E-Waste Management Sector: Identification of Green Business Potential in India

HIGHLIGHTS

Growth Forecast for e-waste in India

Job potential for e-waste sector

Occupational map for e-waste sector

Preamble

E-waste or waste electrical and electronic equipment (WEEE) illustrate discarded appliances that utilize electricity for their functioning. Indian market is engrossed with massive volumes of electrical and electronic goods and gadgets, having tremendously high domestic demand. Consequently, the amount of E-waste being generated in the country is flourishing at an alarming rate, although the management practices and policy initiatives of the same are still in an elementary stage. The current methods of storage, processing, recycling and disposal of E-waste in India have immense potential to harm human health and the environment. Furthermore, the policy level initiatives related to E-waste in India are reasonably recent and inadequate to address the issue.

Informal recycling is a new and expanding low cost recycling practice in managing Waste Electrical and Electronic Equipment (WEEE or e-waste). It occurs in many developing countries, including India, where current gaps in environmental management, high demand for second-hand electronic appliances and the norm of selling e-waste to individual collectors encourage the growth of a strong informal recycling sector.

Informal e-waste recycling is not only associated with serious environmental and health impacts, but also the supply deficiency of formal recyclers and the safety problems of remanufactured electronic products. Experiences from similar markets like China already show that simply prohibiting or competing with the informal collectors and informal recyclers is not an effective solution. New formal e-waste recycling systems should take existing informal sectors into account, and more policies need to be made to improve recycling rates, working conditions and the efficiency of involved informal players. Another key issue will be how e-waste management incentives are to be set-up for informal recyclers so as to reduce improper recycling activities and to divert more e-waste flow into the formal recycling sector.

Contents

Executive Summary

E-waste is a term used to cover all items of electrical and electronic equipment (EEE) and its parts that have been discarded by its owner as waste without the intent of reuse. As per the United Nations University 2014 Report, the estimated amount of total e-waste generated in 2014 worldwide was 41.8 million metric tons (MT) which is forecasted to increase to 50 MT by the end of year 2018. In the past, the expanding population was the main driver of consumption growth, but now the consumption growth also depends overwhelmingly on individuals spending more. This report is an effort to estimate volumes of e-waste that is expected to be generated in India on a short term and long term basis (i.e., up to 2030), related opportunities in term of job potential that this sector will present and the new job roles and skills on which the person were needed to be trained. The ultimate aim of this document is to form the basis of formulating National Occupational Standards (NOS) and Qualification Packs (QP's) for the key occupational Job Roles in this sector in India.

Chapter 2 of this report focuses on projecting growth rate for the e-waste volumes. To estimate the e-waste volumes which are likely to be generated in India, the projections were made considering two different growth scenario's viz., at CAGR*: 25% and at GDP Growth Rate (CAGR ~7.6 %) projected considering base figure of 18.6 lakh MT (which is the amount of e-waste estimated to be generated in 2016).

Chapter 3 and Chapter 4 of this report discusses technological options for e-waste recycling and related business opportunities viz., a series of steps involved in treating the hazardous fractions in an environmentally sound manner; Recovery of valuable material maximally and creating eco-efficient and sustainable business.

Chapter 5 is focused on the estimation of Job potential for the e-waste sector based on the increase in growth volumes. Stakeholder's consultations suggested that an estimated 90 per cent of recycling activities related to e-waste in India is performed in the unorganized sector. Across various cities, these activities are concentrated in slums or dump-yards, where laborers manually dismantle, burn or collect the waste, exposing themselves directly to substances like cadmium, lead oxide or mercury, causing heavy metal poisoning, lung diseases, limb damage and even death. The job creation potential is driven by the larger number of jobs created per ton of material recycled as compared with material landfilled or disposed.

Chapter 6 and Chapter 7 of the document discusses the process mapping and the occupations involved in e-waste management sector. The report concludes with Occupational map for the e-waste management sector identifying key job roles under various departments' viz., operations, administration, quality control etc. with some key job roles focusing of entrepreneurial perspective.

Chapter 1
Introduction

- Background
- Factors contributing to increase in e waste stream
- Potential Environmental contaminants arising from e waste
- Global initiatives / Conventions affecting e waste
- E Waste Management: Indian Context
- E-Waste Stream (Sector-wise)
- Legislations in India related to E Waste

Background

Electronics industry is one of the world's largest and fastest growing manufacturing industry. As the sales of electronic and electrical devices is increasing, so does the rapid product obsolescence especially that of computers and mobile telephones which are disproportionately abundant because of their short lifespan. Electronic products become e-waste when they are deemed at the end of their useful life. As per the ***StEP initiative 2014,*** E-waste is a term used to cover all items of electrical and electronic equipment (EEE) and its parts that have been discarded by its owner as waste without the intent of reuse. Some of the common examples of e-waste include non-functional TV's, computers, printers, photocopiers, cell phones, fax machines, home appliances, lighting equipment etc.

