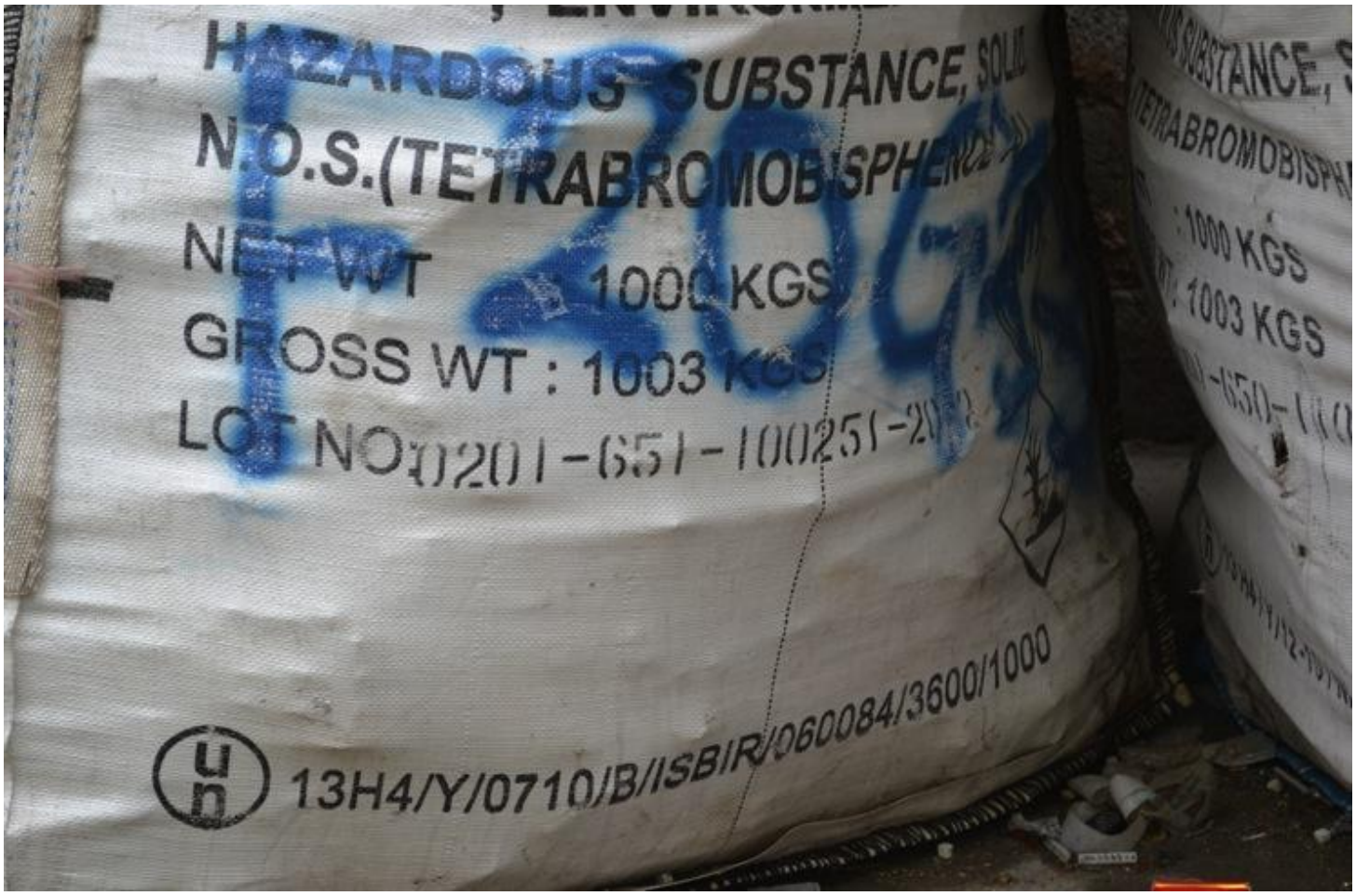
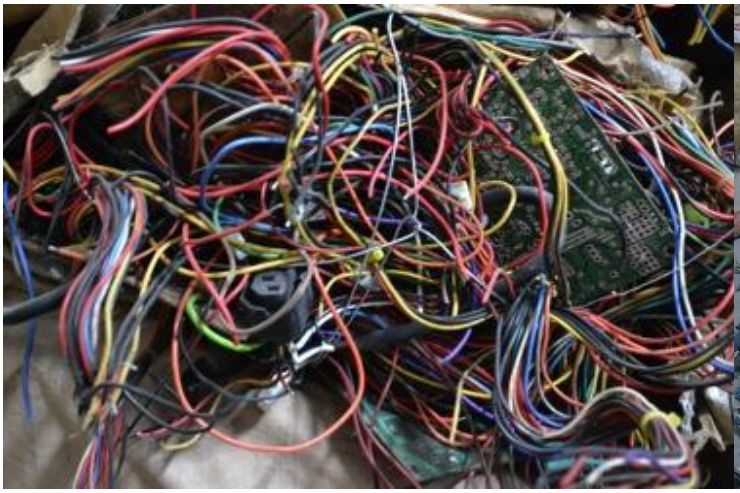


The Labour, Human Health and Environmental Dimensions of E-waste Management in China



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Executive Summary

This research paper examines the labour, human health and environmental dimensions of e-waste management in China, analyzing both the formal and informal sectors. It identifies the needs for synergizing policies and measures concerning environmental pollution control and labour protection in e-waste management.

E-waste can be generated from various sources, including households, corporations, industries, and illegal shipments from other countries to China. The rapid growth in the rate of consumption and replacement of electronics intensifies the generation of e-waste and near-end-of-life electronics. However, e-waste management is different from general waste management because it contains both hazardous substances and valuable materials such as metals, glass, and plastics. E-waste is not collected by municipal waste management services; rather, it is commonly collected by individual waste collectors who supply e-waste to brokers. These brokers then link the e-waste collection channels with informal recyclers, thus facilitating the co-existence of both formal and informal e-waste management sectors in China.

As e-waste recycling becomes an emergent industry in China, the stages of e-waste management can be generally categorized into: collection; dismantling; pre-processing; material recovery; and disposal of residues in landfill or by incineration. Some discarded electronics, or fractions thereof, can be reused or refurbished when sorted during the collection and dismantling phases. In contrast, the recovery and disposal of materials require pollution control and protection measures to prevent leakages of hazardous substances and to mitigate occupational and environmental risks. It is estimated by the Ministry of Environmental Protection of China that 20 to 30 million tons of e-waste are generated per year in China. Furthermore, since the 2009 enactment of a legal framework on e-waste management, 130 formal enterprises have been permitted.

Following the 2011 entry-into-force of the State Council's *Rules on the Administration of the Recovery and Disposal of Discarded Electronic and Electrical Products*, an e-waste management system includes a permit scheme, a multi-channel collection system, and an e-waste recycling and disposal fund. The latter is financed by the manufacturers of electronics, as their extended producer responsibility (EPR). The initial scope of the system targeted five types of e-waste, including television sets, refrigerators, computers, air conditioners, and washing machines. The recovery and treatment of these five types of items in permitted enterprises were subsidized by the national fund through an "old-for-new" scheme that accelerated the development of a formal e-waste collection and recycling system. In addition, the provincial and local Environmental Protection Bureaus have been assigned authorities to examine and approve the qualification of enterprises processing e-waste, and to incorporate e-waste management into local hazardous waste management plans.

Environmental policy is the main intervention at present. A task force has been established among several Chinese ministries to regulate and formalize the e-waste management industry. In the formal sector, this will be achieved through the use of permission and incentives. The informal sector will be restricted and redirected through administrative instruments and implementation of a number of national formalization pilot projects.

Key findings of this research include the following:

- **There is an urgent need for competence, knowledge and training in human health and environmental risk control and management in the e-waste management industry in China.** E-waste management contributes to resource efficiency and energy savings, but the toxins and hazardous materials released as a result of inappropriate e-waste management may pose risks to human health. Despite the large number of people working in the e-waste sector in China, the majority of workers and employers are unaware of or unclear about the severity of the risks to which they are exposed.

- **The e-waste management industry must strengthen occupational safety and health, in order to ensure these rights at work and to support development of sustainable enterprises.** Throughout the cycle of e-waste management, workers in the informal sector are directly exposed to numerous toxins such as lead, cadmium, mercury, chromium, persistent organic pollutants and other chemicals. In formal enterprises where the occupational safety and health management systems are dysfunctional, unsafe e-waste recycling practices have become a threat to human health and the environment, and particularly to children, adolescents and pregnant women. Current labour regulations do not require inspection and compliance in the e-waste industry.

- **In the formal e-waste management sector, the occupational safety and health system should be strengthened to meet further OSH standards.** Currently, the regulation framework in relation to e-waste management in China only offers minimum entry criteria without specific regulation and enforcement of labour protections. Consequently, inadequate labour protection has been found in permitted recycling facilities threatening workers' health. As an integral goal of the existing legal framework, protection of human health should be accomplished by incorporating occupational safety and health standards into the licensing, risk management, auditing and any additional certification schemes. Meanwhile, these standards should be implemented together with environmental standards to ensure the safe operation and adequate risk control of e-waste management.

- **The informal sector is challenging the profitability of the formal e-waste management enterprises; however, the informal sector may continue to exist given its strong connection with the formal sector.** The informal sector is identified as a main obstacle to the supply of resources in formal e-waste management. Because informal businesses do not meet government standards for occupational safety and environmental costs, the informal sector has lower operating costs than the formal sector. This enables the informal sector to offer relatively higher payment for discarded electronics. Furthermore, not all formal enterprises possess the specific technological equipment required for recycling e-waste fractions such as printed circuit boards and television monitors; thus, some e-waste may leak to the informal sector after it has been dismantled.

- **The informal e-waste sector is critical to the success of the formalization and industrial development of e-waste management in China. Addressing the informal sector requires an integrated approach that takes into account the social implications of transformation.** The informal sector is socially vulnerable. Workers in the informal sector have no labour protection and their rights at work cannot be ensured because they are not subject to labour inspections or other forms of administrative supervision. Many of the workers are migrants with low employability and awareness of the hazards involved in informal e-waste recycling. However, the informal sector offers extensive employment opportunities and provides a main source of income in some areas. Therefore, to address the challenges associated with the informal e-waste sector, the root causes and the impacts on the social dimension must be taken into consideration. Alternative livelihoods and capacity building should be provided in the informal sector to build the awareness of the environmental and human health impacts of unsound e-waste recycling practices. Considering the socio-economic and environmental impacts of the informal sector and, where appropriate, upgrading informal businesses may contribute to a new formalization model resulting in the integration of informal sectors into the formal recycling chain. It may also facilitate the creation of sustainable SMEs, most likely specializing in the collection, transport, and sorting of resources.

- **Environmental, health and safety management guidelines should be developed and executed at the enterprise and facility level so that the scaling-up of the e-waste management industry will not impose new environmental and human health risks.** The promotion of integrated environmental and occupational and health standards can foster quality recycling businesses and encourage the dissemination of environmentally-friendly technologies. In addition to the benefits for industrial development, integrated environmental and OSH standards can help

the government identify the allocation of incentives and facilitate the formalization process.

- **A value chain approach is needed to address the multifaceted challenges in e-waste management.** The hazardous substances contained in e-waste are the materials or components in the electronic products. Therefore, product manufacturers have extended producer responsibility (EPR) to improve the design and manufacturing of the electronic and electrical products to mitigate or eliminate hazards from source. Households and other non-individual users of electronics should actively participate in recycling schemes and reduce e-waste through re-use. Depending on the functions in the value chain of e-waste management, businesses are involved in the following processes at various levels: a) collection, transport and sorting; b) storage and dismantling; and c) treatment and recycling. Best practices and codes of conduct should be promoted throughout the e-waste management value chain.

Abbreviations and Acronyms

AKP	Alkaline phosphatase
BAN	Basel Action Network
CRT	Cathode ray tube
EC	European Commission
EEP	Electrical and electronic products
EPR	Extended producer responsibility
E-waste	Electrical and electronic waste
FPTV	Flat-panel TV
ILO	International Labour Organization
LCD	Liquid crystal display
NDRC	National Development and Reform Commission
OSH	Occupational safety and health
PAHs	Polycyclic aromatic hydrocarbons
PBDEs	Polybrominated diphenyl ethers
PCBs	Polychlorinated biphenyls
PCTs	Polychlorinated terphenyls
PBBs	Polybrominated biphenyls
PCDDs/PCDF	Dioxins and furans
PM	Particulate matter
RMB	Renminbi (Chinese Yuan)
SS	Suspended solids
SWOT	Strengths, weaknesses, opportunities and threats
TSP	Total suspended particulates
TV	Television
UNEP	United Nations Environment Programme
WEEE	Waste electrical and electronic equipment

Table of Contents

Acknowledgements ..... **i**
Executive Summary ..... **ii**
Abbreviations and Acronyms ..... **vi**
1. Introduction **1**
1.1 Objective 1
1.2 Basic concepts and scope 1
1.3 Methodology 3
1.4 Structure of the report 3
2. Fundamentals of e-waste management in China **5**
2.1 Dual features of e-waste: Resource rich and high risk 5
2.2 The scale of e-waste management in China 6
2.3 Economic impact 8
2.4 Social impact 9
2.5 Environmental impact 10
3. The e-waste management industry in China **12**
3.1 Main economic sectors 12
3.2 The formal and informal sectors 14
3.3 The e-waste recycling chain 17
3.4 The formalization process and future of the industry 21
4. The legal and regulatory framework in China **24**
4.1 Environmental policies and regulations related to e-waste management 24
4.2 Policies and regulations related to the labour aspects of e-waste management 29
4.3 Regulations and policies on the human health impacts of the e-waste sector 35
4.4 The enforcement and implementation capacity and challenges 36
4.5 Local regulations and initiatives on e-waste management 37
5. The labour dimension of e-waste management in China **39**
5.1 The labour structure and the e-waste life cycle 39
5.2 Comparing the working conditions in formal and informal enterprises 40
5.3 The human health impacts 46
5.4 Labour protection needs 47
6. Enterprise practices in the formal e-waste sector in China **49**
6.1 Major technologies and business practices in collection enterprises 49
6.2 Dismantling and recycling enterprises 50
6.3 The execution of occupational safety and health measures 54
6.4 Synergies between the enforcement of labour and environmental standards 55
7. Case study in the informal e-waste sector **58**
7.1 Technological methods and processes 58
7.2 Case study in Guiyu 61
7.3 Conclusion of the case study in Guiyu 68
8. Other labour and social issues **72**
8.1 Rights at work 72
8.2 Opportunities for improving livelihoods and employability 74
8.3 Social dialogue and the organization of workers 75

8.4 The role of local authorities in progressive formalization 76
9. SWOT analysis of the e-waste recycling industry 78
9.1 SWOT analysis of the formal sector 78
9.2 SWOT analysis of the informal sector 79
9.3 Main challenges and opportunities for environmentally-sound e-waste management 81
9.4 Main challenges and opportunities for decent work 83
10. Conclusions and recommendations 85
10.1 Conclusions 85
10.2 Recommendations 85
11. Specific suggestions for the ILO 87
11.1 Policies for promoting sustainable e-waste recycling in China 87
11.2 Value chain development and green investments for the environmentally-sound management of e-waste recycling 87
11.3 Ways to improve the working conditions in the e-waste sector in China 89
11.4 Formalization process 92
11.5 Critical elements of project 95
Annex 1：Identification of Areas for Further Research 100
Annex 2: Geographic Distributions of Related Enterprises 101
Annex 3: Environmental laws and regulations related to e-waste sector in China 104
Annex 4: Potential environmental risks of recycling plastics, CRTs and CFC in e-waste 109
References 111

1. Introduction

The e-waste issue is of increasing concern for the international community. Given the rapid development of the electronics industry, the quantity of e-waste is growing. This increase is accompanied by growing concerns about the potential adverse effects of the e-waste on human health and the environment. According to the Ministry of Environmental Protection of China, some 20 to 30 million tons of e-waste are generated each year in China. Managing this large quantity of e-waste in an environmentally-sound, resource saving, and socially responsible manner is challenging. In past decades, millions of jobs were created along the e-waste management value chain, ranging from collection, transportation, dismantling and pre-processing, to material recovery and final disposal of e-waste. The informal economy sector, which dismantles and recycles e-waste, has become significant in China, as it employs a large number of rural migrants. However, working conditions in the informal sector, which primarily consists of family workshops and small-scale private enterprises, are generally poor due to the absence of occupational safety and health (OSH) measures to protect workers from exposure to toxic and hazardous substances. In recent years, a series of e-waste-related regulations and policies have been established and enforced in China. A formal e-waste sector, including registered and permitted e-waste dismantling and processing enterprises, has been established. However, while occasional environmental inspections may take place, there is no systematic control of OSH conditions, due to the lack of regulations. Therefore, along with other labour and employment issues in the workplace, occupational safety and health issues in the e-waste sectors should therefore be subject to in-depth research.

1.1 Objective

This study aims to investigate the extent to which the employment, safety and health at work aspects of the rapidly expanding e-waste industry in China have been considered, and to analyse the implications of the research findings for the development of this industry. To answer these questions, an inter-disciplinary approach is used to examine policies and practices in the e-waste sector in China relevant to labour, human health and the environment. The report also explores options to mainstream green jobs and decent work in this critical sector, and identifies measures to improve working conditions and reduce occupational safety and health (OSH) hazards and risks.

1.2 Basic concepts and scope

“Electronic waste” or “e-waste” or “waste electronic and electrical products/equipment” in the report refers to discarded electronic and electrical products or equipment, their discarded parts and components, and the articles and

substances subject to the management of e-waste[1]. It includes: the obsolete products or equipment generated in industrial production and post-consumption; the obsolete semi-finished products and residues; the obsolete products generated in the repair, renovation and reproduction of products or equipment; the products or equipment discarded in the daily life or in the activities of providing services for daily life; as well as the products or equipment of which production is prohibited by any law or regulation[2]. The activities of product repair, refurbishment, and reuse as second-hand goods are explicitly excluded from the range of the *Regulations for the Administration of the Recovery and Disposal of Waste Electric and Electronic Products* enacted by the State Council in 2011.

"E-waste treatment" refers to the *recovery* and *disposal* of waste electronic and electrical products. It includes the following activities[3]:

- Disassembling waste electronic and electrical products;
- Extracting substances from e-waste to be used as raw materials or fuels;
- Reducing the quantity of existing e-waste by modifying its physical properties or chemical composition, and reducing or eliminating its hazardous substances; and
- Collecting such treated e-waste and disposing of it in landfills.

In addition to e-waste treatment, "e-waste management" includes the collection, transport, pre-processing, dismantling, recycling/recovery and disposal of e-waste. It is a multi-stakeholder system involving the collector, broker/trader, recycler (dismantling and/or recycling), disposal facilities, government, industrial association, and third party auditor. In an extended system it should also cover the producers, consumers, and other downstream businesses.

The scope of the research includes the following:

- The formal and informal sectors of e-waste management;
- The current status of e-waste management in China, focusing on the environment, human health and labour aspects;
- The e-waste flow, primarily consisting of the five major electronics as regulated in the present regulatory framework in China (where data are available);
- Reference (existing data) and working knowledge (empirical data);
- Laws, regulations, policies and practices at national and sub-national levels;
- Main environmental, occupational and human health risks; and
- The role of national, provincial and local authorities.

[1] See Article 25 of the *Administrative Measures for the Prevention and Control of Environmental Pollution by Electronic Waste*.

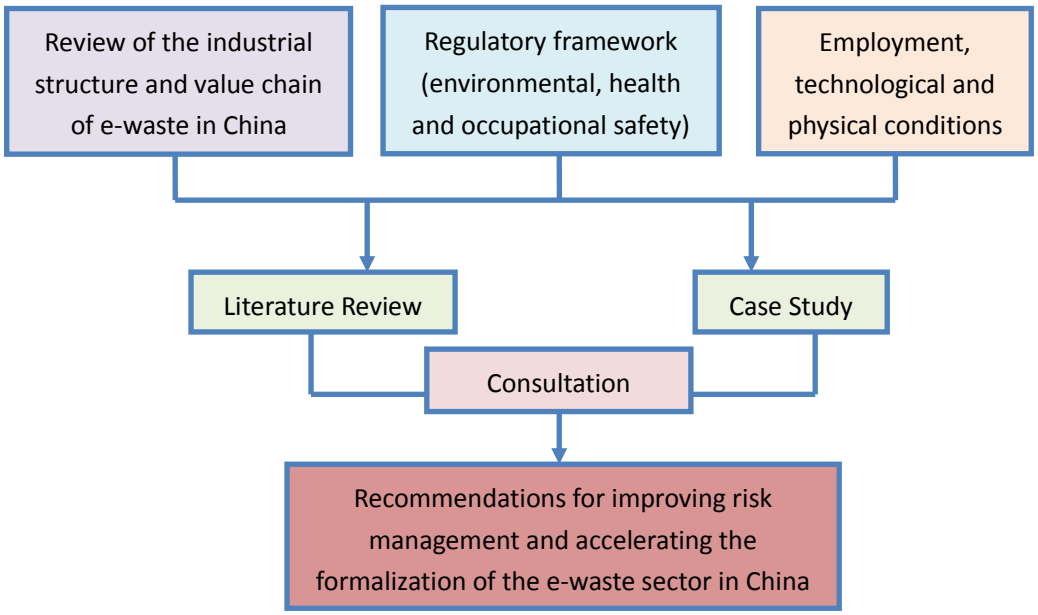
[2] Ibid.

[3] See Article 2 of the *Regulations for the Administration of the Recovery and Disposal of Waste Electric and Electronic Products*.

1.3 Methodology

Case studies, supported by field observations and interviews, are the core methodologies used in the report. As indicated in the figure below, a literature review was conducted to understand the current industrial development and regulatory frameworks in relation to e-waste management, and how the environmental and social challenges are reflected in the policies and practices of the industry, taking into account the formal and informal sectors. Given time and resource constraints and limited data, it was difficult to organize medical surveys and collect data from large sample size. Therefore, field trips to facilities and interviews with individuals working in the formal and informal sectors were carried out to investigate the labour, environment and human health conditions in e-waste management facilities. The preliminary findings were discussed at a consultation meeting among the ILO, the research team, government officials and experts in the fields of environmental protection and work safety. Based on the discussion at the consultation meeting, the report was revised and translated. The ILO then edited and finalized the report.

Figure 1-1 Research method



1.4 Structure of the report

Following the introductory chapter, Chapter 2 introduces the features and scale of the e-waste management industry and its environmental and socio-economic impacts in China. Chapter 3 looks into the formal and informal sectors in the e-waste value chain, outlining the industrial perspective on formalization and standardization as introduced in the evolving policy framework on e-waste management in China. Chapter 4 examines the regulatory framework and legal provisions relevant to from the pollution

control, labour protection and health and safety, specifying the enforcement challenges and highlighting the implications of sub-national initiatives. Chapter 5 looks at the labour structure of the e-waste lifecycle and highlights the urgent need for labour protection by comparing the working conditions and human health impact in the formal and informal sectors. Chapter 6 goes further to examine the business practices in the dismantling and recycling enterprises, focusing on the necessary occupational health and safety measures associated with the technological processes in the workplace. The chapter identifies the synergies between enforcement of environmental and labour standards. Chapter 7 introduces the informal e-waste businesses in Guiyu town as a case study for assessing the measures needed to control the risks of informal practices and to facilitate transformation in the informal sector. Chapter 8 extends the analysis of the social challenges associated with formalizing the e-waste management industry in China, considering both problems and possible solutions. . Reconciling the co-existence of formal and informal sectors, Chapter 9 takes a SWOT (strengths, weaknesses, opportunities and threats) analysis approach to evaluate the main challenges and opportunities for decent work and environmentally-sound management of e-waste recycling. Lastly, Chapter 10 concludes the research and recommends actions to be taken to address the environmental, labour and human health challenges associated with e-waste management in China. Chapter 11 proposes a set of activities to be considered by the International Labour Organization to address social dimension and strengthen labour protection in e-waste management in China. These recommendations may serve as useful example for addressing these common challenges in Asia and the Pacific.

2. Fundamentals of e-waste management in China

2.1 Dual features of e-waste: Resource rich and high risk

Resource rich

The constituent components of e-waste complicate its safe recycling and disposal and dictate the dual nature of e-waste: it is both resource rich and high risk. Since the beginning of the 20th century, the rapid expansion of the electronics industry and high replacement rate, electrical and electronic waste has become one of the fastest growing waste sectors in the world. Electrical and electronic waste contains over one thousand substances that can be generally divided into the following categories: metal, plastic, glass, and ceramics.

E-waste contains metals more valuable than their ores. Recovering the valuable metals and other materials from e-waste normally has much lower costs than refining the same metals from natural mines. For example, operation of a gold mine is economically viable when one ton of gold ore contains two grams of gold. It is estimated that 80 to 1500 grams of high purity gold can be extracted from one ton of printed circuit boards. Another example is that one ton of gold extracted from discarded computer scraps is equivalent to that produced from 17 tons of gold ore. Furthermore, one ton of computer scraps can produce 10 to 50 times more copper than one ton of copper ore. Therefore, e-waste recycling is also called “e-waste mining” because extracting valuable metals from e-waste is more economically lucrative than traditional mining. If managed well, e-waste recycling can contribute to resource efficiency and energy savings.

High risk

E-waste is highly toxic because it contains hazardous substances such as lead, cadmium, mercury, chromium and persistent organic pollutants, all of which can be accumulated and retained in human bodies and the environment. For instance, lead can be found in cathode ray tubes (CRT) glass of television (TV) monitors, and in the solder for printed circuit boards. Cadmium is contained in batteries, transistor resistors, infrared detectors, and semiconductor devices. Mercury is generally found in automatic temperature regulators, inductors, intermittent devices, switches, measuring instruments, fluorescent light bulbs, mobile phones and batteries. Metallic mercury is commonly used in the production of flat panel displays. In discarded air conditioners and refrigerators, chlorofluorocarbon (CFCs) and other cooling agents are strong ozone depletion and climate change inducing factors. Yet, glass and plastics can be recycled from lead-CRT TV monitors, copper can be extracted from plastic-coated wire that contains cadmium, and gold can be recovered from cadmium-and-lead-circuited boards. Dusts containing hazards may leak during the

shredding of e-waste, and toxic fumes may be emitted when heating the printed circuit boards or bathing them with acid in the informal workshops. Therefore, in a closed environment without full the protection provided by a mask, glasses, and gloves, as well as effective dust control equipment and the application of appropriate recycling processes and methods, it is not possible to prevent workers and local communities from exposure to hazards.

The relationship between technology development and e-waste management

It is worth noting the relationship between technology development in manufacturing electronic and electrical products and the hazards of e-waste. For instance, flat panel display products are taking an increasing share of the marketplace, and are replacing CRT products. Notably, the amount of mercury contained in flat panel displays is greater than the mercury contained in the outmoded CRT products. This technological change on the production end needs to be addressed accordingly in e-waste management, particularly during the dismantling, recovery and disposal stages. Other hazardous substances can be found in trendy electronic products. For example, chromium (Cr) is widely used in untreated galvanized steel sheets as a decoration or hardener to prevent corrosion; PVC is used in electrical cable and the casing of electrical appliances; barium (Ba) is used in the panel of kinescope in a computer for controlling and preventing radiation exposure; and beryllium (Be), is commonly used in computer main boards and chips to maintain and strengthen the processing capacity of computers.

These substances, which are often released during improper e-waste treatment, have adverse effects on human health, and particularly on the nervous system and kidneys. Since Chapter 6 reviews in detail the human health impact of these substances, a few examples are provided here to demonstrate how toxic substances contained in and released from e-waste treatment can undermine human health. For instance, lead and its compounds can harm the blood, nerves, digestive system and kidneys, and its effects are often chronic. Serious lead poisoning can cause lead encephalopathy disease. Polychlorinated biphenyls (PCBs) have adverse impacts on skin, nerves, and the liver, can cause significant damage to brain development, and can cause abnormalities in sperm and birth defects.

Given the resource-rich features of e-waste, the, the risks are often overlooked or even dismissed when investors and enterprises, particularly the informal ones, enter the e-waste treatment market. However, if e-waste can be handled and recycled in a safe and environmentally-sound manner, it has significant potential for resource efficiency, energy saving, and job creation.

2.2 The scale of e-waste management in China

The scale or volume of e-waste in China is difficult to measure accurately due to the lack of data on the material flow, as well as the challenge of monitoring the illegal

shipment of e-waste to China. Some data has been reported on a national old-for-new home appliance recycling scheme from June 2009 to December 2011 targeting five types of e-waste, including TV sets, air conditioners, washing machines, refrigerators, and computers. According to the China Household Electronic Appliances Association, 83.73 million units of the five types of household appliances were collected, of which 79% (66.21 million units) were treated by the end of 2011. At the same time, the policy promoted the sale of 81.3 million new appliances that entered the households stock of electronic products[4]. According to the Ministry of Environmental Protection of China, some 82 million units of the five main household appliances were collected by 2011, of which 81% were treated by 2010, and 97% were treated by 96 e-waste enterprises by 2011. These figures indicate that a basic e-waste management value chain including collection, transport, dismantling and treatment has emerged in China. However, there is no data on the rate of treatment, reuse and final disposal of these collected discarded household appliances. It is also clear that certified e-waste enterprises have different capacities when recycling the e-waste. For example, there is only one competent company in China with a permitted facility to recycle CRT glass. As for the residues of the e-waste, effective final disposal can also be problematic because certified disposal facilities have limited capacity to handle these hazardous wastes, and some disposal plants can only store the residues. Therefore, a more comprehensive system of e-waste management remains to be built in China.

