastructure, leaving them unprepared to handle the increased volumes of e-waste they are sure to generate. It is therefore essential that e-waste collection and recycling in rural areas also be included in future national e-waste collection plans.

3.3. Consumer attitudes and behaviour

Chinese people generally recognize that there is value to be generated from many types of household solid waste. Informal peddlers often pay consumers for their waste, which they then sell to brokers, scrap dealers, refurbishers and recyclers. Informal waste collectors are generally able to pay consumers a higher price for their waste materials than formal collectors, due to lower labour costs and flexible and diverse distribution channels. They are also able to offer convenient door-to-door collection. Because Chinese consumers often sell their waste to the highest bidder, the competitive advantage should lie with the informal sector. On the other hand, formal collectors are less efficient in collecting waste from widely-distributed households because it is expensive for them to establish a comprehensive network that can cover each household. Meanwhile, they tend to deliver their collected e-waste to responsible recyclers, which may increase the cost of treatment and thus reduce profitability. In the current Chinese context, these factors combine to make the formal sector less competitive than its informal counterpart.

A 2009 survey of 1,173 Beijing residents' e-waste disposal behaviours shows that the average household had 1.93 waste electrical and electronic products in need of disposal over the previous three years. As shown in Figure 3, 41.79 per cent of these waste items were disposed of through various recycling channels and 36.79 per cent were discarded as municipal waste, while the remaining 21.62 per cent were stored at home [44].

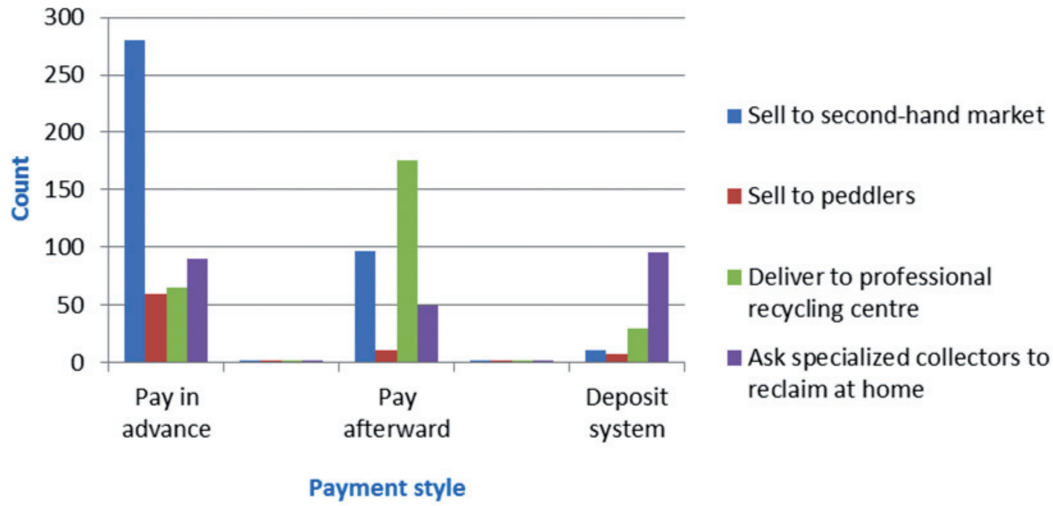
Figure 3: E-waste disposal channels used by Beijing residents in 2009



The survey also asked residents about their preferences regarding the payment of e-waste treatment fees and preferred disposal channels for their waste electrical and electronic products (see Figure 4). In regards to the payment of the e-waste treatment fee, the majority of respondents (50.62 per cent) preferred to pay the fee when purchasing the product, with the fee included in the cost of the item, because it is the most convenient option. Paying the treatment fee upon disposal was a less popular option, while the deposit system, in which consumers pay the deposit when purchasing the product and get refund for a certain proportion of money when turning in their e-waste in accordance with the provisions, proved least popular. Figure 4 shows that residents' preferences for particular disposal channels vary according to their preferred method of paying treatment fees. For instance, over half of respondents (51 per cent) who prefer to pay the treatment fee in advance also prefer to sell their e-waste to the second-hand market, whereas 53 per cent of respondents who prefer to pay the treatment fee upon disposal prefer to hand in their e-waste to professional recycling sites. Finally, of the respondents who preferred the deposit method of paying the treatment fee, 67 per cent prefer to have specialized collectors reclaim waste appliances at their homes. These data suggest that the acknowledging and planning around the relationship between consumer preferences regarding the payment of treatment fees and the use of particular disposal channels might offer a key to increasing formal sector competitiveness.

The survey results also indicate that Beijing residents are less inclined to participate in formal e-waste recycling than residents of developed countries in the West [44]. Just over 63 per cent of the e-waste ended up in either informal recycling channels or in landfills, rather than in formal recycling channels. According to the report, four major factors influenced consumers' choice of disposal means: recycling habits, economic benefits, convenience of recycling facilities and residential conditions. Perhaps predictably, the survey showed that most residents prefer not to pay for e-waste recycling, themselves, and that they prefer the convenience of having e-waste items collected from their homes by collectors. These preferences have enabled informal collection to become the most common form of e-waste collection in Beijing. If the formal recovery sector is to make a greater impact on overall e-waste collection, it must make multiple convenient collection channels available to consumers.

Figure 4: Beijing residents' preferences of payment and recovery means



4. E-waste recycling in China

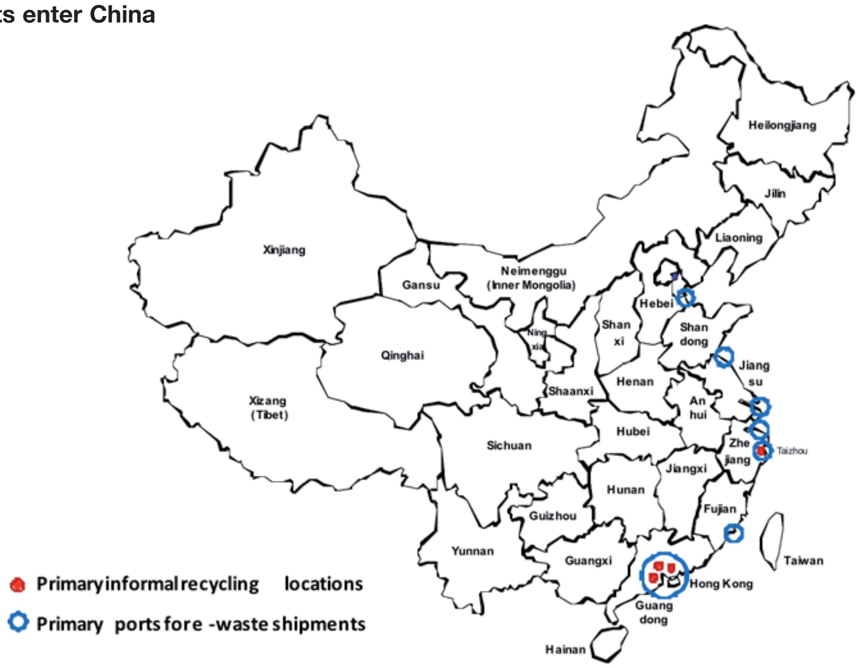
Formal and informal recyclers co-exist within China's current e-waste treatment system. The informal collection and recycling of e-waste emerged as a way of extracting value from waste electrical and electronic equipment through refurbishment and re-use, as well as through scrap recovery and recycling. However, e-waste recycling in the informal sector is characterized by practices that pose significant risks to both workers' health and the environment. In recent years, the formal sector has grown steadily under governmental regulation and financing, which has enabled the establishment of e-waste recycling processes that are safer and more environmentally and economically sound. Nevertheless, large volumes of e-waste continue to flow to and through the informal sector. This section reviews the spatial distribution, recycling capacity, techniques and environmental impact of both sectors.

4.1. Informal recyclers

Informal recycling of e-waste is prevalent in China, particularly in some coastal regions [13, 35]. The term "informal" refers to actors and practices that outside of official institutional and regulatory structures. Informal e-waste recyclers are not registered with the state and are therefore illegal [45, 46]. Informal recyclers generally use substandard processes and lack the appropriate facilities to safeguard human health and the environment. In recent years, the damage to human health and the environment caused by the informal recycling of illegally-imported e-waste from developed countries has drawn global attention [47].

The informal recycling sector in China did not develop overnight. Rather it has developed along with the economy and standards of living, both nationally and locally. In the 1990s, as imported waste began to enter in China as a cheap source for second-hand goods and secondary resources, individual recyclers began harvesting valuable materials from imported electronic waste. The most common outputs of informal recyclers are second-hand components, refurbished appliances and valuable materials.

Figure 5: Spatial distribution of informal e-waste recycling sites and ports through which e-waste shipments enter China



In areas with sizeable electronics manufacturing sector, informal e-waste recycling plays an important role by providing useful components and materials for production [16, 48, 49]. By trading with various business partners, including e-waste importers, private collectors, and dealers of secondary materials and reusable components, informal recyclers have been able to incrementally expand their trading networks and supply chains from the bottom up. Informal recyclers in China tend to cluster around key waterways and ports of entry, with the primary clusters located in Guiyu, Longtang and Dali on the Pearl River Delta, Taizhou on the Yangtze River Delta, Hebei Province, Hunan Province and Jiangxi Province (Figure 5) [6, 48]. The region with the most prominent informal e-waste sector is Guangdong Province. As discussed above, Guangdong Province is geographically adjacent to Hong Kong, making it a logistically-convenient destination for the illegal transboundary transport of e-waste. As such, it is the recipient of a constant in-flow of e-waste for recycling. Furthermore, Guangdong Province is the site of numerous facilities that manufacture electronics equipment, toys, electrical machines and other products. Informal e-waste recyclers have proven integral in meeting the region's industry's ever-growing demand for cheap materials. Finally, because of the scale of e-waste recycling and the resulting efficiencies and concentrations of collectors, buyers, sellers, recyclers etc., Guangdong now also attracts e-waste flows from other parts of China, making it a primary centre for e-waste recycling and trading.

China is not the only country in which the informal recycling sector is growing and flourishing. Many other parts of the world, including Bangalore, Chennai, Delhi and New Delhi in India, Lagos in Nigeria and Karachi in Pakistan, are also seeing an increase in informal e-waste recycling activities [49]. According to Hicks et al. (2005) and Wang et al. (2008), among others, the primary reasons underlying the rise of the informal e-waste recycling sector in developing countries include: (i) unwillingness on the part of consumers to return and pay for disposal of their old electrical and electronic equipment; (ii) high and unregulated levels of importation of e-waste for use as second-hand devices, together with substantial economic benefits from unregulated recycling activities; (iii) lack of awareness among consumers, collectors and recyclers of the potential hazards of improper e-waste handling; (iv) absence of recycling infrastructure or appropriate management of e-waste; (v) lack of financial resources to invest in improved e-waste recycling infrastructure and training; (vi) absence of effective take-back programs for obsolete and end-of-life EEE; (vii) lack of interest in e-waste management by multinational IT companies and lack of incentive to become involved; and, (viii) absence and/or lax implementation of e-waste-specific legislation [47, 50].

In addition to the estimated 440,000 people working in informal e-waste collection, Duan and Eugster (2007) estimate that around 250,000 people in China work in the informal e-waste recycling industry[41], engaging in manual dismantling and material recovery [40]. While informal e-waste recycling occurs in several locations in China, the two largest centres are Guiyu, Guangdong Province, and Taizhou, Zhejiang Province. With a population of 150,000, including 100,000 migrants, Guiyu is home to more than 300 companies and 3,000 individual workshops that are engaged in e-waste recycling. Of Guiyu's 28 villages, 20 are engaged in e-waste recycling [51]. Most of the recycling labourers are rural migrants from outlying agrarian regions such as Hunan and Anhui who take the menial jobs of dismantling and processing e-waste informally for an average wage equivalent to USD 1.5 per day. Many of these workers are women and children [15]. Taizhou, a city famous for secondary material production, has been involved in informal e-waste recycling for nearly 25 years [52]. In the early 1990s, Taizhou began to process imported wastes such as scrap metals, obsolete electric capacitors, household appliances, electric generators and cable wires, with an annual volume of dismantled e-waste exceeding 2.2 million tonnes [53]. However, Taizhou has gradually phased out the informal recycling of e-waste as local manufacturing has shifted away from the production of electronics in recent years. As a result of this shift in local manufacturing and stricter regulation of polluting activities related to e-waste recycling (e.g. leaching of circuit boards), very little informal e-waste recycling has been identified in Taizhou in past five years [28].

Informal e-waste recycling involves labour-intensive and sometimes hazardous manual dismantling of equipment using simple tools like hammers, chisels and screwdrivers to achieve swift separation of the various materials. Waste appliances are manually disassembled and the various components are sorted out. The re-usable parts are directly reapplied and the non-re-usable ones are recycled. Revenue is created from both the component re-use and material recycling [6, 15].