As per the United Nations University Report "*Global E-Waste Monitor 2014*", the estimated amount of total e-waste generated in 2014 worldwide was 41.8 million metric tons (MT) which is forecasted to increase to 50 MT by the end of year 2018. E-Waste is chemically and physically distinct from other forms of municipal or industrial waste; it contains both valuable and hazardous materials that require special handling and recycling methods to avoid environmental contamination and detrimental effects on human health. The growing amount of e-waste has posed a significant challenge to waste management in both developed and developing countries. Another aspect is that hazardous waste is processed very unprofessionally in the country except for few certified e-recyclers.

European Union (EU) has a law that if exporters do over packaging of their products they will not be able to export to EU countries. The need of the hour is that a policy must be articulated such that all electronic products sold in the country are to be collected by manufacturer's distribution network or as deemed fit by them. Also, Extended Producer Responsibility (EPR policy) has to play in a greater role in bringing responsible conduct by international industry. Philips has a system of collecting all its e waste in the developed world yet they do not follow good practices in India.

India needs to develop a coding system for electronic products depending on the number of hazardous materials embedded in the products. For example if some product has a cocktail of four or five hazardous material it get a red star & orange star if less .If in future the hazardous material is completely eliminated then it can have a green star. Educating the customer via. simple symbols is a very important component of sustainable development engagement.

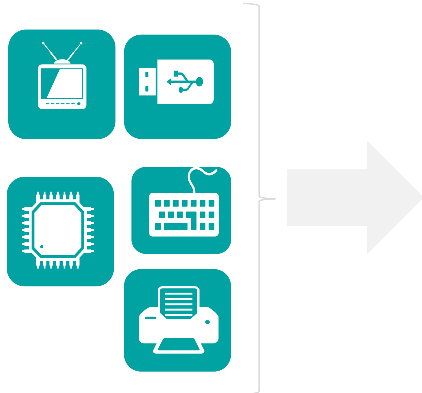
Factors contributing to increase in e-waste stream

The total amount of e-waste produced is exponentially increasing because of multiple factors. Consumer demand and high obsolescence rate lead to frequent and unnecessary purchase of EEE, Apart from these short innovation cycles and low recycling rates contributes to rapidly rising quantities of e-waste. The acceptable consumer life span of electrical and electronic equipment's has been dropping causing significant additions to e-waste. Computers and cell phones are used for a wide variety purposes, including educational campaigns where laptop is provided to students. Computer access and skills are valuable to education but such initiatives also have the unintended consequence of adding to the global e-waste burden.

Potential Environmental Contaminants arising from E-Waste

E-waste may generate dioxins, furans, polycyclic aromatic hydrocarbons (PAHs), poly-halogenated aromatic hydrocarbons (PHAHs), and hydrogen chloride. The chemical composition of E-waste varies depending on the age and type of the discarded item. However, most E-waste is composed of a mixture of metals, particularly Cu, Al, and Fe, attached to, covered with, or mixed with various types of plastics and ceramics. A discarded personal computer with a CRT monitor typically weighs 25 kg and consists of metal (43.7%), plastics (23.3%), electronic components (17.3%) and glass (15%) (Berkhout et al. 2004). Heavy WEEE items, such as washing machines and refrigerators, which are mostly composed of steel, may contain fewer potential environmental contaminants than lighter E-waste items, such as laptop computers, which may contain high concentrations of flame retardants and heavy metals.

Factors Responsible for increase in stream of E-Waste



- Consumer Demand
- High Obsolescence rate
- Short innovation cycles
- Low recycling rates
- Technological innovations
- Short product lifespans

Global Initiatives/Conventions affecting E-Waste

The foremost global initiative aimed at tackling the Waste Electrical and Electronic Equipment (WEEE) issues is the Basel Convention and Basel Ban. This is a global agreement, initiated in 1992, aimed at regulating the movement of hazardous wastes, including WEEE, between countries. As per the technical guidelines of Basel Convention on trans-boundary movement of e-waste, multiple type of e-waste streams based on functionality, need and potential for repair have been classified. These streams are discussed in **Table** below.