It is estimated by the Chinese government that, at the end of 2011, the stock of the five main types of household appliances had reached 1,770 million articles, including 520 million TV sets, 300 million refrigerators, 320 million washing machines, 330 million air conditioners, and 300 million computers[5]. The disposal rate of these electrical products is some 10 million units per year. Other e-waste, such as mobile phones, copy machines, printers, and fax machines, are not included in these figures[6]. The amount of e-waste will continue rising rapidly (UNEP and United Nations University 2009). UNEP estimates that, by 2020, China's e-waste generated from computers will grow 4 times the 2007 level, and e-waste from mobile phones will increase by 6 times. Depending on the market incentives promoting increasing consumption and replacement of electronic products, assuming the average lifespan of these electronics is 10 years, the demand for environmentally-sound e-waste management is yet to peak in the next decade in China.

In addition to the problems associated with domestically generated e-waste, China has become a main destination of e-waste exported from OECD countries and other countries in the Asia and the Pacific, for re-export of e-waste scraps or mixed metals. Imports of e-waste have led to the growth of the informal e-waste sector in the coastal

[4] http://tech.sina.com.cn/e/2011-12-31/08091988353.shtml

[5] Ministry of Finance of the People's Republic of China, 30 May 2012, http://www.mof.gov.cn/zhengwuxinxi/zhengcejiedu/2012zcjd/201205/t20120530_655610.html.

[6] Ibid.

areas of China. For example, since the 1990s, Guiyu, in the Guangdong province, and Taizhou, in the Zhejiang province, have become the major centres of informal e-waste collection, distribution and recycling for a large quantity of the e-waste exported to Asia (Puckett et al., 2002)[7]. In these less developed and densely populated areas, e-waste has been dismantled and recycled for large profits with manual work, low-quality primitive technological equipment, open burning, and disposal of e-waste without non-hazardous-processing. The informal e-waste recycling businesses in these areas have contaminated the environment and caused severe ecological damage, and the impacts on human health of workers and local communities have been studied by a few research institutes. To address the challenges of illegal imports and informal e-waste recycling, the Chinese government banned the import of e-waste in 2000. However, regardless of repeated prohibition, illegal import of e-waste remains incessant in China due to "loopholes" (Driscoll and Siheng, 2009)[8], such as mixing up e-waste with normal imported refuse to complicate the customs inspection, presenting e-waste as secondhand electronic products, and transporting prohibited e-waste and hazardous waste through intermediary ports in Hong Kong and neighboring countries in Asia and the Pacific[9].

2.3 Economic impact

E-waste contains various recyclable and profitable materials, including plastics, iron, aluminum, zinc, copper, silver and gold. Recovering these valuable materials from e-waste is economically attractive due to resource scarcity and high marginal benefits. According to research conducted by Denmark Technical University, one ton of randomly collected electronic boards can lead to recovery of approximately129 kg copper, 0.4 kg gold, 272 kg plastic, 40 kg iron, 29 kg lead, 10 kg antimony (Sb) and 20 kg nickel (Ni). These recovered gold and coppered alone may value more than $25,000[10]. The economic values of different fractions of e-waste vary. For example, on average 450g to 900g gold can be recovered from one ton of discarded printed circuit boards. The scale and supply of e-waste can affect the profitability in the e-waste management enterprises. Therefore, most enterprises in the e-waste recycling business specialize in recycling focus materials. For instance, the Japanese smelting company Yokohama Metal assessed the composition of discarded mobile phones and found every 100g of mobile phones contain approximately 14g copper, 0.19g silver,

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[7] Puckett, Jim, Leslie Byster, Sarah Westervelt, Richard Gutierrez, Sheila Davis, Asma Hussain, Madhumitta Dutta. 2002. "Exporting Harm: The High-Tech Trashing of Asia." The Basel Action Network and Silicon Valley Toxics Coalition. Available online: http://www.ban.org/E-waste/technotrashfinalcomp.pdf.

[8] Driscoll Amy, and Wu Siheng. 2009. "Poverty or Poison? China's Dire Choice in an Electronic World." USAID Asia and Vermont Law School. Available online: http://www.vermontlaw.edu/Documents/Driscoll%20WU,%20Poverty%20or%20Poison.pdf.

[9] According to Hong Kong's Waste Disposal Ordinance, only batteries and CRT are banned from import. There is no clear legislation to prevent other electronic waste and their components entering Hong Kong's ports.

[10] At a price of $1,100 per ton for copper, and 1,500 per ounce for gold.

0.03g gold and 0.01g palladium (Pd). Furthermore, lithium (Li) can be recovered from mobile phone batteries. Based on this assessment, Yokohama Metal processed more than 900 tons of e-waste discarded in seven years, and generated considerable revenues from recovering the valuable metals found in mobile phones.

As a response to the high energy and resource demands of sustaining economic growth in China, the Chinese government initiated a "circular economy" programme to close the resource flow gap between waste and resources. Given that various materials can be recovered from e-waste, e-waste management has been prioritized in the circular economy programme. Some pilot schemes targeting both economic restructuring and formalization of the informal economy in Guiyu and Qingyuan have been launched. Chapter 4 will review these pilot schemes in detail.

2.4 Social impact

The e-waste management industry has created various types of employment in the value chain, ranging from high-skilled work in the large formal enterprises to the low-skilled manual work in the informal sector. No accurate data quantifying employment in the e-waste businesses in China has been found, provided a significant share of the employment is in the informal economy. However, it is clear that as part of the waste management and recycling industry, e-waste management is a job-intensive business that provides employment and poverty alleviation opportunities by easing the employment pressure on surplus labour, especially for the rural migrant and urban unemployed workers. It is estimated that more than 60,000 enterprises are involved in collection and recycling business. Waste collection alone provides more than 10 million jobs in China, including micro and small enterprises as well as individual waste collectors (Feng 2011)[11]. According to the industry association, over 400,000 jobs were created among in the old-for-new scheme, and migrant workers and laid-off urban workers counted for 70% of employment[12].

In the informal sector, the e-waste treatment industry is a main source of income for the local community and migrant workers. Taking Guiyu as an example, over 80% of households are involved in e-waste recycling. The informal sector provides temporary employment, particularly for the migrant workers. However, jobs in the e-waste businesses, particularly in the informal sector, are often high-risk, given the lack of adequate labour protection and low awareness of the human health impacts of improper e-waste recycling practices.

In the formal sector, there is a large demand for professionals and skilled workers as a result of increasing demand for environmental services for the consumers, and for profits and compliance for producers. It is suggested by some researchers that the

[11] Wang. Feng. 2011. "Beijing Municipal Waste Purchaser Group Characteristics Investigation" in *Beijing Social Science*, 3: 67-72.

[12] http://www.beinet.net.cn/topic/kdnx/ttxw/201201/t2021139.htm

establishment of a sector-specific employment scheme targeting the e-waste industry will be an important approach to enhance the job quality and general performance of the e-waste treatment industry (Lingdi, 2008).

2.5 Environmental impact

The toxic and hazardous substances contained in e-waste and released from improper e-waste treatment processes, such as lead, mercury, hexavalent chromium, arsenic, beryllium, nickel, zinc, copper, cadmium, polyvinyl chloride and brominated flame retardants, can damage the safety of human health and the environment.

The toxic substances often found in e-waste can cause cancer, mutation, and birth defects. If not managed and controlled effectively, they will contaminate underground water, flora and fauna, and air quality, and will accumulate in the human body. More severely, when disposed e-wastes mix with rainwater and undergo certain chemical reactions, the underground e-waste will become a "waste penetrant," leading to profound environmental consequences. In concentrated e-waste disassembling areas such as Guiyu in Guangdong and Taizhou in Zhejiang, where open burning, simple crushing, uncontrolled discharging and acid leaching are common practices, these processes not only release toxic substances causing severe heavy metal pollution and persistent organic contamination, but also lead to the release of new contaminants, such as chloro-dioxin, bromo-dioxin, and polycyclic aromatic hydrocarbons, all of which can have serious adverse effects on human health.

A sample survey collected from the dust, soil, river sediments, surface and underground water in an environmental hygiene and health survey in Guiyu town revealed that the concentration of heavy metals and organic contaminants in the area is significant. Similar to Guiyu, many cities in the coastal areas in China, such as Ningbo, Wenzhou, and Taizhou in Zhejiang province, and Dongguan and Chaoshan in Guangdong province, have accumulated large quantities of smuggled e-waste containing palladium and platinum, which are recycled in small workshops using simple technologies. The gases emitted from the burning of e-waste components cause harm to workers and nearby residents. If not processed appropriately, nitric oxide (NO), nitrogen dioxide (NO2) and other kinds of toxic gases that will pollute the atmosphere will be produced in the acid dissolving process.

E-waste, if treated properly, can benefit energy and resource saving as well as contribute to emissions reduction. According to the US Environmental Protection Agency statistics, 40 per cent of water consumption, 90 per cent of raw materials consumption, and 74 per cent of energy consumption can be reduced by using scrapped steel recovered from waste home appliances, instead of producing steel from mining and smelting. China's Ministry of Commerce indicated similar statistics.

Table 0-1 Emission reduction effect of recycling one ton of waste electric products

E-waste	Emission reduction effect (/ton of e-waste)		
	Waste water	Waste gas	Waste residue
TV sets	16.32	7.82	8.48
Refrigerators	23.4	10.58	13.9
Air conditioners	29.5	10.31	21.1
Washing machines	18.25	6.77	6.55

3. The e-waste management industry in China

3.1 Main economic sectors

The e-waste recycling process can be generally categorized as collection, dismantling, treatment and disposal. There are multiple collecting channels constituted by individual traders and peddlers, retailers involved in the "old-for-new" scheme, and the unified collection of governmental authorities and public institutions. Dismantling and recycling enterprises include the enterprises permitted by the "old-for-new" scheme to dismantle e-waste (hereinafter "permitted enterprises"), those listed in the Catalogue authorized by the environmental protection departments (hereinafter "enterprises in the Catalogue"), and informal family workshops and factories. Those dismantled components and articles of e-waste which cannot be reused and recycled are disposed of in landfills or by incineration operated by qualified enterprises. However, in informal businesses, the residues are often mixed with normal wastes without processing.

Figure 3-1 Main economic sectors involved in e-waste recycling

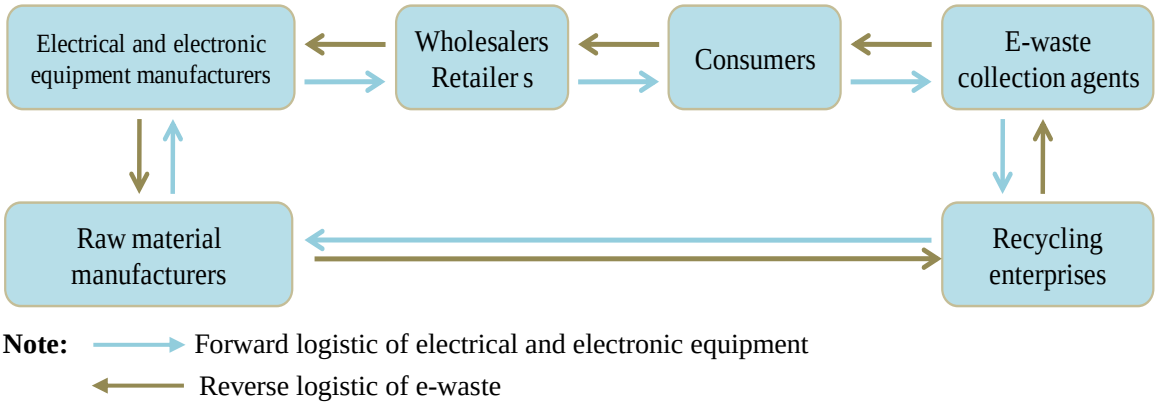


Table 3-1 Practices of e-waste collection, treatment, and disposal in China

Collection	
Purchasing by individual traders and peddlers	Individual traders and peddlers directly purchase from consumers through in-door services. After purchase, the direct reusable parts are sold to the secondhand markets, various trading markets, or small commodity markets, often located between urban and rural areas.
Used-products owners	Owners sell used products to individual traders and peddlers, or on the second-hand market.
Retailers	EEP retailers consigned by the permitted enterprises collect and provide the used EEPs, particularly home appliances or the "five types" of EEPs, to permitted recycling enterprises and receive subsidies from this service.

Waste recycling stations as community service	There are many waste recyclers and centralized recycling stations in the community service near the residential community, but very little e-waste collected through these stations. This is due to the lower purchasing price offered by these stations to the used-products owners, compared to that offered by the individual traders and peddlers. Additionally, it is time-consuming to transport the obsolete EEPs to these stations.
Unified collection of governmental authorities and public institutions	E-waste discarded by the state-owned governmental authorities and public institutions, including universities, governmental authorities, public service institutions hosted by government, and large state-owned enterprises, are sent to the permitted enterprises for recycling and appropriate disposal.
Illegal imports	Illegal e-waste imported to China is often sent to the informal workshops and factories for dismantling and valuable metal component recycling. Although illegal imports are banned in China, the regulatory and enforcement loopholes make it possible.
Dismantling	
Permitted enterprises	As part of the Measures for the Implementation of Old-for-New Home Appliances Replacement Program (2009), the collected household appliances are sent exclusively to the permitted enterprises for dismantling and treatment.
Enterprises in the Catalogue	Pursuant to the Measures on Prevention and Control of Pollution Caused by Disused Electronic Waste, only the Enterprises (including individual industrial and commercial households) in the Catalogue (including the interim catalogue) are authorized to engage in the activities of e-waste dismantling, utilization and disposal. The total number of Enterprises in the Catalogue is currently 129.
Family workshops and factories	The low transactional costs are the key advantage of the informal e-waste recycling sector, which dismantles some of the e-waste that cannot be dismantled or exceeds the dismantling capacity of the formal enterprises, as well as the e-waste imported to China illegally.
Treatment and Disposal	
Reuse	• Direct reuse of functional (well-functioning or fully-functional) obsolete EEPs, their components and articles; e.g., used electrical equipment (e.g., computers, printers and copiers) of government agencies in large cities are donated to schools and government departments in economically undeveloped areas. • Reuse after repair or slight modifications, particularly for malfunctioning laptops, printers, scanners, hard drives, cameras, air conditioners and photocopiers. • Refurbish or reassemble used appliances into new ones using separated fully-functional components or parts of them, such as memory upgrades, main boards, monitors, etc. The

	refurbished EEPs are usually sold in secondhand markets and economically undeveloped areas.
Resource utilization	Resources such as plastic, steel, copper, aluminum and other metals are sold to downstream enterprises for post-recycling utilization.
Landfill or incineration	• Formal enterprises: materials disposed of through technological facilities end up in incineration plants or landfills. • Informal businesses: after the gold, silver, tin and other precious metals are extracted from e-waste in primitive ways, such as acid leaching and open burning, the valueless parts are mixed with household waste to be disposed of in landfills or by incineration.

3.2 The formal and informal sectors

According to the *Qualification and Licensing Guidelines for Waste Electrical and Electronic Products Enterprises*, only designated enterprises possessing qualification permissions can recycle five categories of household appliances, including TV sets, refrigerators, washing machines, air conditioners, and small computers. For other streams of e-waste, enterprises must be qualified and listed in the "Catalogue" or its "Temporary Catalogue", pursuant to the waste electrical and electronic (WEEE) regulations. The informal enterprises are those without qualification permission and are not listed in the Catalogue. By 2010, 129 e-waste treatment enterprises were listed in the Catalogue. Of these, 103 were designated and permitted for recycling waste home appliances as part of the Chinese home appliances recycling policy.

The formal e-waste recycling enterprises are those licensed by law, including those listed in the Catalogue as part of the old-for-new home appliance recycling policy (129 enterprises), and those designated by authorities (103 enterprises) to recycle and dismantle e-waste in line with national regulations and standards. The main differences between the "permitted enterprises" and the "enterprises listed in the Catalogue" can be summarized as follows:

a. Different scope: The enterprises listed in the Catalogue can recycle all kinds of EEPs, whereas the permitted enterprises are those designated by local authorities to recycle the so-called "five types" of EEP (including TV-sets, refrigerators, air-conditioners, washing machines and personal computers) and are subsidized by the government fund.

b. Different legal nature or identity: Enterprises listed in the Catalogue can be "legal persons", such as Ltd. and corporate, or "individual industrial and commercial households", namely smaller-scale businesses owned by individuals. Permitted enterprises must be financially more capable and have the legal nature of "legal persons".

The definition of a formal e-waste enterprise has evolved over time, driven by the development of the policy and regulatory framework on e-waste. The Catalogue was the initial tool used to identify good business practices among a group of e-waste treatment enterprises in a national pilot scheme promoting formal e-waste dismantling, recovery and disposal. For example, in December 2003, with the consent of the State Council, the National Development and Reform Commission (NDRC) selected Zhejiang province and Qingdao city as national e-waste recycling pilot provinces and cities, and selected Beijing and Tianjin as pilot areas to undertake e-waste treatment demonstrating projects. The "designated" enterprises were selected from a subsequent policy scheme on recycling and subsidies for recycling of obsolete home appliances. Although 80 per cent of formal enterprises are both "Catalogue" and "designated" e-waste treatment enterprises, the designated plants are larger scale, corporate units permitted according to more stringent qualification criteria.

The differences between the "Catalogue" and "designated" formal e-waste treatment enterprises are as follows:

- **Business scope:** The designated formal enterprises can only recycle home appliances which were subsidized by the government dedicated home appliances recycling fund (TV sets, refrigerators, washing machines, air conditioners, and small computers); in contrast, the Catalogue enterprises have a broader range of permitted e-waste treatment activities.

- **Nature of enterprises:** The Catalogue enterprises can be corporate units or individual businesses; in contrast, the designated enterprises must be corporate units.

- The designated enterprises are selected from the Catalogue enterprises.

- **Subsidies:** While all formal enterprises can recycle home appliances, only the designated enterprises can be subsidized by the government fund.

Informal sectors consist primarily of informal dismantling factories and small family workshops that do not have the permission and authorized qualification to execute businesses on recycling and disposing e-waste. The informal enterprises are purely profit driven and, therefore, only recycle the parts of e-waste that are of direct and high economic value, such as metal, plastic, glass and other valuable materials. The informal enterprises carry out this recycling by primitive means such as acid leaching and burning. Given the small scale of these workshops and factories, informal enterprises often cooperate with one and another, thereby creating a sophisticated informal recycling network backed by social advantages in locality, such as family ties and shared origins.

Table 3-2 Types of informal e-waste recycling businesses

Family Workshops	• Work using primitive tools such as screwdrivers, pliers, etc. to sort valuable components and articles; • Use simple techniques such as acid baths, , open burning and other technically unsophisticated methods of recycling high-value components; • Do not have the most basic protective measures for workers, so toxins and other hazards can be easily released in workplace, which is often the same venue where the employers and their families live.
Medium-sized Recycling Enterprises	• Install basic e-waste treatment and disposal equipment and facilities; • Perceive workers as being protected from direct exposure to hazards; • Cause secondary pollution in continuous production cycle.

Figure 3-2 Informal e-waste workshops and factories in Guiyu, Guangdong (December 2011)

Currently, the informal sectors of e-waste are concentrated in Guiyu, Longtang, Dali and Qingyuan towns in Guangdong province, and in Taizhou town in Zhejiang province. As the informal e-waste economy develops in these places, there is a possibility of expansion into Hebei, Hunan and Jiangxi provinces. The volume of e-waste processed by the informal sector is 30 per cent of the total estimated volume of e-waste generated in China, not including the illegally imported e-waste processed

by enterprises within this sector (Chen et al. 2009)[13]. The informal sector consists primarily of small family workshops, and is characterized by systematic cooperation among informal businesses. They specialize in dismantling and trading specific materials in e-waste that are of high economic value. After preliminary classification of dismantled e-waste, the parts of e-waste that are not recycled will be processed and recycled by its downstream workshop. For example, the sorted circuit boards, plastic, wire, other parts could be sold to other workshops and factories, thereby promoting regional networked cooperation in Guiyu town.

Despite the regulatory divide between the formal and informal e-waste sectors, there is a niche market for the informal e-waste sector in China. While the construction of formal e-waste treatment enterprises requires high upfront investments and operational and maintenance costs, informal enterprises pay little in terms of compliance costs and investments in technologies and facilities. Thus, the informal sector can offer more attractive prices than the formal sector in the e-waste collection market. According to statistics from China's Resources Recycling Association, only 5 to 10 per cent of e-waste generated in China was sent to the formal sector for recycling before the implementation of the old-for-new policy and the WEEE regulation.

The old-for-new policy provided the recyclers with incentives and subsidies for treatment and disposal of collected discarded household appliances. Therefore, the vast majority of the collect e-waste under the scheme was sent to the formal enterprises. Shanghai is a good example: before the old-for-new scheme was implemented, less than 1 per cent of e-waste was treated by formal enterprises; since the implementation of the policy, 51 per cent of e-waste was recycled by the formal enterprises.

3.3 The e-waste recycling chain

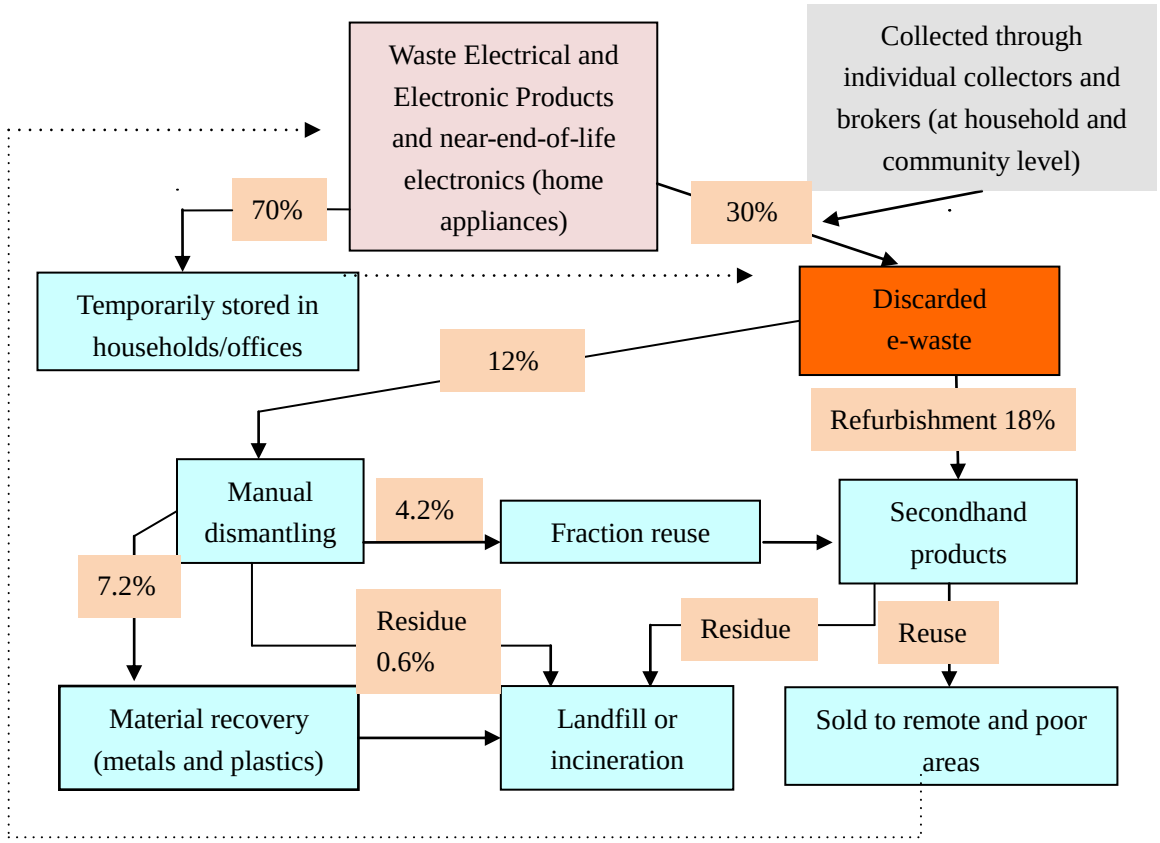
The e-waste recycling chain can be generally divided into the following stages: collection; dismantling, recycling and treatment; and disposal. As indicated in Figure 3-1, in the formal sector, most of the e-waste generated in China is collected through individual traders and institutions involved in the old-for-new policy scheme. Once e-waste is collected from the institutions covered under the scheme (primarily public institutes and state-owned enterprises), they are transported to the designated enterprises and those listed in the Catalogue for recycling.

13 Chen, Xian, Fu Jiang, Cheng Jiehong, Zhou Quanfa. 2009. "The Recycling Situation and Countermeasures of Waste Electrical and Electronic Equipment in China" in *Renewable Resources and Recycling Economy*, 7: 34-38.

The recycled plastics and metals are sold to the downstream enterprises for re-use, and the residues and materials that cannot be recycled are disposed of by licensed and qualified enterprises. E-waste collected through individual vendors and imported through illegal channels before being recycled by the informal sector is handled differently; functional parts are sold to the second hand market or reassembled in informal factories. In these settings, articles containing valuable components are recycled using very basic extraction techniques, the residues are disposed of without proper measures (i.e., they are mixed with normal solid waste). As previously noted, waste EEP (e.g., computer, printers and copiers) generated by government agencies in large cities are usually donated to schools and government departments in less economically developed areas. Furthermore, after repair, laptops, personal computers, printers, scanners, hard drives, cameras, air conditioners and copiers in good condition are often sold in second-hard market. Some are refurbished into "new" EEPs and are often sold in remote areas in China.

There are four major sources of e-waste in China, including: individuals and households; public institutes; EEP producers; and illegal imports. The e-waste treatment enterprises include designated enterprises and those listed in the Catalogue in the formal sector, and the family-owned workshops and factories in the informal sector.

Figure 3-3 E-waste recycling flow in China (Chen et al., 2009)[14]



There are multiple e-waste collection channels constituted mainly by: individual traders and peddlers; reproduction business owners; waste recyclers as a community service providers; retailers involved in the old-for-new policy scheme that established centralized recycling stations at community level; and government-led collection channels. These channels are connecting the sources of e-waste and the process of e-waste treatment in the following ways:

- **Purchasing by individual traders and peddlers:** Individual traders and peddlers purchase recyclable electronic waste directly from the consumers through a point-to-point service in the community. Once the e-waste is collected, the reusable parts and articles are directly sold to the secondhand markets; the rest are sold at various local trading markets and small commodity markets that are normally located in the urban and rural conjunction areas.

- **Reproduction business owners:** This group of e-waste collectors is comprised of small factories that are specialized in reproducing certain electronic products

[14] Chen, Xian, Fu Jiang, Cheng Jiehong, Zhou Quanfa. 2009. "The Recycling Situation and Countermeasures of Waste Electrical and Electronic Equipment in China" in *Renewable Resources and Recycling Economy*, 7: 34-38.

(mainly home appliances and laptops). They purchase higher quality e-waste from individual traders and peddlers or other reproduction business.

- **Retailers involved in the old-for-new policy:** These retailers collect e-waste according to the trade-in policy, and send it to designated e-waste treatment enterprises for recycling. The specialized old-for-new policy fund subsidizes the costs of collection and transportation.

- **Government-led collection channel:** A unified collection channel is established for collecting e-waste discarded by state-owned authorities and institutions, including universities, governmental authorities, public service institutions hosted by government, and large state-owned enterprises, all of which are sources of e-waste for recycling by the designated treatment enterprises.

In addition to the e-waste collection channels listed above, illegal imports are a major source of e-waste. It is estimated that about 70 per cent of the e-waste generated globally is imported into China each year[38], and is subsequently recycled by the family-owned workshops and factories in the informal sector.

After collection, e-waste is transported to the dismantling and recycling enterprises, and is treated in both formal enterprises that are designated and/or listed in the Catalogue and informal family workshops and family-owned factories.

The Ministry of Environmental Protection (MEP), the main government authority responsible for regulating the operation of the e-waste sector in China, focuses on developing recycling policies for household appliances. Regarding the qualification and permission process, e-waste recycling enterprises first need to meet the threshold criteria in order to be listed in the Catalogue (including the interim catalogue); then the local environmental protection authorities report to the provincial government, which in turn will evaluate the reports and issue permits for designated enterprises among those listed in the Catalogue. Once the decision on the designating e-waste enterprises is completed, the provincial government will submit the decision to the MEP within 15 working days. Under the old-for-new policy framework, collected obsolete household appliances are exclusively sent to the designated enterprises for dismantling and treatment. Other non-designated enterprises are not permitted to purchase or process the household appliances.

Regarding the disposal of waste EEP, the MEP issues disposal policies designating the e-waste and components thereof that can be disposed of according to the current solid waste disposal policy. Other types of e-waste require special treatment for disposal. For example:

- CRT glass separated during the dismantling of both black and white and color televisions can be put into landfills as general industrial solid waste;

alternatively, it can be consigned to CRT glass manufacturers for reuse, or disposed of in other ways that are not harmful to the environment.

- CRT glass cones separated by the dismantling of color televisions should be provided to the CRT glass manufacturer for recycling; alternatively it can be utilized or disposed of by the enterprises with an operation license to treat hazardous waste.

- Printed circuit boards and related hazardous waste should be provided or consigned to be utilized or disposed of by the enterprises with the operation license for hazardous waste and appropriate operation range; non-metallic components, if waste printed circuit boards are processed by themselves of its owners should be utilized or disposed in environmentally-sound manner by themselves or the consigned enterprises who comply with the environmental protection requirements.

- Refrigerants from refrigerators or room air conditioners should be recycled and provided or consigned to the enterprises which were recorded by environmental agencies in local provinces (autonomous regions and municipalities) according to "Regulation on the Administration of Ozone-Depleting Substances (State Council Decree No. 573)" for their recycling and utilization, or consigned to the enterprises with the operation license for hazardous waste and appropriate operation range for their disposal.

  Wires, cables and motors should be provided or consigned to the designated enterprises, or other enterprises that comply with environmental protection requirements, to process and utilize the imported waste electrical scrap metal, waste wires and cables, as well as those motors which were approved by Ministry of Environmental Protection.

- As general industrial solid wastes, insulation materials from refrigerators can be disposed of by landfill or incineration in municipal solid waste facilities, or they may be utilized in other environmentally-sound ways.