Informal recyclers target components and materials positive market values. Reusable components like

Table 7: Informal e-waste treatment methods and associated hazards in Guiyu, China (Source: Puckett et al., 2002 [15])

E-WASTE COMPONENTS	PROCESSES WITNESSED IN GUIYU, CHINA	POTENTIAL OCCUPATIONAL HAZARDS	POTENTIAL ENVIRONMENTAL HAZARDS
Cathode ray tubes (CRTs)	Breaking, removal of copper yoke, and dumping	- Silicosis - Cuts from CRT glass in case of implosion - Inhalation or contact with phosphor containing cadmium or other metals	Lead, barium and other heavy metals leaching into ground-water, release of toxic phosphor
Printed circuit board	Open burning of waste boards that have had chips removed to remove final metals	- Toxicity to workers and nearby residents from tin, lead, brominated dioxin, beryllium, cadmium, and mercury inhalation - Respiratory irritation	- Tin and lead conta-mination of immediate environment including surface and ground-water - Brominated dioxins, beryllium, cadmium, and mercury emissions
Gold from printed circuit boards	De-soldering and removing computer chips	- Tin and lead inhalation - Possible brominated dioxin, beryllium, cadmium, mercury inhalation	Air emission of same substances
Chips and other gold-plated components	Chemical stripping using nitric and hydrochloric acid along riverbanks	- Acid contact with eyes and skin may result in permanent injury - Inhalation of mists and fumes of acids, chlorine and sulphur dioxide gases can cause respiratory irritation, pulmonary edema, circulatory failure, and even death	- Hydrocarbons, heavy metals, brominated substances etc. discharged directly into river and banks - Acidifies the river, destroying fish and flora
Plastics from computers and peripherals	Shredding and low temperature melting to be re-utilized in low-grade plastics	Probable hydrocarbon, brominated dioxin, and heavy metal exposures	Emissions of hydrocarbons, brominated dioxins and heavy metals
Computer wires	Open burning to recover copper	Brominated and chlorinated dioxin, polycyclic aromatic hydrocarbons (PAH) (carcinogenic) exposure to people living and working in the burning areas	Hydrocarbon ashes (including PAH) discharged into air, water and soil
Miscellaneous computer parts encased in rubber or plastic (e.g. steel rollers)	Open burning to recover steel and other metals	Hydrocarbon (including PAH) and potential dioxin exposure	Hydrocarbon ashes (including PAH) discharged into air, water and soil
Toner cartridges	Use of paintbrushes to recover toner with no protective gear	- Respiratory tract irritation - Carbon black is a possible human carcinogen - Cyan, yellow, and magenta toners contain unknown toxicity	Cyan, yellow, and magenta toners contain unknown toxicity
Secondary steel, copper and precious metal smelting	Furnace recovers steel or copper from waste, including organics	Exposure to dioxins and heavy metals	Emissions of dioxins and heavy metals

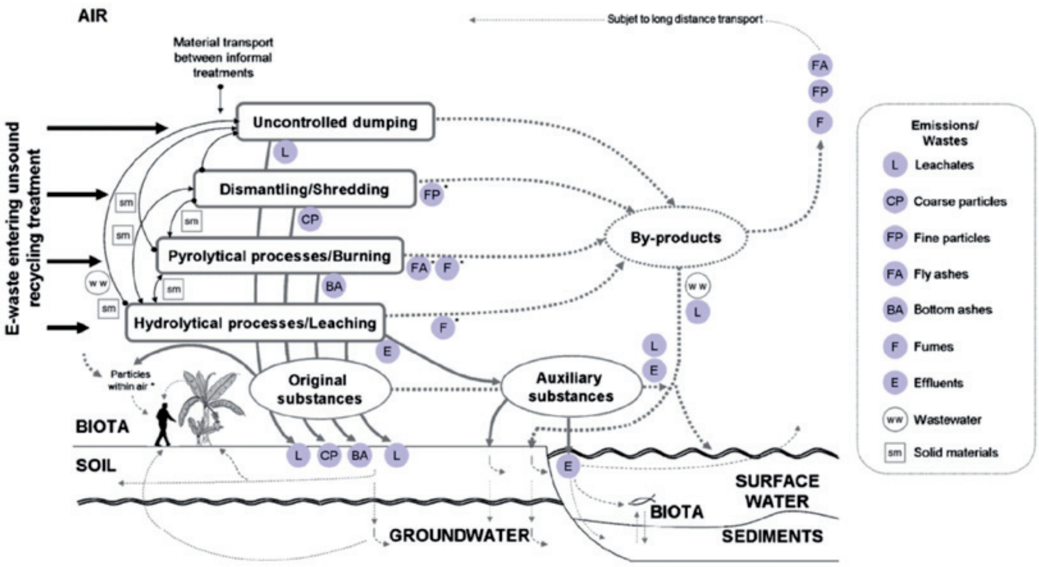
Li-ion and Ni-MH batteries, toner cartridges, motors, compressors, power supplies, cables, circuit boards and chips (such as memories, smart cards, mother boards) and accessories are given priority for recovery during the dismantling. These parts are then sold to the refurbishers for repair and re-assembly. Secondary materials with market value are also singled out during the dismantling processes and then upgraded through various refining processes. The most sought-after secondary materials include precious metals, ferrous and non-ferrous metals (copper, aluminium, magnet, various alloys etc.) and plastics. Among these materials, fractions containing precious metal (e.g. circuit boards and contacts) possess the highest market values and provide major revenues for informal recyclers [15, 16, 54, 55].

Like formal recyclers, informal recyclers seek to extract maximum value from e-waste by separating and upgrading secondary materials. However, unlike formal recyclers, informal recyclers lack the appropriate technology, equipment and training to undertake such operations in a safe and environmentally-responsible manner. Substandard informal recycling practices include open burning or direct melting of plastics, toner sweeping, dumping of lead-containing CRTs, acid stripping of printed wiring boards (PWB) and de-soldering of chips, as well as dumping unwanted residuals such as CRT glass, polychlorinated biphenyl (PCB) liquid, and chlorofluorocarbon (CFC) liquid, among others, directly onto the soil or into water sources. These common practices pose direct risks to the health of workers and to the local environment [56-60]. Although these informal e-waste recycling practices have been banned by the government, the environmental damage they cause will persist for many years and require substantial effort and resources to mitigate. Table 7 provides a snapshot of the hazards associated with various informal recycling practices, as determined by Puckett et al. (2002) [15].

According to Sepúlveda et al. (2010) [59], three main groups of substances are released during informal recycling: (i) original substances, which are constituents of electrical and electronic equipment; (ii) auxiliary substances, which are used in recycling processes; and (iii) by-products, which are formed by the transformation of primary constituents. These substances can be found within the following types of emissions or outputs (represented as circles in Figure 6):

- Leachates from dumping activities
- Particulate matter (coarse and fine particles) from dismantling activities
- Fly and bottom ashes from burning activities
- Fumes from mercury amalgamate “cooking”, de-soldering, and other burning activities
- Wastewater from dismantling and shredding facilities
- Effluent from cyanide leaching, other leaching activities or mercury amalgamation

Figure 6: Emissions and environmental pathways from informal e-waste recycling (source: Sepulveda et al., 2010 [59])



Much of the research on e-waste issues in China was triggered by the environmental calamity in the Guiyu area. In 2002, Greenpeace and Basel Action Network first exposed the pollution and ecological damage in the e-waste recycling town in their report titled “Exporting Harm” [15]. This report attracted global attention to China’s backyard e-waste recyclers and sparked a great deal of research seeking to evaluate the presence of heavy metals, persistent organics and other hazardous substances in the water, air, soil and even human bodies in e-waste recycling sites like Guiyu and Taizhou. Through on-site investigations, toxicity and pathology analyses, and other methods, these studies have clearly demonstrated the environmental and health damage caused by improper recycling of e-waste [51, 53, 61-68]. However, most research related to the informal sector has been limited to investigations of toxicity. More research is needed from the social sciences, geography and economics in order to understand the underlying social and economic aspects of the issue, which can in turn help address the root causes that fuel the informal recycling sector.

4.2. Formal recyclers

The “Administrative Measures on the Prevention and Control of Environmental Pollution by Electronic Waste” (SEPA, No.40, effective since February 2008) prohibits any individuals or enterprises not listed in the e-waste dismantling enterprise list to engage in the dismantling, recycling and/or disposal of e-waste. Furthermore, according to “Regulations on the Administration of Recycling and Treatment of Waste Electric and Electronic Equipment” (Decree of the State Council, No.551, effective since January 2011), enterprises that handle any or all of the five primary types of e-waste – televisions, refrigerators, washing machines, air conditioners and computers – must first receive a treatment license signifying that they have received qualification permission.

Formal e-waste recyclers in China can thus be defined as designated recycling enterprises that are included on the e-waste Dismantling Enterprise List and who have received a treatment license. Recycling licenses for e-waste are issued by provincial Environmental Protection Bureaus. Depending on the type of material to be recycled, licenses for handling hazardous waste are also sometimes necessary, as required by SEPA, No.40 (discussed above) and the “Administrative Measures on treatment license of Waste Electrical and Electronic Equipment” (MEP, No.13, effective since January 2011). In order to ensure that the operating capacity of their local e-waste recycling industries match local needs, provincial governments develop five year plans for the e-waste recycling industry in their administrative territories and award a corresponding number of licenses to local recyclers.

Currently, 130 e-waste recycling enterprises are registered on the e-waste Dismantling Enterprise List. As of May 2012, 53 e-waste treatment enterprises in 15 provinces and cities have received the necessary treatment licenses, indicating that they have met the required technical and environmental standards over a three-year monitoring period.

During the “Old for New Program”, which was implemented in nine pilot provinces and cities from June 2009 to December 2011, 22 designated dismantling enterprises were selected to dismantle the collected e-waste. Later, as the program expanded to other provinces and municipalities, it stimulated a rapid increase in the number of e-waste collection and treatment facilities. As such, the designated dismantling enterprises received and disposed of a large volume of e-waste. According to the official website of the “Old for New Program”[43], there were 1,137 sales enterprises, 1,116 collection enterprises and 105 designated dismantling enterprises distributed across 37 provinces and cities.

Data from China Ministry of Commerce, shows that, between September 2009 and November 2011, a total of 81.30 million new household appliances were sold, 83.73 million waste household appliances were collected, 66.21 million units were dismantled, and 0.97 million tonnes of iron and steel, non-ferrous metals, plastics and other resources were recycled [69]. According to the official collection figures, 81 per cent of the collected and recycled appliances were waste televisions; the remaining 19 per cent, in order of volume from most to least, were refrigerators, washing machines, computers and air conditioners.

Figure 7 presents a spatial overview of the distribution of formal recyclers who participated in the "Old for New Program" in each administrative region. Designated dismantling enterprises tend to be more concentrated in more economically-developed areas and are primarily distributed in central (Henan and Hubei Provinces) and eastern (Shanghai, Jiangsu and Anhui Provinces), as well as the northeast (Heilongjiang and Jilin Provinces) and Guangdong Province in the South. Henan and Hubei provinces are both home to seven designated dismantling enterprises, more than any other region. Meanwhile, provinces in western China, which generate much lower volumes of e-waste, have only one or two designated recyclers. As discussed above, the penetration rate of home appliances in these regions is still low and most of the purchased equipment has not come to the end-of-life phase yet. Provinces with vast land areas and only one or two designated recyclers, such as Neimengu (Inner Mongolia), Xizang (Tibet), Xinjiang, and Qinghai, face both logistical challenges and higher costs related to e-waste collection.

Figure 7: Spatial distribution of registered formal e-waste recyclers in China

Although the formal e-waste treatment sector in China has been growing since 2008, it is still in the early stages of development and has not yet achieved the goal of high recycling rates and low emissions. Due to the rapid growth of the formal recycling sector, e-waste recycling facilities across China possess uneven handling capacities and capabilities. For example, many facilities were only partially built, and most formal recyclers have adopted manual dismantling processes and use only basic mechanical technologies. Only a few enterprises possess sufficient dismantling capacity and refining technologies for various disassemblies [6, 27].

In 2009 and 2010, the authors visited Beijing, Shanghai, Shandong, Jiangsu and Fujian Provinces and discovered that the activities of most of the designated dismantling enterprises were largely confined to the dismantling and treatment of the five primary EEE product types: televisions, refrigerators, washing machines, air conditioners and computers. The reason that designated recyclers focus on these five types of e-waste is that the current e-waste legislation and subsidies only cover these five products. For designated recyclers, it is easier and cheaper to obtain e-waste directly through formal channels than to collect the waste themselves in the market. A few enterprises process e-waste other than the five primary types, including office equipment (including printers, copiers and fax machines), fixed telephones and parts from small home appliances obtained from producers.

The treatment of e-waste by designated recyclers varies depending on the type of e-waste to be processed. The recycling of CRT televisions entails cutting through the monitor with heated wire in order to separate the cone from the funnel glass, which is usually then resold. The prevailing method for treating printed circuit boards is a combination of mechanical shredding and hydrometallurgical recovery of the precious metals, copper and other nonferrous metals. For cooling and freezing equipment, automatic and hermetic treatment systems have been installed in some facilities in order to capture the coolants. However, the recovery rate for CRT glass, mixed non-metallic materials from equipment such as polyurethane foam plastics found in refrigerators, and other potentially recoverable materials, is still low in practice. The same is true of the recovery and treatment of waste circuit board components and lithium batteries. At present, many e-waste recycling processes lack emissions controls. Many formal recycling facilities lack ventilation systems, thus endangering the health of workers. While the dismantling techniques, knowledge and equipment for advanced treatment process and technology, emission control and comprehensive utilization of resources have improved in recent years, much room remains for further improvement [27].