Classification multiple E-Waste Types (*Source: Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal, 1989*)		
Stream Type	**Classification**	**Description**
New and Functioning EEE	Non-Waste	▪ New Products or components
Used and Functioning EEE suitable for direct reuse	Non-Waste *(Export/import restrictions may apply in some countries)*	▪ No repair, refurbishment or hardware upgrading required
Used and Non-functioning but repairable EEE	Non-Waste / Waste (Depending on country) *(Classification of this stream is under discussion by Basel Parties, as the repair process may result in hazardous parts being removed in the country of repair, thus possibly resulting in trans-boundary movement of hazardous waste)*	▪ Equipment that can be repaired. ▪ Testing is required to determine this condition
Used and Non-functioning but repairable EEE	Waste	▪ The common form of e-waste. Can be mislabeled as "Used EEE"

WEEE	Waste.	▪ WEEE that is waste within the meaning of the Waste Framework Directive context, including components and sub-assemblies.

Many countries have understood the importance of the regulatory approach (laws and regulations) to tackle the ever increasing quantum of WEEE, and framed and formulated various laws and regulations to restrict the negative impact of WEEE on environment and occupational health. Apart from these laws, there are some ongoing initiatives which are aimed at finding solutions to the e-waste problems from a global perspective. One of the initiative is *StEP Initiative* ('Solving the e-waste problem', *StEP*) which was started in 2004 at the 'Electronic Goes Green' Conference in Berlin, it intends to build an international platform to exchange and develop knowledge on WEEE Systems and reverse supply chain. Table below gives an overview of some of the Conventions, Directives and initiatives for addressing WEEE.

Overview of some of the key international initiatives addressing e-waste	
Convention / Directive / Initiative	**Overview**
Basel Convention	▪ Enacted in 1992 to keep hazardous waste within producer countries, or ones able to safely process it. ▪ 172 signatory nations. Does not specify penalties.
Bamako Convention	▪ In force since 1998 in African Union countries. ▪ Sets more stringent waste import limits than the Basel Convention, and sets penalties. Seldom evoked.
European Union (EU) WEEE Directive (2002/96/EC)(EU 2002a)	▪ Effective from August 2004.Adapted by all EU members by 2007. ▪ Establishes systems of collection and recycling based on producer take-back, for 10 categories of electrical goods.
Restriction on Hazardous Substances Directive (RoHS) (EU 2002b)	▪ Complements to the scope of WEEE directive (except medical devices and control equipment's). ▪ Restricts amounts of lead, mercury, cadmium, hexavalent chromium, PBB, and PBDE used in manufacture. Versions adapted by many other countries, including China and India.
Solving the E-waste Problem (StEP)	▪ Instituted formally in 2007 by UN agencies. ▪ StEP partners with prominent academic and government organizations on promoting reuse of recycled materials and control of e-waste contaminants.
US NGOs—Basel Action Network (BAN), Silicon Valley Toxic Coalition (SVTC), Electronics Take Back Coalition (ETBC)	▪ These three act together for workable national e-waste collection and recycling programs. ▪ Internationally promote the "Basel Ban," a more restrictive waste export amendment to the Basel Convention.

Recent Development:	
Joint UN Workshop on Towards building effective partnerships for sustainable management of e-waste (5th May 2016)	▪ Event was co-organized by ITU, the Secretariat of the Basel Convention, ECLAC, UNIDO, WHO and WIPO with an aim to generate awareness on e-waste management and to strengthen collaborations on e-waste related issues within the United Nations.

E Waste Management: Indian Context

Unlike most of the developed countries, the Indian E-waste management system is not formally developed and is very ill defined. In India, most of the activities relating to e-waste management *viz.,* collection, transportation, segregation, dismantling *etc.* are done by unorganized (informal) sector primarily involving manual operations and various low-end management alternatives such as disposal in open dumps and backyard recycling. This informal sector include small units engaged in the production of goods and services whose activities are not recognized or regulated by the public authorities. A 2007 study on Indian e-waste sector estimated that total share of informal sector in recycling of e-waste in India was about 97% while the formal sector worked under capacity *(Pandey P. et al. (2014); Ref 3).*

The various sources from which e-waste is generated in India include industrial, commercial, household and institutional sectors however, one of the key source of e-waste in India is the illegal import from developed countries. As per 2011 estimates, the estimated quantity of e-waste imported in India was 50,000 MT /annum out of which only 11% is formally recycled and majority goes to the informal sector (*(Pandey P. et al. (2014) and Vats et al. (2014)).*