In the informal sector, after the valuable materials are extracted from e-waste with primitive methods such as acid leaching and open burning, the valueless residues are thrown away or mixed with household waste to be disposed by landfill or incineration.

3.4 The formalization process and future of the industry

During the last decade, the informal e-waste sector in China has formed naturally through market incentives, without consideration for work safety and the environment. Since the media exposed the e-waste dismantling industry in Guiyu in 2001, the negative impacts of this sector on human health and the environment have been

relayed throughout the world and led to extensive focus on the e-waste issue in China. The public and international pressure has encouraged the Chinese government to pay attention to the recycling and treatment of electronic waste.

In order to establish a formal, standard e-waste recycling system; build experience for the development of related policies, regulations, and standards; and simultaneously promote the development of a circular economy, the National Development and Reform Commission (NDRC) listed Zhejiang province and Qingdao city as the national pilot province and city for recycling old and waste household appliances in December 2003. Furthermore, in order to generate more resources to support the construction and operation of the pilot projects in Zhejiang province, Qingdao city, Beijing and Tianjin, were incorporated in the energy saving and resource integration project in the national debt plan. However, these e-waste recycling corporations ran into problems because there were no clear recycling channels to generate the levels of e-waste needed to optimize the operation costs and benefits. Consequently, the bearing the high daily operation and maintenance costs became burdensome. The demanding capital flow of these corporations made it challenging to continue the businesses.

A series of policies have been developed, drawing on lessons learned from the pilot phase of the national e-waste recycling pilot project (2003 to 2009). In order to resolve the supply shortage for designated e-waste enterprises in pilot areas, the local authorities in Qingdao, Zhejiang and Shandong issued various policies and regulations that require governmental agencies, public institutions, state-owned enterprises and the army to:

- Collect and send the obsolete e-wastes to pilot and designated corporations for treatment;

- Make clear the obligation of household appliance retailers and after-sale service institutions commissioned by the EEP producers and pilot corporations to take back used and waste appliances; and

- Regulate the e-waste collected therein; it must be sent to the pilot corporations for treatment and must not be sold or disposed of by other means.

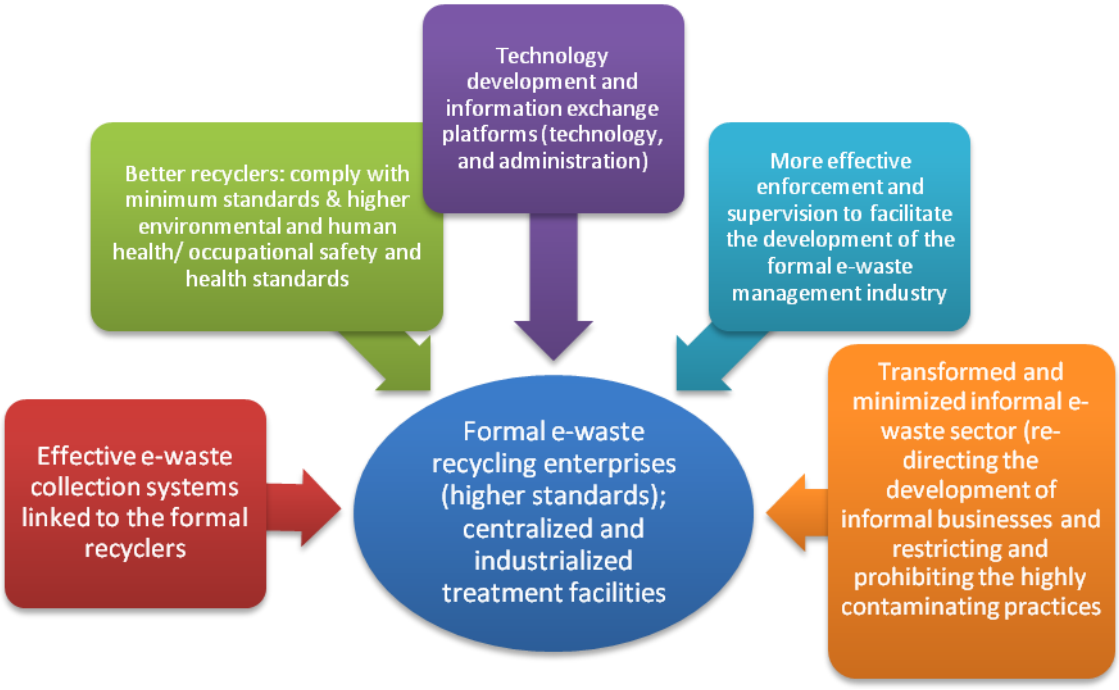
As for the e-waste generated from individual consumers, voluntary recycling is encouraged but non-binding. In addition to the intervention measures taken by the government, the pilot corporations took proactive measures to ensure adequate supply, including recycling at community level, collaborating with large-scale home appliance retailers and on-line recycling platforms, and opening free recycling hotlines. These measures were proven helpful to mitigate the shortage of e-waste supply faced by the formal enterprises. However, no dedicated measures are provided for the main source of e-waste: individual consumers and enterprises.

Since the end of the pilot projects, e-waste policy has moved away from an "intervention-centered" approach to "economic incentive-oriented" one. A national old-for-new household appliance recycling scheme was established between 2009 and 2011 to encourage individual consumers and enterprises to recycle obsolete EEP by connecting them with formal e-waste recycling enterprises for treatment and disposal. The implementation of the old-for-new policy has gradually changed consumers' attitudes and habits towards waste appliances, and has improved the recycling channels of e-waste generated from domestic production and consumption.

Following the rapid informal development of the e-waste sector, the sector is in its initial stage of formal development. Administrative measures are being used to control the expansion of the informal sector; meanwhile, policy and economic incentives are facilitating development of the formal and centralized e-waste sector through centralized e-waste treatment sites and industrial parks.

In the future, the informal workshops and factories that are not able to comply with sector standards will be automatically eliminated by the market, whilst the purchasing and collecting channels of the formal enterprises will expand to promote the development of the e-waste sector in China towards a large-scale, employment and technology intensive, industry. In the long term, the e-waste sector in China will lead both by the formal enterprises and enterprises specialized at resource recycling that are licensed and operated at large scale, and by the centralized e-waste treatment cities that comply with higher environmental and occupational standards (see Figure 3-4).

Figure 3-4 Future development of e-waste management in China



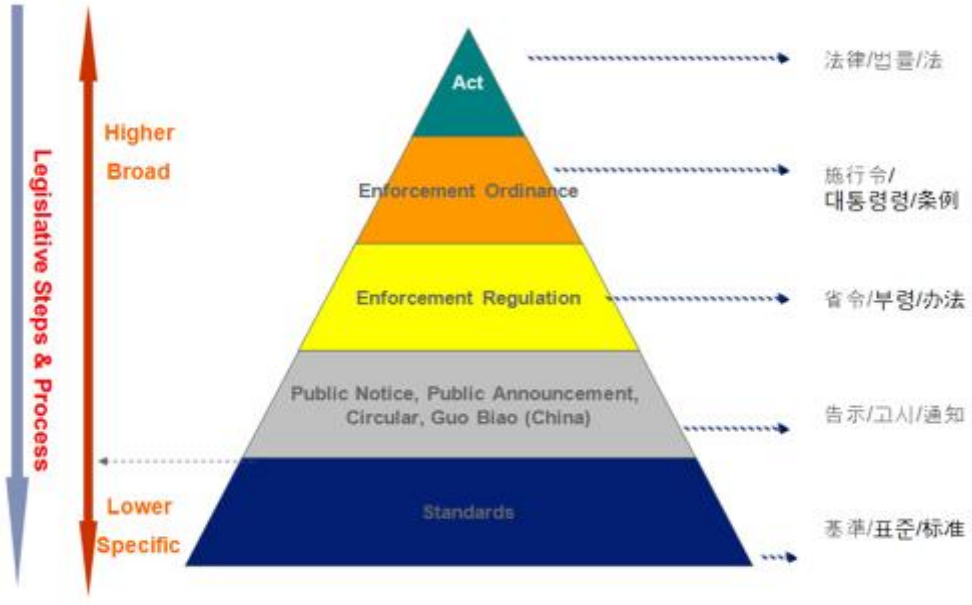
4. The legal and regulatory framework in China

China has established a series of laws and regulations related to the e-waste sector, mainly focusing on its environmental output and pollution control. Regulations or regulatory provisions directly targeting the human health and work safety impacts of the e-waste sector are yet to be developed. Some argue that the existing general regulatory framework on labour and human health is applicable to the e-waste sector, although its enforcement cannot be guaranteed due to the lack of sector focused labour inspection. However, there is a clear occupational safety and health focus in the regulatory framework on chemical management that potentially can be linked to or learned by the evolving legal framework on e-waste management. This chapter introduces the most visible existing legal and policy instruments that are contributing to the integrity of the e-waste sector in China.

4.1 Environmental policies and regulations related to e-waste management

There is a series of policies and regulations directly or indirectly important to the management of the e-waste sector in the Chinese legislative hierarchy, categorized by law, ordinance, regulation, administrative notice, measure, announcement, and industrial standards (see Figure 4-1).

Figure 4-1 Chinese Legislative Hierarchy (source: www.ynpglobal.com)



While the majority of e-waste regulations are centered in the middle or even towards the bottom of the legislative hierarchy, the Solid Waste Pollution Prevention and Control Law (1995), the Clean Production Promotion Law (2002), the Circular

Economy Promotion Law (2008) and their supplementary provisions have provided a high-level legal basis as a "stepping stone" to development of an e-waste sector-specific legal framework (see Annex 3). For example, hazardous substances such as PCBs, PBBs, mercury and lead, contained in components and articles of e-waste, have been listed in the National Catalogue of Hazardous Wastes (2008) pursuant to the Solid Wastes Law. The Regulation on the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products (the so-called "China WEEE Regulations"), promulgated in 2009 by the State Council, is the most important regulation because it established an e-waste management system in China, starting with a limited list of electronics.

Among the laws and regulations introduced above, the core of China's e-waste regulations consists of the *Management Measures for the Prevention and Control of Pollution from Electronic Information Products*, the so-called China Restrictions on Hazardous Substances, or "China RoHS", and the *Regulation on the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products*, the so-called "China WEEE Regulations". While China RoHS targets control and management of hazardous substances on the production side, China WEEE regulations focus on appropriate recycling and disposal once these products move into the waste stream. The latest iteration of China RoHS and China WEEE are introduced in the tables below.

Background of China Restrictions on Hazardous Substances (RoHS)

2006 China RoHS, i.e., *Management Measures for the Prevention and Control of Pollution from Electronic Information Products (EIP)*, defines EIP as follows: "Electronic information products mean electronic radar products, electronic communication products, broadcast and television products, computer products, household electronic products, electronic measurement instrument products, security products for electronics, electronic component products, electronic application products, electronic material products, and other relative products and their accessory parts".

It stipulates two phases of managing the hazardous substances:

- Phase 1 is a labeling requirement only. All EIP must be marked with the appropriate pollution control logo and indicate the environmental protection use period. This took effect on March 1, 2007.
- Phase 2 applies to products listed in the Catalogue for Priority Pollution Control, by which RoHS substances are prohibited. This is enforced by China's compulsory product certification (CCC).

The First List of Controlled Electronic Information Products (sometimes translated as "First Catalogue/Directory") was issued in 2009 by competent Chinese ministries, including the: Ministry of Industry and Information Technology; Ministry of Commerce; General Administration of Customs; State Administration for Industry and Commerce; General Administration of Quality Supervision, Inspection and Quarantine; and Ministry of Environmental Protection. The inter-ministerial decision-making process appears to be very cautious about the scope of the Catalogue. The First Catalogue includes only limited EIP for which the hazardous substances are "technically mature and economically viable". However, it is important to notice the key features of the Catalogue:

- The catalogue will evolve over time, expanding as the technology for RoHS substitutions develops and becomes mature.
- Products will be added to the catalogue after "extensive consultations" with businesses, industry associations, experts and relevant government departments.
- Revisions to the catalog will be considered annually.

New China RoHS: On 16 July 2010, the Ministry of Industry and Information Technology released the "*Draft Measures for the Pollution Control of Electrical and Electronic Products*". A major change is the modification of the coverage from "Electronic Information Product (EIP)" to "Electrical and Electronic Products (EEP)" in China RoHS. The new definition of "Electrical and Electronic Products (EEP)", largely corresponds to the definition of "Electrical and Electronic Equipment" in the EU RoHS Directive (2002/95/EC) and would appear as "Equipment or its accessories which work with a voltage rating not exceeding 1500 volts for direct current and 1,000 volts for alternating current". If the new definition of EEP replaces the previous definition of EIP in China RoHS of 28 February 2006, all EEP would immediately be subject to China RoHS. This would represent even broader coverage of regulated products than that discussed in the EU Recast proposal.

Background of China WEEE

Pursuant to the Climate Production Promotion Law and Solid Waste Pollution Prevention and Control Law, the 2009 Regulation on the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products, the so-called "China WEEE Regulations", became the main instrument for regulation of the e-waste sector. It establishes a licensing system that qualifies competent enterprises for recycling and disposing of e-waste in an environmentally-sound manner. In addition, China WEEE intends to set up a multi-channel and centralized e-waste recycling system, supported by a government fund to subsidize the recovery and disposal of electrical and electronic products. In order to disburse the subsidies to qualified enterprises, the fund requires the formal e-waste recycling and disposal enterprises to meet a set of requirements, verified mainly by the Ministry of Environment Protection and the Ministry of Finance, including to establish an environmental impact monitoring system and to treat e-waste in compliance with the national standards on resource utilization, environment conservation, and labour protection. While all sources of funding have not yet been identified, but levies from EEP manufactures and consignees of import electric products or their agents will subsidize the recycling enterprises and manufacturers' work to recover obsolete EEP from consumers.

On 8 September 2010, the National Development and Reform Commission, the Ministry of Environmental Protection, and The Ministry of Industry and Information Technology jointly issued the First Product Catalogue of China WEEE, which included five types of products as the first batch of EEP for formal recycling and disposal: televisions, refrigerators, washing machines, air conditioners, and computers, including laptops. While the three China WEEE steering ministries established a Catalogue Management Committee, which is responsible for the formulation and adjustment of the Catalogue, producers and importers of these products have corresponding duties from 2011, including:

- Pay fees to set up the national fund for the dismantling and recycling of waste electrical and electronic products.
- Design environmentally-friendly products and try to use material without hazardous substances.
- Inform consumers about the potential for hazardous substances in existing in products, and mark collection and treatment information in products or user manuals.

Table 4-1 First Product Catalogue of Waste Electric and Electronic Products for Disposal

Type	Product	Range
1	Television	Cathode ray tubes (black and white, color) TVs, plasma TVs , LCD TVs , rear projection TVs , and others with functions of receiving signals and restoring the image and audio terminals.
2	Refrigerator	Combined refrigerator and freezer compartments, freezer compartments, refrigerator compartments, and other insulated compartments which have refrigeration systems and use energy to cool.
3	Washing machine	Pulsator washing machines, tumbling-box washing machines, mixed-type washing machines, dewatering machines, and others appliances that rely on mechanical action to wash clothes (including a drying function).
4	Air conditioner	Packaged air conditioners (window type, through-wall type, etc.), split air conditioners (split-wall type, split-cabinet type, etc.), multi-split air conditioners, and other room air appliances with a cooling capacity below 14000W.
5	Computer	Desktop computers (including host, split or whole form of monitor, keyboard, mouse), portable computers (including pocket PCs), and other information-processing entities.

Note: The New Harmonized System Codes (HS codes) of imported and exported electrical and electronic products listed in the Catalogue are to be disseminated separately by the National Development and Reform Commission, General Administration of Customs, the Ministry of Environmental Protection, and other related departments.

Old-for-New Policy

Following the inclusion of the five product types in China's WEEE regulations, a corresponding household appliance recycling programme was initiated following provisions in the Measures for the Implementation of Old-for-New Household Appliances Replacement Program published in 2009. This programme provides a range of subsidies for the recycling and reuse of obsolete products. According to the Announcement on the Work of Further Regulating the Old for New Household Appliances Replacement Program, released by the Ministry of Commerce, Ministry of Finance and Ministry of Environmental Protection in 2011, the enterprises successfully bidding for collecting the discarded household appliances in the old-for-new scheme need to transfer the waste to licensed e-waste recycling and disposal enterprises within 45 working days. Because the collected e-waste contains toxins and hazardous substances that should be strictly regulated, the recycling and disposal enterprises need to install a real-time video monitoring system that is connected to the local departments of environmental protection, which can then supervise the recycling process constantly to control environmental contamination from e-waste recycling.

In addition to the legislation targeting the e-waste generated from domestic production and consumption, as a member state to the Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal (Basel Convention), a series of laws and regulations focusing on the import and export management of e-waste have been enacted in China (see table 4-2).

Table 4-2 Laws and regulations on import and export management of electronic waste in accordance with the Basel Convention

Laws and regulations	Date of enactment and implementation	Enactment authorities
Measures for Administration of Hazardous Waste Export Approval	Promulgated on 25 January 2008. Effective on 1 March 2008.	The former State Environmental Protection Administration (SEPA)
Statements on Adjustment of the Catalogue of Import Solid Wastes	Promulgated on 3 July 2009. Effective on 1 August 2009.	The Ministry of Environmental Protection, the Ministry of Commerce, the National Development and Reform Commission (NDRC), the General Administration of Customs, the General Administration of Quality Supervision (AQSIQ)
Measures on the Administration of Import of Solid Waste	Promulgated on 8 April 2011. Effective on 1 August 2011.	The Ministry of Environmental Protection

4.2 Policies and regulations related to the labour aspects of e-waste management

Analysis of the present legal framework indicates that there is no legislation focusing on labour protection and occupational safety and health impacts of the e-waste sector in China, despite a wide range of workplace risks in this sector. However, the concept of laws and regulations on labor is very broad and inclusive. Any law or regulation related to labor systems, workers' legitimate rights, or labor relations is part of laws and regulations of labor. These laws and regulations are universal laws that regulate the e-waste recycling. The laws and regulations on labor in China can be divided into three categories: labor protection; safety; and occupational health.

Table 4-3 Major laws and regulations of labour in China

No.	Laws and regulations	Date of enactment	Date of implementation	Enactment authorities
Related to labour protection				
1	Labour Law	5 July 1994	1 January 1995	The Standing Committee of the

				People's Congress
2	Trade Union Law	27 October 2001	27 October 2001	The Standing Committee of the People's Congress
3	The Employment Contract Law	29 June 2007	1 January 2008	The Standing Committee of the People's Congress
4	Regulation on Work-Related Injury Insurances	8 December 2010	1 January 2011	The State Council
Related to production safety				
1	Production Safety Law	29 June 2002	1 November 2002	The Standing Committee of the People's Congress
2	Regulation on Production Safety License	13 January 2004	13 January 2004	The State Council
3	Regulations on Labour Protection for Using Toxic Substances in Workplace	12 May 2002	12 May 2002	The State Council
4	Regulation on the Safety Management of Hazardous Chemicals	2 March 2011	1 December 2011	The State Council
Related to occupational health				
1	Law of the People's Republic of China on Work Safety	29 June 2002	1 November 2002	The Standing Committee of the People's Congress
2	Occupational Diseases Prevention and Control Law	27 October 2001	1 May 2005	The Standing Committee of the People's Congress
3	The Catalogue of Occupational Diseases	18 April 2002	18 April 2002	Ministry of Health, Ministry of Labour
4	Provisions on Supervision of Hazard Ratings of Toxic Works	26 January 1994	26 January 1994	Ministry of Labour
5	The Classification Catalogue of Occupational Disease Inductive Factors	11 March 2002	11 March 2002	Ministry of Health

The foundational legislation on occupational safety and health and labour protection in China is composed of the *Occupational Diseases Prevention and Control Law*, promulgated in 2001, and the *Production Safety Law*, approved in 2002. The Occupational Diseases Prevention and Control Law defines "occupational disease" as "disease resulting from exposure of workers to industrial dusts, radioactive substances, and other poisonous and harmful substances in the workplace". It also clarifies: the occupational health rights of workers; the obligation of employers to protect the

health of their employees; the responsibilities of governments at various levels; and trade unions' representation in workers' health protection. The law stipulates basic principles governing: the prevention and control of occupational disease; protective measures; hazards monitoring and management in workplaces; diagnosis of occupational disease; health authority inspections; and the liabilities incurred by those violating the law. The Ministry of Health, in coordination with the Ministry of Labour and Social Security (now the Ministry of Human Resources and Social Security), is responsible for defining and amending the "Catalogue of Occupational Diseases". Workers incurring the listed diseases are eligible for occupational disease compensation. The present Catalogue includes 115 diseases in ten categories. The law also requires all new construction, expansion, and re-building of premises, as well as technical transformation and import projects that could produce occupational hazards when put into operation in the future, to simultaneously install occupational hazard controls. Before any installation begins, the owner or employer should assess its effects on occupational hazard control and apply to the health authority for inspection and supervision. No project should begin operation until it satisfies the occupational health standards (see Figure 4-2). The law delineates workers' rights in workplaces (Figure 4-3) and requires employers to take responsibility for the control of occupational hazards and prevention of occupational diseases (see Figure 4-4).

Figure 4-2 Basic Occupational Health Requirements in the Workplace

Basic Occupational Health Requirements in the Workplace

(Occupational Disease Prevention and Control Law, 2001)

- Control of the intensity or concentration of an occupational hazardous substance in compliance with the national occupational health standards;
- Institution of appropriate occupational disease prevention facilities;
- Rational production layout in compliance with the principle of separating dangerous operations from safe areas;
- Deployment of appropriate sanitation facilities such as dressing rooms, bathhouses, and rest rooms for pregnant women;
- Ensuring that equipment, tools, and appliances comply with requirements for protecting the physical and psychological wellbeing of workers;
- Other requirements established by laws, regulations, and administrative rules related to workers' health protection published by competent bodies for health and safe production under the State Council.

Figure 4-3 Workers' rights and interests in workplaces

Safeguarding Workers' Rights and Interests in Workplaces
(Occupational Disease Prevention and Control Law, 2001)

- The opportunities to receive occupational health education and training;
- Access to occupational health services (e.g. health examinations, occupational disease diagnosis, and rehabilitation etc.);
- The right-to-know of the health effects of hazards in the workplace and how to protect oneself from work-related harm;
- The opportunity to request and claim improvement of working conditions and personal protective equipment;
- The right to criticize and accuse perpetrators of malpractices that violate the law and regulations and harm health;
- The right to reject illegal orders and commands to undertake operations without appropriate safeguard measures;
- The right to participate in the democratic management of the employer's occupational health practices, and to make comments and suggestions with regard to the occupational disease prevention practices of the employer.

Figure 4-4 Key measures for employers to prevent occupational diseases

Key measures for employers to control occupational hazard and prevent occupational disease

(Occupational Disease Prevention and Control Law, 2001)

- Establish an occupational health organization staffed with full-time or part-time occupational health professionals for in-plant occupational health management and service;
- Implement a plan and concrete programs for hazard control;
- Monitor workplaces regularly and evaluate effective hazard control actions;
- Inform the employee of any occupational diseases that may be contracted at work, its consequences, and the measures adopted to protect workers against harm;
- Organize and pay for workers' health examinations and keep accurate occupational health records (workplace hazard monitoring and workers' health examinations);
- Prepare an emergency rescue counter-plan;
- Provide pre-placement and regular training to inform workers about protection from specific occupational hazards and the need to strictly adhere to work safety rules;
- Consider as production costs all expenses for prevention and control of occupational hazards, workplace monitoring, workers' health examinations, and occupational health training.

Supplemental to the Occupational Disease Control and Prevention Law, the *Regulations on Labour Protection for Using Toxic Substances in Workplace* should be complied with by enterprises with operations involving exposure to highly toxic substances. Labour inspections can generally be applied to formal enterprises in the e-waste sector, despite the fact that labour inspectors may require sector-specific knowledge and the ability to supervise the safety of the e-waste recycling and disposal enterprises. Research on occupational health and safety legislation and implementation in China (Zhi Su, 2003) reveals that:

The implementation and enforcement of these labour focused regulations is primarily through labour inspection and supervision. In light of the Occupational Disease Prevention and Control Law, employers who cause poisoning accidents will be asked to compensate the victims and will be penalized. If an employer commits any violation of the law, the health authority may issue a warning and order the employer to rectify the situation within a prescribed time limit, and may also impose a fine of up to RMB 500,000 Yuan, according to the circumstances. For a serious infraction of the law, the health department may either order the employer to cease any part of its operations that endangers the health and safety of employees or request the relevant government to order the employer to shut down its workplace. Where criminal law is

violated, the person chiefly in charge and other directly responsible personnel shall be prosecuted for criminal liability according to the relevant provisions of the Criminal Law (1997).

In relation to the health inspection system in China, the Institute of Health Inspection, directly affiliated with the State Administration of Work Safety and health administrations of various levels of government, is responsible for executing health inspections (see Figure 4-5).

Figure 4-5 Health inspection measures in China (Zhi Su, 2003)

Health Inspection Measures
• Audit and approval of preventive assessment of industrial premises that are being constructed, expanded or re-built, as well as technical transformation and import projects that might produce occupational hazards; • On-site inspection of enterprises/workplaces for implementation of the law and hazard-control measures, and environmental monitoring, to ensure the concentrations or intensities of occupational hazards in workplaces meet national industrial hygienic standards; • Checking whether the pre-placement and periodic health examinations of workers exposed to occupational hazards have been in compliance with national law and regulations; • Ensuring workers who are suffering from occupational diseases receive proper treatment, recuperate, and are transferred to other jobs suitable for them, in keeping with relevant regulations; • Supervising occupational health record-keeping and occupational disease reporting.

Despite the labour inspection and occupational safety and health frameworks established as a result of the Safety Production Law and the Occupational Disease Prevention and Control Law, these frameworks are general, and do not specifically look at the risk features of the e-waste sector. In practice, the implementation of these existing general frameworks is rather limited due to the fact that: first, enterprise compliance costs are significantly higher than the penalties; and second, there is lack of coherence between the legal enforcement branches. While the State Administration of Work Safety is responsible for executing the Safety Production Law, the Department of Health executes the Occupational Disease Prevention and Control Law.

Therefore, it is suggested that lessons be drawn from the experience of developed countries, and that sector-specific legislation be created to control and prevent occupational hazards faced by workers in the e-waste sector. In addition, some lessons can be drawn from the existing chemical management system in China, which includes a comprehensive regulatory framework on chemicals to ensure the public health, safety of workers and the protection of the environment. China has a long

history of regulating chemicals, dating back to the 1970s, when regulations focused on the health and safety of workers. In the 2000s, Chinese chemical regulations addressed health and safety of workers and the protection of the environment in a balanced manner. Figure 8 briefly introduces a regulatory framework on chemical management in China, which is composed of a comprehensive range of considerations that are more balanced between the environmental and work safety concerns.

4.3 Regulations and policies on the human health impacts of the e-waste sector

The e-waste sector can have profound human health impacts on the sector's workers, as well as on residents in the nearby community, depending on how toxins are handled during the treatment processes. Consequently, regulations were introduced by both environmental and health and work safety administrations in China. Nonetheless, these regulations are insufficient to guide and improve the common practices in the sector in the absence of a dedicated, integrated, and human health-sensitive system.

China WEEE Regulations require that recycled and reused EEPs comply with the mandatory national technical specifications in order to prevent harm to human health, personal and property safety. Article 15 explicitly requires treatment processes to conform to the requirements on human health protection, resource efficiency, labour safety and environmental protection. In order to mitigate the human health and environmental impacts when recycling and disposing the discarded products, China RoHS requires producers, importers and sellers of electrical and electronic products to comply with the rules requiring disclosure of the names and levels of toxic and hazardous substances contained in EEP.

Review of the broader range of regulations reveals that although human health protection is identified as one of the legislative objectives, this focus is rarely reflected in the technical content of these laws. As a result, practitioners in the e-waste sector are often unaware of the issues associated with human health. While, at present, environmental protection appears to be motivating policymakers to regulate the e-waste sector. Additional socio-legal studies need to be conducted to create a foundation for developing a clear common understanding of how to develop policies and regulations on labour and human health protection in the e-waste sector.

By the same token, it is necessary to clearly indicate the relationship of environmental legislation with human health issues, in order to ensure that efforts to improve the social and environmental performance of the e-waste sector can be achieved from more than one angle. In Japan, for instance, the statutory environmental standards in the basic environmental law are two-tiered, including both standards of projects related to human health and standards of projects related to the environment. Following this example, measurement of the human health index could be added to the system of environmental standards. Doing so creates an opportunity to combine the environmental and labour and health inspections, which will facilitate better understanding of precise impacts and possible ways to improve policies and practices

in the e-waste sector.

4.4 The enforcement and implementation capacity and challenges

According to data from the National Bureau of Statistics of China, the annual volume of obsolete household appliances and mobile phones has reached 20 million and 70 million, respectively, since 2001. The total volume of e-waste generated in and imported to China is expected to continue increasing at least until 2015, primarily driven by the rapid development of information technology and the accelerating renewal speed of EEP, of which China is the largest producer and consumer. Meanwhile, some research indicates that approximately 70 per cent of global e-waste produced each year is imported to China. This poses another challenge to formalization of the e-waste sector, and particularly formalization of the information sector. While the demand for e-waste recycling will continue to rise, the effectiveness of the current legal and compliance framework has yet to be determined. However, empirical evidence indicates that a safely operated e-waste sector must be put onto the new policy agenda to resolve some of the greatest challenges, including: the lack of a specific policy framework integrating the labour and human health dimensions of the e-waste sector; limitations on sector-specific knowledge among the inspectors; the long history of the informal economy within the sector; and illegal trafficking of e-waste, particularly to the informal market segment that is currently beyond supervision and control.