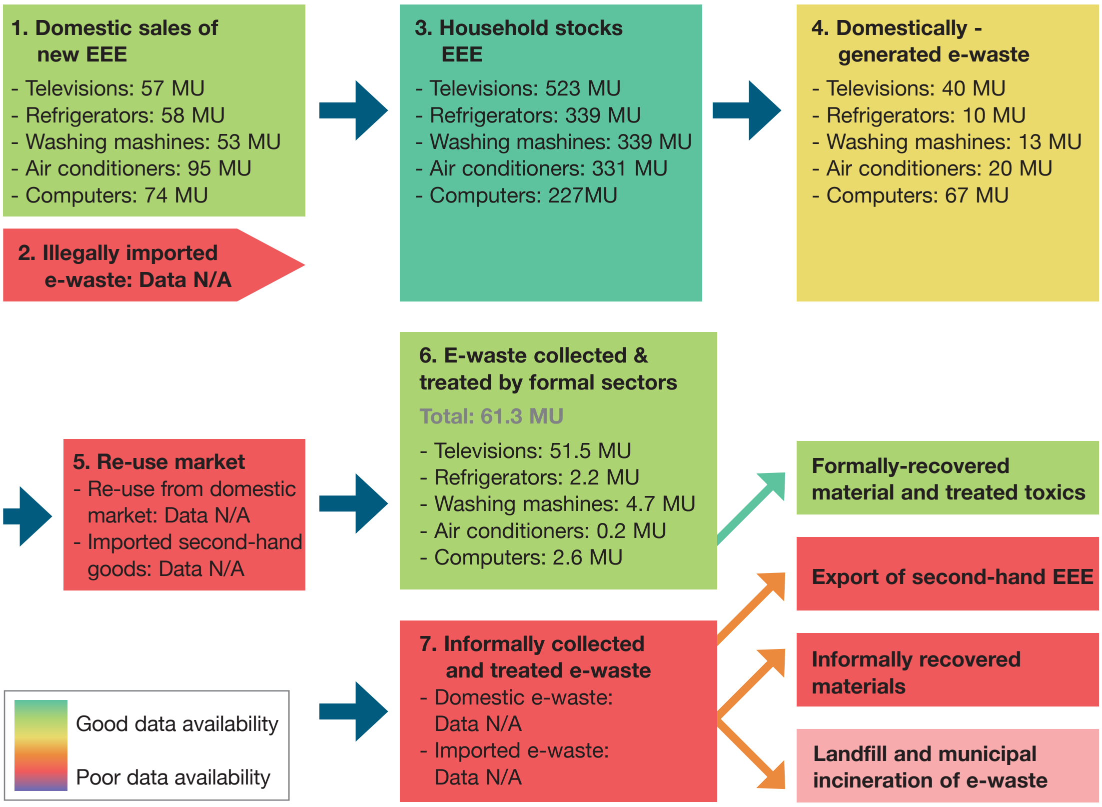
A systematic evaluation of the technical, environmental and economic performances of the e-waste recycling industry – including an analysis of costs, mass balances and recycling efficiencies – can help to identify the major technical and management barriers to improved performance. To date, however, the necessary research has not been conducted to facilitate a comprehensive analysis based on real-time data.

4.3. Summary: e-waste flows in China

In 2011, there were around 336 million home appliances (televisions, refrigerators, washing machines, air conditioners and computers) put on the domestic Chinese market. Most of the 61.3 million home appliances collected and treated by the formal sector in 2011 – 84 per cent of which were televisions – were collected through the "Old for New Program". In 2011, the number of televisions put on the market roughly equalled the number of waste televisions generated, which suggests that televisions may have reached near market saturation. For the four other primary home appliances – refrigerators, washing machines, air conditioners and computers – the number of waste units generated annually is lower than the number of new units purchased, meaning that there is still considerable room in the market to grow. In addition to the waste appliances collected, an estimated 1.76 billion units of the five primary home appliances currently being stocked in homes will become obsolete and be discarded in the future. As for home appliances not covered in the rebate program, most will go to informal recyclers or second-hand markets, or will be discarded as municipal waste or temporarily stored in homes.

Figure 8 represents a compilation of the analyses from Chapters 2, 3 and 4 of this report in a chart of e-waste flows in China (as of 2011). The chart is colour coded to indicate the availability of relevant data. Figure 8 includes data on EEE sales, stocks and e-waste generation, as well as the quantities of e-waste collected and treated through formal channels. Due to the difficulty of data collection, however, reliable data on the collection and recycling capacity of the informal sector, as well as on the volume of e-waste that is illegally imported and treated by the informal sector, are largely unavailable. In order to gain a more thorough understanding of the systemic flows of e-waste in China, more complete and reliable data on all sectors must be collected. Suggestions for follow-up research, projects and collaborations are included in chapter 8 of this report. It is important to emphasize here that part of the data presented in Figure 8 reflects the flow of e-waste during the "Old for New Program", which incentivized consumers to hand in their e-waste to subsidized formal collectors. This program significantly shortened the lifespan of home appliances and led to higher volumes of e-waste being collected than were collected in the years before the rebate program. Because the rebate program ended at the end of 2011, it is likely that the amount of e-waste collected and treated through formal channels will decrease significantly from 2011 levels and that the amount of e-waste flowing through informal channels may rise to pre-rebate program levels. It is therefore necessary to continue to gather data for 2012 and beyond in order to gain a more complete and accurate understanding of e-waste flows in China.

Figure 8: Overview of e-waste flows in China in 2011, millions of units (MU)

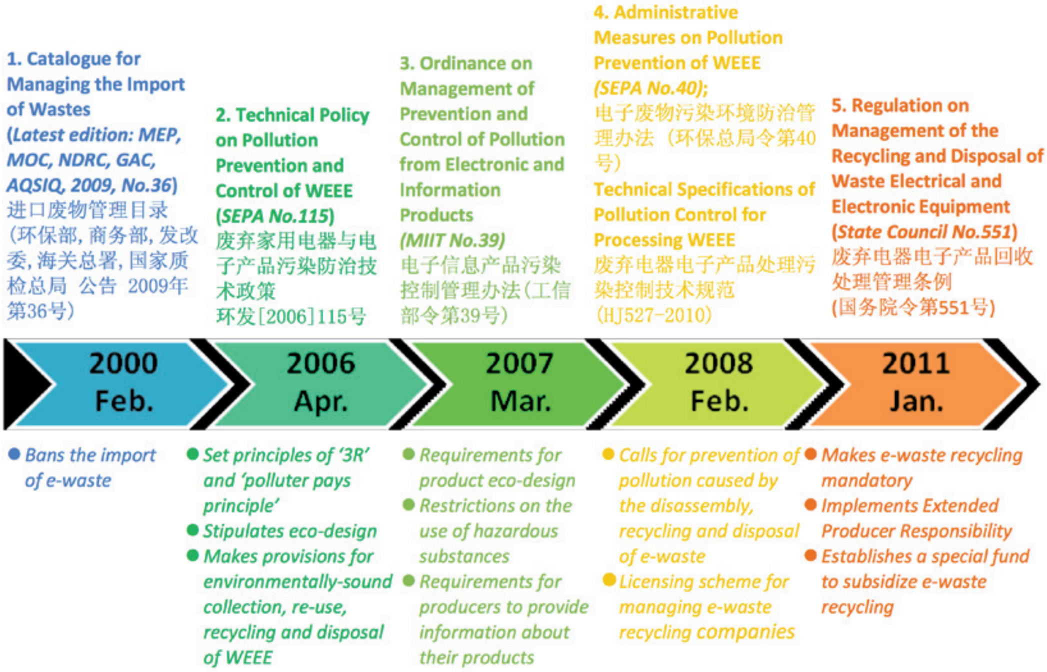


5. Legislative developments

5.1. Overview of legislation on e-waste

The Chinese government has issued a variety of environmental laws, regulations, standards, technical guidance and norms related to e-waste management over the past decade. Five of the most important ones are shown in Figure 9 [42].

Figure 9: Key national legislation and policies related to e-waste management in China



MEP: Ministry of Environmental Protection
MIIT: Ministry of Industry and Information Technology
NDRC: National Development and Reform Commission
NPC: National People's Congress

In order to deal with the problems arising from the illegal import of e-waste, the government has passed numerous regulations to restrict and even ban the importation of e-waste and has signed on to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, a multilateral environmental agreement, as well as the Basel Ban Amendment. The first policy in Figure 9, Catalogue for managing the import of wastes, which was passed in 2000, included second-hand electronic equipment and e-waste in the "List of Prohibited Goods to be Imported for Processing or Trade", which is updated regularly. However, as discussed in section 2.3, e-waste is still entering China through multiple illegal channels despite of the official ban. Effective enforcement and monitoring mechanisms are therefore necessary for this policy to be effective.

The second key policy in Figure 9, The Technical Policy on Pollution Prevention and Control of WEEE, was enacted in 2006 in order to reduce the overall volume of e-waste, to increase the reutilization rate for discarded electrical and electronic equipment, to increase standards for e-waste recycling. It sets forth the overall guiding principles of "Reduce, Re-use and Recycle" (3R) and "Polluter Pays" (i.e. shared responsibility of producers, retailers and consumers). It provides a list of environmental measures to minimize environmental pollution during the storage, re-use, recycling and final disposal of e-waste [47].

The third policy, The Ordinance on Management of Prevention and Control of Pollution from Electronic and Information Products, was implemented in 2007 with the dual goals of reducing the use of hazardous and toxic substances in electronic appliances reducing the pollution generated in the manufacture, recycling and disposal of these products [70]. The ordinance shares many similarities with the EU RoHS Directive (Restriction of Hazardous Substances Directive), including requirements for eco-design, restrictions on the use of six hazardous substances (lead, mercury, cadmium, chromium, and polybrominated biphenyl or polybrominated diphenyl ethers) in electronic products, and requirements for producers to provide information on the components and hazardous substances present in their products, as well as the period of safe use and the potential for recycling.

The fourth policy in Figure 9, Administrative Measures on Pollution Prevention of Waste Electrical and Electronic Equipment, was enacted in 2008 with the goal of preventing pollution caused by the storage, transport, disassembly, recycling and disposal of e-waste. This policy applies to e-waste recycling companies seeking treatment licenses once it has been confirmed by local environmental departments that the company has complied with treatment standards and requirements. The policy stipulates that the MEP shall take responsibility for supervising efforts to prevent pollution from e-waste. As a supporting standard for this policy, The Technical Specifications of Pollution Control for Processing Waste Electrical and Electronic Equipment, provides the technical standards and specifications for various e-waste treatment processes and activities such as storage, transport, dismantling and waste handling, as well as for equipment and material fractions.

The Regulation on Management of the Recycling and Disposal of Waste Electrical and Electronic Equipment can be regarded as the counterpart of the EU's WEEE Directive (Waste Electrical and Electronic Equipment Directive) and is a pivotal piece of national legislation for e-waste management in China. Implemented on 1 January 2011, the regulations stipulate that e-waste should be collected through multiple channels and recycled by licensed recycling enterprises. The regulations also establish a "specialized fund" to subsidize the formal collection and recycling of e-waste. Producers and importers of electronic products are required to contribute to this fund. As of August 2012, only the five types of home appliances discussed in this report (televisions, refrigerators, washing machines, air conditioners and computers) have been regulated so that producers must pay taxes on these products (according to their respective estimated treatment and management costs) in order to support the e-waste treatment subsidy. This list of regulated and taxable products will be updated in the future as more products with higher environmental impact and social relevance are identified. The regulations also stipulate a standard and certification system for e-waste recycling and disposal enterprises in

Table 8: Stakeholder e-waste management responsibilities under national e-waste legislation

STAKEHOLDERS	RESPONSIBILITIES
Producers (including importers & agents)	- "Green" design and production of EEE - Pay treatment fees for products put on the market
Retailers and service companies	- Provide information in their stores/companies regarding e-waste collection and treatment through formal channels
Refurbishment companies	- Guarantee the quality and safety of refurbished products - Clearly label repaired equipment with "refurbished product" label
E-waste collection companies	- Provide multiple channels and means to consumers for convenient collection of e-waste - Transfer collected e-waste to licensed e-waste treatment companies
E-waste recycling and treatment companies	- Obtain e-waste treatment license - Comply with national e-waste treatment standards - Establish environmental quality monitoring system for treatment facilities - Establish information management system for treated e-waste, and report the information to local EPA

order to monitor and ensure the safe and responsible processing of e-waste. However, the regulations do not explicitly define specific collection or recycling targets. To date, the effectiveness and outcomes of the regulations have yet to be evaluated. In July 2012, the Chinese government released the details of the China e-waste Fund Management Measures, which specifies the treatment fees, means and frequency of fee collection, fund contributors and list of eligible recyclers [71, 72]. Table 8 lists the primary responsibilities of different stakeholders as stipulated under the regulations.

According to the management measures stipulated in the "specialized fund" for e-waste treatment [73], producers and importers of EEE must pay specified treatment fees for the products they put on the Chinese market. The collected fees will be placed in the fund and then allocated to licensed recyclers to cover costs related to the collection and treatment of e-waste. Table 9 lists the product-specific fees to be paid by producers and the subsidies to be received by recyclers in 2012 [72]. Due to lack of managerial experience and baseline data on such a program, official collection and recycling targets have yet to be set.

Table 9: National "specialized fund" for e-waste treatment in China, product-specific fees and subsidies (2012)

	TV (CRT and flat panel)	**REFRIGE-RATOR**	**WASHING MACHINE**	**AIR CONDI-TIONER**	**COMPUTER** (desktop and laptop)
Producer fee (per unit sold)	RMB 13 / USD 2	RMB 12 / USD 1.9	RMB 7 / USD 1.1	RMB 7 / USD 1.1	RMB 10 / USD 1.6
Treatment subsidy to recycler (per unit treated)	RMB 85 / USD 13.5	RMB 80 / USD 12.7	RMB 35 / USD 5.5	RMB 35 / USD 5.5	RMB 85 / USD 13.5

In summary, the Catalogue for Managing the Import of Wastes, which closely resembles the Basel Convention in nature, focuses on the control of illegal e-waste shipments through customs administration. The Technical Policy on Pollution Prevention and Control of WEEE stresses the importance of proper e-waste management in China. However, it is only a guiding law that lacks the specifics necessary for implementation. The "Ordinance on Management of Prevention and Control of Pollution from Electronic and Information Products" primarily regulates the environmentally-friendly design of new electrical and electronic equipment and restricts the use of hazardous materials therein. This policy applies exclusively to producers and manufactures of electrical and electronic equipment. The "Administrative Measures on Pollution Prevention of WEEE" establishes the licensing system for recycling companies and stipulates the technical and environmental standards with which companies must comply to receive a treatment license. Finally, the "Regulation on Management of the Recycling and Disposal of Waste Electrical and Electronic Equipment" is the most critical and comprehensive e-waste legislation to date. It establishes a national e-waste collection and recycling system and outlines various stakeholders' responsibilities, including per-product fees and treatment subsidies for producers and recyclers, respectively.