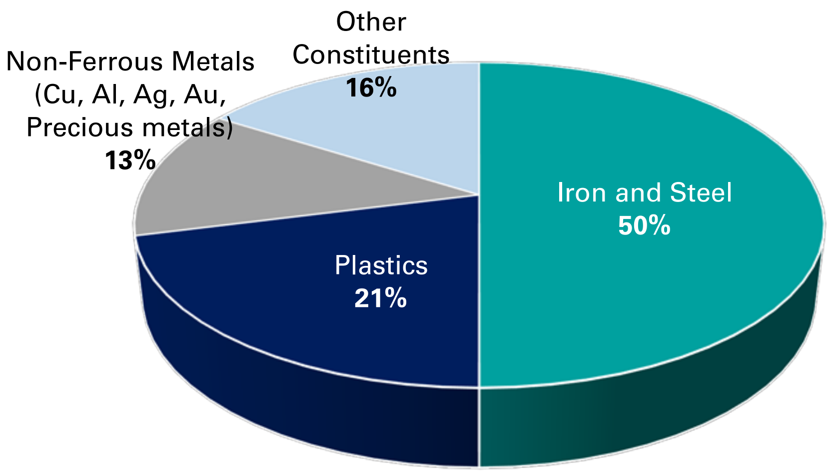
E-Waste Stream (Sector-wise)

There are three main constituents of e-waste, namely, glass, plastics, and metals. The glass may be re-melted for production of glass or for recovery of lead. The thermosetting plastics are difficult to recycle. The other types of plastics can be recycled for use as fuels or production of chemicals. The metals may be separated from the plastics and processed for recovery of individual metals. It may be said that physical separation techniques followed by metallurgical treatment is the best proposition for the recovery of metals.

Composition of e-waste is very diverse and differs in products across different categories. It contains more than 1000 different substances, which fall under "hazardous" and "non-hazardous" categories. Broadly, it consists of ferrous and non-ferrous metals, plastics, glass, wood & plywood, printed circuit boards, concrete and ceramics, rubber and other items. Iron and steel constitutes about 50% of the e-waste followed by plastics (21%), non-ferrous metals (13%) and other constituents. Non-ferrous metals consist of metals like copper, aluminum and precious metals ex. silver, gold, platinum, palladium etc. The presence of elements like lead, mercury, arsenic, cadmium, selenium, and hexavalent chromium and flame retardants beyond threshold quantities in e-waste classifies them as hazardous waste.

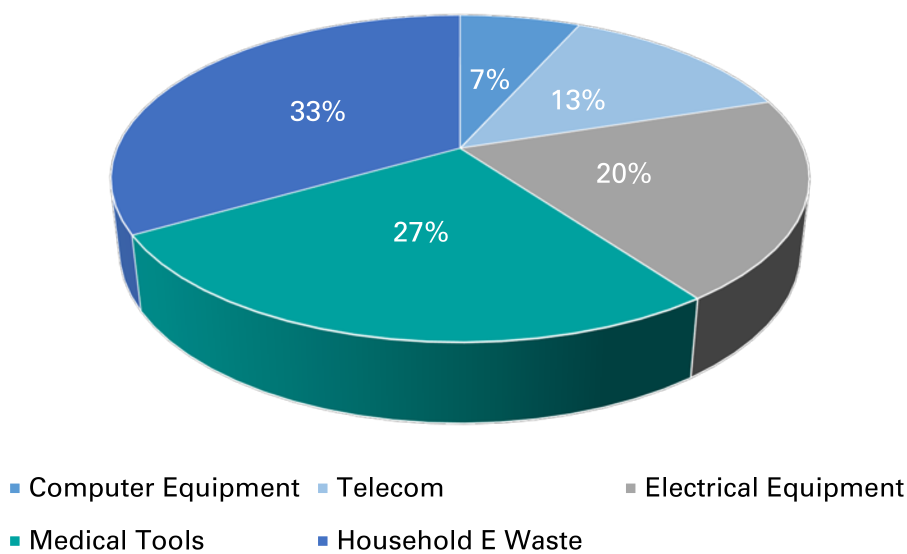
E-waste Stream Composition: Indian Context

(CPCB, 2008)



E Waste Stream (Sectorwise)