The occupational health and safety and human health interventions must be equally involved in the management of the e-waste sector in China. The current labour protection regulations entitle formal enterprises to supervision by the related labour administration. However, expanding the scope of labour supervision to include the informal sector presents a significant enforcement challenge. Workers employed in this sector should have equal rights to labour protection, in which hazards and risks are poorly controlled. The Director-General of the ILO made this point as long ago as 1991, saying[15]:

> "It must now be our priority to discover practical ways of overcoming the obstacles to the full application to the informal sector of the legal provisions guaranteeing these rights and this protection. Secondly, it is indisputable that simple laws and regulations, and the flexible and efficient administration of these laws and regulations, are the prerequisites for the gradual legalisation of the informal sector. In other words, the legalisation of the informal sector must be achieved by simplifying and streamlining the legislative regulatory and administrative machinery of the whole society. Thirdly, we must be careful in our efforts to streamline not to destroy what is essential. […] Even if the precarious situation of the informal sector makes the immediate application of some of these standards impossible, and even if certain aspects of this legislation would gain

[15] ILO. 1991. "The Dilemma of the Informal Sector, Report of the Director-General."

from being simplified, there can be no question of going back on these social gains simply in order to allow the informal sector to become legalised. These must remain goals to be achieved gradually, as soon as possible, in the informal sector"[16].

Some dedicated e-waste recycling schemes and pilot projects implemented at various levels illustrate both the progress and challenges in meeting these aims. For example, implementation of the old-for-new household appliance recycling scheme has led to a 51 per cent increase of supply to formal e-waste recycling enterprises. While the legal framework aims to formalize the e-waste sector in China, in the absence of a holistic intervention, it will be difficult to transfer the large number of informal, specialized family businesses in Guangdong, Zhejiang, and remote inland areas into formal enterprises.

4.5 Local regulations and initiatives on e-waste management

E-waste management is a multi-faceted opportunity and challenge. The creators of national e-waste policy have taken a learn-by-doing approach to policymaking, drawing lessons from local pilot projects and initiatives. The old-for-new policy is one example of this approach. Approved by the State Council in 2004, the National Development and Reform Commission (NDRC) announced the selection of Zhejiang province and Qingdao city as locations for pilot projects establishing a recycling system for obsolete household appliances and electronic products. Responding to this decision at the end of 2004, Zhejiang Economic and Trade Commission, in coordination with the Science and Technology Administration and other departments, jointly published interim measures to initiate the pilot scheme. In 2006, Qingdao Development and Reform Office, in collaboration with other administrations on environmental protection and science and technology development, issued interim measures for implementing the national pilot programme, which initiated both the principle of fixed-point recycling and centralized disposal. Based upon the experience on the pilot schemes in Zhejiang and Qingdao, in June 2009 seven ministries jointly published the national Old-for-New Home Appliances Recycling Measures. This policy required all provinces to provide implementation plans and designate qualified enterprises to establish e-waste recycling and treatment systems. In November 2011, the Ministry of Environmental Protection issued Waste Electrical and Electronic Products Development Planning Guidelines in order to implement Waste Electrical and Electronic Products Recycling Regulations and to guide the formation of the regional waste electrical and electronic products development plan. The Guidelines require a joint consultation process, led by the Leading Planning Group, constituted by the Environmental Protection agencies of the provincial government departments, industry and information technology departments, managerial level practitioners in recycling waste EEP in the region, and professionals

[16] Reply of the Director-General to the Discussion of His report, Record of Proceedings, International Labour Conference, 78th Session (Geneva, 1991).

and experts engaged in the EEP production process. The Group will map out the key details needed for establishing the local e-waste recycling system, including; overall processing capacity; structure; scale; and technological profile. Figure 4-4 lists the local pilot plans. As for the informal e-waste businesses in centralized areas such as Guangdong and Zhejiang provinces, information about how to integrate the legalization of e-waste business into local economic development and re-structuring is essential. A main consideration is to cluster the family workshops and factories into centralized treatment areas or industrial parks and to supervise them for legalization.

Table 4-4 Provincial and local initiatives on e-waste treatment

Local pilot	E-waste recycling implementation plan
Beijing	Twelfth Five-Year Plan period of waste electrical and electronic products processing development planning (draft)
Shanghai	Waste electrical and electronic products processing development planning (draft) of Shanghai city
Tianjin	Disposal of waste electrical and electronic products development planning (draft) of Tianjin city
Chongqing	Waste electrical and electronic products processing development planning of Chongqing city (2011-2015) (draft)
Fujian province	Disposal of waste electrical and electronic products in Fujian province Twelfth Five-Year development planning
Guangxi municipality	The Guangxi Zhuang Autonomous Region disposal of waste electrical and electronic products development planning (2011-2015)
Hebei province	Disposal of waste electrical and electronic products in Hebei Province Development Planning (2011-2015) (draft)
Henan province	Disposal of waste electrical and electronic products in Henan Province Development Planning (2011-2015)
Jilin province	Disposal of waste electrical and electronic products in Henan Province Development Planning (draft)
Zhejiang province	Disposal of waste electrical and electronic products in Zhejiang Province Development Planning (draft)
Jiangsu province	Disposal of waste electrical and electronic products in Jiangsu province Twelfth Five-Year development planning (draft)
Shanxi province	Disposal of waste electrical and electronic products in Shanxi Province Development Planning (2011-2015) (draft)

5. The labour dimension of e-waste management in China

5.1 The labour structure and the e-waste life cycle

The staggering growth of EEP production and consumption requires intensive human resources for managing the resulting e-waste. The complexity of suppliers is one of the features of the supply chain in the e-waste recycling industry. In China, e-waste mainly comes from households, administrative institutions, electrical and electronic equipment manufacturers and illegal imports; e-waste generated from households accounts for the vast majority of the total e-waste supply. While e-waste generated from administrative institutions and manufacturers of electrical and electronic equipment are often recycled by formal enterprises through formal contracts, personal relationships and networks facilitate the supply of e-waste illegally imported to China to the informal factories and workshops.

Individual collectors play a very important role in Chinese e-waste supply chain because they collect decentralized household recyclable waste at household and community level in most of the cities. Also called "informal waste pickers", most of these individuals are migrant workers with a low level of education and limited occupational skills who, due to structural unemployment in rural areas and urban cities, are living on informal jobs. Data from the Ministry of Agriculture of China reveals that 87.5 per cent of migrant workers have junior high school educations, and only 2.4 per cent have professional and technical titles (Zou and Li, 2006)[17]. Moreover, the employment capacity in the formal e-waste recycling sector is rather limited for these migrant workers. Since the implementation of the old-for-new scheme in 2010, it is estimated that approximately 10,000 workers have been employed in the 129 enterprises listed in the Catalogue.

Wang Feng (2011) [18]conducted random surveys of group characteristics of 160 individual traders and peddlers in Beijing (with 156 valid questionnaires). The study found that the majority of informal waste collectors and brokers are middle-aged migrants with low levels of education.

[17] Zou, Minshe and Li Changan. 2006a. "The Impact of Labour Structure on the Economic Growth Model in China." Shanghai Equity and Stock Research Institute. Available online: http://theory.people.com.cn/GB/49154/49369/6109407.html

[18] Wang Feng, Survey on Collective Characteristics of Waste Collectors in Beijing [J], Beijing Social Sciences Academy, 2011, (3): 67-72

Table 5-1 Hometowns of individual waste collectors in Beijing[19]

Province	**Henan**	**Anhui**	**Shandong**	**Sichuan**	**Others**
Number of people	96	24	14	9	13
Proportion	59%	17%	9%	7%	8%

Table 5-2 Age structure of individual collectors in Beijing[20]

Age	*Under 20*	*20-35*	*36-50*	*Above 50*
Number of people	4	30	103	19
Proportion	3 %	19 %	66 %	12 %

The labour structure of the formal enterprises does not vary significantly, given that their supply chain structures, profit models and operations are similar. Taking one of the national pilot e-waste recycling enterprises as an example, the registered capital of this enterprise is 30 million Chinese Yuan (4.8 million USD). It has several dismantling and treatment lines for computers, televisions, refrigerators, air conditioners, washing machines, automated circuit board processors, and other electronic articles. Its annual treatment capacity is 240 million units. According to one administrative manager of the enterprise, it has 200 employees on the dismantling lines, and most of them are migrant workers. Thus, the labour structure of this e-waste recycling enterprise does not differ greatly from conventional manufacturing enterprises.

In both the formal and informal e-waste sectors, the recycling work is labour intensive and employs many migrant workers. However, the situation will have to change over the coming years, as the supply of labour from rural areas is declining. According to the 2007 Green Paper on Population and Labour, the transferable young labour force has peaked in three quarters of the rural area in China. It is anticipated that the labour supply surplus will reverse during the Twelfth Five-Year-Plan period (2011-2015). A critical implication of this is that the era of stimulating economic growth based on cheap labour, and particularly migrating labour from rural areas in China, is coming to an end. As for the e-waste recycling industry, it needs to move away from the low labour cost-driven profit model, and upgrade the general quality and capacity of the sector.

5.2 Comparing the working conditions in formal and informal enterprises

Enterprises in the e-waste sector can be broadly categorized into family workshops, medium-size enterprises and environmentally-sound enterprises[2]. This section

[19] Ibid

[20] Ibid

compares the working conditions in various forms of enterprises and businesses in e-waste recycling sector. Details of the working conditions in the formal sector will be introduced in the following chapter.

Environmentally-sound and medium-size enterprises deploy modern technologies and put a management system in the workplace for the sake of productivity and profitability. Formal enterprises use appropriate physical methods to dismantle, crush, and separate e-waste, and apply technologies and mechanical solutions to achieve recycling. Employees are provided with protective equipment, such as glasses, dust masks, gloves, and earplugs, to reduce risks in workplace.

In contrast, the technological process applied in informal family workshops is extremely simple and technologically primitive. There is hardly any investment in industrial equipment other than normal household appliances, such as stoves for heating, fans for blowing the fume and dusts, manual toolkits for dismantling and sorting, and containers for acid washing. There are no ventilation facilities in the closed-door households or in backyards. In the case of Guiyu, the family workshops are located in a three- or four-story building where the owners and the owners' families live. The ground floor is often used as a dismantling workshop or for storage, as well as for a living room. Many owners of the businesses rent space from the neighbors or use their private premises as basic warehouse-style factories that are convenient for transporting and recycling e-waste. With primitive recycling methods, the family workshops specialize in certain e-waste articles and components, and send the remaining components to partnership workshops in the same village or nearby. The complementary focuses help these informal workshops ensure the aggregate gain of their businesses, both in terms of keeping the e-waste recycling at a scale that is profitable, and in strengthening the social fabrics and family ties. Many of these informal workshops and factories, such as those in Guiyu, Guangdong, rely on trust, a kind of social capital, in their big family groups.

In addition to the lack of a structured organization of the informal e-waste recycling business, it is more noteworthy that there is little awareness among the workers and employers about the hazards and risks to human health and the environment. Workers who directly touch, dismantle, and extract valuable metals and other materials from the e-waste normally do not understand the severity of the risks to which they are being exposed.

Six of the most harmful substances can be found in most of the electrical and electronic equipment and its waste. These substances include lead, cadmium, mercury, hexavalent chromium, polyvinyl chloride plastic and brominated flame retardants. Manufacturers of computers use more than 700 kinds of chemical raw materials, in which more than 300 kinds are harmful to human health[3]. These substances can leak during use. Its backward processing method alone can cause severe damages to

human health and the environment, not to mention during its transportation and storage process. Taking circuit boards as an example, Table 5-3 illustrates the risks associated with e-waste recycling practices in informal workshops and factories, and their impacts on human health.

Table 5-3 Potential environmental and security risks in the process of dismantling, recycling and disposal of the circuit board (Jinhui Li, 2010)[21]

Dangerous practice	Purposes	Sources of pollution/pollutants	Risks	Impacts on human health
Heating the circuit board on the coal stove	Recycle components on the circuit board	Dust, dioxin, benzene, phenols, volatile halogenated hydrocarbons	Damage to the human body and the surrounding environment caused by tin-containing dust, dioxins, benzenes (benzene, toluene, xylene, styrene, bromobenzene, etc.), volatile halogenated hydrocarbons (methyl bromide, ethyl bromide, etc.)	Dust can cause lung disease. Benzenes are strong carcinogens. Chronic benzene poisoning can irritate the skin, eyes and upper respiratory tract. The long-term inhalation of benzene can cause aplastic anemia. If the hematopoietic function is completely destroyed, it will cause the fatal disappearance of granular white blood cells, and leukemia.
Heating the circuit board again when the components were removed on pans or iron boards	Recycle the solder	Dust, dioxin, benzene, phenols, volatile halogenated hydrocarbons	Damage to the human body and the surrounding environment caused by tin-containing dust, dioxins, benzenes (benzene, toluene, xylene, styrene, bromobenzene, etc.), volatile halogenated	Dust can cause lung disease. Benzenes are strong carcinogens. Chronic benzene poisoning can irritate the skin, eyes and upper respiratory tract. Long-term inhalation of benzene can cause aplastic anemia. If the hematopoietic function is completely destroyed, it will cause the fatal disappearance of granular white blood cells, and leukemia.

[21] Li Jinhui et al, Waste Electrical and Electronic Products Management Policy Study, China Environmental Sciences Press, Beijing, 2011

			hydrocarbons (methyl bromide, ethyl bromide, etc.)	
Dissolving in strong acid liquid for solution	Recycling metal	Waste acid vapor, antimony, copper, lead, arsenic, chromium, cadmium, tin	Damage to the human body and the surrounding environment caused by waste hydrochloric acid and nitric acid vapors	Waste acid vapors have a serious impact on the respiratory tract. Antimony can irritate the mucosa and cause the damage to internal organs and acute poisoning. Lead and its compounds can harm blood, nerves, digestive system and kidneys. The occupational poisoning is mainly chronic. Damage to the nervous system includes mainly neurasthenic syndrome and peripheral neuropathy (motor function damage is more visible); more serious damage can cause lead encephalopathy disease. A large number of inhaled arsenic can cause acute poisoning, but less severe gastrointestinal symptoms. Chronic poisoning: long-term exposure to arsenic compounds cause gastrointestinal symptoms, liver and kidney damage, skin pigmentation, hyperkeratosis or verrucous hyperplasia, and peripheral neuritis.
Smelting in the blast furnace	Recycling metal	Dioxin, benzene, phenols, volatile halogenated hydrocarbons, copper, lead, antimony, tin	The incineration of the circuit board with brominated flame retardants may cause the formation of dioxins, furans, CuBr2, and HBr	Benzenes are strong carcinogens. Chronic benzene poisoning can irritate the skin, eyes and upper respiratory tract. The long-term inhalation of benzene can cause aplastic anemia. If the hematopoietic function is completely destroyed, it will cause the fatal disappearance of granular white blood cells, and leukemia. Antimony can irritate the mucosa and cause damage to internal organs and acute poisoning. Lead and its compounds can harm the

				blood, nerves, digestive system and kidneys. Occupational poisoning is mainly chronic. Damage to the nervous system includes mainly neurasthenic syndrome and peripheral neuropathy (motor function damage is more visible); more serious damage can cause lead encephalopathy disease.
Incineration	Disposal	Dioxin, lead, benzene, phenols, volatile halogenated hydrocarbons	The incineration of the circuit board with brominated flame retardants may cause the formation of dioxins, furans, CuBr2, and HBr	Lead and its compounds can harm the blood, nerves, digestive system and kidneys. Occupational poisoning is mainly chronic. Damage to the nervous system include mainly neurasthenic syndrome and peripheral neuropathy (motor function damage is more visible); more serious damage can cause lead encephalopathy disease. Benzenes are strong carcinogens. Chronic benzene poisoning can irritate the skin, eyes and upper respiratory tract. The long-term inhalation of benzene can cause aplastic anemia. If the hematopoietic function is completely destroyed, it will cause the fatal disappearance of granular white blood cells, and leukemia.
Discarded	Uncontrolled disposal	Heavy metal, PCBs, brominated flame retardants	The surrounding air, soil and groundwater contamination caused by the leakage of PCBs, brominated flame retardants, lead, cadmium, copper and other chemicals and metals	Heavy metal can destroy the neural system and kidneys. PCBs affect the skin, nerves and liver, and destroy calcium metabolism, resulting in damage to the bones and teeth and the possibility of chronic carcinogenic and mutagenic of genetic mutation. In addition, PCBs cause significant harm to the skin and liver, have adverse impacts on brain development, and cause abnormal sperm and birth defects.

				Long-term exposure to brominated flame retardants can hinder the development of the brain and bones, and cause permanent harm to the nervous system and behaving capacity. Brominated flame retardants can also disrupt the endocrine system.

The various toxic substances released from e-waste during inappropriate recycling can cause severe health damage. To list a few examples, lead build-up in the environment may be chronically toxic to animals, plants and microorganisms, causing damage primarily to the nervous system, blood, kidneys and endocrine system. If lead enters the body of pregnant women, it may affect fetal development and result in deformities. High levels of lead in the blood also affect children's mental development (Howell, 2001[22]; Zhu Zhongping et al., 2006[23]). Mercury released into water can be converted into methylmercury and biomagnified in the food chain; ingestion can cause chronic damage to the nervous system. Furthermore, cadmium compounds can be enriched in the body, particularly in the kidneys, and may cause irreversible damage to humans. Cadmium compounds enter the body through inhalation or ingestion, and due to their long half-lives, can build up in human tissues (Wang Renqun et al., 2006)[24]. Chromium can have a variety of toxic effects, such as severe allergic reactions and DNA damage. The toxicity of chromium is related to its state of valence; hexavalent chromium is easily absorbed through the cell membrane and accumulated in the body, and its toxicity is 100 times higher than trivalent chromium (Zhang et al., 2006)[25].

The negative impact of these substances is transferred from the workshops and factories in which e-waste is recycled into the local communities and broader environment. The atmospheric concentration of heavy metals in Guiyu is much higher than that of other big cities in Asia. In particular, the concentrations of chromium, zinc, and copper are 4 to 33 times greater than concentrations found in other areas of Asia (Deng et al. 2006)[26]. Furthermore, the concentrations of other toxic heavy metals such

[22] Howell B. Electronic waste: the dangers [J]. Hazardous Technical Information Services, 2001, 11: 1-4.

[23] Zhu Zhongping, Shen Tong, Yu Cuilian et al, Research on the effects of environmental lead pollution on child behavior [J], Environment and Health Magazine, 2006, 23(2): 102-105.

[24] Wang Renqun, Zhao Su, Qiu Yupeng et al, Research on kidney damages of residents in Cadmium polluted areas [J], Environment and Health Magazine, 2006, 23(3): 202-204.

[25] Zhang Wenhao, Yang Peihui, Function mechanism of chromium composition in leading to DNA structural changes [J], Environment and Health Magazine, 2006, 23(3): 221-224.

[26] Deng W.J., P.K.K. Louieb, and W.K. Liuc. 2006. "Atmospheric Levels and Cytotoxicity of PAHs and Heavy Metals in TSP and PM2.5 at An Electronic Waste Recycling Site in Southeast China" in Atmospheric Environment, 40: 6945-6955.

as nickel and lead are significantly higher in the river sediment in Guiyu (Wong, 2007)[27].

In addition to these toxic substances, persistent organic pollutants, such as polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs), and polychlorinated dibenzodioxins/polychlorinated dibenzofurans (PCDDs/PCDFs), can also lead to profound health consequences. Evidence shows that PBDEs interfere with thyroid hormone secretion, and exposure can lead to nerve damage in newborn mammals. Pregnant women, fetuses and infants are particularly sensitive, thus comprising high-risk groups (McDonald, 2002[28]; Thomsen et al., 2002[29]). Dioxins or furans can have carcinogenic effects and cause immunodeficiency disorders, diseases of the nervous system, endocrine disruption, reduced lung function, and changes in plasma hormone levels. Changes to thyroid hormones, immune function, and the nervous system are also related to PCBs. Exposure to PCBs can cause liver function changes, skin diseases and improve cancer risk. PAHs can change propagation rates, affect cell division, and lead to cancer by enzyme induction.

5.3 The human health impacts

Due to limited time and funding, the research team could not carry out a comprehensive investigation of the human health impact of the e-waste recycling sector. However, the health consequences for e-waste workers have been identified through a review of relevant literature. Studies have shown that the blood of e-waste workers in e-waste dismantling sectors contains a variety of brominated flame retardants, and that the levels of these toxins were significantly higher than those of the control group (Sjmdin et al., 1999)[30]. In a 2001 study, Wu Nanxiang et al. [31]concluded the e-waste recycling industry had caused cytogenetic changes and affected the blood routine, liver function and immune function indicators industry workers, local residents and children. In the affected population, e-waste workers in family workshops who directly handled e-waste without labour protection suffered the most from exposure to the toxins and hazardous substances contained in e-waste. Symptoms experienced by the workers included but were not limited to dizziness, insomnia, headaches, and nausea. Qiu Bo et al. (2005) carried out a survey in five villages in Guiyu Township (Beilin, Huamei, Longgang, Dutou, and Nanyang), and

[27] Wong CSC, Wu SC, Duzgoren ANS, et al. Trace metal contamination of sediments in an e-waste processing village in China[J]. Environmental Pollution, 2007, 145: 434-442.

[28] McDonald, Thomas, A perspective on the potential health risks of PBDEs [J]. Chemosphere, 2002, 46: 745-755.

[29] Thomsen C, Lundanes E, Becher G. Brominated flame retardants in archived serum samples from Norway: a study on temporal trends and the role of age [J]. Environmental Science Technology, 2002, 36: 1414-1418.

[30] Sjmdin A, Hagmar L, Klasson WE, et al. Flame retardant exposure: polybrominated diphenyl ethers in blood from Swedish workers [J]. Environ Health Perspect, 1999, 107: 643-648.

[31] Wu Nanxiang, Yang Yinmei, Yu Suxia et al. Health impact on professional population and normal residents of e-waste dismantling. Environment and Health Magazine, 2001, 18(2): 97-99.

found the most common symptoms included: headaches, dizziness, insomnia, memory deterioration, cough, sniffles, angina, nausea, emesis, urinary stones, and pruritus (itching). (See Annex 1 for more information.)

5.4 Labour protection needs

Despite the risky profile of the e-waste recycling industry, apart from the general policy framework identified in Chapter 3, there are currently no specific laws, regulations or policies that address the need for stringent labour protection in the e-waste recycling industry. The existing e-waste policies and regulations have not specified the labor protection and occupational safety and health requirements in the e-waste recycling process. Recently the government has issues a series of labor protection and occupational safety and health policies and regulations, which are generally applicable for all sectors including the e-waste recycling industry. However, no progress has been made in establishing labour inspections or providing guidance to continuously improve workers' safety in the e-waste recycling sector. For example, Article 15 of *Regulation on the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products* explicitly requires that any disposal of waste electrical and electric products comply with state standards for comprehensive resource utilization, environmental protection, labour safety and protection of human health. However, the enforcement branch of the Ministry of Environment Protection primarily focuses on the establishment of an e-waste recycling system in China. It does not have the capacity to monitor and supervise enterprises to comply with the state requirements related to labour safety and human health protection. Secondly, the ministries of labour and health are currently not involved in the group of institutions governing the e-waste sector; therefore, these ministries do not formulate any specific "control provisions" to supplement the enforcement of the environmental policies. Rather, they focus on the issues prioritized on their respective agendas.

The following policies and standards are particularly relevant to the e-waste recycling sector, including:

- *General Graphic Design of Industrial Enterprises* (GB50187-1993)
- *General Principles for the Requirements of Safety and Health in Production Process* (GB12801-1991)
- *General Principles for the Requirements of Safety and Health in Production Facilities* (GB5083-1985, 1999 edition)
- *Hygienic Standards for the Design of Industrial Enterprises* (GBZ1-2010)
- *Occupational Exposure Limits for Hazardous Agents in the Workplace Part 1: Chemical Hazardous Agents* (GBZ2.1-2007)
- *Occupational Exposure Limits for Hazardous Agents in the Workplace Part 2: Physical Agents* (GBZ2.2-2007)
- *Classification of Health Hazard Levels from Occupational Exposure to Toxic Substances* (GB5044-1985)
- *Code for Design of Noise Control of Industrial Enterprises* (GBJ87-1985)

- *Safety Signs (GB2894-1996)*
- *Safety Requirement of Guard on Machinery* (GB8196 -1987)
- *Code of Design on Building Fire Protection and Prevention* (GB50016-2006)
- *Design Code for Protection of Structures Against Lightning* (GB50057-94, 2000 edition)
- *Code for Design of Extinguisher Distribution in Buildings* (GB50140-2005 version)
- *Requirements for the Placement of Fire Safety Signs* (GB15603-95).

Requirements specific to e-waste recycling enterprises are as follows:

- When selecting a site for constructing e-waste recycling enterprises, in addition to assessing the economic and technical aspects, design and planning must follow the *General Graphic Design of Industrial Enterprises* (GB50187-1993) to allocate the residential area, fresh water, and the discharge points for waste gas, water and residue. Meanwhile the transport channels, sidewalks and safety equipment should be planned according to the size of the enterprise in concern, and highways and railways should not be located near the recycling plant.

- In order to ensure safety, the overall layout of an e-waste recycling enterprise should pay attention to the location of storage sites, dismantling workshops, and warehouses that contain or may contain dangerous and harmful elements. Exposure distance, fire-fighting access, fire water supply and other facilities and devices in raw materials storing fields, dismantling workshops, product warehouses and other workplaces should meet the relevant standards and regulations. The distance between office buildings, dismantling workshops, product warehouses and other buildings should comply with requirements of ventilation, lighting and fire prevention. The transport network in plants should be reasonably arranged based on the production process and the logistical features, and should meet requirements for fire and dust prevention and gas defense. It should be fire-proof, explosion-proof, anti-vibration, anti-dust, anti-toxin, anti-electric shock, and meet other health and safety standards. The network should also ensure that fire engines and ambulances can easily access the venue in case of accident.

- As for the labour protection of e-waste workers, enterprises should provide quality personal labour protective articles and equipment according to the types and intensity of exposure to risk and harm. The Rules of Selecting and Applying Labour Protection Articles (GB11651-89) issued in 1989 can be taken as a reference for selecting proper labor protection articles.

6. Enterprise practices in the formal e-waste sector in China

6.1 Major technologies and business practices in collection enterprises

Since the implementation of the old-for-new policy at the national level, 1116 formal e-waste collection enterprises have been established and located in 37 provinces and cities[32]. It is estimated that there are at least 5,000 workers in these formal enterprises. According to the related requirements in some provinces which regulate every enterprise, formal enterprises should employ no less than 4 registered workers. Taking the old-for-new scheme as an example, the operational process of the old collection enterprises is as follows:

1) Reservation

Collection enterprises must publicize their contact details, providing telephone and online consultancy services regarding e-waste recycling policies and procedures.

2) Collection of obsolete household appliances

a) Door-to-door pick-up service:
b) Collection enterprises arrange pick-up from households that would like to return their obsolete appliances.
c) Based upon the guidance on recycling price, the household and the collection enterprise staff agree on the price of the returned household appliance in question. The collection enterprise pays the household in cash with a certificate for "old-for-new" scheme.
d) Waste household appliance collection at stores:
e) The stores of collection enterprises set up a household appliance old-for-new counter, in order for customers to come to sell waste household appliances.
f) Based upon the guidance on recycling price, the household and the collection enterprise staff agree on the price of the returned household appliance in concern. The collection enterprise pays the household in cash and provides a certificate for "old-for-new" scheme.

3) Sale

a) The collection enterprises must ensure that the collected waste household appliances will not enter into the market again. All collected waste must be sold to the designated enterprises for appropriate recycling.

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[32] Rules of Implementation of the Old-for-New Household Appliances Recycling Policy in Weihai City (Interim Arrangement), 24 September 2009, http://www.wdcz.gov.cn/html/rdzl/bzms/64.html and http://www.wdcz.gov.cn/item/Print.asp?m=1&ID=64.
Waste Electrical and Electronics Equipment - Industrial Analysis Report, 9 October 2011, http://www.ltmic.com/Article_51/2011109103724679-1.html.

b) The collection enterprises should store the waste household appliances separately according to the five categories of the old-for-new policy, and the storage sites must comply with environmental requirements.
c) The collection enterprises must provide duplicates of the old-for-new certificates for all of the collected waste household appliances (one-for-one) to the designated recycling enterprises.

6.2 Dismantling and recycling enterprises

Pursuant to the *Technical Policies of Pollution Prevention and Control of Waste Household Electrical and Electronic Products* issued by the Ministry of Environment Protection, enacted in 2006, e-waste dismantling and recycling enterprises must comply with the following technical specifications in their practices.

Dismantling

1) Waste EEP that cannot be repaired or upgraded for reuse should be manually or mechanically dismantled and treated. After dismantling, the functional articles and components should be considered for reuse. Those that cannot be reused should be sent to factories specializing in recycling the metal, glass, plastic and other useful elements.

2) The following listed components and their articles should be dismantled and collected separately:
    a. Cathode ray tubes (CRT) in monitors and televisions
    b. Liquid crystal displays (LCD) with a surface area over 100 cm^2 and the gas discharge bulbs
    c. Printed circuit boards with a surface area over 10 cm^2
    d. Plastic cables, wires, and casings that contain PBBs or PBDEs
    e. PCB capacitors and components containing mercury
    f. Nickel-cadmium recharging batteries and lithium batteries
    g. Refrigerant and lubricating oil in the compressors of the waste refrigerators, air-conditioners and other refrigeration machines.

Treatment of components containing hazardous substances

1) CRTs
    a. Color CRTs with lead glass cores and non-lead glass screens should be collected separately. The glass core containing lead may be used as raw materials for CRT manufacturers or recycled in other ways, and must be disposed of safely.
    b. The fluorescent powder coat covering the glass screen can be cleared using dry or wet methods.

2) LCDs
    a. Portable computers and other LCDs with a surface area over 100 cm2 should be separated in a non-destructive way to remove the backlight module, the driver integrated circuit, and the liquid crystal board without leaking any of the covering liquid crystal.
    b. The liquid crystal substances can become harmless when treated by heat precipitation and catalytic decomposition.
    c. The cold cathode fluorescent tubes removed from the backlight module can be delivered to the professional mercury collection plants for collecting the mercury/hydrargyrum or be disposed of as hazardous waste substances with other fluorescent tubes containing mercury.