5.2. Enforcement of e-waste legislation: challenges and opportunities

The five pieces of legislation discussed above cover most aspects of national e-waste management in China. However, challenges still exist regarding the implementation and enforcement of this legislation. Regarding the transboundary shipment of e-waste, for the ban on the import of e-waste into China to be effective, substantial administrative reforms in customs control are required. For example, Hong Kong is a major loophole through which e-waste can be indirectly shipped from sources such as the US or the EU into mainland China. Furthermore, strict and on-going enforcement of points of entry are necessary, as there is strong evidence that illegal e-waste still enters into China through various routes (discussed in section 2.3). Dedicating more resources to investigating illegal shipment routes, logistical mapping, key players and quantities of illegal shipments would facilitate the development and implementation of more effective legislation.

Regarding the management of e-waste recycling, the “Administrative Measures on Pollution Prevention of WEEE” (Policy 4 in Figure 9) clearly establishes the qualification requirements for licensed recyclers, which enables more centralized monitoring to ensure that standards are met. However, the issue of informal recycling has been largely ignored. In contrast to formal recyclers, which are relatively few in number and tend to be large operations, informal recyclers are numerous, widely distributed and operate on a small scale. Without proper monitoring and enforcement, simply forbidding informal recycling activities will yield limited results. China’s massive and diverse population and the diversity of industries within the country both necessitate and shape the division of responsibilities between the central and local governments [42]. This administrative division and de-centralizing of many governmental responsibilities means that local authorities are responsible for monitoring and policing of activities that pose risks to the environment and human health. Due to the economic importance of informal recycling, however, some local governments may view restrictions on this industry as contrary to local interests. For instance, the recycling activities in Guiyu generate a significant portion of the local government’s annual revenues. This disconnect between the policies of the central government and local-level enforcement is still an issue in many places. Improvement of informal recycling practices and environmental remediation of polluted sites must therefore be planned simultaneously.

The third challenge relates to how the national government approaches and organizes the suite of policies and governing bodies [42]. The first major problem is that no single administrative institution fully supervises and implements policies and laws related to e-waste. As introduced in Section 7.1 of this report, at least six national institutions are involved in the legislation, management and monitoring of e-waste and related issues. While the sharing of responsibilities offers advantages to each organization and to the broader e-waste management effort, it also disperses administrative powers, potentially leaving organizations constrained in their ability to fully address issues on their own. For example, MEP is responsible for supervising e-waste recycling; however, its effectiveness as supervisor of illegal activities in various sites and ports is contingent on the passage of stronger laws. Furthermore, existing e-waste regulations do not comprehensively consider the entire life cycle of EEE. For example, most of the regulations do not specify how to distinguish between second-hand electronic products and e-waste [74]. Additionally, there is very little legislation addressing the issue of re-use, which affects regulatory efforts aimed at the informal sector.

Another constraint limiting the effectiveness of e-waste legislation is that no clear policy target has been established. For instance, the amount of e-waste to be collected and treated annually by the formal sector has not yet been stipulated in national e-waste legislation (Law 5). This lack of clarity will make local-level implementation difficult because local planning of collection activities and treatment capacities is based on such baseline targets. This lack of clarity also renders other key targets undefined, including those related to recycling efficiency, removal and control of toxic materials, level of customs control on illegal flows, and re-use, among others.

E-waste legislation in China is moving toward the gradual construction of a domestic collection system and recycling infrastructure under a national treatment subsidy program. More explicit policy targets and stronger local-level enforcement of customs control and pollution checks, as well as upgrading of the informal sector, are necessary to further improve the implementation of national e-waste legislation.

6. Projects related to e-waste

6.1. National projects

Apart from developments in e-waste legislation, the Chinese government, producers and recycling industries have implemented a series of national pilot projects in order to identify the most suitable treatment technologies, collection channels and financing scheme for e-waste management. These pilot projects helped the government and other key actors identify critical logistical challenges and make further improvements and revisions before implementing the programs on a wider scale.

6.1.1. Pilot on e-waste collection and recycling (2003-2006)

In 2003, the National Development and Reform Commission (NDRC) initiated pilot projects in four target cities to explore technical solutions to the e-waste problem. The pilot project aimed to explore the feasibility of approaches to collecting e-waste from different available channels, develop standards and regulations for e-waste management, and develop key technologies and equipment for e-waste recycling. Table 10 (below) lists the detailed activities of these four pilot projects.

The pilot projects have achieved important successes, including the establishment of disassembly lines for major home appliances in the pilot cities and the accumulation of cost data and experience in the e-waste trading market. The pilot projects also encountered challenges. For example, very slow progress has been made on the establishment of an e-waste collection network due to high

Table 10: Overview of NDRC pilot projects on e-waste collection and treatment

TARGET CITY OR REGION	SCALE OF INVESTMENT	ACTIVITY	TREATMENT CAPACITY
Beijing (city)	RMB 80 million (USD 11.7 million)	- Construct an e-waste sorting and treatment centre (three recycling/treatment lines & warehouse) of 40,000 m^2 - Construct an e-waste inspection centre - Set up collection channels and telephone hotline, collect production waste and e-waste from government offices - Launch public education program	1,200,000 units per year
Tianjin (city)	RMB 110 million (USD 16.1 million)	- Construct a treatment facility of 66,667 m^2 - Set up an online transaction platform for e-waste collection - Collect e-waste from waste trading market and government offices - Set up collection point in residential communities	333,000 units per year
Qingdao (city)	RMB 80 million (USD 10 million)	- Construct treatment facility for CRT TVs, refrigerators, PWBs etc. - "Old for New" collection trial in retail stores - Set up collection channels for production waste and for e-waste from residential communities and government offices - Set up information system to register data on e-waste properties, collection sources, logistics, treatment etc.	600,000 units per year
Zhejiang Province	RMB 100 million (USD 12.5 million)	- Construct treatment plants for CRT TVs, refrigerators, air conditioners, ICT equipment - Set up multiple channels for collection of e-waste from retailers, collection points in residential communities, government offices and schools, and production waste from producers and OEMs	800,000 units per year

collection costs and competition from the informal sector. The formal (pilot project) recyclers suffered financial losses in the recycling of many appliances due to insufficient inflows of e-waste and lack of recycling subsidies [6]. The key lesson from this project is that the stream of e-waste coming to formal recycling facilities must be both consistent and sufficiently large. Merely constructing the treatment facilities without preparing a complete recycling and supply chain will lead to discontinuous operation and insufficient performance. Furthermore, it became evident that a proper financing scheme to cover the deficits incurred by formal recycling facilities is essential to run the system under an effective business model.

6.1.2. Home Appliance Old for New Rebate Program (2009 – 2011)

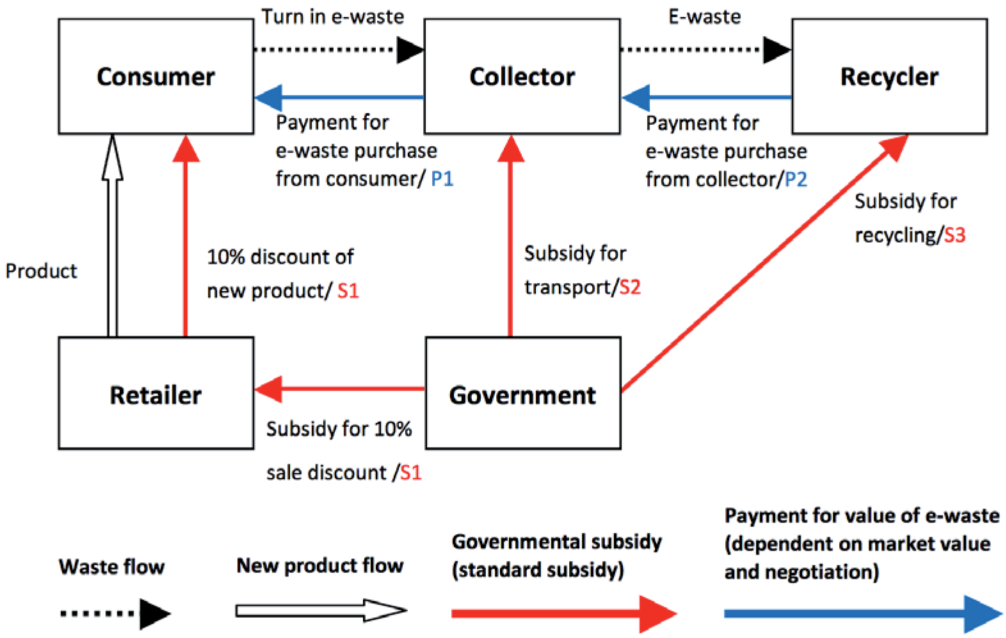
In July 2009, while in the midst of the global economic recession, the Chinese government unveiled the "Home Appliance Old for New Rebate Program" ("Old for New Program") in five large cities and four provinces. This program was a joint effort by the Ministry of Commerce, Ministry of Finance, NDRC, Ministry of Industry and Information Technology, MEP, State Administration for Industry & Commerce, The General Administration of Quality Supervision, Inspection and Quarantine. Under this program, consumers who purchased a new home appliance and also returned one old appliance to a designated retailer or formal collector received a 10 per cent discount on the new appliance's purchase price. This program was prepared with two objectives: 1) to stimulate domestic purchases of new home appliances, which would benefit the national economy; and, 2) to explore a possible model for e-waste take-back by providing urban consumers with economic incentive to dispose of their e-waste through formal collection channels. The "Old for New Program" ended on 31 December 2011.

Figure 10 (below) shows the working mechanism of the "Old for New Program" [75]. When a consumer purchases a new home appliance from an appointed retailer or store, if the consumer is able to turn in one old home appliance for recycling through an official collection channel, the consumer will receive a 10 per cent discount on the new appliance (S1 in the figure). To turn in their old appliances, consumers can call an appointed collection or logistics company to pick up their waste from their houses. After the logistics company checks the type of the appliance in the consumer's house, the company will issue to the consumer a ticket/coupon that certifies the handing in of e-waste, which can then be used to secure a 10 per cent discount on a new appliance. The collection company will also pay the consumer for the remaining value of the waste appliance, as judged by the collector according to the type, size and material composition of the waste appliance (P1 in Figure 10). The government did not provide a unified price list for the remaining values of different waste equipment, which vary greatly case from case. However, the government did issue a list of minimal collection prices for five types of waste home appliance in order to prevent collectors from underpaying consumers. Upon showing the ticket in the retailing store, the consumer is entitled to a 10 per cent discount on the price of a new home appliance. Under the "Old for New Program", then, consumers are able to receive a double financial benefit – the 10 per cent discount on a new home appliance (S1) and the cash payment from collectors (P1) – from discarding their old home appliances through formal collection channels.
Participating retailers who sell new equipment to consumers at a 10 per cent discount turn in the tikkets/coupons from consumers (certifying that they turned in a waste appliance to a formal collector) and are then reimbursed by the government according to the number of discounted appliances they sold (S0 in the figure; S0 equals S1). In this way, retailers are able to sell more products without losing any money from the discount.

Collection and logistics companies are responsible for collecting waste appliances from consumers' homes and paying the consumers for the remaining value of these appliances (P1). The collection and logistics companies must then deliver the waste appliances to an appointed recycling company, to whom they sell the equipment at a certain price (P2). In principle, collectors should make a profit from their collection activities, so the price at which they sell the waste appliances to the recyclers (P2) is higher than the price they paid to consumers for the appliances (P1). The government has not established fixed prices for P1 and P2, so collectors and recyclers are left to come to an agreement on the sale price based on the type and quality of the e-waste being sold. Collection and logistics companies, however, are also able to collect a transport subsidy from the government based on the numbers, type and size of waste equipment they transport, as well as the distance transported (S2). Like consumers, participating collection companies can benefit doubly, from the sales of the collected e-waste to recyclers (P2-P1) and from the transport subsidy from the government (S2).

Recyclers pay the collection companies to acquire the e-waste resources (P2). And like the collection companies, they also receive a recycling subsidy from the government (S3). The amount of the subsidy to be paid to recyclers is based on the average treatment cost for a specific product type and the deficit that recyclers incur in treating products. This subsidy guarantees that recyclers are able to stay profitable while conducting environmentally-sound treatment of e-waste.

Figure 10: "Home Appliance Old for New Rebate Program" flow chart



Procedure for the "Home Appliance Old for New Rebate Program"

1. The consumer turns in an old appliance to an official collector. The collector will pick it up, pay the consumer for the remaining value of the e-waste (P1 in the figure) and issue the consumer a voucher.
2. By redeeming the voucher in an eligible retailing store, the consumer can buy a new appliance at a 10 per cent discount.
3. The government reimburses participating retailers for the 10 per cent discount they give to consumers (S1). There is an upper limit for the subsidy allowed for each type of appliance (see table 11).
4. The collector ships the collected e-waste to an official recycler. The recycler pays the collector for the value of the e-waste, based on the market value and negotiated price (P2).
5. The collector receives a logistics subsidy from the government (S2), based on the amount and type of e-waste collected and transport distance (see table 11).
6. Recycler will receive a treatment subsidy from the government (S3), based on the type of e-waste treated.