Source: ASSOCHAM/Frost Sullivan Study, 2014



Legislations in India related to E Waste

The radiation tragedy of Cobalt-60 at Mayapuri area of Delhi in April 2010 in which one person died and six others were seriously injured drew attention to the informal recycling of e-waste and the hazardous conditions for the workers in dismantling and recycling (Ref 12). Consequently, the Government of India notified the Hazardous Waste (Management, Handling and Trans-boundary Movement) Rules, 2008 for proper management of hazardous waste, including e-waste. These rules could not be applied to radiation of Cobalt-60, however, which is regulated by the Atomic Energy Act, 1962. Recognizing the limitation of the rules, the Government formulated E-waste (Management and Handling) Rules, 2011 with effect from 1 May 2012 and made it obligatory for all persons/organizations dealing with the collection, segregation, storing, dismantling and recycling of e-wastes to comply with these rules. Accordingly, all dismantlers and recyclers of electronic wastes are required to obtain authorization and registration from the State Pollution Control Board, and they are required to ensure that no damage is caused to the environment during the storage and transportation of e-wastes and that the dismantling processes do not have any adverse effect on health and environment. Recently, the Ministry of Environment and Forests (MoEF) has notified e-waste (Management) Rules 2015 which lays emphasis on Extended Producer Responsibility (EPR) for manufacturers. These rules will come into force from October 2016.

Indian E-Waste Regulations	
India: - **Guidelines for Environmentally Sound Management of E-Waste**	▪ Approved by Ministry of Environment and Forests (MoEF) on March 12, 2008. ▪ Provides guidance for identification of various sources of waste electrical and electronic equipment's and prescribed procedures for handling E-waste in an environmentally sound manner.
- **E-Waste (Management and Handling) Rules, 2011**	▪ To enable the recovery and/or reuse of useful material from Waste Electrical and Electronic Equipment (WEEE), thereby reducing the hazardous wastes destined for disposal and to ensure the environmentally sound management of all types of waste electrical and electronic equipment.
- **E Waste (Management) Rules, 2015** (Implementable from October 2016)	▪ Enhanced focus on Extended Producer Responsibility (EPR) ▪ Refurbishers, dealers and producer-responsibility organizations (PROs) are some of the inclusions made in these upcoming Rules.

E-waste means electrical and electronic equipment, whole or in part discarded as waste by the consumer or bulk consumer as well as rejects from manufacturing, refurbishment and repair processes (as per e-waste (Management) Rules 2015 notified by MoEF on 23rd March 2016). E-Waste generated in India has to be managed as per the e-waste (Management) Rules 2015 (referred to as e-Waste Rules hereinafter) notified by MoEF, Government of India (GoI). These rules will come into force from 1st October 2016. As per the Schedule-I of e-waste Rules, e-waste is divided into two broad categories: - (i) IT and Telecommunication Equipment (ii) Consumer Electrical and Electronics. **Table** below gives the classification of e-waste and the corresponding equipment codes as per upcoming Indian E-waste regulations.

Categories of e-waste and equipment codes as per e-waste Rules 2015	
Information technology and telecommunication equipment (Equipment Code)	Consumer Electrical and Electronics (Equipment Code)
▪ Centralized data processing: Mainframes, Minicomputers (ITEW1) ▪ Personal Computing: Personal Computers (Central ▪ Processing Unit with input and output devices) (ITEW2) ▪ Personal Computing: Laptop Computers(Central ▪ Processing Unit with input and output devices) (ITEW3) ▪ Personal Computing: Notebook Computers (ITEW4) ▪ Personal Computing: Notepad Computers (ITEW5) ▪ Printers including cartridges (ITEW6) ▪ Copying equipment (ITEW7) ▪ Electrical and electronic typewriters (ITEW8) ▪ User terminals and systems (ITEW9) ▪ Facsimile (ITEW10) ▪ Telex (ITEW11) ▪ Telephones (ITEW12) ▪ Pay telephones (ITEW13) ▪ Cordless telephones (ITEW14) ▪ Cellular telephones (ITEW15) ▪ Answering systems (ITEW16)	▪ Television sets (including sets based on (Liquid Crystal Display and Light Emitting Diode technology) (CEEW1) ▪ Refrigerator (CEEW2) ▪ Washing Machine (CEEW3) ▪ Air-conditioners excluding centralized air conditioning Plants (CEEW4) ▪ Fluorescent and other Mercury containing lamps (CEEW5) ▪ Solar Panels