3) Circuit boards
    a. When removing the components on the circuit board by melting down the tin lead solders, the exhaust cover should be installed to absorb the lead fume and dust, which can only be discharged after processing.
    b. The chips, metal linkers and other components containing valuable metals separated from the circuit board can be processed through corrosion, pickling, electrolysis and refining methods in treatment facilities to recycle valuable metals such as gold, silver and palladium.

4) The PCB capacitors removed from the circuit board must be delivered to plants specializing in the treatment of hazardous waste for disposal.

5) After removing the chips, capacitors and other components, circuit boards can be crushed in closed facilities with special equipment for absorbing dust in order to recycle the cuprum, fiberglass and resin.

6) Cables, cords and plastic cabinets containing PBBs or PBDEs should be collected separately from normal cables, cords and plastic.

7) To recycle cuprum and aluminum from cables and cords containing PBBs and PBDEs, physical methods such as crashing and sorting in fully closed facilities should be used. The separated cables and cord covers should be safely processed.

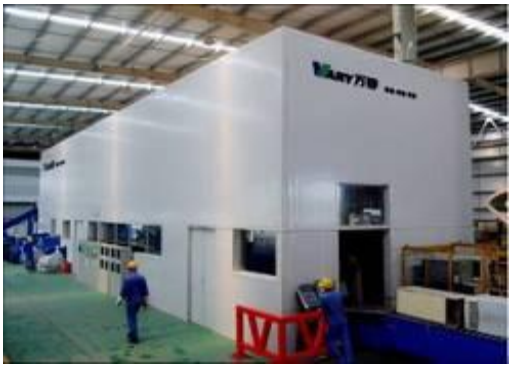
8) Plastic cabinets containing PBBs and PBDEs should be safely processed.

Research and development case studies of e-waste recycling enterprises in the old-for-new scheme

(1) Hunan Vary Tech Co., Ltd. is a company that focuses on recycling the “urban mining” resources from e-waste and industrial waste. Through investing in research and development (R&D), it acquires automatic production line technology for recycling waste printed circuit boards, and the technology and

equipment for environmentally-sound recycling and disposal of waste refrigerators. Below are some examples:

Waste refrigerator sound disposal



Waste printed circuit board crushing and recycling

Modification filling equipment of thermosetting plastic

Disposal equipment of waste wire and cable

Cutting equipment of CRT glass

Crushing and separation of CRT glass

(2) Shenzhen GEM High-Tech Co., Ltd. is another company that specializes in recycling "urban mining" resources from e-waste and waste batteries. This enterprise focuses on technological innovation and has developed patented technologies to create products such as wood plastic composite, the ultra-fine cobalt powder and ultra-fine nickel powder used in cobalt and nickel industries, and other high value-added products through the recycling of e-waste, waste batteries and other waste that contains cobalt and nickel.

(3) Huaxin Lvyuan Environmental Protection Development Co., Ltd. is a large-scale and high-tech environmental enterprise specializing in: environmental technology research and development; environmental facilities development and manufacturing; investment and operation of environmental projects; and logistics. The company runs the national old-for-new pilot project on recycling waste home appliances. Its centralized e-waste recycling park was established in 2011 with modern technologies and equipment for processing televisions, computers, refrigerators, air conditioners, washing machines and automated circuit boards. It has an annual recycling capacity of 2.4 million units.

CRT dismantling line

CRT treatment

(4) DOWA ECO-System Co., Ltd. is jointly supported by the Suzhou New District Economic Development Group Corporation and the Japanese DOWA Holdings Co., Ltd. It is mainly engaged in the recycling of gold, copper and e-waste disposal.

6.3 The execution of occupational safety and health measures

According to the *Regulation on the Administration of the Recovery and Disposal of Waste Electrical and Electronic Product* and *Measures on the Prevention and Control of Pollution Caused by Disused Electronic Waste*, e-waste recycling enterprises need to go through a series of administrative examination and approval processes and obtain required qualifications and licenses in order to establish, construct and operate their businesses. As part of the administrative process, enterprises need to acquire occupational safety and health (OSH) certification as well as the environmental impact assessment approval. Once an enterprise obtains all the necessary approvals and licenses, the local government departments oversee its operation and compliance with national and local regulations and standards.

In the field trip to the e-waste recycling plants of Huaxin Environmental Protection Development Co., Ltd. (hereinafter referred to as Huaxin) it was found that Huaxin had obtained the credentials for its OSH system, and was generally compliant with the existing laws and regulations on OSH. Following are some observations of Huaxin's OSH system and its implementation:

1) During the construction of the plant, Huaxin carried out safety production pre-evaluation and examination. This ensured the implementation of integrating the OSH system into the construction process, and put the OSH system into operation when the principal part of the e-waste recycling plant was in use (hereinafter referred to as "three simultaneous systems of safety facilities").

2) On the site selection and general layout, the plant is located in the outskirts of Beijing, a safe distance away from surrounding enterprises. The office buildings, dismantling plants, storage sites and other workshops are separated and constructed in a logical layout. The pedestrian and transport paths are separately installed and do not affect each other. Inside the plant and the dismantling workshop, different working zones are divided according to the operational requirements and technological features of different streams of e-waste. This arrangement is in line with the *General Graphic Design of Industrial Enterprises* (GB50187-93), *Code of Design on Building Fire Protection and Prevention* (GB50016-2006), and *General Principles for the Requirements of Safety and Health in Production Process* (GB12801-1991). But the shortfall is that in the open space in the dismantling workshop, only natural ventilation is used. There is no dust control equipment, so the dust released from the dismantling lines can spread and affect the workers' health.

3) On labour protection, safety signs and warnings are clearly arranged throughout the plant pursuant to the Safety Production Law, which requires enterprises to set up visible safety signs on facilities and equipment that may

cause harm. These signs are designed appropriately in line with the requirements of *Safety Signs* (GB2894-1996).

4) On individual safety measures, workers are provided protective clothes and other protective gear, but the provision of the labour protection is deviating from that is required in the *Selection Rules of Articles for Labour Protection Use*. For example, in the dismantling workshops workers dismantling TV sets and refrigerators with their hands wore ordinary gloves rather than insulated gloves; workers who were crushing, carrying and sorting the e-waste components wore normal masks rather than special dustproof masks; no one was observed wearing ear protectors despite the noise in the workshop; and the protective clothing did not cover the whole body. The on-site observation revealed that Huaxin does provide workers certain labour protection; however, it failed to strictly implement the related OSH regulations. It also indicated the need for improving the OSH system in the workplace and enhancing the safety awareness of both employers and workers.

6.4 Synergies between the enforcement of labour and environmental standards

Before exploring the synergies between the labour and environmental regulatory systems related to the e-waste industry, it is important to acknowledge that these regulations are formulated by different ministries and the "sense of urgency" to improve the sector differs for each one. As the steering government department regulating the e-waste sector, the Ministry of Environment Protection (MEP) is prioritizing the e-waste issue, given its profound impact on the environment, particularly in the areas where informal e-waste businesses are centralized, and the related international environmental concerns such as chemical management and persistent organic pollutants. In contrast, the labour government administration, namely the State Administration of Work Safety and the Ministry of Human Resource and Social Security, is focusing on more severe work safety threats in the coal, construction, chemical and mining industries. Notwithstanding the different attention and interests in the government bodies, the State Council of China is taking an inter-ministerial approach to addressing the challenges on e-waste recycling. This approach provides an opportunity to explore possible synergies between enforcing the labour and environmental regulations with greater impact.

At present there is little synergy between enforcing the labour and environmental standards in the e-waste sector. Environmental protection is the dominating policy in the sector. This is followed by a value chain approach to regulate the e-waste recycling industry, moving from controlling the source of e-waste to environmentally-sound recycling and appropriate disposal. As many of the toxins and hazardous substances in e-waste are both factors for causing environmental contamination and a threat to occupational safety and health in the workplace, they

converge as a critical point relevant to both labour inspection and environment protection. Furthermore, as safety production and occupational safety and health are included in the environmental policy as basic principles, they provide a legal basis for the environment and labour inspectors and the administration to collaborate to ensure the operation of the e-waste sector is consistent with these principles.

From a geographic perspective, the distribution of the e-waste industry is very dense in the coastal area, and is expanding into inland and less economically developed areas as a means of employment creation and driver of growth. In the coastal areas, particularly in Shantou city, Guangdong province, and Taizhou city, Zhejiang province, where the business is large in scale, e-waste recycling has become a major economic sector and a main source of income. Therefore, there is strong interest among local stakeholders in maintaining the growth derived from e-waste recycling. E-waste also captured the attention of central government and ministries, which now operate national pilot schemes of circular economy in this area. As the e-waste industry, and particularly the informal sector, is expanding and transferring some of its most polluted recycling work into this area, a great challenge will be to fill the policy and implementation gap on both the environment and labour issues related to e-waste recycling.

From an institutional perspective, it is stipulated in the *Regulation on the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products* that the environmental protection departments under the State Council, as well as other departments related to resource efficiency and industrial information under the State Council, are responsible for organizing the formulation of e-waste recycling policies and coordinating and overseeing the policy implementation. The commerce departments under the State Council are responsible for the management of recycling of waste electrical and electronic products. Finance, business, quality supervision, taxation, customs and other departments under the State Council are responsible for related management work in their respective areas. As it is the serious environmental problems caused by e-waste recycling which are currently under the spotlight, governments at all levels mainly, if not exclusively, focus on dealing with the environmental impacts of the industry. Labour protection and OSH shortfalls, including the impacts on human health, are not considered and responded to at the same level.

The Ministry of Environment Protection (formerly the State Environmental Protection Administration) has issued departmental rules, such as *Measures on Prevention and Control of Pollution Caused by Disused Electronic Waste,* and the environmental protection standard in the sector, *Technical specifications of pollution control for processing waste electrical and electronic equipment* (HJ527-2010), targeting the e-waste collection, transportation, storage, dismantling, recycling and other related processes. However, for the labour protection and OSH problems in the e-waste recycling industry, neither the Ministry of Environment Protection nor the State

Administration of Work Safety has formulated specific departmental rules or industry codes and standards for labour protection and OSH on e-waste recycling. Furthermore, none of the official documents under the Ministry of Human Resources and Social Security and the State Administration of Work Safety has been found to directly relate to the e-waste sector, which is currently not under the day-to-day supervision of and inspection by the labour ministry.

As the e-waste recycling industry captures more policy attention, greater synergies between the environmental and labour dimensions of e-waste recycling should be explored to mutually reinforce and enhance the aggregate effectiveness of policy interventions in the sector. For instance, Article 15 of *Regulation on the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products* and Article 4 of *Measure on the Administration of the Licensing of Qualifications for Disposal of Waste Electrical and Electronic Products* both stipulate that "the recycling of waste electrical and electronic products should conform to requirements of comprehensive resource utilization, environment protection, labour safety and protection of human health." In addition, in the OSH hierarchy what is required first and foremost is that employers should remove and avoid dangerous pollution sources to ensure occupational health and safety of employees. Therefore, joint implementation and enforcement of the environmental and labour standards can complement both the environmental protection and labour protection goals.

7. Case study in the informal e-waste sector

The informal e-waste recycling sector plays an important role in the e-waste industry in China. It processes 50% of the domestic e-waste in China, in addition to dismantling and recycling e-waste imported to China through illegal channels. The informal sector is comprised of family workshops and factories located mainly in Guangdong, Zhejiang, Hebei, Hunan and Jiangxi provinces. The research team took a field trip to Guiyu town, Shantou city, Guangdong province in December 2011 in order to investigate the social fabric, business plans, and concerns of workshop owners and workers in the informal sector.

7.1 Technological methods and processes

The vast majority of informal workshops adopt a fully manual disassembly method. Family workshops use very basic and simple tools, such as screwdrivers and pliers to dismantle e-waste, and sort valuable components with hands, or use simple acid-soluble, open burning and other simple methods to recycle high value-added components. The remaining components that are difficult to recycle are abandoned into normal waste streams without appropriate disposal. Despite direct exposure to e-waste that contains toxins and hazardous substances, there are no protective measures provided to workers.

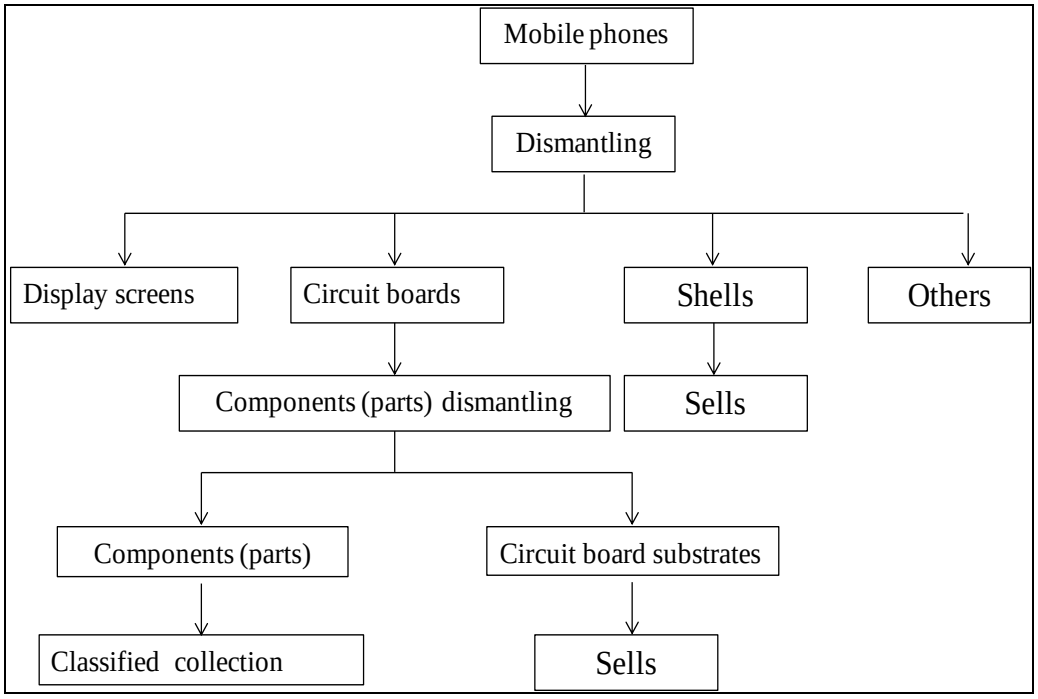
Among the informal businesses, there are some medium-sized informal recycling factories that install main e-waste treatment and disposal equipment and facilities, but in order to reduce costs, the necessary pollution prevention equipment are often not installed, therefore it can easily cause secondary pollution in continuous production.

The following is a list of examples that illustrate the recycling practices applied in the informal sector:

1) Circuit boards of mobile phones

The components and articles in mobile phone circuit boards imported from overseas are generally dismantled in informal family workshops using rather simple methods. After opening the mobile phone shell with a screwdriver and removing the circuit board, workers melt the solder with hair dryers, then remove the components and articles from the circuit boards with tweezers. These components and articles are then classified for treatment and recycling (Figure 7-1).

Figure 7-1 Dismantling processes of mobile phones



Compared with stove baking the circuit boards for removing the components and articles, the "hair dryer recycling" method generates less pollution and damage. However, the majority of informal family workshops still use the stove-baking method. Figure 7-2 depicts a medium-sized informal dismantling workshop for mobile phones. This kind of informal business is generally engaged in collecting the valuable articles and components in circuit boards, which they then sell to other recycling workshops.

Figure 7-2 A medium-sized informal dismantling workshop for mobile phones

2) Wire stripping businesses

Businesses that specialize in stripping wires and cables (to separate the metal and plastics) use the following basic process: first, an iron mold is used to fix wires, then workers use their hands to pull the end of wires to strip the exterior coating.

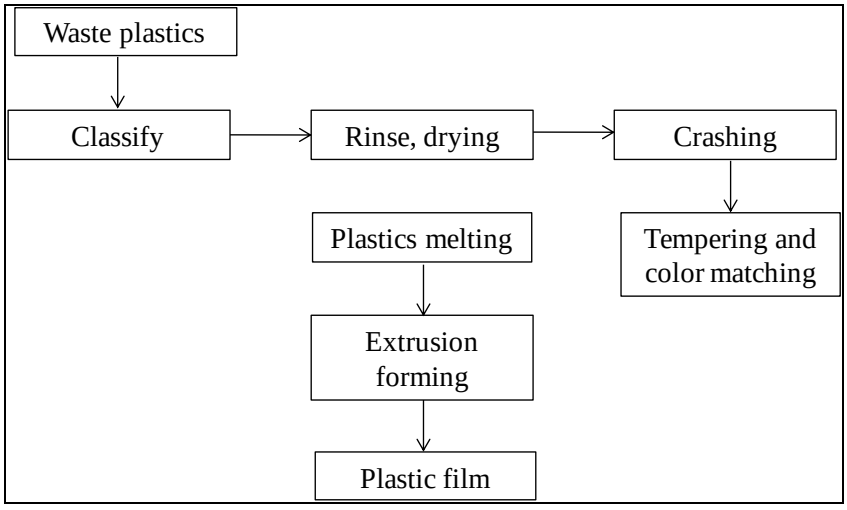
Figure 7-3 depicts this kind of workplace. This method can isolate high purity metals and plastics; however, in the case of very thin wire, this stripping method is ineffective. Very thin wires need to be crushed first. Winnowing machines are then used to separate the metal and plastics based on their different densities.

Figure 7-3 Wire-stripping businesses

3）Manufacturing enterprises for plastic packaging film

Some plastic packaging film manufacturing businesses are engaged in recycling waste plastics provided they normally have the production equipment and other large mechanical equipment to provide plastic packaging film. The production process includes the following steps: first, crushing the plastic; then melting it using plastic packaging film production equipment; and finally, extruding the melted plastics into different forms. Colorants can be added to produce plastic films in different colors. The film can then be batched into canisters and sold according to weight. This manufacturing process can release hazardous fumes and odors, but protection measures are rarely implemented by informal businesses.

Figure 7-4 Recycling waste plastics and manufacturing plastic packaging film



7.2 Case study in Guiyu

Demographic and geographic background

Guiyu town is located in west Chaoyang district of Shantou city, Guangdong province, in southern China. The total area of Guiyu is 52.17 square kilometers. Within in this area are 26 villages, including 27,921 households, with a total population of 145,537, according to 2009 statistics. Because the town is located in the center of a low-lying area, agricultural production in Guiyu used to suffer from serious waterlogging problems. Following the illegal importation of e-waste and rapid growth of EEP consumption in China, e-waste was gradually transported to Guiyu town. In 1995, the local communities started to specialize in recycling e-waste. In 2003, the production value of dismantling and recycling e-waste was more than 600 million RMB (95 million USD), accounting for 90% of the industrial output value of the whole Guiyu town. Tax income from dismantling and recycling e-waste was 8 million RMB (1.3 million USD), and was the largest source of industrial-commercial tax in Guiyu. By 2004, 21 out of 26 villages in Guiyu carried out e-waste recycling in more

than 300 family workshops.

Over the years, Guiyu established highly organized e-waste collection and recycling networks. It was reported by the local government that in the past 13 years, over 20 million tons of e-waste was dismantled and treated in Guiyu. E-waste recycling has become the core industry driving local economic growth, as measured by GDP, let alone the quality of growth less in the largest e-waste dismantling base in China, or even in the world. In 2005, Guiyu was selected as the first-tier national circular economy pilot area in which to explore pathways to environmentally sustainable and economically viable development, and to demonstrate the formalization of the e-waste recycling industry. An e-waste recycling industrial park of 253 hectares has been planned to convert the "Guiyu model" from highly polluting economic growth to green growth.

Figure 1 Guiyu National Circular Economy Pilot Project Layout

The employment structure

There are four large recycling enterprises in Guiyu, with a combined annual capacity to process over 20,000 tons of plastic, copper and iron Over 60% of the local population in Guiyu is involved in the e-waste businesses, which are spread across some 5,500 e-waste recycling family workshops that employ more than 50,000 migrant workers migrated from Sichuan, Hunan, Jiangxi, Anhui, Guizhou and other provinces. Workers are generally satisfied with their wages, which vary according to the role undertaken within the recycling process. The highest wage jobs are those in

the most difficult working conditions, such as circuit board backing for 100 RMB (16 USD) per day. Other jobs, like crushing and sorting, are often paid on an hourly basis, and the working hours change according to the amount of e-waste transported to the workshops and factories. In addition to the e-waste businesses, there are also small- and medium-sized enterprises manufacturing underwear and plastic products for the domestic market and for export.

Working Conditions

The working conditions in the informal e-waste sector are perilous. Due to the inappropriate methods use and lack of protective equipment in the workplace, workers are exposed to unrecognized risks. During the research team's field trip to Guiyu in December 2011, it was observed that manual operation in family workshops and factories was the most common method of recycling, and that measures of occupational safety and health protection and risk prevention were basic or non-existent. When recycling and abstracting valuable substances from waste circuit boards, workers baked them directly on fire and then removed the chips, capacitors, and tin. In some workshops, there were fans or simple ventilating equipment above the stove, and workers wore sleevelets and tin gloves. However, none of the workers observed during the field trip wore masks (see Figure 7-6). When asked if they were concerned about the risk of health damage resulting from breathing the pungent fumes, a middle-aged female worker baking hundreds of circuit boards answered: "It doesn't smell good. But one just doesn't work long on this." The answer revealed that in spite of perceived risks, some workers, and possibly the majority, may accept or ignore the poor working conditions in the informal sector. In those places where some ventilation equipment had been installed, it was connected with a chimney that directly released the unprocessed fumes into the air. The neighborhood is on the opposite side of the street (Figure 7-7).

Figure 7-6 Female workers backing circuit boards in a family workshop in Guiyu

Figure 7-7 E-waste freighted to an informal factory in Guiyu (left); family workshops equipped with chimneys to direct fumes into the air (right).

In 2003, Zhongshan University reported that, given the lack of equipment that can identify the kinds of plastics, in the pelletizing phase workers recycling plastics from e-waste use primitive and perilous methods to put samples of plastics on fire. The workers then differentiate the types of plastic by smelling the fumes, which can cause serious long-term health problems. After identification, the plastic will be further smashed and melted in a furnace to create a threadlike consistency. It will then be cut to particles that serve as raw materials for producing low-quality plastic products, which are in high demand in the Shenzhen, Jiangsu and Zhejiang provinces. According to analyses conducted by the Basel Action Network[33] and Silicon Valley Toxics Coalition, the gases released from burning plastic samples and melting large amounts of plastics very likely contain dioxins, furans and other highly toxic substances. However, simple ventilation devices will do little to prevent exposure to these toxins. Notably, of course, some facilities do not have any air purification facilities at all. Overall, occupational safety and health measures are lacking in the informal sector. Facemasks, eye protectors, protective clothing and more effective protecting equipment are needed, and wastewater, waste gas, and other residues should be disposed of appropriately to prevent local environmental contamination.

Occupational safety and health hazards

There are various kinds of occupational safety and health risks in the informal e-waste recycling process. The main OSH hazards include dust, waste acid vapor, toxic fumes and gases, falling, fire accidents and explosions.

[33] Basel Action Network. 2010. "2009 and 2010 Annual Report of BAN." Available online: http://ban.org/library/BAN_AnnualReport_Final_2009.pdf and http://ban.org/library/BAN_Annual_Report_Final_2010.pdf（2011.12.26）

In the process of collection, transportation and storage, workers often manually move large amounts of e-waste from one place to another within the limited space in family workshops and factories. This practice causes physical injury, especially to a worker's neck, back, lower back, legs and feet (Figure 7-8). When handling televisions and computer monitors, CRTs and picture tubes must be moved smoothly because severe vibration may cause explosions; furthermore, the fluorescent substances in the air can damage the respiratory system. Without careful management, combustible materials, such as plastic shells and cable and wire covers, can cause fire accidents.

Figure 7-8 Transporting and storing e-waste in the informal e-waste recycling sector

In the e-waste dismantling process, workers are not provided with any individual protective equipment when baking circuit boards over coal stoves. The heating process leads to the spread of toxic gases (e.g., flame retardants), that can have adverse effects on workers' health. Melting tin and other solder on the circuit board may cause fire accidents and scalding. When extracting gold from circuit boards by acid bath and purifying gold by heating, the burning acid and vapor can cause skin corrosion and contaminate the working environment.

Figure 7-9 Gold extraction sites and the workplace in Guiyu

When recycling glass from waste CRTs, OSH risks arise from application of inappropriate methods and techniques. For example, to separate the panel glass and cone glass of CRT, the electric-heat-wire method and saw/diamond-cutting method

can release toxic and hazardous dusts, and hot acid baths and burning methods involve the burning of strong acid, which generates waste acid vapor. Toxic heavy metals threaten the workers' and local communities' safety and health.

Environmental and human health impacts

The inappropriate recycling of e-waste not only contaminates the work environment and increases the occupational safety and health risks of workers, but also threatens public health and the environment in local communities. For instance, once the toxins and hazardous fumes and gases are released in the open air in Guiyu town, the negative impact on health spreads into the local community, particularly affecting children. In 2005, the Medical College of Shantou University conducted an independent study of the levels of lead in blood in Guiyu. It tested 165 children, aged one to six years old, and showed that the blood lead level was high, with 81.8% of children shown to have had some extent of lead poisoning. Of these, 24.4% had moderate-level lead poisoning. On average, the blood lead level among children in Guiyu was significantly higher than that of children who lived in locations in which there were no e-waste recycling[4]. Doctors generally identified respiratory illnesses and kidney stones as the most common local diseases, second only to head colds.

Two other surveys of the blood lead levels of children found levels that were higher among children near the e-waste dismantling sites in Guiyu, than those of the control group (Xu Xijin et al. 2006[34]; Han Dai 2007[35]). The investigation of Li Yan et al. (2007)[36] showed that the geometric mean of chromium content in the umbilical cord blood of newborns in Guiyu was 14.9 times higher than that of the control group. Furthermore, high blood lead and cadmium levels were consistently found among children in Guiyu (Zheng and Wu et al., 2008); and there was an inverse correlation between lead levels and IQ among the age group of three to six year olds. According to the media research of Shantou University Medical College, the blood lead and cadmium levels of newborns in Guiyu were significantly higher than those of newborns in other areas in China. The Guiyu and control groups were also found to have significant differences in the DNA damage of cord blood lymphocytes in neonates.

The toxins and hazardous substances in e-waste that contaminate the environment can be categorized as halogenated flame-retardants or heavy metal pollutants. Halogenated flame retardants can be found in plastic wires, shells, circuit boards and

[34] Xu Xijin, Peng Lin, Li Wei et al. Blood lead level of children in e-waste dismantling areas [J]. Environment and Health Magazine, 2006, 23: 58-60.

[35] Han Dai, Huo Xia, Zheng Liangkai et al. Survey on blood lead level and intelligence of children in e-waste dismantling areas [J]. Shantou University Medical School Press, 2007, 20: 170-172, 175.

[36] Li Yan, Huo Xia, Zheng Liangkai et al. Chromium level in the umbilical cord blood of newborns in e-waste dismantling areas [J]. canceration•distortion•mutation, 2007, 19: 409-411.

other materials. It becomes a potential source of dioxins when burned or heated. Some countries have identified materials containing halogenated flame-retardants as toxic pollution requiring special treatment to mitigate its environmental impact. Another source of pollution is heavy metals, such as mercury, nickel, cadmium, lead, and chromium, which can be released inappropriate e-waste recycling practices such as those used in the informal sector, including acid leaching, open burning and discarding residues directly after extracting valuable metals. The potential environmental risks of recycling plastics, electrical appliances containing CRTs, and electrical appliances containing chlorofluorocarbons (CFCs, commonly known as the commercial product "Freon"), are outlined in Annex 4. The potential environmental risks of dismantling circuit boards are identified in Table 5-3, Chapter 5.

E-waste recycling also releases persistent organic pollutants (POPs) into the environment. POPs remain intact in the environment for long periods, are subject to long-range environmental transport, accumulate in the fatty tissues of living organisms, and are toxic to humans and wildlife. Studies have shown that the process of dismantling e-wastes can increase workers' body burden of PBDEs, which are used as brominated flame retardants and can transfer into the environment and human body (Leung et al., 2007)[37]. Researchers have detected PBDEs in the serum of dismantling workers, and have found that the concentration of PBDEs is 11 to 20 times higher than that of the control group38. The overall concentration of PBDEs in the sediment of the bank of Nanyang River in Guiyu range from 4434-16099ng/g (dry wt)[39]. The concentrations of PBDEs in the river bed mud of Nanyang River and Lianjiang River are 55-445 and 51.3-365 ng/g (dry wt) respectively[40]. The concentration of PBDEs samples collected from the e-waste acid bath sites in Guiyu is 930 times higher than those collected from the Nanyang River Reservoir, which is also located in Guiyu[41].

It is important to recognize the relationship between reducing risks and exposure to pollutants in workplace and the effects of such measures on the wider community and environment. The average concentrations of heavy metals in dust released from circuit

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[37] Leung, Anna O.W., W.J. Luksemburg, A.S. Wong, and M.H. Wong. 2007. "Spatial Distribution of Polybrominated Diphenyl Ethers and Polychlorinated Dibenzo-p-dioxins and Dibenzofurans in Soil and Combusted Residue at Guiyu, an Electronic Waste Recycling Site in Southeast China" in *Environmental Science and Technology* 41(8): 2730-7.