Table 11 lists the various subsidies and prices involved in this program. The level of recycling subsidies paid to recyclers is fixed for each e-waste category, but other subsidies are subject to the specifics such as e-waste type and logistics conditions. Taking TVs as an example, when a consumer turns in an obsolete TV to a collection company, the minimum price that the collector can pay the consumer is

Table 11: Subsidies and suggested collection price in "Home Appliance Old for New Rebate Program" (USD per unit)

PRODUCT	REGULATED UPPER LIMIT OF SALES DISCOUNT (S1)	TRANSPORT SUBSIDY (S2)		TREATMENT SUBSIDY (S3)	ADVISED COLLECTION PRICE FOR WASTE PRODUCT (P1)
		<150 KM	≥150 KM		
TV	58.5	4.4 ~ 5.9	5.9 ~ 7.3	2.2	2.9 ~ 13.2
Refrigerator	43.9	5.9 ~ 7.3	7.3 ~ 8.8	2.9	8.0 ~ 9.5
Washing machine	36.6	5.9 ~ 7.3	7.3 ~ 8.8	0.7	12.4
Air conditioner	51.2	4.4 ~ 7.3	7.3 ~ 8.8	0	8.8 ~ 43.9
Computer	58.5	4.4 ~ 5.1	5.9 ~ 6.6	2.2	2.9 ~ 8.8

USD 2.2 (this number varies depending on the product type and remaining re-use value). Furthermore, the consumer receives a 10 per cent discount coupon, though the maximum discount a consumer may receive off the price of the new TV is USD 58.5, as indicated in Table 11. For instance, if the price of the new TV is USD 400, the discount is USD 40; if the price of the new TV is USD 700, the discount is USD 58.5, not USD 70.

When the e-waste collection company sells the old TV (or other home appliance) to a recycler, the collector charges the recycler a higher price than the collector paid the consumer and also receives a government transport subsidy, so that a collector who paid a consumer USD 5, for an old TV may receive USD 5.9 in subsidies (depending on type of material and distance transported). Finally, the recycler also receives a treatment subsidy of USD 2.2 for recycling the old TV. While this example focused on TVs, the program also extended to other major home appliances, including refrigerators, washing machines, air conditioners and computers.

All the subsidies issued in this program (S1, S2, and S3) are fully financed by the central and local governments. The data on the "Old for New Program" [76] suggest that this program achieved considerable success in driving both sales of new products and collection of old appliances from consumers. As of 11 May 2011, 20 months after the program was launched, a total of 49.9 million obsolete home appliances had been collected from consumers and 48.1 million new appliances (valued at USD 27 billion) had been sold.

Despite these successes, the program and the subsidies on which it depended proved too expensive for the government. For example, when one new TV is sold and one old TV is collected, the government must pay three subsidies (to the consumer, collection company and recycler), which can add up to between USD 41 and USD 68 per unit (calculated from Table 11). Furthermore, site visits by the authors to several recyclers in 2012 revealed that the volumes of e-waste collected from consumers through formal channels has declined considerably since government subsidies ceased at the end of 2011, thus indicating that, in the absence of subsidies, consumers are likely to once again sell their waste appliances to the informal sector, which offers both competitive prices and home pick-up. It seems, then, that the long-term viability of a collection program such as the "Old for New Program" depends on the ability to establish a cost-effective financing scheme. Now that the program has ended, the next key step is to learn from this program's successes and failures and to translate these lessons into effective national e-waste legislation. Whether high collection rates can still be achieved without heavy government subsidies will be a key issue moving forward.

The "Old for New Program" demonstrated convincingly that, when provided with sufficient collection subsidies, the formal sector can collect large quantities of e-waste within a short period and stay competitive with the informal sector. When ensured a constant and sufficiently-large supply of e-waste, and when recycling deficits are offset by government subsidies, formal recycling operations can be economically viable and effective over the long-run. Nevertheless, the determination of subsidy levels and the allocation of responsibilities are aspects of formal recycling that need to be researched and discussed further to ensure the economic and logistical viability of the formal sector.

6.2. International collaboration and projects

6.2.1. Cooperation with the Swiss government

Switzerland was the first country to cooperate closely with the Chinese government on issues of e-waste research and the development of e-waste management projects. In 2004, the Swiss State Secretariat for Economic Affairs (SECO) launched a project called "Knowledge Partnerships in e-waste Recycling" in South Africa, India and China. The project in China was managed by EMPA (Swiss Federal Laboratories for Materials Testing and Research) and supported by the Embassy of Switzerland in Beijing. One sub-project in China was to support the National People's Congress on e-waste legislation. The other sub-projects also helped to review the current state of e-waste recycling in China and to identify optimal treatment technologies [77].

In September 2005, SECO financed the "Financing e-Waste Management and Extended Producer Responsibility in China" symposium as part of the R'05 7th World Congress on Recovery, Recycling and Re-Integration in Beijing. In August 2006, SECO invited a diverse group of stakeholders from India, South Africa and China on an "e-waste study tour", where they visited e-waste treatment facilities in Switzerland. Chinese participants included officials from National People's Congress and experts/professors from Peking University and Renmin University. The tour provided an opportunity for participants to learn more about technological, financial, logistical and legal solutions to e-waste challenges faced in their own countries. In October 2006, experts from the Chinese Electronic Engineering Design Institute were invited to visit Switzerland for another study tour.

Meanwhile, under a signed memorandum of understanding between EMPA and NDRC, a sub-project was set up to support the establishment of a pilot e-waste recycling system in four target cities in China.

In December 2006, SECO funded a workshop called "Legislation on e-waste Recycling", which was organized by the Environmental Protection & Resources Conservation Committee, National People's Congress of China. Participants included officials and experts from Swiss and Chinese institutions and universities. At the workshop, participants discussed the current state of e-waste recycling and the challenges related to e-waste legislation in China [77].

As a result of this collaboration, EMPA and the Chinese research institutions and universities have published a number of journal articles and reports on e-waste issues in China. The publications range from analyses of the progress of e-waste legislation in China [47, 78] and the current state of China's national e-waste treatment system [70] to studies of the environmental impacts of the Chinese EEE industry [79] and comprehensive investigations of consumer behaviours in Beijing and Taizhou [80, 81]. These studies provide an overview of the e-waste management and treatment situation in China from 2006 to 2008, and provide a solid foundation on which to develop follow-up research to identify research gaps and potential areas for improvement.

The cooperation between the Swiss government and research institutes and Chinese officials and experts helped to bring information and knowledge on e-waste management and treatment from Europe to China. This cooperation also initiated legislation, research and discussion on the formal administration of e-waste problem and establishment of treatment industries in China. Importantly, this cooperation also demonstrated that improvements can be made on critical environmental issues in developing countries through diplomatic collaboration, knowledge exchange and technology transfer.

6.2.2. Best-of-2-Worlds project (StEP Initiative)

"Best of 2 Worlds" (Bo2W) is a project of "Task Force ReCycle" of the StEP (Solving the e-waste Problem) Initiative, an e-waste initiative coordinated by the United Nations University. Bo2W provides a network and pragmatic solution for the treatment of e-waste in and from emerging economies. It seeks technical and logistical integration of best pre-processing practices in developing countries – primarily manual dismantling of e-waste – and best end-processing practices to treat hazardous and complex disassemblies in state-of-the-art end-processing facilities in developed countries [82]. This project has so far been developed and tested in China and India [36, 37]. In China, the Bo2W project has conducted material testing by dismantling 15 tonnes of various types of e-waste and establishing pilot treatment plants (mainly for IT equipment and small and large household appliances). The Bo2W project focuses explicitly on recycling of Chinese domestic e-waste; no illegal transboundary waste will be involved.

The Bo2W project aims to find an eco-efficient approach to carrying out e-waste recycling while also complying with environmental, health and safety standards and fulfilling all existing legal requirements. Below is an outline of the rationale behind Bo2W:

- For the pre-processing stage, manual dismantling (simple technology, low cost) of e-waste is preferred over mechanical separation (advanced technology, high cost). Manual dismantling achieves higher separation rates without breaking the original form of components and materials, which is easier to sort and improves re-usability. Importantly, it does not depend on expensive or advanced technologies, so it can be relatively easily implemented in developing countries. Given the abundant current and potential workforce, high levels of mechanization and automation in pre-treatment processes cannot be justified, due to high investment in training and infrastructure, higher energy consumption, and the elimination of jobs for the poor and a decrease in revenues because of lower-grade shredding outputs.

- For the end-processing stage, technically-advanced facilities that are able to effectively recover valuable and treat toxic materials while maintaining a high environmental health and safety performance are clearly preferable to less-advanced informal refining techniques, which pose high environmental, health and safety risks. Such facilities are rarely present in developing countries, and it is in most cases not feasible to establish the necessary infrastructure and facilities to locally treat e-waste at all stages of the treatment chain. Under the limitations of economy of scale, access to global state-of-the-art end-processing facilities can be a pragmatic solution to the challenge of dealing with critical fractions in developing countries.

The B02W project is built on the belief that combining manual dismantling at the local level with proper environmental, health and safety standards and high-tech end-processing on a global scale offers the most sustainable solution for the treatment of e-waste in developing countries.

6.2.3. UNEP pilot project in Suzhou

Suzhou city (in Jiangsu Province), is a key centre for the electronics manufacturing industry in China. To encourage consumers and enterprises to dispose of their e-waste through the formal recycling sector, UNEP initiated an e-waste collection pilot project in Suzhou in 2010 [83, 84]. This project is called the “Pilot Project on Public-Private Partnership for e-waste Collection” and is conducted by the Basel Convention Regional Center for the Asia and Pacific Region in China (BCRC Beijing). It aims to build a cooperative partnership among electronics manufacturers, retailers and consumers, while fostering cooperation among recycling companies, schools and communities. The pilot project encourages electronics manufacturers to take social and environmental responsibility for e-waste recycling. It also encourages schools to help guide green electronics consumption through education programs. Finally, it encourages residents to take environmental responsibility by giving their e-waste to formal recyclers instead of to informal collectors.

Local authorities and experts have investigated the challenges related to the formal collection and treatment of e-waste and have developed effective practices to address these challenges by involving local treatment enterprises, retailers, legal authorities and consumers. Furthermore, another e-waste collection and treatment program in Suzhou run by APFED (Asia-Pacific Forum on Environment and Development) has improved public awareness of and promoted recycling, collection and treatment of e-waste in the city.

Through the UNEP program, as well as related programs like the APFED program, industry and other stakeholders have been made more aware of and recognized the importance of efforts to improve formal sector collection and treatment of e-waste. BCRC Beijing has held two workshops on the development of the e-waste collection partnership and experiences exchange. An e-waste information system platform on the BCRC Beijing website has been established and is updated regularly to enhance communication and information sharing on the e-waste collection partnership in Suzhou. Through the implementation of this project, the following outcomes have been achieved: 1) the establishment of a public-private partnership between e-waste treatment enterprises and EEE manufacturers in Suzhou; 2) awareness-raising activities and promotion of the public-private partnership concept to increase awareness of environmentally-sound management of e-waste; and, 3) monitoring of the main e-waste flows in Suzhou, as identified by the public-private partnership. Furthermore, the e-waste information system platform on the BCRC Beijing website regularly publishes up-to-date information to monitor e-waste flows in Suzhou under the partnership. Finally, questionnaires about such practical target indicators as collection and treatment volumes were completed by partnership members, including both e-waste generators and e-waste treatment enterprises.

The goals of the next project phase are:
1. to strengthen and increase the flow of e-waste to the formal collection and treatment sector.
2. to contribute to other related activities of UNEP/SBC (Secretariat of the Basel Convention) where appropriate (e.g. the partnership for action on computing equipment).

This project will include six main activities in Suzhou:1) investigate the e-waste life cycle; 2) consult with and engage relevant stakeholders; 3) achieve a multi-stakeholder agreement for the environmentally-sound management (ESM) of e-waste; 4) carry out ESM activities through the partnership; 5) monitor the collection and treatment practices under the partnership; and, 5) share the experiences and lessons learned with other stakeholders in the region [85].

6.2.4. Sino-Dutch Solid Waste Exchange Project

Between 2008 and 2010, the Chinese and Dutch governments ran a project called the Sino-Dutch Solid Waste Exchange Project (SiDuWEX), which sought to build a platform involving companies, educational and research institutions, and government organizations from both China and the Netherlands for promoting dialogue and cooperation on the issue of solid waste management in China. The short-term goal was to set up the Sino-Dutch Research, Demonstration and Training Centre for Waste Management. The centre is expected to be commercialized and play a key role in human resources development in the field of solid waste management [86].

Among the key issues covered by SiDuWEX is the issue of e-waste. In 2008, a field visit to the state-of-the-art treatment facilities of e-waste in the Netherlands was organized for Chinese researchers, representatives from recycling companies and governmental officers. In 2009, an international review of the state of e-waste management in China was drafted. In 2010, experts and policymakers from the Netherlands and China held two training sessions for e-waste researchers, collection and recycling companies, system managers and policymakers in China.

7. Stakeholder analysis

Various institutions, agencies, researchers, private companies and industrial groups are engaged in e-waste issues of China. This chapter gives an overview of key stakeholders and their work domains and areas of expertise.