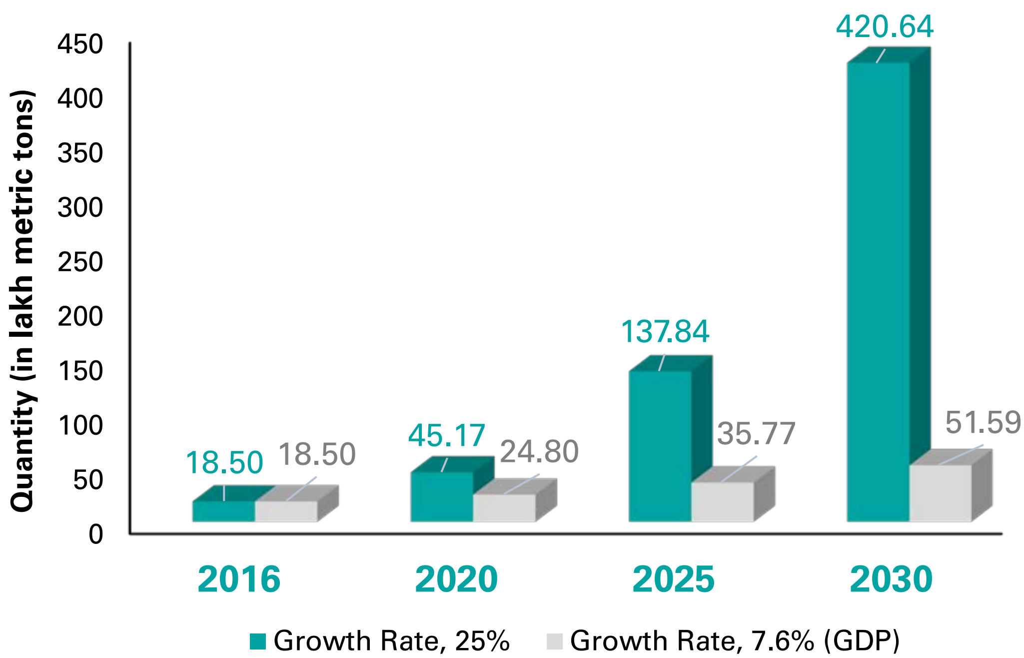
Chapter 2
Growth Forecast

- **Forecast for Growth in E Waste**
- **Projections for E Waste collection**

Forecast for Growth in E-waste

To estimate the e-waste volumes which are likely to be generated in India, the projections are made considering two different growth scenario's *viz.,* at CAGR*: 25% and at GDP Growth Rate (CAGR: 7.6 %) projected considering base figure of 18.5 lakh MT (which is the amount of e-waste estimated to be generated in 2016). **Figure** below gives the projected volumes of e-waste based on two different scenarios on scatter plots.

(*) This CAGR of 25% is based on the discussions and consultations done with the stakeholders working in the e-waste sector. Most of the stakeholder were of the opinion that this is the actual rate prevalent in the e-waste industry currently.



Projected growth volumes of e-waste generated in different growth rate scenarios (At a growth rate of 25% and at the estimated GDP growth rate)

Note: These estimates are for e-waste generated in India and does not take into account the e-waste coming and processes in to the country illegally

Table below gives the growth estimates under various scenarios as represented in graph above.

Year	High: (CAGR: 25%)	GDP Growth Rate: CAGR: 7.6%
	Quantities in lakh metric tons	
2016	18.50	18.50
2017	23.13	19.91
2018	28.91	21.42
2019	36.13	23.05

2020	45.17	24.80
2021	56.46	26.68
2022	70.57	28.71
2023	88.21	30.89
2024	110.27	33.24
2025	137.84	35.77
2026	172.29	38.49
2027	215.37	41.41
2028	269.21	44.56
2029	336.51	47.94
2030	420.64	51.59

Projections for E Waste Collection

As per the upcoming e-waste rules, 2015, there is a mandate to bring e-waste which is generated each year under extended producer responsibility (EPR) which is a formal system for e-waste collection. The volume of e-waste which is to be managed under this formal system is estimated by extrapolating the projected waste under two scenarios which includes 10% of the e-waste which will be generated beyond the legal compliance / obligations. The data is represented under Figure below:

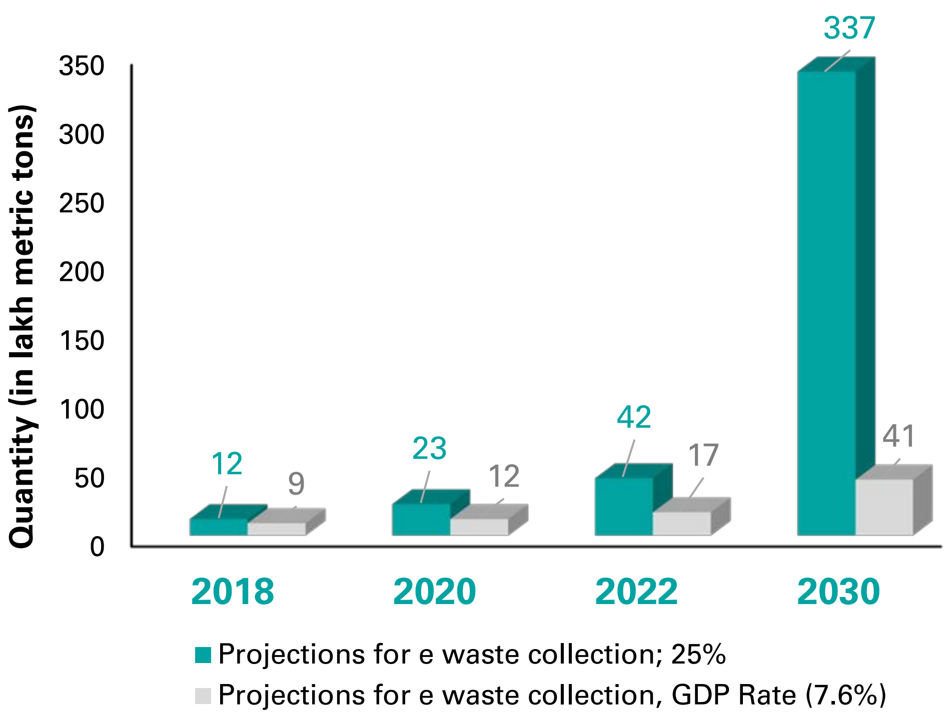


Table below gives the projected estimates for e-waste collection under various scenarios as represented in graph above.

Year	High: (CAGR: 25%)	GDP Growth Rate (CAGR: 7.60%)
	Quantities in lakh metric tons	
2018	12.0	9
2020	23.0	12
2022	42	17
2030	337	41

Chapter 3
Technological Options

- **Technological options for E Waste Management**
- **Pre-processing Methods/Technologies**
- **End-processing Technologies**

Technology Options for E-Waste Management

The e-waste recycling chain could be divided into three main subsequent steps: (1) collection, (2) dismantling and pre-processing and (3) end-processing for final metal recovery. Technology plays a crucial role especially in the second and third steps and, in particular, in pre-processing and end-processing. After the collection phase end-of-life appliances are treated in order to obtain components (to be reused or refurbished) or materials fractions (to be recycled and reused as raw materials). Components or material fractions that are not reused or recycled (due to their intrinsic hazardous content or lack of secondary markets) are sent to a suitable disposal site.

The main objectives of e-waste recycling and basic considerations for innovation are:-

- Treat the hazardous fractions in an environmentally sound manner;
- Recover valuable material maximally;
- Create eco-efficient and sustainable business;
- Consider social impact and local context.

Pre-processing Methods /Technologies

Equipment Type	Objectives	Options
Cooling and Freezing Appliances	o Control over hazardous fractions o De-gassing (CFC & HCFC)	- Automatic units - Removal of coolant and oil in the same step with a proprietary de-gassing unit - Removal of coolant and oil in separate stages
	o Removal mercury containing switchers and PCB capacitors o Control over hazardous fractions	- Manual dismantling
	o Recovery of components or materials e.g., Compressor o Control over hazardous fractions e.g., Oil	- Manual dismantling - Residual of CFC in oil to be separated
	o Recovery of (valuable) components *viz.,* Compressors, doors, electric parts, glass shelf, salad crisper, relay, bulb	- Manual dismantling
	o Recovery of material fractions *viz.,* Ferrous, Non-ferrous (Al, Cu), Non-metals, CFC/HCFC in foams, Plastics, rubber, Woods, Remaining fractions (waste, polyurethane)	- Manual dismantling, - Shredding and separation through magnetic belts, eddy currents, magnetic inductions, vibrations, density, dielectric properties or melting temperature
Information and Communication Technology Appliances (ICT)	o Removal of: Ink cartridges, PCB containing capacitors, Mercury containing switchers, batteries	- Manual dismantling/sorting.
	o Recovery of (valuable) components	- Recovery of (valuable) components.