[38] Leung, Anna O.W., et al. Heavy Metals Concentrations of Surface Dust from e-Waste Recycling and Its Human Health Implications in Southeast China. Environ. Sci. Technol. 2008

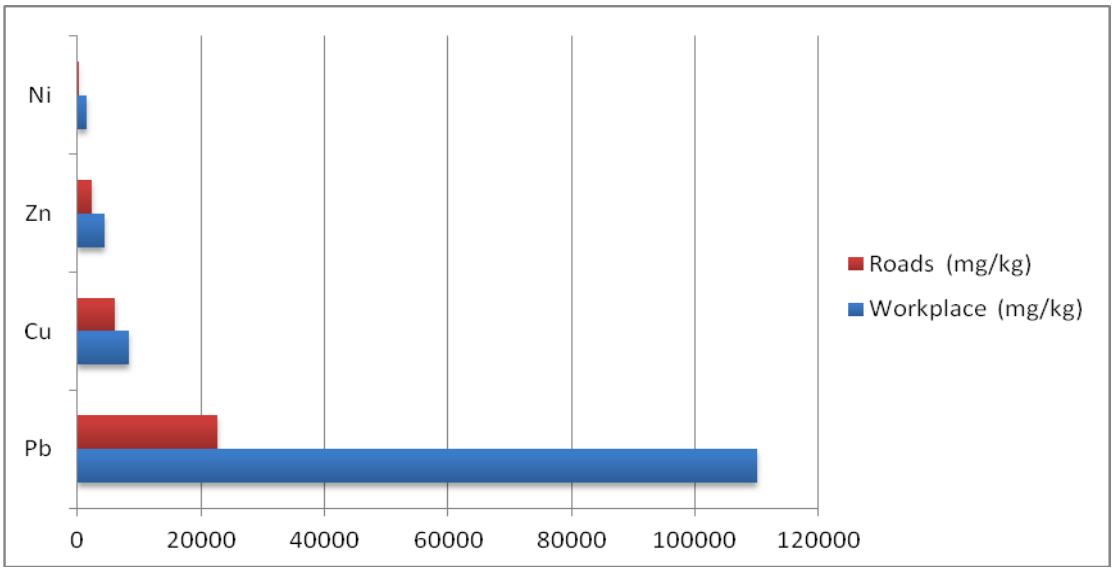
[39] It can be used as brominated flame retardant and has various bromide toxicity. It can be transferred in ambient medium and accumulate biologically through food chain.

[40] Wu Kusheng et cal. Environmental distribution of polybrominated diphenyl ethers. Occupational health. 2008, Issue 22, Vol. 24.

[41] Leung, Anna O.W., et al. Spatial Distribution of Polybrominated Diphenyl Ethers and Polychlorinated Dibenzo-p-dioxins and Dibenzofurans in Soil and Combusted Residue at Guiyu, an Electronic Waste Recycling Site in Southeast China. Environ. Sci. Technol. 2007, 41.

board dismantling found in the dismantling sites and surrounding roads at Guiyu are higher than those found further away. For example, in the workplace, lead is 110,000 mg/kg, copper is 8,360 mg/kg, zinc is 4,420 mg/kg, nickel is 1,500 mg/kg; lead is 22,600 mg/kg, copper is 6,170 mg/kg, zinc is 2,370 mg/kg, nickel is 304 mg/kg in the surrounding roads. All of these heavy metals pose potential health risks to exposed locals in the surrounding schools, open-air food market and other public places[42].

Figure 7-10 Concentrations of heavy metals detected in workplace and on roads of Guiyu



7.3 Conclusion of the case study in Guiyu

- It was found that the majority of employment in the informal family workshops was in manual work. There is a clear division of labour among several workshops that dismantle and recycle certain types or even components of e-waste. This increases the efficiency and profits of these informal businesses.

- There is also innovation in the informal sector. As the skills and expertise in the informal sector become increasingly sophisticated, many workshop owners and workers are able to refurbish e-waste and articles (e.g., debugging assemblies, burnishing tubes, and mounting), and then assemble televisions, laptops, and other appliances to be sold the rural market.

- The e-waste that cannot be refurbished is recycled using dangerous methods such as circuit board baking, manual dismantling and sorting, and acid leaching to recycle heavy metal, plastics, glass and other components.

[42] Coby S.C. Wong, et al. Trace metal contamination of sediments in an e-waste processing village in China. Environmental Pollution, 2006.

Throughout these processes, workers are inadequately protected from exposure to toxins and hazardous substances. Informal workshops and factors also lack risk prevention and protection equipment.

- There are two tiers of informal workshops:
    - The first tier is composed of large-scale workshops and factories that specialize in dismantling and recycling metal from all sorts of e-waste in large volume. These workshops select and sell the e-waste that can still be used in the second-hand market; sell the low- value e-waste to the second tier workshops; and use the remaining e-waste for fine dismantling and recycling.
    - The second tier of disassembly workshops is composed of small-scale businesses in Guiyu. They recycle e-waste directly purchased or outsourced from the first-tier workshops. They are often well connected or operated by the owners with first-tier recycling factories, such as the plastic particles raw material production factory, rolling copper factory and aluminum alloy material factory.

It is challenging to regulate the operation of the informal e-waste businesses, given their large number, informality and the lack of enforcement capacity in local government. The sector plays a vital role in the local economy; it is a major local industry, employment provider, and polluter. Therefore, it is necessary to transition informal businesses into small and medium enterprises that can comply with regulatory requirements and become truly sustainable sources of income, jobs and quality development. Given the impact of the informal e-waste sector on local development, employment, and productivity, there is an urgent need to improve the sector's working conditions and occupational safety and health standards. Suggested measures follow:

- Carry out OSH trainings in the workplace and increase the awareness of risk prevention and protection;
- Increase workers' social security, including insurance and wages;
- Control working hours and ensure workers have enough time for rest;
- Provide the necessary protective measures for workers to avoid occupational poisoning hazards; and
- Phase out the primitive equipment and install environmentally-sound technologies and facilities.

In addition, during the transition of the informal e-waste sector, the main pollutants should be monitored closely to increase understanding of the industry, local community and government of the risks of inappropriate operation of e-waste recycling, and to track the effectiveness of different measures (See Table 7-1).

Table 7-1 Main pollutants derived from processing e-waste

No.	Treatment method	Main pollutants	Pollution medium
1	Dry treatment of CRT	Lead and dust	Atmosphere
2	Wet treatment of CRT	Lead, cadmium, nickel	Water
3	Treatment of polyurethane foaming plastics	Dust	Atmosphere
4	Dismantling the backlights of liquid crystal displays	Mercury	Atmosphere
5	Wet treatment of liquid crystal separation	Mercury	Water
6	The separation of LCD panel glass and organic film	Dust, benzene series, phenols, and volatile halogenated hydrocarbons	Atmosphere
7	Circuit board burning (dry treatment)	Dioxin, copper, lead, antimony, nickel, benzene series, phenols, volatile halogenated hydrocarbon	Atmosphere
8	Circuit board (wet treatment)	PH, antimony, copper, lead, arsenic, chromium, beryllium, cadmium, and nickel	Water
9	Circuit board (mechanical treatment)	Copper, nickel, lead	Atmosphere
10	Heat treatment of nonmetal materials produced by processing circuit boards	Dioxin and antimony	Atmosphere
11	Burning cable and wires	Dioxin, lead, benzene series, phenols, and volatile halogenated hydrocarbons	Atmosphere
12	Treatment of switches and light bulb tubes	Mercury	Atmosphere
13	Treatment of nickel cadmium battery	Dust and cadmium	Atmosphere
14	Treatment of lead-acid battery	Lead and PH	Atmosphere and water
15	Treatment of lithium battery	PH	Water
16	Treatment of capacitor containing printed circuit boards	Polychlorinated biphenyl	Water

Note:

1. Benzene series includes benzene, toluene, xylene.

2. In addition to monitoring the pollutants listed above, related government agencies should also monitor suspended solids (SS), chemical oxygen demand, ammonia nitrogen, etc.

3. As for the recycling processes not specified above, monitoring should take place according to the: type of products to be processed; production process; and characteristics of pollutants.

8. Other labour and social issues

8.1 Rights at work

The rights at work (e.g., labour rights) are comprised of personal, economic, political and cultural rights. It is recognized as one of the most fundamental human rights in China's domestic legislation. For example, Article 42 of the Chinese Constitution specifies that citizens of the People's Republic have the rights as well as obligations to work; the government should create employment conditions, strengthen labour protection, improve working conditions, and improve labour compensation and benefits on the basis of expanded production through various means.

The *Labour Law*, implemented on 1 January 1995, and the *Labour Contract Law*, implemented on 1 January 2008, provides more specific provisions related to the right to work and the rights at work. The provisions can be universally applied in all sectors and businesses in China, with the exceptions of customized regulations in Hong Kong, Macao, and Taiwan. Although there is no sector-wide labour regulation targeting the e-waste industry, labour and human health protection have been referenced in some of the existing sector policies, such as the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products, implemented on 1 January 2011, which requires e-waste recycling enterprises to comply with relevant regulations related to the comprehensive utilization of resources, environmental protection, labour safety and compliance with health requirements. Moreover, the Chinese government ratified the International Convention on the Economic, Social and Cultural Rights on 28 February 2001, and therein recognized and defined the rights at work as a series of rights related to work and labour, such as the right to equal employment, career freedom, equality of remuneration, job security, and organization of and participating in trade unions. All workers, including those employed in both the formal and informal e-waste sectors, should be protected against from violations of their rights at work. However, the e-waste recycling industry in China is at the preliminary stage of development, and the co-existence of formal and informal businesses in the industry suggests there is divergence of realization of the rights at work in the formal and informal e-waste recycling enterprises.

Following are a number of examples that compare the rights at work in the formal and informal sectors:

- *Equality of remuneration.* In formal enterprises, workers and employers enter into labour contracts that specify wages, methods of payment, basic insurance, health examinations, compensation, etc. In the informal enterprises, as long as the business owners and workers reach consensus on wages and ways of payment, a de facto labour relationship is established.

- *Working hours, leave and holidays*. The Labour Law stipulates that the employer should guarantee that workers can have at least a one work-free day every week, and that the average weekly working hours should not exceed 44. If longer working hours are needed, employers should consult with the workforce. Overtime should be no more than three hours per day. The implementation of this regulation is more consistent in the formal e-waste enterprises. To a significant degree, the working hours in the informal sector depend on the intensity of the workload. According to the research team's interviews in Guiyu, the average working hour in the informal e-waste workshops is 10 hours per day.

- *Rights of occupational safety and health protection*. The Safety Production Law requires employers to educate and supervise employees to execute the safety production rules and regulations in the workplace. Furthermore, employers are obligated to inform workers of the risk factors, prevention measures, and accident emergency measures. In the formal enterprises, workers often receive personal protection equipment and rather basic entry training focusing on the rules and safety precautions. But there is a lack of specific trainings on professional safety protection, self-rescue and mutual aid skills, and prevention measures. In the informal sector, the family workshop owners rarely caution against or even fully understand the risk and hazards in the e-waste recycling processes. As a result, workers use primitive protection like gloves and sleevelets by themselves as very limited protection measures against the largely unrecognized risks in the workplace.

- *Child labour and female workers*. When signing labour contracts, the formal sector requires personal information verified by the identification cards to avoid child labour. In contrast, in the informal sector, family workshop owners usually do not sign labour contracts with workers. Furthermore, their recruitment differs from that of the formal enterprises because it often relies on the peer-group knowledge. Migrant workers from the same province or hometown introduce labour to the informal workshops and factories, including young labour. Therefore, it is not fully clear whether child labour is absolutely prohibited in the informal sector. As for gender equality, formal enterprises put forward gender requirements and consideration when hiring and organizing the workforce. The investigation in a national pilot formal enterprise, Huaqing, indicates that the majority of workers are young males around the age of twenty, and only male workers were seen in the dismantling workshop. In the informal sector, there are both male and female workers, including young to middle age workers.

- *Social insurance and welfare*. The Safety Production Law and Regulation on Work-related Injury Insurances stipulates the responsibility of employers to register and provide workers with basic insurance, and to cover the insurance

premium. Under the supervision of the State Administration of Work Safety, formal enterprises comply with this regulation. In the informal sector, no insurance or welfare is provided to workers.

In conclusion, the rights at work are executed at different levels in the formal sector under government supervision and inspection. In contrast, in the informal sector he rights at work cannot be guaranteed and are often breached where there is a lack of labour inspection.

8.2 Opportunities for improving livelihoods and employability

As an inevitable consequence of the rapid growth in domestic electronic and electrical products production and consumption, the development of the e-waste sector in China presents both challenges and opportunities for socio-economic development and livelihood improvement.

First, as an emerging industry supported by government policies and incentives such as pilot programs, subsidies and concessional offers, e-waste collection and logistics can provide employment opportunities and revenue. For example, the old-for-new home appliances recycling scheme offered a market opportunity for the growth and expansion of the e-waste enterprises in the formal sector, and consequently created significant number of jobs in both operating and managing e-waste collection, transport, dismantling, treatment and disposal. Pursuant to the *Regulation on the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products*, the e-waste recycling markets will continue to grow as planned at national and provincial levels, and will bring substantial opportunities for job creation and skills development.

Second, establishment an environmentally-sound and worker-friendly e-waste industry in China requires quality development of the e-waste sector as a whole to implement standardized treatment processes, ensure the occupational safety and health and social security of workers, and contribute to the welfare development of local communities. The evolving regulatory framework targeting e-waste management has been the most critical driving force to improving the quality of employment in the e-waste sector. For example, the environmental protection standard (HJ527-2010) *Technical Specifications of Pollution Control for Processing Waste Electrical and Electric Equipment* requires the application of the best available technology and necessary measures to the recycling of e-waste, in conformity with the relevant national regulations on environmental protection, labour safety and human health protection; prioritization of reuse and classification of all e-waste transported to the recycling enterprises; establishment of a ledger to register the weight and/or the amount and provide information to government administration for monitoring the e-waste flow; prohibition of direct landfill, open burning, and use of a simple cupola furnace and acid leaching. Moreover, the Technical Specifications stipulate labour

protection measures throughout the e-waste recycling process. It requires workers to be equipped with protective measures before removing the CRT and to wear protective masks, gloves and working clothes when dissembling waste refrigerators and air conditioners backlight. Furthermore, it requires the workshop to be equipped with facilities that reduce noise when crushing and sorting dismantled components, in line with relevant provisions of the *Occupational Exposure Limits for Hazardous Agents in the Workplace Part 2: Physical Agents* (GBZ 2.2-2007). It also requires implementation of OSH risk assessment when collecting, transporting, dismantling e-waste, and/or in treatment processes. It also requires employers to provide complete protective equipment and measures, and supervision of and training for workers operating on the dismantling and treatment lines.

Finally, according to the e-waste-related environmental regulations in China, the e-waste sector will be gradually formalized. While some businesses in the informal sector will be transformed into formal enterprises under guidance, the decline of the informal e-waste businesses will cause job losses and increase the demand for re-employment. Consequently, proactive re-skilling programmes and measures should be provided to the informal sector to facilitate formalization of the e-waste sector.

8.3 Social dialogue and the organization of workers

As initially defined by the International Labour Organization, "social dialogue" includes all types of negotiation, consultation and exchange of information between or among representatives of governments, employers and workers on issues of common interest. Social dialogue in China started in the 1990s following the opening up of the country. Although China has not ratified the ILO Recommendation concerning Consultation and Co-operation between Public Authorities and Employers' and Workers' Organizations at the Industrial and National Levels (R113, 1960), it has been continuously establishing and refining a legal and institutional framework to create enabling conditions for social dialogue.

Given the resource-rich and risky profile of e-waste, workers and employers in the e-waste sector should become fully aware of the risks and risk prevention methods, and take proper measures in the workplace in order to achieve safe work and increase productivity. However, this goal cannot be achieved without engaging the workers, employers and governments in communication. Social dialogue offers an approach to adapt labour laws to meet the challenging socio-economic needs and improve labour administration and labour relations with regard to e-waste recycling. Without adequate and effective occupational safety and health measures in the workplace, workers in both the formal and informal e-waste sectors can be prevented from safeguarding and defending their rights and interests. When workers' rights are at risk in formal e-waste enterprises, workers can appeal to the competent authorities, industrial associations or the relevant government departments, such as the work safety department and the labour department. In contrast, workers in the informal

sector are particularly vulnerable given the very limited options they have for appeal, except negotiating directly with the employers.

In addition, third-party industrial associations and councils can become helpful moderators to promote social dialogue between workers, employers, and government. For example, China Resource Recycling Association (CRRA)[43] and the Waste Electrical and Electronic Product Recycling Branch under the CRRA have been providing technical and consultative services to enterprises and governments.

8.4 The role of local authorities in progressive formalization

The informal e-waste sector has undergone rapid growth in recent decades and has formed unique "competitive advantages" in the highly specialized areas such as Guiyu and Taizhou, where practitioners have accumulated substantial expertise in terms of understanding the characteristics and value of different components and articles in e-waste, and the precision of dismantling and recycling. The informal sector provides significant income and job opportunities at the cost of the safety and health of workers and local community, as well as the cost of the environment. Therefore, the current industrial development pathway in these areas is not sustainable and must be transformed in line with development needs at local and national levels.

In order to improve people's livelihood and employment and promote a win-win solution with economic and environmental benefits, some local governments are taking a transitional approach to formalize the informal e-waste businesses, developing their capacity to comply with national standards and scale up business size and management quality. Eventually the informal sector could serve as a prototype of a circular-economy and resource-efficient, environmentally-friendly society.

The government of Qingyuan city, Zhejiang province, takes an industrial park model, namely "business permission within the park, management in target area", to direct all informal e-waste workshops to an industrial park for centralized management, monitoring and pollution prevention. Taking Hua Qing circular economy park as an example, in the industrial park owners of the recycling enterprises can operate and manage their businesses on their own or by commissioning the park for procurement and sales. The park provides market information, pollution control, infrastructure, training, and technology upgrading services to the businesses.

In Guiyu, a national e-waste recycling pilot park was agreed and assigned in 2004. The Shantou city government sought to attract strategic national and international business partners and investors to bring in advanced technologies and financial resources, and thus designed policies and measures to support the development of the e-waste industry in a formalized, specialized and harmless way, and to accelerate the

[43] The CRRA was founded in December 2009 as a national non-profit industrial association affiliated with the All-China Federation of Supply and Marketing Cooperatives, the so-called "China Co-Op".

development of a circular economy in Guiyu town. In October 2010, the Guiyu e-waste centralized recycling park (pilot) project launched under the joint venture of TCL Group Ltd., Shantou Deqing Waste Electrical and Electronic Products Recycling Ltd., and the local government. The park intends to establish four zones for: e-waste treatment; waste plastic recycling; hazardous waste treatment; and composite waste treatment. The operation of the park will be facilitated by the construction of four centers of different functions, including: international environmentally-friendly technology exchange; human resource development and training; comprehensive service; and logistics and a trading market of rare metal and waste materials. Once the construction is complete, the local government will follow the approach of "closing down, remediating and enhancing" to categorize the informal e-waste businesses into three levels, gradually direct them to enter the industrial park, and take measures to centralize dismantling and control pollution.

However, to achieve the formalization goal, the "industrial park" approach alone may not be sufficient to generate enough motivation for the necessary change. It was found during the field trip in Guiyu that there is rather strong resistance in local community, particularly from the informal workshop owners who are concerned about the future of their businesses. They fear the national and international enterprises entering the park will be dominant and will increasingly squeeze out the space for remediating and facilitating the formalization of the currently informal e-waste workshops and factories. Despite the fear, some of the financially more-capable informal workshop owners are very sensitive to the policy development related to the e-waste recycling businesses, and have been thinking of leapfrogging and transit into a formal enterprise mainly by upgrading their business operations.

9. SWOT analysis of the e-waste recycling industry

9.1 SWOT analysis of the formal sector

Strengths

- **The formal e-waste recycling enterprises are entitled to subsidies by government funds.** According to the *Regulation on the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products* and the licensing system, the designated enterprises and those listed in the Catalogue can receive subsidies from the National WEEE Recycling Fund in order to level the competition with the informal sector, and ensure reasonable revenue of the subsidized formal e-waste recycling enterprises to facilitate the growth of the formal e-waste recycling sector. In addition, the fund intends to indirectly transfer the subsidies to other formal enterprises in the value chain. In order to receive the subsidies, the recycling enterprises need to provide reliable storehouse records and dismantling inventories to the Ministry of Environment Protection and the Ministry of Finance. This process can help maintain an information management system on the formal e-waste recycling enterprises.

- **Dedicated e-waste supply channel.** In the old-for-new home appliances recycling scheme, e-wastes collected from public institutions are directly matched with formal recycling enterprises under the government supervision to ensure the supply of e-waste to the formal recycling enterprises.

- **Better risk prevention and control measures on human health and the environment than that of informal counterparts.** Under the supervision of competent departments, the formal enterprises need to comply with the specific environmental laws and regulations and obey general requirements in relation to safety production. For example, according to the provisions in the *Industrial Enterprises Design and Hygienic Standards (GBZ 1-2010),"* formal enterprises should design, construct, and establish their facilities integrating systems to prevent or reduce the occupational hazards and risks, focusing on occupational disease prevention and control, health care systems, and workplace hazards monitoring.

- **Greater e-waste recycling capacities, more advanced technologies and competent human resources specializing in safety production, enterprise management and environment protection.** The licensing system sets clear criteria with regard to the technological, environmental, and productivity aspects of the e-waste recycling enterprises. These criteria are essential to the establishment and development of the e-waste enterprises, as they will

facilitate appropriate management of the risks associate with e-waste and maximize the resource-rich and efficient feature of the industry.

Weaknesses

- **The formal e-waste recycling enterprises require high upfront investments and have much higher operating costs than their informal counterparts.** Their supply purchase prices do not have advantage in the market compared with those of the informal businesses. In addition to the high compliance costs, large upfront investments are required for the design, construction, operation and maintenance of the installations and management systems in formal enterprises. When certain e-waste components and articles cannot be recycled due to lack of technologies and expertise, they must be sent to other qualified enterprises for appropriate treatment and disposal, imposing additional costs on the enterprise. Moreover, a proportion of the collected e-wastes are devalued when the certain high economic value components are broken, which can negatively affect profits. Furthermore, despite the dedicated e-waste supply channel from public institutions, a significant amount of e-waste flows to the informal collecting channels and recycling businesses, provided the collecting price of the formal enterprises is on average lower than that of the informal sector.

- **There is deficiency in compliance in formal enterprises.** The demand for constant supervision from competent government departments has surpassed the current capacity of the responsible government bodies. Therefore, compliance in formal enterprises is sometimes not stringent, particularly on issues of labour protection such as: lack of a preventative OSH culture; weak or inconsistent implementation of OSH measures; lack of labour protection equipment; and low awareness among workers of risks and hazards. In addition, given the high compliance costs and low non-compliance penalties, there are informal activities in the formal sector, including, for example, workers on dismantling lines without adequate protection, and the installation of ventilation systems that are insufficient or not used properly.

9.2 SWOT analysis of the informal sector

Strengths

- **The informal e-waste recycling enterprises and practitioners have developed significant expertise in recognizing the characteristics and economic value of e-wastes.** The informal practitioners and enterprises entered into the e-waste recycling industry long before the development of the formal enterprises, and sophisticated operating systems with clear divisions of

labour have been developed. The practical knowledge regarding precise sorting and purposeful recycling, despite the primitive methods deployed, has become a comparative advantage in the informal sector. Employment in the informal sector fluctuates less in than formal enterprises in general. Workers are introduced to the informal e-waste workshops and factories based upon stable social ties such as the referral of friends or acquaintances from the same hometown or city. Hence, workers in the highly specialized informal workshops accumulate practical knowledge on sorting and recycling certain e-waste components and articles, as well as clear understanding on their economic value.

- **In some areas of China, the informal e-waste sector has become the major source of income and a strong impetus for local economic development.** As introduced in the case study, informal e-waste recycling has become a main industry in Guiyu town, with significant employment of migrant workers from southwest China. The e-waste businesses provide over 90% of tax revenue to the local government, and some of the financially capable family groups provide services such as road construction and renovation in the local community.

- **Some informal enterprises have expanded e-waste recycling businesses into the downstream of the value chain.** Some informal businesses refurbish or assemble high-quality discarded electronic devices and components into new products such as televisions, DVD players and laptops. They then sell these products on a large scale at appealing prices to the third-tier cities in less-developed areas in China.

- **Strong social and business networks support capital mobilization and risk sharing.** Despite the informality of many e-waste recycling businesses, many of them are interconnected and supported through social relationships and kinship among the business owners. In Guiyu, those powerful family groups often comprise a "family committee," which plays a role similar to that of board members in formal enterprises. The committee makes important business decisions and advises on the development and advancement of the family businesses, including mobilization of capital and investments for the expansion and upgrading of these businesses.

Weaknesses

- **The primitive methods and equipment used in the informal sector expose workers, the local community, and the environment to profound risks.** The majority of the informal sector is comprised of small- and medium-sized family workshops that are beyond the bounds of regulatory enforcement. The toxins and hazardous substances released from inappropriate recycling affect not only public health in local community but also the broader environment.

Despite these risks, most members of the workforce are migrant workers with low employability, and the interviews in Guiyu town indicated that many of the workers are content with the current jobs in the informal workshops, especially when compared to the working conditions and payment in the neighboring textile factories.

- **Formalization pressure and declining market space.** The informal sector faces pressure to be rectified or banned by existing laws and regulations. Because many informal e-waste recycling businesses predate the establishment of the evolving regulatory framework on e-waste, when the environmental impact of the informal sector received increasing attention from the government, a mandatory approach was taken to prohibit the primitive recycling methods such as acid leaching, open burning and circuit board baking in the informal sector. However, the mandatory approach has not proven effective; these methods are still commonly used in the informal businesses. In addition, the government enforcement branch that lacks capacity is not collaborating with other relevant administrative branches working at the local level. However, several national and local initiatives are being implemented as part of a transitional approach to formalize the informal businesses.

9.3 Main challenges and opportunities for environmentally-sound e-waste management

Main challenges

- **The increasing pressure of e-waste recycling caused by the rapid growth of consumption and update rate.** As the overall living standard is rising in China, there is continuing high demand for electronic and electrical products. This is accompanied by high turnover rate to newer product models. The average life span of EEP is declining, which challenges the capacity and quality of recycling the e-waste in China. Other critical tasks to be addressed include determining how to effectively stop the illegal import of e-waste, which is largely recycled in the informal e-waste sector, and to formalize the e-waste economy.

- **The environmental contamination and ecological damage caused by inappropriate e-waste recycling, particularly in the informal e-waste sector.** The informal e-waste recycling businesses are concentrated in Guangdong, Zhejiang, Hebei, Hunan and Jiangxi provinces in China. Although some pilot projects and formalization industrial parks have been established, environmental pollution of most of the informal e-waste recycling workshops is currently uncontrolled.

- **The further development, implementation and enforcement of the e-waste related environmental laws and regulations.** An e-waste regulatory system strongly driven by environmental concerns has been established in China. However, determining how to provide guidance to the e-waste enterprises in order to facilitate compliance remains a substantial challenge. Additionally, many of the policies need to be further stipulated and a facilitative branch needs to be developed in order to guide the e-waste practices at enterprise levels. For example, when enterprises encounter difficulties in complying with the technical standards due to financial and/or technological problems, responsive policy guidance that clearly indicate the supporting technologies, equipment, and operational standards can considerably help the e-waste recycling enterprises re-orient their business plans and strategies, and therefore promote business adaptation to environmentally-sound management.

- **How to effectively control environmental pollution in the informal e-waste businesses.** This is another challenge to the success of environmentally-sound management of the e-waste sector as a whole. Mandatory environmental control measures are ineffective for the family-type businesses in the informal sector. Therefore, to achieve the environmental management target in the e-waste sector, or in highly polluted areas, requires consideration of how to direct informal businesses to another development pathway; preferably one that takes into account the environmental and socio-economic perspectives of the informal e-waste businesses and the livelihoods related to the businesses.

Main opportunities

- **The evolving regulatory framework on e-waste management offers opportunities for sustainable sectoral governance.** The e-waste management framework covers source control, transport and logistics, and pollution control of the final recycling and disposal. It is constituted by: a catalogue registry; a qualification and permission system; fund management; technical standards; and specific supporting policies and regulations. The stakeholders of the framework include regulators, producers, and individuals involved in collection and transport, disassembling, recycling and disposal enterprises. The main interventions of the framework include: government guidance; policy and financial support; and support on market development and technology innovation. It provides a broad platform for qualified enterprises that comply with the environmental and pollution control requirements to expand their business, and at the same time to gradually mitigate and eliminate the primitive informal businesses.

- **E-waste industry planning has been integrated into the Twelfth Five Year Plan, the national and local development planning process, which offers opportunities for formalization in the context of sustainable development, taking into account the socio-economic impacts.** The industry development plan of the e-waste sector has been grounded in the context of decontamination and sustainable development in line with the national Twelfth Five-Year-Plan (2011-2015) that highlights the quality of development and livelihood. In order to implement the *Waste Electrical and Electronic Products Recycling Regulations*, the Ministry of Environmental Protection has provided guidance to local governments on how to develop local e-waste industry plans. The majority of local governments have integrated the planning of the e-waste industry with their Twelfth Five Year Plans. For example, in Jiangsu province, the local e-waste industry development plan includes the objective of managing the whole e-waste recycling process in accordance with the development strategy of circular economy and sustainable development. That requires reasonable planning and distribution of the e-waste enterprises, centralization of the disposal facilities, and management of the whole e-waste recycling process, ranging from collection, transport, and treatment to disposal, in order to realize circular development in the e-waste industry.

9.4 Main challenges and opportunities for decent work

Main Challenges

- Despite the large number of people working in the e-waste industry in China, the majority of workers and employers, and especially those in the informal sector, are **unaware of or unclear about the occupational safety and health risks of an e-waste industry that lacks systematic occupational safety and health management, which undermines the objective to achieve safe production**.

- Given the formalization process in the e-waste industry, there will be job losses particularly in the informal sector. This creates the challenge of **re-employment and transition in the related labour market**. The majority of workers in the informal e-waste sector are migrant workers with relatively low levels of employability.

- In the current e-waste regulatory framework, explicit reference is made to the need to comply with national standards on labour protection, but the **enforcement of effective labour inspection is missing.** Better policy coordination between relevant government departments, and provision of operational guidelines to inspectors in order to achieve green and safe production in the e-waste industry, are required.