7.1. Governmental agencies

In China, the government is in the pivotal position to coordinate and manage e-waste flows, activities and policies. At present, there is no single government agency to supervise and legislate the range of activities related to e-waste management, including collection, refurbishment, treatment logistics, financing, pollution control, import and export, and monitoring. Instead, the responsibilities and tasks have been allocated to various government agencies in accordance with their respective administrative domains. Table 12 gives a brief overview of the government agencies at the national level (ministries) involved in the legislation, management, monitoring, and communication of e-waste issues in China [87]. At the provincial and city level, there are corresponding departments that are subordinate to the national ministries, and which fulfil the same administrative duties locally and report to the national ministries.

To summarize, each of the aforementioned government agencies plays a key role in e-waste management in China. NDRC is responsible for developing macroeconomic plans and pilot projects related to the socially-, economically- and environmentally-responsible treatment of e-waste. MEP is the agency with the greatest role in defining treatment standards, emissions and pollution controls, licensing for recyclers, transboundary shipment controls and monitoring related to e-waste. MIIT is most relevant to the electronics manufacturing industry, as it is responsible for encouraging cleaner production and eco-design of EEE. MOC is responsible for the establishment of e-waste collection channels. MOF is responsible for defining and managing subsidies on logistics, collection and recycling of e-waste. Customs is responsible for port control, checking containers, registration and reporting of shipments, and

Table 12: Government agencies involved in e-waste management

NATIONAL AGENCY	ROLES AND RESPONSIBILITIES	SUMMARY
National Development and Reform Commission (NDRC)	- To study and resolve major problems concerning the coordinated development of economy, society, environment and resources - To put forward polices and plans for resource conservation and comprehensive utilization - To participate in the formulation of environmental protection plans, coordinating work related to environmental protection, and promoting clean production - To coordinate the implementation of key demonstration projects and the popularization of new products and technologies.	- Plan pilot projects - Define the categories of e-waste for management - Develop financing scheme for e-waste management - Define responsibilities for various stakeholders
Ministry of Environmental Protection (MEP), Department of Pollution Control (DPC)	- To formulate and organize the implementation of laws, regulations and rules to prevent air, water, soil and noise pollution - To organize the implementation of environmental management systems such as registration of pollution discharge applications, pollution discharge permits, deadline treatment of pollution sources and standard-attaining discharges, registrations for the import and export of toxic chemicals, operation permits for hazardous wastes and e-waste, and regulation of compulsory emissions treatment by EP authorities - To organize the formulation of environmental function zoning plans - To undertake the examination and approval of import and export permits for wastes to be used as raw materials	- Establish e-waste treatment standards - Manage licensing system for recyclers - Monitor and check environmental performance of recyclers - Establish list of products/waste for import and export - Study best treatment technologies

Ministry of Industry and Information Technology (MIIT)	- To study the medium-term and long-term development plans, policies and measures for the manufacture of electronics and IT products and industry of software - To modify product instructions - To organize and coordinate the development and production of important system products and basic products such as micro-electronics - To organize and coordinate the localization of integrated products, components, apparatuses and materials which are demanded in national important engineering projects; To work out guidance of industry investment - To extend the useful life of electronics and IT products	- Manage EEE manufacturing industry - Encourage eco-design and regulate use of toxics in EEE - Define responsibilities and communicate with EEE producers and OEMs
Ministry of Commerce (MOC)	- To study, manage and implement policies and regulations regarding technology commerce - To establish product lists for those technologies for which import is encouraged, limited or forbidden - To monitor, analyze and manage the import and export of electrical and electronic equipment	- Establish and manage e-waste collection channels and systems
Ministry of Finance (MOF)	- To formulate and implement strategies, policies and guidelines for economic development and public financing for revenue sharing between the central and provincial governments - To propose tax legislation plans and review proposals on tax legislation and tax revenue regulations - To formulate and implement accounting regulations for government and private corporations and to promote accountability and transparency	- Define responsibilities and communicate with EEE producers and OEMs
General Adminis-tration of Customs (GAC)	- To manage the import and export of goods into China. Duties include registration, inspection, gathering and maintaining statistics, reporting etc. - To collect value added tax (VAT), customs duties, excise duties, and other indirect taxes - To monitor and prevent smuggling, illegal import and export	- Register EEE import and export figures - Monitor and check illegal activity at customs checkpoints

monitoring of illegal activities. Collectively, these institutions work to tackle the complex challenges of e-waste management. While many of their roles and responsibilities are clearly defined, there continue to be areas of overlapping responsibilities/jurisdictions or grey areas where roles and responsibilities have not yet been clearly defined. In order to maximize the effectiveness and efficiency of these agencies in their respective roles, it is important to further clarify and update their respective domains and responsibilities according to the latest legislation and political, economic and technological developments.

7.2. Industry

7.2.1. Producers

Most international electronics companies have established branches and production lines in China. Meanwhile, domestic electronics companies have also shown stable growth over the past 20 years, as producers both for their own brands and for multi-national companies. MIIT is responsible for the administration of the production, sales and industrial development for EEE producers. In China, producers tend to follow the e-waste management system established by the central government through national e-waste legislation. This is because all producers (including importers) who sell the products listed in the managing category, are obligatory to pay for the recycling fee set by the government, according to the fifth legislation introduced in Chapter 5. The government is in the central position to arrange and management the take-back system, while the cost is mainly paid by producers.

Meanwhile, some producers have set up take back program to offer free recycling services to consumer. However the current take back volume is relatively low due to most China consumers' preference to sell their e-waste to the informal sector for higher monetary return. Most producers plan to leverage on their existing sales and service centers to offer wider geographical collection. Hence the central government's support in providing proper recycling guidelines is essential to create awareness and shape consumer attitudes towards reliance of proper e-waste recycling infrastructure offered by the producers.

7.2.2. E-waste collection and treatment companies

Both the formal and informal sectors are engaged in the collection and treatment of e-waste in China, as discussed in Chapters 3 and 4 of this report. Their activities have been largely shaped by China's social-economic conditions, legislation, level of enforcement, market demand and consumer awareness. As introduced in section 4.2, there are approximately 130 e-waste recycling enterprises that have been recognized as formal treatment companies with treatment licenses issued by local environmental agencies. These companies are the focal points for practices related to e-waste collection and potential quantification, and play a key role in determining treatment efficiency, treatment processes, pollution control measures and EHS performance as it relates to e-waste recycling, re-use and refurbishment. Informal collectors and treatment operations, on the other hand, are difficult to monitor and regulate and frequently engage in e-waste treatment practices that pose serious environmental and health risks. The actual number of informal collectors and treatment operations in China is still unknown.

7.2.3. Industry associations

Industry associations play a coordinating role in relations among and between industries, the government and the public in China. They represent industry members, support compliance with governmental legislation, improve the sustainability of the industry, and also provide advice to both the industry and the government. Below is a brief overview of some of the most influential industry associations in China related to EEE and e-waste management.

China Household Electrical Appliances Association

China Household Electrical Appliances Association (CHEAA) was established in December 1988. A self-composed, non-profit social and economic organization, CHEAA is composed of Chinese manufacturers in the household appliances industry, related businesses and auxiliary enterprises, research institutions and other voluntary agencies [88].

CHEAA's main objective is to represent interests from the EEE industry, to defend the legal rights of its members, and to promote a fair and orderly competitive market environment. In doing so, the association aims to serve its members, the appliance industry and the government, and to contribute to the healthy and sustainable development of the industry. They have published annual reports about the development of the Chinese EEE industry [89] that cover such aspects as market situation (production, import, export, domestic sales of various EEE), opportunities and challenges, and development planning. CHEAA thus possesses valuable expertise in market analysis related to EEE sales and e-waste generation.

Executive Committee of Foreign Investment Companies

Founded in July 2002 upon registration at the Ministry of Foreign Trade and Economic Cooperation, the Executive Committee of Foreign Investment Companies (ECFIC) is a self-regulatory and services-oriented institution composed of foreign holding companies invested in China. It is a subcommittee of the China Association of Enterprises with Foreign Investment (CAEFI) [90].

The mission of ECFIC is to create a platform for its member companies to communicate, cooperate and exchange information with the government; to help its member companies better understand government policies and regulations; to coordinate issues among member companies and enhance communications between members; and to utilize the advantages of foreign investment companies regarding legal awareness, business operation and human resources in order to introduce more foreign direct investment and improve the performance of foreign companies in China

In the field of EEE, the members of ECFIC include most of the major multinationals from the EU, the US, Japan and South Korea (including Microsoft, Philips, Siemens, HP, Dell, Sony and Canon, among others). There are regular meetings and workshops for member companies to discuss and study the latest issues of standards of electronic products (such as standards for design, production, and energy consumption), e-waste legislation, corporate social responsibility, and environmental protection during manufacturing and logistics. ECFIC's expertise lies in its global implementation experience with EPR (extended producer responsibility), including in China.

China Resources Recycling Association
China Resources Recycling Association (CRRA), established in 1992, is a national non-profit organization whose members are NGOs, research institutions and companies engaging in collection and recycling of secondary resources. CRRA aims to establish, strengthen and coordinate both the relationship among domestic recyclers of ferrous and nonferrous materials, paper, plastics and tires, and the relationship between the recycling industry, government agencies and civil society [91].

CRRA has assisted government such as NDRC, MOC, MEP and MOF in developing and evaluating various pilot projects related to recycling, developing legislation for waste recycling, drafting technical standards for waste treatment companies, and five-year planning for the recycling industry in China. In 2010 and 2011, CRRA led the planning process for two NDRC projects: “Planning and utilization of urban mining (2011-2015)” and “Planning of collection system for secondary resources (2011-2015)”. CRRA also provides consultation on three MOC standards: “Management measures for sorting centres of secondary resources”, “Management measures for collection points of secondary resources” and “Management measures for distributive markets of secondary resources”. Meanwhile, CRRA has also completed a series of research projects on developing e-waste collection and recycling systems, as well as a taxing system for the recycling of secondary resources. Based on these activities, CRRA possesses significant expertise regarding the ways in which formal e-waste collection and recycling in China can be improved and made more environmentally sound.

China Electronics Energy Saving Technology Association
China Electronics Energy Saving Technology Association (CEESTA) serves as an intermediary between the EEE industry and the government. CEESTA promotes the development of energy-saving EEE through the dissemination of new, energy-saving technologies, organizing trainings and workshops, offering consultation on energy-saving technologies and products, and researching the use of energy-saving products in Chinese society [92].

As a branch of CEESTA, the E-waste Comprehensive Unitization Work Committee (ECUWC) is a non-profit organization that receives support from MIIT and has been registered with the Ministry of Civil Affairs [93]. ECUWC supports policy decision-making on issues of e-waste management in China; promotes international communication on both policy and technology issues in e-waste recycling among public and private sectors; promotes the adoption of the extended producer responsibility principle in e-waste management policy; promotes research and development activities and standardization of recycling processes; initiates e-waste take-back programs; shares information on recycling technologies and markets; provides consulting and training services for recycling companies; prepares for future (producer and recycler) registers for e-waste management in China; and evaluates recycling projects and technologies in China.

7.3. Consumers
Consumers are important actors in the e-waste disposal chain because they choose the disposal channels and destinations for their household e-waste. In China, consumers tend to sell their equipment to the collectors who offer the best collection price, regardless of their actual technical and environmental performance. This behaviour strongly influences the financial model of the formal collection system, which must compete with the informal sector. The formal sector must offer consumers convenient services such as home pick-up and cash pay-back when collecting e-waste in order to stay competitive towards the informal counterpart for collecting sufficient volumes.

7.4. Research institutions

In China, research on key issues related to e-waste has been carried out in various research institutes and universities. It is quite common for policymakers to take direct advice from researchers when drafting legislation and making policy decisions. Some of the domestic organizations that have done substantial research in this field are briefly outlined below:

Tsinghua University

Tsinghua University is one of China's leading technical and engineering universities. Its School of Environment and Department of Precision Instruments and Mechanology have become the foremost centres for research on e-waste and related issues in China. They have accumulated abundant knowledge and conducted comprehensive research on treatment technologies, material flows, policy development, pollution, and e-waste management measures in China. Through years of research, they have made outstanding progress on the development of e-waste recycling technologies, including: equipment and technologies that can efficiently dismantle equipment and refine disassemblies; equipment installation and process monitoring in recycling facilities; and recycling guidelines for treating waste computers, refrigerators, washing machines, televisions, air conditioners and other electrical and electronic products. They have also served as direct advisors to the MEP during the process of establishing domestic e-waste legislation, defining policy targets and formulating treatment standards. They have established a mature communication network with StEP, BCRC Beijing and various research institutions in regions like Taiwan, Macau, Japan and South Korea.

Basel Convention Regional Center for the Asia and Pacific Region in China (BCRC Beijing)

Basel Convention Regional Center for the Asia and Pacific Region in China (BCRC Beijing) was established in 1997 according to the decision of the third meeting of the Conference of the Parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal. BCRC Beijing serves as a regional coordinating centre to provide technical assistance and promote the transfer of technology to assist developing countries and countries with economies in transition to fulfil their obligations under this Convention. In May 2009, BCRC Beijing was endorsed as the Stockholm Convention Regional Centre for Capacity-building and the Transfer of Technology by the fourth meeting of the Conference of the Parties of Stockholm Convention on Persistent Organic Pollutants. In the November 2009 initiation of the Regional 3R Forum in Asia, BCRC Beijing was one of the initiated organizations. And in May 2010, BCRC Beijing was designated as the regional focal point in Northeast Asia for the StEP Initiative.

On the issue of e-waste, BCRC Beijing has conducted research on e-waste policy and management, as well as experimental analysis and technical development. BCRC Beijing has also helped to implement successful projects such as the "Collection and Treatment Schemes for e-waste in Suzhou" (2008-2009), part of the APFED showcase program; the Basel Convention Secretariat Trust Fund Project (2008-2009) titled "Import/Export Management of E-Waste and Used EEE - Import/Export Criteria Research and Regional Workshop"; and "E-waste Management and Pollution Control Demonstration in Macau" (2010 - 2011).

Chinese Academy of Science

The Chinese Academy of Science (CAS) is a national academy for the natural sciences in China, and it is an institution of the State Council of China. The Research Centre for Eco-Environmental Sciences is a branch of CAS and is the first comprehensive research institution engaged in research on environmental science and technology in China. On the issue of e-waste, CAS has successively carried out ground-breaking work, including an environmental background survey in Taizhou and studies on the eco-toxicological effects of persistent organic pollutants. CAS also has expertise in life cycle analysis of various electronic products and treatment processes, material flows of e-waste, valuable resource recycling technology for e-waste, and environmentally-sound management of e-waste in China. The Institute of Process Engineering, another branch of CAS, is engaged in research in the fields of energy, chemical and biochemical engineering, materials engineering and resources/environmental engineering. It has conducted basic research on the key technologies involved in e-waste recycling.

China National Electric Apparatus Research Institute

The China National Electric Apparatus Research Institute (CEI), established in 1958, is affiliated with the China National Machinery Industry Corporation. CEI's research and development activities focus on eco-design, use of materials, manufacturing technologies, energy saving and national testing of EEE. Guangzhou Vkan Certification & Testing Institute (CVC), the certification and testing base of CEI, is the biggest EEE testing organization with the broadest capabilities and business reach in Asia. CVC cooperates with testing organizations from more than 38 countries, including the US and the UK, in the field of data exchange. The scope of testing includes household electrical appliances, electronic products, automobiles, hardware, steel and iron, petrochemicals, materials and electric power. CVC is capable of testing over 30,000 items according to more than 2,000 standards and issues over 30,000 test reports every year for up to 3,000 enterprises all over the world [94]. CVC has extensive expertise in material analysis (including both toxic and valuable content) and energy consumption for specific products as pertaining to the assessment of recycling technologies and to aligning e-waste composition with corresponding treatment capabilities.

China Household Electric Appliance Research Institute

The China Household Electric Appliance Research Institute (CHEARI), established in 1965, is hosted by the State-Owned Assets Supervision and Administration Commission of the State Council. CHEARI is a key institution for scientific innovation and technical services in the Chinese EEE industry, focusing on EEE research, testing, certification, standardization, metering and calibration, public education and training, as well as in related areas such as industrial designs and intellectual property protection. CHEARI's services help EEE enterprises to improve product quality, optimize production processes, and improve management levels and their overall performance [95].

E-waste Recycling Technology and Equipment Institute

The e-waste Recycling Technology and Equipment Institute was established in 2005 as a part of the School of Environmental Science and Engineering, Shanghai Jiao Tong University. The institute's primary research areas include e-waste treatment and recycling and recycling technology for e-waste and waste metals. At present, they have the broken-crush high voltage electrostatic separation technology for waste printed circuit boards and vacuum distillation technology for recycling substrate materials and metals from circuit boards.

Chinese Research Academy of Environmental Sciences

The Chinese Research Academy of Environmental Sciences (CRAES) was established in 1978 under SEPA, which is now the MEP. As a national non-profit institute for environmental protection, CRAES carries out basic scientific research on environmental protection, adopting the national strategy of sustainable development as the central focus. CRAES is also dedicated to providing strategic scientific and technological support for national environmental management and decision-making, and providing technical consulting on environmental issues related to social and economic development. CRAES thus plays an irreplaceable role in improving the scientific decision-making related to environmental protection in China. With its scope and collective experience, CRAES is an important institution in supporting e-waste recycling and treatment research, policy and practice.

Engineering Centre for e-waste Resource Recycling in Jiangsu

The Engineering Centre for e-waste Resource Recycling in Jiangsu, established in 2009 as part of Jiangsu Teachers University of Technology, conducts research on e-waste resource recycling and deep processing of precious metals. The centre aims to build: a public technology research and development platform and information consulting service centre for e-waste, non-ferrous metals (precious metals) and waste resource recycling industry in China; an industrial platform for introducing comprehensive resource utilization; complete sets of engineering equipment for non-ferrous metals and precious metals recycling; and a training base for waste resource recycling.

Other domestic research institutes

Apart from the aforementioned organizations, other domestic universities and institutes also engage in research on e-waste. Shanghai Jiaotong University conducts research on e-waste collection networks and treatment technologies for circuit boards and major home appliances. Macau University conducts research on e-waste management policy and Life Cycle Analysis (LCA). Jiaxing University conducts research on the informal sector and the development of recycling industry. Nankai University conducts research on estimations of amounts of e-waste generated and on the informal sector. And Guangzhou Institute of Geochemistry in the Chinese Academy of Sciences, Sun Yat-Sen University and Hong Kong Baptist University conduct research on pollution arising from the informal sector and informal recycling sites.

Overseas researchers

In addition to mainland Chinese researchers, there are a number of overseas research institutions also focusing on e-waste issues in China. The StEP Initiative conducts research on the best e-waste treatment technologies in developing countries like China. EMPA has established substantial knowledge and research projects in China related to domestic e-waste flows, consumer willingness, life cycle analysis of electronic products and treatment technologies. And research institutions like the Japan National Institute of Environmental Studies (NIES) and Kansai University have focused their studies on e-waste flows from Japan to China.

7.5. NGOs

The activity and influence of NGOs has been generally limited in China. However, in 2002, Greenpeace (HK and global divisions) and BAN (Basel Action Network) were the global forerunners in revealing the illegal export of e-waste to China and the consequences in informal e-waste recycling sites like Guiyu and Taizhou in China. Their in-depth investigations of e-waste recycling activities, environmental quality, and livelihoods and working conditions of local workers in Guiyu laid the foundation for subsequent e-waste research and campaigns.

7.6. Findings from 2012 stakeholder workshop

On 16 and 17 July 2012, the “Stakeholder Workshop & StEP Open Meeting in China” was held in Beijing, organized by the United Nations University (UNU), the StEP Initiative and BCRC Beijing. This workshop was supported by the MEP and the US Environmental Protection Agency (US EPA). It provided an interactive platform for understanding on-going and upcoming stakeholder activities on e-waste management in China, identifying the roles and responsibilities of different stakeholders, and facilitating cooperation among stakeholders based on shared priorities and goals.

More than 50 participants attended the workshop, with representatives from various UN organizations, both Chinese and international governmental agencies, research institutions, electronics producers, and e-waste collection and recycling companies. Prior to the workshop, participants received and completed a survey to introduce their own activities and share their priorities on e-waste management in China.

In response to the survey question “Which other ministries, organizations and/or industrial sectors are most essential to your China-related e-waste work?”, a majority of respondents pointed to “organizations involved with the regulation or standardization for financing, collection and processing of e-waste”. This confirms the finding from the literature study and analysis that the government is in the pivotal role in regards to the planning, organizing, regulating, monitoring, implementing and supporting of the formal collection and recycling of e-waste in China. The relevant policies, standards, certificates and licenses, along with subsidies, from the central government directly influence the development of the e-waste recycling industry and the definition of various stakeholders’ responsibilities.

Survey participants were also asked “What are the most critical issues related to environmentally-sound e-waste management in China?” The following issues were highlighted as the most significant, in order from highest priority: collection channels, legislation and subsidies, recycling standards and license management, and others topics (e.g. understanding the quantities and flows of used electronics and e-waste in China).

When asked for "suggestions for further improvement of environmentally-sound e-waste management in China", respondents provided the following suggestions:

- Develop formal e-waste collection channels to increase volume.
- Enhance coordination among relevant stakeholders.
- Implement strict WEEE dismantling qualifications and license management.
- Evaluate the efficiency of China's WEEE treatment system.
- Enhance enforcement of legislation and monitoring of performance related to policy targets, collectors and recyclers.
- Establish a transparent system for managing and publishing information.
- Identify the routes and flows of transboundary e-waste shipments.
- Improve the working conditions of informal recyclers.
- Conduct public education and outreach.
- Develop the scale and quality of the recycling industry.
- Encourage eco-design of EEE.
- Provide the best available and most economical recycling technologies and promote demonstration plants.
- Formulate clear standards for second-hand products.

During the workshop, participants exchanged their knowledge, insight and experience on e-waste management in China. Listed below are the key shared priorities for future development that were proposed and discussed throughout the workshop:

- Effective regulations must be put in place in order to promote higher collection rates and more environmentally-friendly and efficient recycling technologies and practices.
- Holistic policies are needed that incorporate education, certification and licensing of recyclers, as well as research and development across academic and industrial sectors.
- A communication platform is needed for stakeholders from different sectors to understand and be responsive to each other's e-waste-related policies, activities and requirements.
- A third-party certification system is needed to ensure that licensed recyclers comply with required standards and avoid secondary pollution. Such a system will also help to create a level playing field
- Capacity building is essential to improve conditions in the informal sector. Building institutions (such as certification programs) related to the informal sector is also important to ensure the long-term viability of improvements.
- It is important to learn from the international community and to share experiences related to e-waste management, best available technologies and system development.

7.7. Summary

Figure 11 provides an overview of key stakeholders relevant to e-waste issues in China. As shown in the figure, the government is in the central position to regulate, manage and coordinate the collection, treatment and disposal of e-waste. Producers contribute substantially to the formal management of the system by performing their designated end-of-life responsibilities (primarily in the form of financing), as outlined in national e-waste legislation. Because the formal sector is still in its relative infancy, the scale and influence of formal collectors and recyclers are still limited and they remain dependent on government support and subsidies. Meanwhile, the scale and influence of informal collectors, refurbishers and backyard recyclers remain significant. Consumers are becoming accustomed to selling their obsolete equipment to the informal sector, turning to the formal channels set up by the government in most cases only when doing so yields greater economic benefit. Cooperation from foreign governments and international organizations helps to bring state-of-the-art treatment technologies, management strategies and policies to China, which improves the effectiveness and efficiency of domestic e-waste management. Scientific research also plays an important role in the process of problem definition, impact assessment and decision making, and researchers regularly advise policymakers regarding e-waste legislation.

Figure 11: Overview of key stakeholders in e-waste issues in China

8. Potential directions for future work

The broad range of action points that might serve as the focus of future multi-stakeholder activities on e-waste in China in the future includes research cooperation, technology development, establishment of a communications platform and capacity building. From a content point of view, key topics demanding future attention include transboundary shipments, legislation implementation and assessment, emissions control, technology transfer and upgrade, financing, and eco-design of products. This section highlights some potential areas of interest for future projects and development, according to the research and knowledge gaps identified in the previous sections.

8.1. Transboundary shipments

From the data analysis in section 4.3, it is apparent that there is a lack of data and information related to the transboundary routes and the quantity of e-waste flowing into China. Defining the scale and nature of the problem can help to improve enforcement and cooperation among customs agencies. It can also help support mutual understanding of different countries' import and export provisions and terminology, which may help reduce or eliminate negative environmental impacts arising from such activities.

8.1.1. Capacity building on management of transboundary shipments

In order to effectively manage e-waste flows, it is essential to determine and monitor the routes through which e-waste from the developed countries is transferred into China. One possibility for tracking transboundary e-waste flows is to monitor various collection points or scrap yards in selected countries and using GPS to track their shipment routes. Key sources of illegally-shipped e-waste include the US (although only certain e-waste exports are illegal under US law), Europe, Japan and South Korea. This type of monitoring, however, is very challenging work that requires considerable coordination and effort. The investigation of shipments and underground trading of e-waste requires assistance from government agencies (such as police, customs, municipalities etc.) both in China and in the source countries. Furthermore, the collection of quality of information and data must entail rigorous customs checks, tracking and sampling of containers.

In the meantime, conducting training activities and workshops on the monitoring and management of transboundary e-waste flows can increase awareness and capacity among key stakeholders, such as customs officers. Clearly defining e-waste, product categories and administrative policies and disseminating them effectively among relevant stakeholders can also help to improve mutual understanding and collaboration.

8.1.2. Quantity of illegal shipments to China

From a strategy perspective, determining the volume of e-waste shipments entering China would greatly further understanding of the scale of the transboundary shipment problem and provide important information to domestic e-waste customs agencies seeking to manage both outgoing and incoming shipments. Many efforts are under way to calculate global flows of used electronics, including the StEP ADDRESS database and collaborative projects between the US EPA, StEP and the Massachusetts Institute of Technology, as well as through the Commission for Environmental Cooperation. While these efforts may be able to estimate the quantities of used electronics exported from the US, Europe, and other developed countries, complementary efforts to identify shipments that reach China and that are imported against Chinese law would help support best practices and customs enforcement at the global level.

8.2. Domestic e-waste flows in China

Both the amount of e-waste being generated in China and the destinations for e-waste within China remain unclear. It would be worthwhile to carry out a national study on existing e-waste flows and update it regularly. The information and data would help policymakers to understand the roles of the various actors within the formal and informal systems and the material flows between and among them. Such information would also help formal sector planning regarding the number of collection points, the capacity of recycling facilities, and the level of financing necessary, and it would enable a more accurate grasp of the scale of the informal sector and complementary flows.

8.2.1. Standardizing calculation of EEE sales and e-waste generation

Various methods and data sources are used to calculate the amount of new EEE put on the Chinese market. As shown in section 2.2 of this report, some of the calculations produced are inconsistent or incompatible with each other. It is therefore essential to establish a standardized method for calculating the amount of EEE put on the market. Currently, UNU is doing such research in the Netherlands and other EU countries, applying the Eurostat data and coding system. A similar method can be applied in China by using data on domestic production and international trade.