- **To ensure decent work in enterprises of different size and scale requires both enforcement and facilitative approaches.** As a fundamental human right, the rights at work should not be differentiated in formal and informal e-waste enterprises, or in large or small enterprises. However, in practice there are both malfunctions and complete absence of infrastructures for decent work at the enterprise level, which creates obstacles to the realization of decent work in the workplace.

Main Opportunities

- The continuous improvement of the regulatory system on e-waste and safety production offers an **opportunity for introducing a set of labour standards and/or practical guidelines** in the e-waste industry to improve working conditions and labour protection.

- There are **existing initiatives for building the employment capacity of migrant workers, including vocational training and skills development programmes** that are supported by government subsidies. The arrangement suggests opportunities for facilitating re-employment and transition in the informal e-waste sector, if initiatives can be implemented in e-waste businesses concentrated areas.

- **The central and provincial governments are scaling up financial support for the organization of trainings focusing on the employability of migrant workers.** Various ministries and government agencies, such as the Ministry of Human Resources and Social Security, Ministry of Education, Ministry of Science and Technology, and Ministry of Housing and Rural Urban Development, support these training initiatives. The local government can seize opportunities from these initiatives to enhance working conditions and to implement skills-training in the formal e-waste enterprises, and to organize skills re-training in the informal e-waste businesses.

- The "Safety Production Twelfth Five-Year Plan" has mandated the relevant government ministries to improve the safety production and occupational safety and health measures at a national level, which offers a unique opportunity to strengthen the labour dimension of the e-waste industry. The plan emphasizes occupational safety and health as a core task and project, and a number of key measures have been identified to accomplish the objective of the plan. These measures include: organizing an occupational hazard census; strengthening the monitoring capacity on occupational hazards; establishing a comprehensive framework related to the entry, qualification and training of special occupations; building up OSH databanks in key industries (sectors); and improving supervision on occupational hazard protective equipment and labour occupational health protection. Key projects targeting occupational hazards and toxic substances have been developed targeting dust pollution, benzene, formaldehyde and heavy metals such as lead and cadmium.

10. Conclusions and recommendations

10.1 Conclusions

In summary, the environment, labour and human health impacts of both the formal and informal e-waste recycling sectors in China, the development of the industry as a whole offers both great opportunities and challenges. If managed well, e-waste can provide tremendous socio-economic benefits derived from recovery of resources from the "urban mine", in line with the promotion of a circular economy. However, given the various kinds of toxic and hazardous substances contained in the waste electronic and electrical products, and which can be released during the recycling processes, greater synergies between producers and recyclers and between policies and practices are necessary to ensure the integrity of the e-waste recycling and management industry. Acknowledging the positive economic contributions of e-waste recycling, this research demonstrates the need for stringent occupational safety and health measures and collaborations between environment and labour inspections to ensure a sustainable development pathway in the e-waste recycling industry in China.

10.2 Recommendations

It is indicated in the research that a sustainable development approach that takes into account the social pillar of formalizing the e-waste industry is critical. Where the informal e-waste businesses provide a primary source of income and employment at the local level, an inclusive growth model is needed to ensure equity and social participation in the formalization process. An integrated approach taking into account the impacts on the environment, human health, and rights at work can increase productivity and provide opportunities for green jobs and decent work in the e-waste recycling industry in China.

In order to achieve the safe production and environmentally-sound operations of e-waste recycling, the following measures are recommended:

1. To stipulate the occupational safety and health regulations, standards and guidelines related to the e-waste recycling industry;

2. To increase safety production in the e-waste sector through OSH trainings at sector level, demonstration of OSH management system, and guidelines on operation procedure and standards.

3. To raise awareness among workers and employers of the risks and appropriate measures to recycle e-waste.

4. To enhance the environmental performance through introducing environmentally-sound technologies and facilities with safe operational systems.

5. To eliminate or reduce the toxic and hazardous substances in the production of electrical and electronic products, so as to control the risks from source of pollution and to extend the responsibilities of retailers on risk-free e-waste recycling.

6. To organize and promote pilots of sustainable and safe e-waste recycling.

7. To take an integrated approach, supported by relevant administrations, facilitating the transformation of informal e-waste businesses into the formal market.

11. Specific suggestions for the ILO

11.1 Policies for promoting sustainable e-waste recycling in China

1) Research should be undertaken on policies and economic measures to encourage the development of the formal e-waste sector, including research on how to ensure the e-waste collected from various sources flows into formal and qualified e-waste recycling enterprises. Research should also explore ways of providing appropriate economic incentives to promote formalization in the e-waste sector, as well as ways of responding to the need for sustainable development at the sectoral level.

2) Support should be given for research on an occupational qualification certification system in the e-waste recycling industry. The Ministry of Labour and Social Security (MoLSS, now the Ministry of Human Resources and Social Security) authorized the All-China Federation of Supply and Marketing Cooperatives (China CO-OP) to accredit occupational skills in the resource recovery sector. However, there is no standardized provision on the occupational qualifications in the e-waste sector under the China CO-OP, and the qualified e-waste recycling enterprises only provide limited entry-level training to workers.

11.2 Value chain development and green investments for the environmentally-sound management of e-waste recycling

Formal sector

1) Support should be given for research and development of best available technologies, and the application of environmentally-friendly materials in the production process should be encouraged. For example, the German enterprise RWE Umwelt AG, as the largest enterprise engaging in resource recovery and waste disposal in Germany, provides waste treatment and disposal services, including for e-waste, for customers in Germany and overseas. The environmental standards applied in its installations in Germany are also used in the company's plants in other countries. This represents an opportunity to learn from the best practices and to share experiences, particularly on labour protection across national boundaries. Meanwhile, to improve the occupational safety and health standards in the e-waste recycling sector, it is also important to reduce and eliminate the toxic and hazardous substances in the production phase in order to reduce the occupational and environmental risks from the source.

2) The value chain should be extended to downstream deep processing in order to increase the efficiency of resource recovery and the capacity of hazardous waste management. The 48 permitted e-waste treatment enterprises in Japan are large scale facilities that can recycle discarded televisions, refrigerators, air conditioners and washing machines. The resource recovery rate increased rapidly

between 2001 and 2008, ultimately reaching 83 per cent. In contrast with Japan, most of the formal e-waste enterprises in China specialize in dismantling and pre-processing. For example, in the old-for-new scheme, the majority of designated enterprises are involved in household appliance dismantling, and few of them have extended the value chain to deep processing and material recovery.

3) Training activities should be carried out on occupational safety and health, vocational skills, and environmental and labour protection at enterprise level. It is important to raise awareness and enhance the capacity among workers and employers to contribute to the effective implementation of pollution prevention and labour protection measures in enterprises. The training programme targeting formal enterprises can focus on operationalizing an OSH system based on the existing infrastructure at enterprise level, including a management system, technologies and facilities, protective equipment and labour protection measures. The training programme targeting the informal e-waste businesses should be developed strategically with local stakeholders, and implemented in proactive informal businesses that are close to the threshold of formalization. The OSH training in the informal business should encourage capable family businesses to transform into formal enterprises as a good demonstration of socially inclusive formalization.

4) Development of formal e-waste enterprises should be supported through policy and economic incentives. To mainstream the supply of e-waste to the formal sector, an information exchange platform system should be established to monitor the collection of e-waste from multiple channels. This data could facilitate government monitoring of the e-waste, as well as provide the basis for incentives, such as subsidies and tax exemptions or reductions.

Informal sector

1) The prospects of the informal sector should be redirected through: provision of green transition training and skills development programmes; consideration of the impacts on livelihood; and focus on access to transformational development and environmental and health protection. As a result of the fast-changing labour and economic structures, informal economy becomes a source of employment and job creation, particularly in developing countries. Parts of the informal e-waste sector should be re-directed and upgraded in order to integrate them into the formal market, while harmful businesses and practices should be prohibited and replaced.

2) Public and private investment should be aligned, and public-private-partnerships should be established to support transformation in the informal sector. A financial mechanism for formalization should be considered to facilitate alignment of public and private investments, including those from bilateral and multilateral development agencies and financial organizations, in order to address root

problems and integration challenges in the informal sector.

11.3 Ways to improve the working conditions in the e-waste sector in China

Suggestions for the formal sector

1) Training activities aimed at implementing the laws and regulations on safe production and labour protection at enterprise level should be carried out.

- Training is needed to support simultaneous integration of the occupational safety and health measures and equipment into the design, construction and operation of the plants.

- On-site investigation at the e-waste enterprises indicates that the OSH system in the formal sector meets the basic conditions required by the laws and regulations on labour protection in China. There is significant potential to improve the OSH conditions and effectively prevent incidences in the formal sector.

- Interventions can be staged in the project approval and construction phases to supervise the integration and compliance of labour protection measures in the design, construction and operation of the plant. The interventions may be related to site selection, the general layout, building structures, fire safety arrangements, detection and control of toxic and harmful factors, and other measures that help the enterprises to comply with the provisions of safety standards specified in the Code for Design of General Plan of Industrial Enterprises (GB50187-1993), General Principles for the Requirements of Safety and Health in Production Process (GB12801-1991), General rules for Designing the Production Facilities in Accordance with Safety and Health Requirements (GB5083-1985, 1999 edition), Hygienic Standards for the Design of Industrial Enterprises (GBZ1-2010), Occupational Exposure Limits for Hazardous Agents in the Workplace Part 1: Chemical Hazardous Agents (GBZ2.1-2007), Occupational Exposure Limits for Hazardous Agents in the Workplace Part 2: Physical Agents (GBZ2.2-2007), Classification for Hazards of Occupational Exposure to Toxicant (GB5044-1985), Specifications for the Design of Noise Control System in Industrial Enterprises (GBJ87-1985), Safety Signs (GB2894-1996), and Safety Requirements of Machinery and Equipment Shield (GB8196-1987).

- Safe production and operation trainings and demonstrations should be organized. Considering it is difficult to eliminate some of the toxic and hazardous substances in the short term, it is necessary to: apply mechanized recycling technologies and smart control systems; monitor the OSH risks; and strengthen the individual labour protection in the workplace. Standardized training and skills provisions targeting both employers and workers will

support prevention of risks at work and improve the safe production performance of enterprises.

- Guidance on safety practices for e-waste recycling should be prepared and disseminated. The State Administration of Work Safety of China (SAWS) has been organizing a series of standardization activities of work safety at the national level, including in the formal e-waste recycling enterprises. It would be a critical contribution to the work safety standardization at national level if the ILO could demonstrate a work safety manual at the sectoral level that could be replicated in other industries in China. The manual could cover a range of issues, including the: institutional frameworks; safety investments; code(s) of practice; training; equipment and installations; field management; risk control; hazard monitoring; occupational safety and health; emergency management; accident reports; and performance appraisals. This could help enterprises understand the liability of work safety; operationalize a work safety mechanism; prevent risk and incidents; standardize behaviors; and continuously improve the OSH environment in workplace. The guidance could support enterprises' compliance and self-examination, as well as offer the administrator a good instrument through which to achieve the objectives on work safety.

2) Synergies with other regulatory frameworks should be created, particularly with those contributing to the improvement of labour protection in the e-waste recycling sector through compliance schemes that combine environmental and labour standards. As some of the technical standards and specifications related to pollution control have direct impacts in the workplace (e.g., the China WEEE regulations), better coordination between the objectives of labour and environmental protection is needed. The environment authorities have provided a starting point for understanding the risks and hazards of the e-waste recycling process. This knowledge can be linked with consideration of risk in labour protection and consequently transformed into concrete measures in the workplace. The existing work on identifying hazardous wastes carried out by the environment authorities can also inform action to mitigate and prevent the effects of these hazardous wastes on workers. Therefore, hazardous waste management, including environmentally-sound management of e-waste, should also include consideration of occupational safety and health management.

3) Further certification schemes should be developed, building on the current legislation on permission (including the minimum basic criteria) with the aim of combing the resource efficiency, safety and environmental and health standards to reflect the quality of e-waste management. Combing the environmental, efficiency and health standards has become an international practice in relation to e-waste management. Combing can be voluntary or mandatory, and can effectively complement legislation, and support policy development and implementation. The

scope of the certification schemes can be flexible to target the e-waste management value chain, or the critical stages such as collection, storage, transport, treatment and disposal of e-waste. In the US, the "Responsible Recycling (R2) standards" and "e-Stewards®" have been recognized by the US EPA at the federal government level. In Europe, following the European WEEE Directive, a certification scheme called WEEELABEX is widely applied among the recyclers in Europe. In Japan, the government is developing environmentally-sound management (ESM) guidelines in order to differentiate among the quality of recyclers. Australia and New Zealand have created common standards (AS/NZS 5377). Among all these certification schemes, occupational safety and health standards are integral. Furthermore, such schemes are indispensable for a quality e-waste management system.

Suggestions for the informal sector

The informal e-waste sector plays an important role in the development of the e-waste recycling industry in China, and consideration of its implications for livelihoods and local development is critical to the realization of decent work for all. This is also fundamental to the new ILO vision of development that links economic growth with low environmental impact, social inclusion and decent jobs. It is clear that the informal e-waste sector will undergo transition towards a circular economy. Therefore, ILO's intervention in this transition at the sectoral level could demonstrate how to create significant opportunities for better employment and more sustainable enterprises, and lift millions of workers out of risky jobs. There are several measures that can be taken.

1) Training and other facilitative activities targeting informal businesses can help transform the informal sector. The research team's investigation found that the informal sector employs a large number of migrant workers who have low skills and awareness of their rights and risks at work in the informal family workshops and factories. However, the investigation in the informal sector also indicates that there are business owners who are planning to enter the market as formal enterprises. Given their financial capability, influence in the related networks of informal e-waste businesses, and social relations with the local community, there is potentially value in demonstrating a model of formalization in collaboration with proactive informal businesses, the local authority and other key stakeholders. This is particularly the case in the context of the national and provincial pilot schemes on e-waste recycling, such as in the case of Guiyu.

2) Demonstration projects on work safety and labour protection in the centralized e-waste parks are encouraged. For example, Guiyu town, Guangdong province was listed in the first batch of national circular economy demonstration projects, and the local district and municipality governments have formulated a work programme of 15 million RMB (2.4 million USD) to establish a central e-waste recycling park. The urban planning, land use planning and detailed layout of the

park have been completed, and the park is currently under construction. In the context of promoting the circular economy at the sectoral level in a national pilot scheme, the ILO could consider a project to demonstrate safe operations and labour protection in centralized e-waste dismantling, processing and treatment, and pollution control processes, which can be replicated at the national level to promote the formalization, standardization, professionalization and harmless operation of e-waste recycling.

11.4 Formalization process

Informality and formalization

In the early 1970s the ILO launched the concept of the "informal sector". It is in the institutional memory of the ILO that the concept of informality has been deliberated over time, with consideration of both its role in the economy and its link with formal activities. For a long time the "informal sector activities were largely ignored, rarely supported, often unregulated and sometimes actively discouraged by the Government" (ILO 1972)[44]. It is understood by the ILO that informal activities are characterized by:

a. *Ease of entry;*
b. *Reliance on indigenous resources;*
c. *Family ownership of enterprises;*
d. *Small scale of operation;*
e. *Labour-intensive and adapted technology;*
f. *Skills acquired outside the formal school system; and*
g. *Unregulated and competitive markets* (ILO 1972).[45]

The 2002 International Labour Conference on Decent Work and the Informal Economy adopted a resolution that included a broad range of conclusions and directions to address the decent work deficits in the informal economy and to facilitate its integration into the mainstream economy. The 2007 Interregional Symposium on the Informal Economy: Enabling Transition to Formalization indicated that informality does not necessarily recede as countries grow; rather, the symposium notes, several countries are experiencing increasing informalization despite good economic performance. In some countries, the majority of the new jobs created are informal (ILO 2007)[46]. It was emphasized that transition to formalization should be achieved through policies that promote economic dynamism, employment opportunities, enterprise creation, effective application of standards, and inclusive

[44] ILO. 1972. "Employment, incomes and equity: a strategy for increasing productive employment in Kenya." Geneva.

[45] Ibid.

[46] ILO. 2007. "Report of the Tripartite Interregional Symposium on the informal economy: Enabling Transition to Formalization." Geneva.

social protection and social dialogue. The ILO efforts have forged a global consensus on, *inter alia*: the limited capacity of workers in the informal economy due to the fact that "most of them are unable to find other jobs or start businesses in the formal economy". There is also global consensus on the importance of considering the impacts on livelihood during formalization: "…to promote decent work, it is necessary to eliminate the negative aspects of informality while at the same time ensuring that opportunities for livelihood and entrepreneurship are not destroyed, and promoting the protection and incorporation of workers and economic units in the informal economy into the mainstream economy." [47]

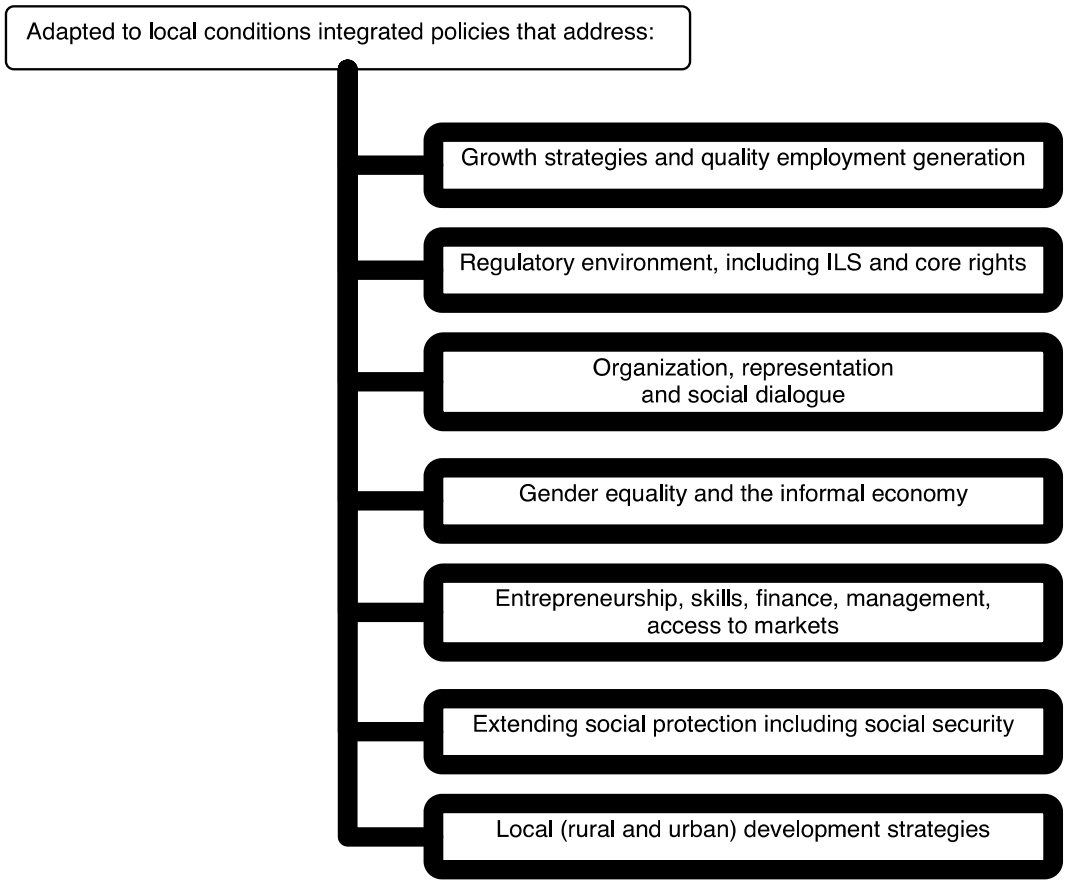
The transition to formalization of the e-waste recycling industry in China requires a "comprehensive approach" that includes the workers and employers in the informal sector who will be most affected by the formalization process. The current policy framework in China does not sufficiently engage workers and entrepreneurs in the informal sector, let alone a local development strategy incorporating the economic and development challenges facing the informal e-waste groups in critical areas such as Guiyu and Qingyuan. The investigation into local e-waste communities reveals the lack of facilitative activities and measures to provide access in the informal sector to basic economic, social and legal resources that are related to formalization.

Integrated local development strategies

As mentioned in the 2002 Consensus on resolution and conclusions of the International Labour Conference on decent work and the informal economy, commonly known as the "2002 Consensus", integrated local development strategies are among the most promising strategies for a comprehensive and multifaceted approach to facilitating a transition to formality. These strategies link the macroeconomic dimensions of the informal economy with micro-level interventions, including at the municipal- and village-level. These levels are considered to be the first frontier for engaging informal economy workers and entrepreneurs. In light of the decent work strategies for the informal economy (see Figure 11-1), the following activities can be considered as possible interventions:

[47] Resolution and conclusions on decent work and the informal economy, adopted on 19 June 2002, ILC 90th Session, Geneva, 2002.

Figure 11-1 Decent work strategies for the informal economy (ILO, Geneva, 2007)[48]



Given the ILO's existing institutional understanding of the informal economy, and taking into account the national and local context related to the e-waste sector in China, it is recommended that the ILO take a decent work approach to collaborating with the local players. The ILO should focus on creating an enabling environment and closing the capacity gaps to formalize the informal e-waste recycling industry. The ILO can consider providing a set of technical inputs, including:

- To identify and recognize the capacity gaps in target areas, and to organize targeted skills and entrepreneurship training for the informal e-waste workers and entrepreneurs.

- To promote of a minimum package of working conditions, wage standards and social benefits for workers in the informal e-waste sector.

- To raise awareness of work-related hazards jeopardizing the health and safety

[48] ILO. 2007. "Report of the Tripartite Interregional Symposium on the informal economy: Enabling Transition to Formalization." Geneva.

of workers, and the need and means for prevention through OSH training.

- To promote the inclusion and representation of workers and small business owners in the formalization process by setting up a consultative mechanism that fosters economic integration and the development of local and informal businesses.

- To facilitate the establishment of local initiatives promoting local employment creation, especially for disadvantaged youth and women, and encouraging labour-intensive methods to deliver goods and services in the e-waste recycling industry.

- To encourage interaction between economic and social policies to understand and address the root causes of informality, and not only its symptoms and manifestations.

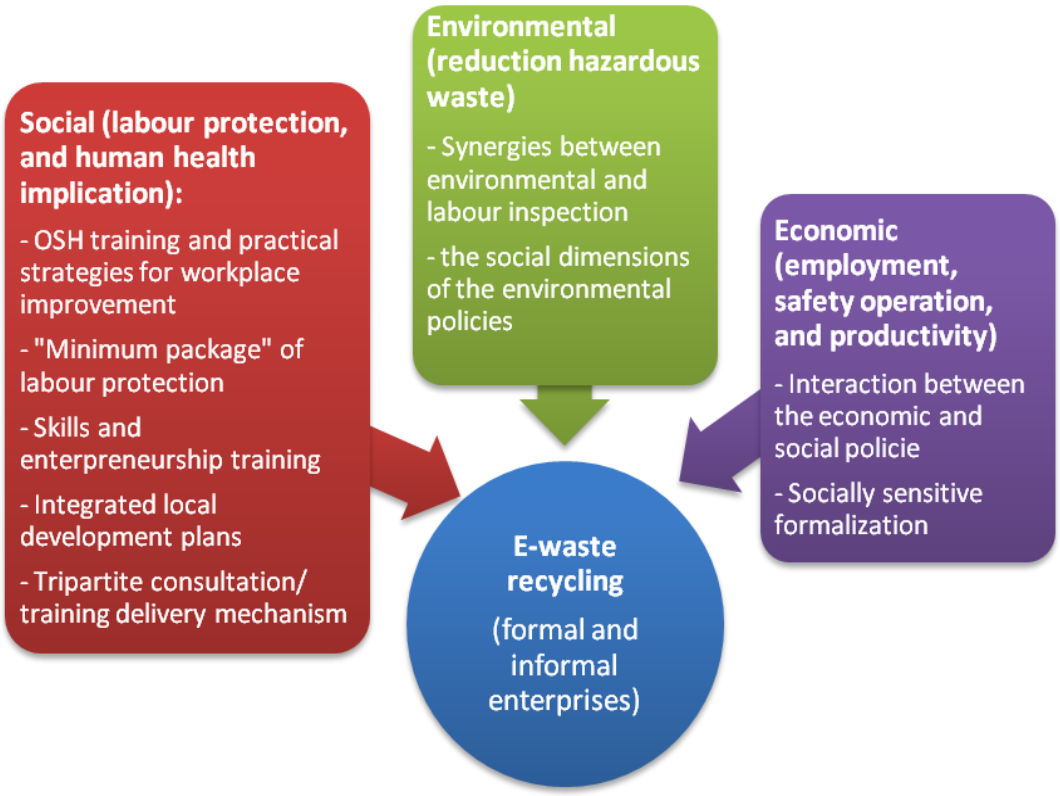
- To use existing knowledge within the ILO and especially the resource database on poverty, local development and decent work, which contains more than 200 tools and resources focusing on poverty from a macro and/or local development perspective.

The ILO has the unique ability to mobilize and organize workers and entrepreneurs in the informal economy to engage in the formalization process, and to access necessary enabling resources. Moreover, the ILO can help to create and expand understanding of the root causes of informality, build capacities of the tripartite constituents, and promote interaction between economic and social policies and environmental regulations in order to support formalization in an inclusive way.

11.5 Critical elements of project

This initial ILO research on the triple dimensions of the e-waste industry in China indicates the following areas can be taken into account as critical project elements.

Figure 11-2 Critical project elements



- Comparative advantage: Taking a sustainable development and decent work approach into consideration of the social, environmental and economic dimensions of the e-waste recycling industry in China, develop cross-cutting yet differentiated strategies that targets the formal and informal e-waste sectors to enhance the overall performance of the sector, focusing on the creation of decent work during the formalization.

- Partnership building: Mobilize and coordinate the participation of the tripartite constituents, including the representation from the informal e-waste sector, at both the national and local levels. Promote successful pilots and replicate the project model through the partnership network.

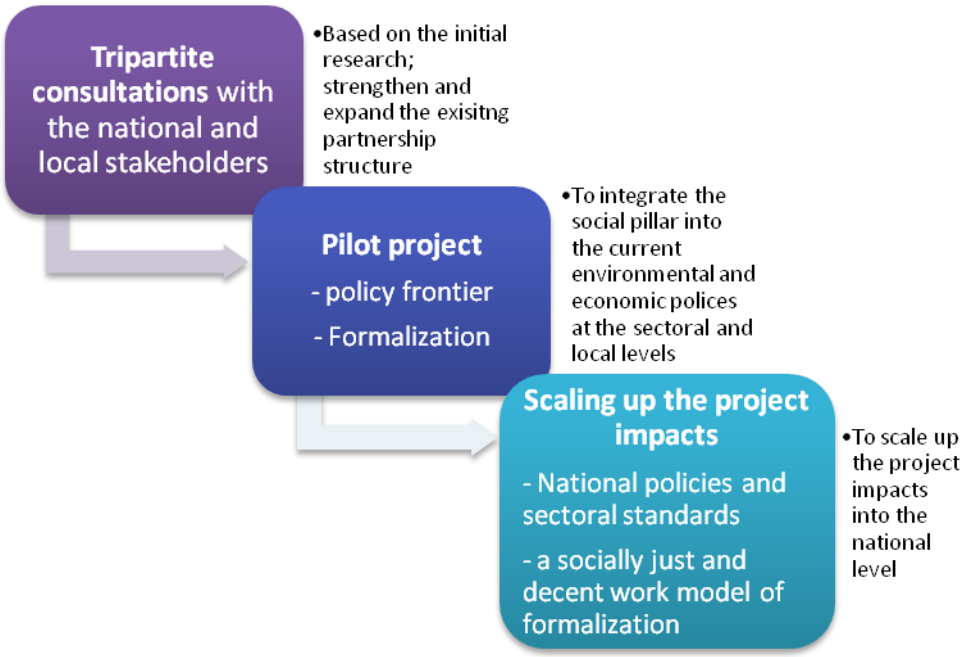
- Synergies building: Experiment and promote joint enforcement of the labour and environmental regulations in relation to the e-waste industry by forging collaboration between the labour and environmental ministries and related departments.

- Support research on the limits of hazardous substances of specific pollutants released in the e-waste recycling process. Besides the *Hazardous Degree of Industrial Dust at Workplace* (GB5817-1986), there are no relevant occupational standards and classifications of e-waste pollutants issued by the Ministry of

Human Resources and Social Security of China. The Ministry of Health issued and implemented the *Occupational Exposure Limits for Hazardous Agents in the Workplace Part 1: Chemical Hazardous Agents* (GBZ2.1-2007), *Occupational Exposure Limits for Hazardous Agents in the Workplace Part 2: Physical Agents* (GBZ2.2-2007). Therefore a guideline similar to the occupational exposure limits (OEL) of Japan limiting the occupational risks should be developed and constantly updated to limit and prevent the exposure to hazardous pollutants in the workplace and wider environment.

- Support the development of occupational safety and health standards in the e-waste recycling industry and organize OSH trainings, including practical strategies for workplace improvement at a sectoral level, on a tripartite basis.

Figure 11-3 Possible project roadmap



The report indicates that the Ministry of Commerce, Ministry of Finance, and Ministry of Environment Protection are revisiting the e-waste related policies to promote the green recycling of e-waste at the national level, with pilot projects launched at local level to establish role models in both the formal and informal sectors. The ILO can consider initiating an e-waste project in areas where these national government pilot projects are already in place. The ILO may also consider building partnerships with leading institutions and providing technical assistance to ensure the creation of decent work in the e-waste industry in China.