A standardized method for calculating the amount of EEE put on the market and the amount of e-waste generated might include the following steps and components:

- **i.** Define the categories and scope of e-waste generated according to various data sources and known product properties.
- **ii.** Link the type of EEE/e-waste to national and international registration, statistics, and trading and goods codes.
- **iii.** Calculate the total EEE put on the Chinese market over time.
- **iv.** Investigate the average lifespan of various types of EEE in China over time.
- **v.** Determine the average weight of various types of EEE in China over time.
- **vi.** Determine the re-use rates for various types of EEE and their feedback loops into sales and home stocks.
- **vii.** Investigate household penetration rates for various types of EEE.
- **viii.** Study consumer attitudes and habits regarding the discarding of EEE.

8.2.2. Research highlights for domestic e-waste flows

This research has identified the following research gaps and areas for future research:

- **A.** Current e-waste legislation and research focuses, perhaps overly so, on only five types of EEE (those discussed in this report); the quantity, flows and treatment situation for other waste appliances (e.g. other large household appliances, small household appliances, consumer equipment, lamps etc.) remain unclear.
- **B.** Most e-waste studies focus on China’s urban areas. However, China’s rural population exceeds 50 per cent of the national population and the rural market for EEE is developing rapidly. Effective management of e-waste in rural areas requires investigation into the purchasing patterns, stocks and discarding trends in rural areas.
- **C.** The cultural, economic and policy differences between China’s geographic regions is significant. Studying the geographic distribution of e-waste generation and treatment in these different local contexts is important for tailoring policy decisions to different regions.
- **D.** The refurbishment and re-use market remains large in China due to high demand from low-income residents and people in rural areas for second-hand EEE. The re-use of EEE changes the value chain and material flows of obsolete appliances. Further research on the re-use market in China would help illuminate the consumption patterns and domestic flows of second-hand EEE.
- **E.** The “Old for New Program” showed that consumers are motivated to hand in their e-waste to the formal channels only if the payment is higher than they would receive from the informal sector. Further consumer questionnaires would shed light on the ways in which collection subsidies affect consumer use of formal or informal collection channels. Studies on establishment of effective collection channels and schemes with strong public participation are also functional for achieving higher collection rates.

8.3. Improvement of health and environmental conditions for the informal sector

The informal sector can be generally divided into informal collectors (scavengers, dealers, and brokers), refurbishers and recyclers. Most of the environmental impact has been generated by the informal recyclers, though other stakeholders greatly contribute to the formation and operation of informal e-waste trading networks.

Informal collectors are doing an efficient job of collecting obsolete equipment from consumers. Informal collectors have both higher penetration rates (into communities) and are more flexible than formal collectors. The primary concern around informal collection is that the collectors sell most of the collected e-waste to informal recyclers, whose activities have been proven to have negative impacts on both the environment and workers' health. It is therefore necessary to work with informal collectors and recyclers to improve the health and safety of the informal recycling industry without sacrificing economic opportunities for people who work in the informal sector.

Informal treatment of e-waste in China involves intensive labour and low-tech treatment of various subassemblies. A thorough investigation of informal treatment practices is necessary to determine which practices are acceptable and which practices cause damage to the environment and to the health of workers. Environmental studies of such process can help to characterize and quantify exposure pathways and identify hazardous products or processes that involve high levels of bio-accumulative toxics. Technical, economic and social assessments of informal recycling processes can help to identify opportunities to change, upgrade or abandon particular informal treatment activities.

According to various investigations [64, 66, 96-98], the accumulation of toxic substances such as heavy metals, PCBs and dioxins in the water, soil and air at the recycling sites in Southern China has reached a critical level. Without concerted environmental remediation measures in polluted sites, these persistent chemicals will continue to pollute the water, soil and air of these sites for a long time, posing significant health risks to local residents. In order to prevent further damage to local ecological systems and threats to the well-being of local residents, environmental rehabilitation and pollution prevention measures must be taken in key e-waste recycling sites, such as Guiyu and Taizhou. In addition, solution oriented research (such as environmental and affordable technologies, economic measures, effective managing policy) will fundamentally help to transfer or upgrade the pollution activities of informal recycling recycling.

8.4. Development of domestic e-waste legislation in China

In early 2011, a key piece of China's domestic e-waste legislation called "the Regulations on the Administration of Recycling and Treatment of Waste Electric and Electronic Products" went into effect. Known as China WEEE due to its equivalence to the EU WEEE Directive, the purpose of this legislation is to institute proper e-waste collection and recycling in the country. The StEP Initiative has accumulated abundant knowledge about the progress of WEEE Directive implementation in the EU. Experiences and insights from WEEE legislation implementation in the EU and other countries could be drawn upon to help guide the implementation of e-waste legislation in China and help Chinese policymakers adapt successful policies and avoid making the similar mistakes. Finally, the experiences of other countries, such as the US, where the federal government has developed national recommendations for electronic stewardship and many states have developed electronics take-back laws, may also be helpful in shaping Chinese policy and practice.

Exploration of the following topics may contribute to the development of effective e-waste legislation in China:

A. Develop clear terminology, definition and scope of EEE and e-waste.
B. Develop clear targets for China's e-waste legislation (e.g. collection targets, re-use and recycling targets etc.).
C. Develop effective a method for evaluating the implementation of e-waste laws.
D. Develop and implement treatment standards.
E. Improve the formal sector's collection performance.
F. Determine appropriate financing schemes and methods of determining subsidy rates (e.g. for collection and logistics) and treatment fees.
G. Define and allocate the responsibilities of producers and other stakeholders.

H. Establish a monitoring system for legislative implementation and improve transparency.
I. Create learning loops and mechanisms for swift improvement in practices after evaluations.
J. Stimulate eco-design through legislation.
K. Raise public awareness of e-waste issues.

A shared priority that emerged during the stakeholder workshop was increasing the amount of e-waste collected through formal channels, which is essential for the development of the formal treatment industry. Further research is needed on how to construct efficient and cost-effective collection channels and achieve high levels of consumer participation.

8.5. Improvement and promotion of enterprises involved in e-waste treatment

8.5.1. Project demonstration

Many formal e-waste treatment enterprises have grown and prospered as a result of the implementation of the "Old for New Program" and the promulgation of China's e-waste legislation. Some formal treatment enterprises have not thrived, however, due to factors such as lack of treatment capacity, appropriate technologies or best practices. Project demonstration can enhance the introduction and exchange of best technical, economic and environmental processing practices.

8.5.2. Establishing a certification system

In the US, there are currently two accredited certification programs for electronics recyclers: the Responsible Recycling Practices (R2) and the e-Stewards standards. They aim to reduce environmental and human health impacts from improper recycling. In China, establishing a third-party certification system, which would operate in conjunction with the current licensing system, could help strengthen standards for the environmentally-sound management of e-waste.

8.6. Technology assessment, identification and transfer

8.6.1. Technology assessment towards different treatment processes

China's economy and its e-waste recycling industry are currently undergoing a transition period. There is a wide spectrum of e-waste treatment facilities and practices, ranging from low-tech and manual labour-intensive informal treatment to high-tech and highly-mechanized formal treatment. However, there is a lack of detailed technical, environmental and economic assessment of these facilities. This would require specific investigation into the various treatment processes, including full records of material balances and emissions. Such detailed assessments would help fill technical and knowledge gaps and would provide valuable insights for further improvement on such important aspects as control of emissions and toxic substances, among others.

Below is a list of treatment aspects and indicators that may be used when comparing the treatment processes and technologies (and the associated EHS protections) in China, the EU and the US:

Aspects of treatment:

A. Treatment categories of waste products
  a) Large household equipment
  b) Small household equipment
  c) ICT equipment
  d) CRT, LCD and LED TV and monitors
  e) Lamps

B. Pre-processing (treatment technology, step 1)

a) Manual dismantling
b) Shredding (mechanical processing)
c) Combination of manual and mechanical method

C. End-processing (treatment technology, step 2)

a) Base metal recycling
b) Precious metal recycling (e.g. gold, silver, platinum, palladium etc.)
c) Plastic recycling (e.g. normal plastics and plastics with flame retardant)
d) Treatment of CRT glass
e) Lamps
f) CFCs and foams
g) Recycling of strategic metals (e.g. rare earth metals)
h) Final disposal of residuals (e.g. landfill, incineration, storage etc.)

D. Indicators:

a) Mass balances of different systems
b) Recycling rates for specific materials or substances
c) Re-use potential and re-use rates for components and intact equipment
d) Life cycle assessments of hazardous materials, emissions and toxic processes
e) Economic gains/losses in different systems

8.6.2. Technology identification and transfer

Technology assessments will help identify and explain variations in the environmental and economic performances of different treatment processes and recyclers. Adopting and adapting the technologies and best practices from industrialized and other developing countries will help improve specific waste treatment processes and technologies. Key objectives in this type of cooperation are to improve the safety of workers, better control environmental pollution and obtain high recycling efficiency.

It is important to note that technologies and practices adopted from other countries must be adapted to local contexts and needs. Direct duplication of technologies or practices might result in failure if local social conditions are not taken into account, such as economies of scale, working and living conditions, legal frameworks and enforcement, labour costs, availability of investment capital, market potential and financing, the availability of related technologies and infrastructure, workforce training. It is therefore advisable that industries and/or the companies adopting such technologies or processes should carry out full-scale feasibility studies of the imported technologies and/or processes before adopting them or investing in their development.

9. Conclusion

China plays a key role in the global electrical and electronic products industry, including both the manufacturing, the refurbishment, and reuse of EEE and recycling of e-waste. Due to the global nature of the electronics market and industry, e-waste management and legislative developments in China have significant influence on the environmentally-sound management of used electronics at the international level. China is now facing increasing e-waste problems due to the growing domestic consumption of electronics and the influx of large volumes of e-waste, mostly from the US, the EU and other developed countries.

Under the progressive development of pilot projects and domestic e-waste legislation over the past five years, the formal e-waste recycling industry in China has shown considerable growth in both treatment capacity and quality. With the construction of formal collection channels and recycling infrastructure by the government and treatment subsidies from producers, the formal e-waste treatment industry can expect further technological and economic improvement. The growth of the formal sector is important for lessening the environmental and health impacts of e-waste treatment. However, due to a range of social and economic factors discussed in this report, informal collectors continue to play a major role in the collection and recycling of e-waste, and informal processing often leads to detrimental effects on the environment and the health and safety of workers and local communities. In the coming years, the formal and informal sectors will both continue to operate.

The Chinese government plays a central role in the planning, administration and monitoring of the e-waste system in China. Other actors, including universities and research institutions, companies, industry associations, NGOs and foreign governments and agencies also play important roles. Improvements in the e-waste management system can thus be achieved through a combination of legislative development and implementation evaluation, technology transfer and innovation, research, knowledge exchange and international cooperation. Potential approaches and topics for future work include: establishing explicit policy targets and comprehensive policy assessment, mapping the material and financial flows of e-waste, technology assessment and development, improving the conditions of the informal sector and controlling transboundary shipments. This work will facilitate better understanding of the whole e-waste system and provide key information and insights that will contribute to the achievement of the goal of reducing the negative environmental impacts from e-waste treatment while improving resource efficiency and the benefits to society.

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ABOUT THE StEP INITIATIVE:

"StEP envisions a future in which societies have reduced to a sustainable level the e-waste-related burden on the ecosystem that results from the design, production, use and disposal of electrical and electronic equipment. These societies make prudent use of lifetime extension strategies in which products and components – and the resources contained in them – become raw materials for new products."

Our name is our programme: solving the e-waste problem is the focus of our attention. Our declared aim is to plan, initiate and facilitate the sustainable reduction and handling of e-waste at political, social, economic and ecological levels.

Our prime objectives are:

- Optimizing the life cycle of ecological and electronic equipment by
  - improving supply chains
  - closing material loops
  - reducing contamination
- Increasing utilization of resources and re-use of equipment
- Exercising concern about disparities such as the digital divide between industrializing and industrialized countries
- Increasing public, scientific and business knowledge
- Developing clear policy recommendations

As a science-based initiative founded by various UN organizations we create and foster partnerships between companies, governmental and non-governmental organizations and academic institutions.

StEP is open to companies, governmental organizations, academic institutions, NGOs and NPOs and internationally organizations which commit to proactive and constructive participation in the work of StEP by signing StEP's Memorandum of Understanding (MoU). StEP members are expected to contribute monetarily and in kind to the existence and development of the Initiative.

StEP's core principles:

1. StEP's work is founded on scientific assessments and incorporates a comprehensive view of the social, environmental and economic aspects of e-waste.
2. StEP conducts research on the entire life cycle of electronic and electrical equipment and their corresponding global supply, process and material flows.
3. StEP's research and pilot projects are meant to contribute to the solution of e-waste problems.
4. StEP condemns all illegal activities related to e-waste including illegal shipments and re-use/ recycling prac-tices that are harmful to the environment and human health.
5. StEP seeks to foster safe and eco/energy-efficient re-use and recycling practices around the globe in a socially responsible manner.

Contact:
StEP Initiative
c/o United Nations University
Institute for Sustainability and Peace (UNU-ISP)
Operating Unit SCYCLE
Hermann-Ehlers-Str. 10
53113 Bonn, Germany

Phone: +49-228-815-0271
Fax: +49-228-815-0299

info@step-initiative.org
www.step-initiative.org
www.isp.unu.edu

UNITED NATIONS UNIVERSITY
UNU-ISP
Institute for Sustainability and Peace