Table 11-1 Recommendations for stakeholders

	Stakeholders	Recommended Course of Action
1	Government	- Set policy and economic measures to encourage and support formal enterprise. - Establish a certification system on e-waste recycling with professional qualifications. - Establish occupational safety and health standards and interim provisions on e-waste recycling, including a minimum package of standards as guidance for formalization. - Set hazardous material restrictions and standards to prevent hazardous pollutants in e-waste recycling. - Provide guidance and assistance to the informal sector to carry out a formalization process considering and proactively mitigating the social impact. - Provide guidance and assistance to the formal sector to carry out a process to improve the productivity and occupational safety and health environment at the enterprise level.
2	Formal e-waste enterprises	- Take measures to enhance work safety, especially with regard to occupational safety and health, at the workplace through awareness building, OSH environment creation, and the provision of adequate occupational protection and skills. - Take measures to improve compliance with the environmental and labour regulations. - Enhance the technological and human capacity to recycle e-waste in an environmentally friendly and safe manner. - Extend the value chain of the formal sector to meet the increasing demand for e-waste recycling in China. - Extend the producers' responsibility to eliminate and reduce the use of toxic and hazardous substances in the electrical and electronic products, and to recycle these products in collaboration with e-waste recycling enterprises.
3	Informal e-waste businesses	- Participate in facilitative activities on formalization. - Invest in business upgrading and participate in the capacity-building projects that facilitate the formalization of small e-waste recycling businesses. - Participate in the stakeholder consultations on formalization.
4	Research institutes	- Carrying out research on the policy incentives and mechanisms to promote a just and socially inclusive transition to a safe and environmentally friendly e-waste recycling industry in China. - Synthesize and share the national and international best practices in formalization of the e-waste recycling industry. - Develop occupational safety and health standards and interim policy provisions on safe and environmentally friendly e-waste

		recycling. - Conduct hazardous substances standard research to better understand the characteristics of pollutants in e-waste recycling.
5	Others	- Support the implementation of transforming activities, such as OSH training in the formal e-waste enterprises, and formalization trainings in the informal e-waste businesses. - Support the implementation of demonstration projects on safe and environmentally friendly e-waste recycling at the enterprise level. - Support the multi-stakeholder participation in safe and environmentally friendly e-waste collection and recycling. - Raise awareness of the OSH and environmental protection in the e-waste recycling industry.

Annex 1：Identification of Areas for Further Research

1. **Systematic risk prevention research:** Establish an information-collection database covering the e-waste value chain, including the source of e-waste, in order to monitor the e-waste flows in the formal and informal sectors. Also establish indicators to monitor the occupational safety and the environment in e-waste enterprises; and establish a public scrutiny mechanism.

2. **Risk control research:** Develop measurable standards on health and emissions of pollutants by monitoring the environmental quality, public health and toxicology effects in designated enterprises. Considering various local circumstances, develop variable standards and propose the threshold value of the controlled standards.

3. **Epidemiological investigations:** Investigate issues such as the incidence of disease, symptoms and levels of harm.

4. **Physical examination:** Conduct site testing, including macro tests.

5. **Field surveys:** Conduct interviews, questionnaires and other forms of testing to understand the severity of occupational health effects.

6. **Specific recommendations:** Make recommendations to transform informal e-waste businesses to formal enterprises.

7. **Standards studies:** Carry out studies on the environmental risks prevention and occupational safety and health standards in the (formal) e-waste enterprises.

Annex 2: Geographic Distributions of Related Enterprises

Figure 1 Distribution of the sales companies involved in the household appliances old-for-new policy scheme

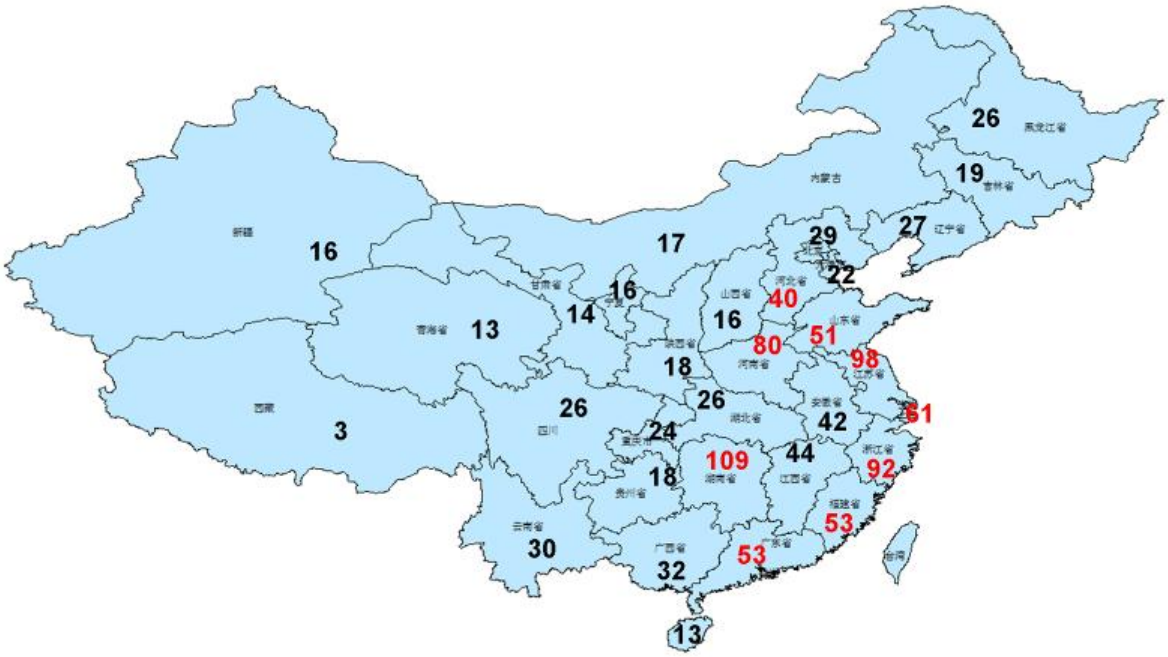


Figure 2 Distribution of the collecting enterprises involved in the household appliances old-for-new policy scheme

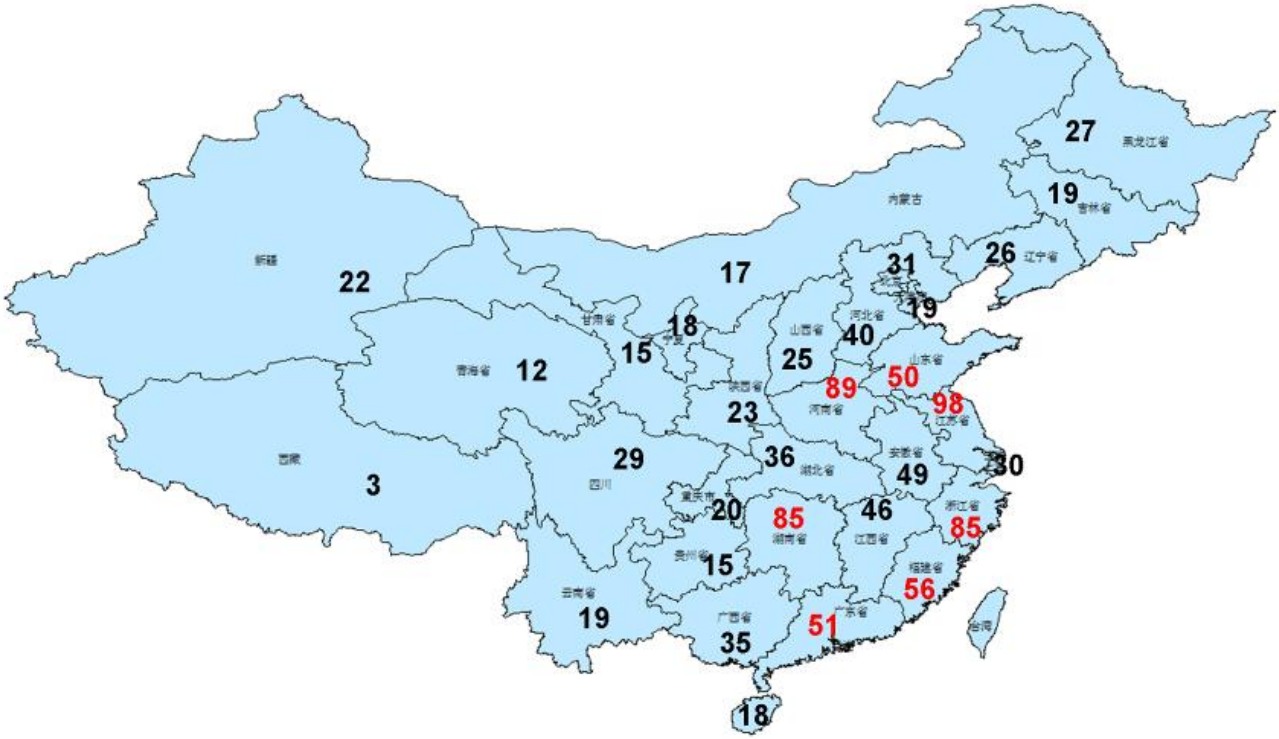


Figure 3 Distribution of the first batch of permitted recycling enterprises

Figure 4 Distribution of the permitted recycling enterprises

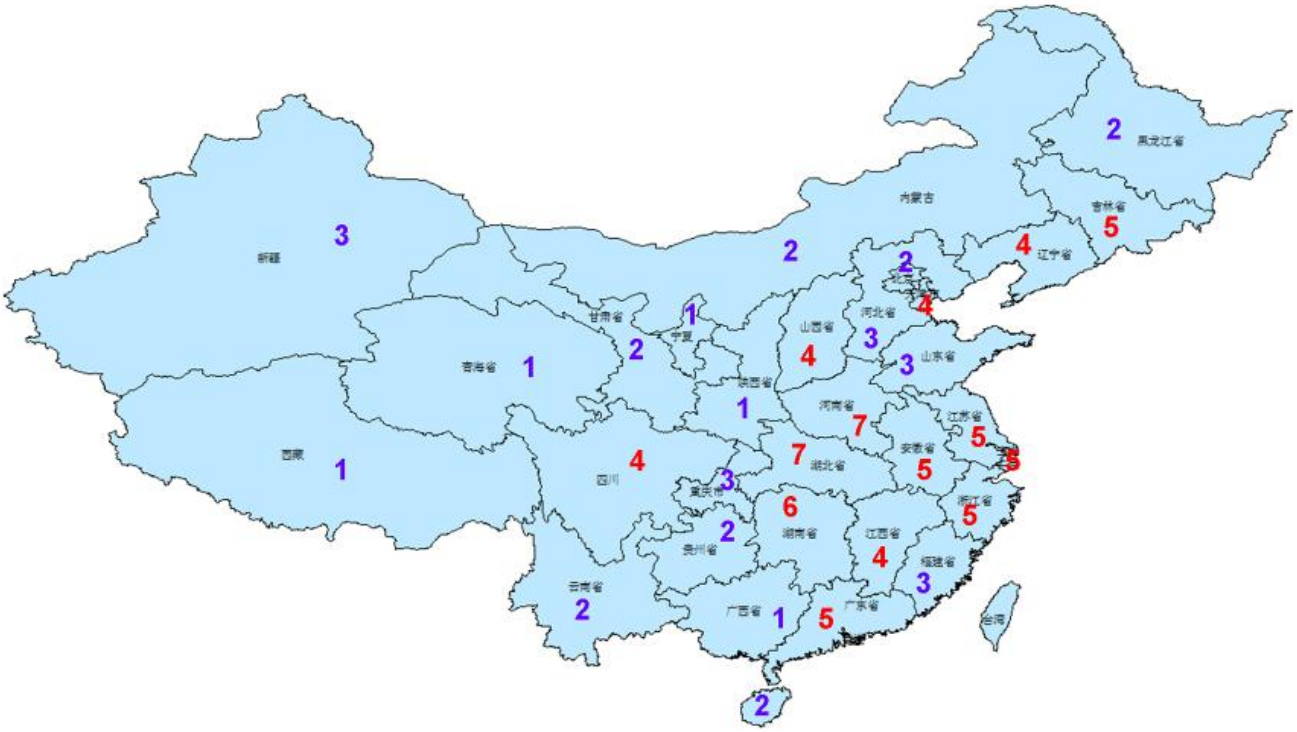


Figure 5 Distribution of the enterprises listed in the catalogue

Annex 3: Environmental laws and regulations related to e-waste sector in China

Legal focus	Laws and regulations	Enactment and implementation	Responsible authorities	Remark
Solid Waste	Law of the People's Republic of China on the Prevention and Control of Environmental Pollution by Solid Waste or the "Solid Waste Pollution Prevention and Control Law" (固体废物污染环境防治法)	Adopted on 30 October 1995; amended on 29 December 2004; became effective on 01 April 2005	Order of the President of the People's Republic of China	Defines "solid waste", "industrial solid waste", "municipal solid waste" and "hazardous wastes"; establishes a solid waste management system, including environmental inspection, and liability; requires the provincial and central governments to integrate solid waste management into socio-economic development plans, supported by economic, technology and policy incentives; mandates the competent administrative department under the State Council to formulate a "time bound national elimination catalogue of hazardous waste, including unified criteria and methods for identifying and distinguishing hazardous wastes (Article 51)."
	Law of the People's Republic of China on the Promotion of Clean Production or "The Clean Production Promotion Law" (清洁生产促进法)	Approved on 29 June 2002	Order of the President of the People's Republic of China	
	Circular Economy Promotion Law of the People's Republic of China (循环经济促进法)	Approved on 29 August 2008	Order of the President of the People's Republic of China	
Hazardous Waste	National Catalogue of Hazardous Waste (国家危险废物名录)	Approved on 06 June 2008; became effective on 01 August 2008	Ministry of Environmental Protection (MEP), National Development and Reform Commission	Pursuant to the Solid Waste law, the 2008 catalogue overrides that enacted in 1998 and expands the scope of "solid waste" to both solid and liquid waste as long as it has one of the following hazardous features:

			(NDRC)	corrosiveness, toxicity, ignitability, reactivity and infectivity; and adopts a precautionary approach that "the waste cannot prove of excluding the hazardous features, and may cause harmful impacts on the environmental and human health, should comply with the hazardous waste provision (Article 2)"; codifies 49 categories and 400 types of hazardous waste, and identifies their industrial and sectoral sources. A number of hazardous substances found in the e-waste recycling and treatment are listed, such as PCBs, PBBs, mercury, lead-acid batteries, nickel-cadmium batteries, and mercury switches
Production of electronic and electrical products	Management Measures for the Prevention and Control of Pollution from Electronic Information Products (电子信息产品污染防治管理办法), so-called China Restrictions on Hazardous Substances (RoHS).	Approved 28 February 2006; became effective on 01 March 2007	The former Ministry of Information Industry (MII), NDRC, Ministry of Commerce, General Administration of Customs (GAC), State Administration of Industry and Commerce (SAIC), General Administration of Quality Supervision (AQSIQ), former State Environmental Protection	Defines "Electronic Information Products" as "electronic products manufactured by information technologies"; defines "pollutions from electronic information products" as the products containing toxic, hazardous materials and substances, or those exceeding the tolerable level in national or industrial standards, causing harmful or negative impacts on the environment, resources, human health and safety of property (Article 4); scopes "pollution control measures" ranging from design, production and re-production, trade to import; identifies the following substances as "toxic, hazardous", including lead,

			Administration (SEPA49)	mercury, cadmium, hexavalent cadmium, PBB, PBDE, and others included in national regulations" that are often found in e-waste recycling and treatment.
Subsidiary legislations and standards supporting the China RoHS	Measures for the Pollution Control of Electrical and Electronic Product (电子电气产品污染控制管理办法), 16 July 2010			Changes the coverage of products by modifying the definition from "Electronic Information Product" (电子信息产品) to "Electrical and Electronic Product" (电子电气产品).
	First List of Controlled Electronic Information Products (电子信息产品污染控制重点管理目录（第一批）) 29 September 2009			So-called "first China RoHS Product Catalogue"; requires the listed electronic information products must bear the China Compulsory Certification (CCC) label, and have to obtain Goods Entry Clearance Document.
	Procedure for Development of the Key Administrative Catalog for the Pollution Control of Electronic Information Products (电子信息产品污染控制重点管理目录制定程序) 10 October 2008			
	Standard of Concentration Limits for Certain Hazardous Substances in Electronic Information Products (SJ/T 11363-2006) (电子信息产品中有害物质的限量要求) 6 November 2006			
	Standard of Marking for Control of Pollution Caused by Electronic Information Products (SJ/T 11364-2006) (电子信息产品污染控制标识要求) 6 November 2006			
	Standard of Testing Methods for Hazardous Substances in Electronic Information Products (SJ/T 11365-2006) (电子信息产品中有毒有害物质的检测方法 (SJ/T 11365-2006)) - 6 November 2006			
	General Disassembly Requirements for Testing Hazardous Substances in Electrical and Electronic Products (GB/Z 20288-2006) (电子电气产品中有害物质检测样品拆分通用要求 (GB/Z 20288-2006)) - 20 June 2006			

[49] Ministries of Environmental Protection (MEP) succeed the former State Environmental Protection Administration (SEPA).

Recycling of e-waste	Regulation on the Administration of the Recovery and Disposal of Waste Electrical and Electronic Products (废弃电器电子产品回收处理管理条例)	Promulgated on 25 February 2009; became effective on 01 January 2011	Enacted by the State Council; system catalogue developed by NDRC; quality permit system and the planning guide developed by MEP; fund system developed by the Ministry of Finance	So-called "China WEEE Regulations"
	First Product Catalogue of China WEEE	Published on 8 September 2010; implemented from 1 January 2011		Includes five types of products (television, refrigerator, washing machine, air conditioner and computer) as the first batch product to obey China WEEE.
	Measures for the Implementation of Old-for-New Home Appliances Replacement Program and its revised version	Promulgated in June 2009; revised in June 2010	Ministry of Commerce, the Ministry of Finance, NDRC, Ministry of Industry and Information Technology, MEP, State Administration of Industry and Commerce, and AQSIQ	
	Announcement on the Work of Further Regulating the Old for New Home Appliances Replacement Program Released by Ministry of Commerce, Ministry of Finance and Ministry of Environmental Protection (商务部、财政部、环境保护部关于进一步规范家电以旧换新工作的通知)	Promulgated on 12 April 2011	Ministry of Commerce, Ministry of Finance, and MEP	
Treatment	Technical Policies of Pollution Prevention and	Effective on 27 April 2006	SEPA, Ministry of Science and	Provides technical guidance to the environmentally friendly

and disposal of e-waste	Control for Waste Household Appliances and Electronic Products (废弃家用电器与电子产品污染防治技术政策)		Technology, MIIT, and Ministry of Commerce	design, collection, transportation, storage, recycling, reuse and disposal of EEP contained in the WEEE Catalogue; for example, the crash and separation of components and parts contenting toxic and hazardous substances in waste products shall be processed in facilities in isolation; the exhaust gas and dust shall be collected, purified and discharged in compliance with the technical standards.
	Measures on Pollution Prevention from Electronic Waste (电子废物污染环境防治管理办法)	Promulgated on 27 September 2007; effective on 01 February 2008	SEPA	Intends to standardize the e-waste recycling and disposal processes; and to establish a standardized project reporting system; explicitly prohibits a range of techniques that are often used in the informal e-waste sector, such as open-air burning; stipulates the liabilities of formal e-waste recycling and disposal enterprises listed in the Catalogue.

Annex 4: Potential environmental risks of recycling plastics, CRTs and CFC in e-waste

Recycling process	Purpose	Pollutants	Potential Environmental Risk
Plastic			
Manual dismantling	To separate plastic and non-plastic components	Dust	The dust which contained flame retardants can spread and cause high levels of flame retardant in the blood of workers
Classification through ignition	To identify different types of plastic	Gas	Toxic gas can seriously damage workers' health and the surrounding environment
Cleansing	To clean the classified plastics	Waste water	The waste cleansing water can pollute the surrounding water source and ground water
Crushing		Dust	The dust which contained flame retardants can spread and cause high levels of flame retardant in the blood of workers
Heating		Waste gas	Toxic gas can seriously damage workers' health and the surrounding environment
Incineration	Recycling the heat energy	Waste gas	Generate dioxins and furans
CRTs electrical products			
Dismantling	To separate CRT from other components	Blast	Broken glass from explosion can cause injury, and the fluorescent material inside the CRT can harm the human respiratory tract
Electric wire method	To separate screen glass and cone glass	Cullet dust	Dust containing lead causes serious harm to workers and the surrounding environment
Electric saw/diamond cutting		Dust	
Hot acid bathing method		Waste gas	Waste steam containing acid can cause serious harm to workers and the environment
Pyrometallurgy	To recycle lead	Gas and dust	Dust and gas containing lead causes serious harm to the workers and the environment
Hydrometallurgy		Waste acid	Waste steam containing acid can cause serious harm to workers and the environment
Landfill/discard	Disposal	Heavy metal	Heavy metal contaminates groundwater, soil and water source
Electrical products containing CFC			
In case the sealing process for extracting refrigerants from refrigerator and air conditioner is incomplete and leaking occurred (refrigerant leakage)	To recycle refrigerant	Refrigerant	Freon refrigerant in refrigerator or air conditioner compressor may leak, causing ozone depletion and high carbon emissions

When extracting refrigerant if the concentration of Freon above certain threshold		Refrigerant	High concentration of Freon/ CFC may cause workers' death by suffocation
Compressor oil leakage during dismantling	To recycle compressor oil	Compressor oil	The leaking compressor oil can contaminate the soil and groundwater
Crushing refrigerator tank	To separate polyurethane with metal	Foaming agent	Foaming agent may spread to the air and pollute the environment
Polyurethane incineration	Disposal	Foaming agent	
Landfill/ discard	Disposal	Heavy metal	Heavy metal causes pollution to groundwater

References

"Seeing the Boundaries of the Market from the Guangdong Guiyu e-waste pollution case." *60 Minutes*, CBS. 2008. Television. Available online: http://www.xici.net/d97818959.htm

"The Place of Second-Hand E-waste." 2006. Available online: http://bj9huo.com/g4/see_xw.asp?id=144

Basel Action Network. 2010. "2009 and 2010 Annual Report of BAN." Available online: http://ban.org/library/BAN_AnnualReport_Final_2009.pdf and http://ban.org/library/BAN_Annual_Report_Final_2010.pdf（2011.12.26）

Chen, Xian, Fu Jiang, Cheng Jiehong, Zhou Quanfa. 2009. "The Recycling Situation and Countermeasures of Waste Electrical and Electronic Equipment in China" in *Renewable Resources and Recycling Economy*, 7: 34-38.

Deng W.J., P.K.K. Louieb, and W.K. Liuc. 2006. "Atmospheric Levels and Cytotoxicity of PAHs and Heavy Metals in TSP and PM2.5 at An Electronic Waste Recycling Site in Southeast China" in *Atmospheric Environment*, 40: 6945-6955.

Driscoll Amy, and Wu Siheng. 2009. "Poverty or Poison? China's Dire Choice in an Electronic World." USAID Asia and Vermont Law School. Available online: http://www.vermontlaw.edu/Documents/Driscoll%20WU,%20Poverty%20or%20Poison.pdf.

Feng, Wang. 2011. "Beijing Municipal Waste Purchaser Group Characteristics Investigation" in *Beijing Social Science*, 3: 67-72.

Wang, Feng. 2011. "The Characteristics Study of Beijing's Scrap Buyer Groups" in Beijing Social Science of Beijing, 3: 67-72.

Han Dai, Huo Xia, and Zheng Liang. 2007. "Investigation on Blood Lead and Intelligence Levels of Children in Electronic Waste Recycling Area" in *Journal of*

Shantou University Medical College, 20: 170-172, 175.

Hotta, Y., Y. Totoki, and S. Hayashi. 2012. "Towards Harmonized Recycling Certification in Asia – Exploring the Feasibility and Potential Benefits of Harmonized Recycling Certification." IGES Discussion Paper.

Howell, Beverly. 2001. "Electronic Waste: The Dangers" in Hazardous Technical Information Services Bulletin, 11: 1-4. Available online: http://infohouse.p2ric.org/ref/02/01010.pdf.

Huanyi, Wang, Ma Zengyi, and Ma Pan. 2011. "Forming and Scavenging of Hydrogen Bromide during Combustion of Waste Printed Circuit Boards in Fluidized Bed. *Energy Engineering*, (2): 45-49.

ILO. 1972. "Employment, incomes and equity: a strategy for increasing productive employment in Kenya." Geneva.

ILO. 1991. "The Dilemma of the Informal Sector, Report of the Director-General." International Labour Conference, 78th Session, Geneva, Sfr. 12.50.

ILO. 2007. "Report of the Tripartite Interregional Symposium on the informal economy: Enabling Transition to Formalization." Geneva.

Jinhui, Li, Liu Lili, and Li Boyang. 2011. "Management and Policy on Waste Electrical and Electronic Products" *Beijing: China Environmental Science Press.*

Leung, Anna O.W., W.J. Luksemburg, A.S. Wong, and M.H. Wong. 2007. "Spatial Distribution of Polybrominated Diphenyl Ethers and Polychlorinated Dibenzo-p-dioxins and Dibenzofurans in Soil and Combusted Residue at Guiyu, an Electronic Waste Recycling Site in Southeast China" in *Environmental Science and Technology* 41(8): 2730-7.

Leung, Anna O.W., Nurdan S. Duzgoren-Aydin, K.C. Cheung and Ming H. Wong.

"Heavy Metals Concentrations of Surface Dust from e-Waste Recycling and Its Human Health Implications in Southeast China" in *Environmental Science and Technology* 42(7): 2674-2680.

Li Yan, Huo Xia, Zheng Liangkai. 2007. "Umbilical Cord Blood Chrome Level of Newborns in an E-waste Recycling Area" in *Carcinogenesis,Teratogenesis & Mutagenesis*, 19: 409-411.

"Occupational Exposure Limit Recommended Japanese by Commission on Occupational Health" (OEL, 2009-2010). *Journal of Occupational Health*, 51 (5): 454-470.

McDonald, Thomas A. 2002. "A Perspective on the Potential Health Risks of PBDEs" in *Chemosphere*, 46: 745-755.

Nanxiang, Wu, Yang Yanmei, and Yu Suxia. 2001. "Health Effects of Dismantling Waste Electrical Appliances on Occupational Population and Residents" in *Journal of Environment and Health*, 18(2): 97-99.

Ongondo, F.O., I.D. Williams, and T.J. Cherrett. 2011. "How are WEEE Doing? A Global Review of the Management of Electrical and Electronic Wastes" in *Waste Management*, 31(4): 714-730.

Puckett, Jim, Leslie Byster, Sarah Westervelt, Richard Gutierrez, Sheila Davis, Asma Hussain, Madhumitta Dutta. 2002. "Exporting Harm: The High-Tech Trashing of Asia." The Basel Action Network and Silicon Valley Toxics Coalition. Available online: http://www.ban.org/E-waste/technotrashfinalcomp.pdf.

Renqun, Wang, Zhao Su, Qiu Yupeng, et al. 2006. "Renal Damage in Cadmium Exposed Residents in Cadmium Polluted Areas" in *Journal of Environment and Health*, 23(3): 202-204.

Sjmdin A., L. Hagmar, and W.E. Klasson. 1999. “Flame retardant exposure: polybrominated diphenyl ethers in blood from Swedish workers” in *Environmental Health Perspectives*, 107: 643-648.

Sun Yat-sen University (Department of Anthropology) and Greenpeace. 2003. “Anthropology Investigation Report of E-waste Dismantling Industry in Guiyu, Shantou.”

Tao, Yu. 2007. “Waste Collection and Handling Present Situation Diagnosis and Countermeasure Research of Huizhou.” Dissertation submitted to Guangzhou University of Technology for the Degree of Master of Environmental Engineering.

Thomsen C., E. Lundanes, and G. Becher. 2002. “Brominated Flame Retardants in Archived Serum Samples from Norway: A Study on Temporal Trends and the Role of Age” in *Environmental Science Technology*, 36: 1414-1418.

Wong, Coby S.C., S.C. Wu, Nurdan S. Duzgoren-Aydin, Adnan Aydin, and Ming H. Wong. 2007. “Trace Metal Contamination of Sediments in An E-waste Processing Village in China” in *Environmental Pollution*, 145: 434-442.

Wu Kusheng. 2008. “Environmental Distribution of Polybrominated Diphenyl Ethers” in *Occupation and Health*, 24(22).

Xiezhi, Yu, Markus Zennegg, Magnus Engwall, Anna Rotander, Maria Larsson, Ming Hung Wong, and Roland Weber. 2008. “E-waste Recycling Heavily Contaminates a Chinese City with Chlorinated, Brominated and Mixed Halogenated Dioxins” in *Organohalogen Compounds*, Volume 70: 813-852.

Xijin, Xu, Peng Lin, and Li Wei. 2006. “Investigation on Blood Lead Level of Children Aged 1-6 in Electronic Waste Disposing District” in *Journal of Environment and Health*, 23: 58-60.

Yu X.Z., Y. Gao, and S.C. Wu. 2006. “Distribution of Polycyclic Aromatic Hydrocarbons in Soils at Guiyu Area of China, Affected by Recycling of Electronic Waste Using Primitive Technologies” in *Chemosphere*, 65: 1500-1509.

Zhang, Wenhao, Yang Peihui. 2006. “Study on the Mechanism of DNA Conformation Change Induced by Cr(VI)-GSH Complex” in *Journal of Environment and Health*, 23(3): 221-224.

Zhongping, Zhu, Shen Tong, Yu Cuilian, et al. 2006. “A Cohort Study of the Effect of Environmental Lead Exposure on Children Behavior Problems”. Journal of Environment and Health, 23(2): 102-105.

Zou, Minshe and Li Changan. 2006a. “The Impact of Labour Structure on the Economic Growth Model in China.” Shanghai Equity and Stock Research Institute. Available online: http://theory.people.com.cn/GB/49154/49369/6109407.html

Zou, Minshe and Li Changan. 2006b. “The Structure of the Labour Force Affects China’s Economic Growth Pattern.” Shanghai Securities News, 3(13).

http://news.xinhuanet.com/fortune/2006-02/25/content_4226706.htm

http://www.beinet.net.cn/topic/kdnx/ttxw/201201/t2021139.htm

http://lvse.sohu.com/20080617/n257559556.shtml