	o Recovery of material fractions viz., Ferrous, Non-ferrous (Al, Cu), Non-metals, Plastics, rubber, woods and remaining fractions	- Manual dismantling and sorting; - Shredding and separation; - Magnetic belts, eddy currents, magnetic inductions, vibrations, density, dielectric properties or melting temperature.
	o Recovery of Material fractions	- Smelters, Integrated smelters.
Monitors and Television Sets	o Removal of CRT Manual dismantling	- Removal of CRT manual dismantling.
	o Recovery of valuable components or materials: electron gun, printed wiring board (PWBs)	- Manual dismantling/sorting PWBs: subsequent (manual) removal of large aluminum and iron parts recommended.
	o Recovery of coatings and lead containing glass	- Manual or semi-automatic split of CRT (hot wire cutting, thermal shock, laser cutting, diamond wire, diamond saw, water jet) to separate the funnel glass from the front panel glass; - Manual or (semi)-automatic removal of coating from the front panel glass o Plastic Media Blasting; o Water Circulation; o Fluidized Bed Cleaning System. - Automatic shredding of CRT and recovery the material fractions (including the coating).
	o Recovery of Materials	- Manual sorting of front panel glass (max 4% Pb) and funnel and neck glass (22-30% Pb); - Automatic sorting techniques such as density separation, sizing, UV light, visible light or X-ray fluorescence.
LED and LCD Televisions/CFL	o Recovery of mercury from gas discharge lamps o Recovery of precious and Rare Earth Metals	- Manual Dismantling - Water Jet Cutting - Laser Cutting
Notebooks (Lithium ion Batteries)		- Sorting - Manual or (semi)-automatic removal of coating - Detoxification - Shredding

Solar / Photovoltaic Panels	o Recovery of Glass and Semi-conducting Material	- Manual separation of module from aluminum panels and junction boxes including glass, black-sheet and cells - Mechanical Pre-processing in hammer mill (Shredding) - Separation (using leach drum and vibrating screen)

End-processing Technologies

For the end-processing of the material fractions from ICT and CRT appliances a distinction has to be made between different material streams. Each material stream has a specific set of technologies that can be used to recover the metals. The unit operations or equipment's (often proprietary or patented) that are combined into highly effective end processing flows can be roughly grouped into:

Pyro-metallurgy, which use high temperatures to chemically convert the feed materials and separate metals and impurities into different phases so valuable metals can be recovered. The high temperatures in the furnace or smelter are generated via the combustion of fuel or via electrical heating. Examples of technical hardware are submerged lance smelters, converters, rotary furnaces, electric arc furnaces etc.

Hydro-metallurgy, which use strong acidic or caustic watery solutions to selectively dissolve and precipitate metals e.g. leaching, cementation, solvent extraction etc. differ from pyro-metallurgical processes in that the desired metals are separated from other materials using techniques that capitalize on differences between constituent solubility's and/or electrochemical properties while in aqueous solutions. Recycling on a smaller scale is done using hydrometallurgical processes, which utilize acidic leaching agents to recover metals. However, traditional leaching agents, such as cyanide and aqua-regia, result in hazardous effluents that must be handled and disposed of properly. Advanced Technology Materials Inc. (ATMI) has developed a selective chemical process that recovers valuable materials from obsolete wiring boards (PWB) using a "green chemistry" technology. Non-toxic hydrometallurgical processing is a promising recycling method for e-waste.

Electro-metallurgy, which use electrical current to recover metals, e.g. electro-winning and electro-refining of copper, zinc etc.

Bio-metallurgical methods using bacteria or fungi are in a research stage only and are currently not applied in the e-waste recycling chain.

All the above processes are used for recovery of different metals from different e-waste categories. The various processes for some specific categories are presented below:

Category	Technology Option
Printed Circuit Boards (PCB's) and Small Electronic Devices	- Integrated Smelting (Integrated copper and precious metal smelter-refinery operations) - Off-Gas Cleaning Systems (adiabatic coolers, scrubbers, filters and catalytic decomposition) for removal of VOC's, Dioxins and acid gases)
Metallic Fractions	- Copper Smelters (with precious metals) - Smelting (without precious metals)
Aluminum	- Smelters (Aluminum Recycling Operation/Aluminum Smelting)

Ferrous Metals	- Blast Furnace - Basic Oxygen Furnace (BOF)
Lead (Pb) glass from CRT	- Lead Smelters (and use as fluxing materials)
Notebooks (Lithium ion batteries)/ Smartphones	- Pyro-metallurgical refining for recovery of Cobalt (Co) and Nickel (Ni) - Advanced Refining and Recovery (Precious and Rare Earth Metals)
Solar/ Photo-voltaic	- The Ethylene Vinyl Acetate (EVA) pieces are collected in another conveyor while the glass falls through the screen to a chute where it is further handled to rinsing. Having been cleaned, the glass is deposited into recycling containers and rinse waters are pumped to a precipitation system for metal recovery. - The metal parts are precipitated in a three-stage process by increasing pH using sodium hydroxide. Once the solid compounds have settled and been process into a metal rich filter cake it is basically ready to be processed into semiconductor grade raw material.

Processing Technologies developed by M/s Panasonic and Hitachi Group

High-Precision Resin Sorting System (Mass Production Equipment):

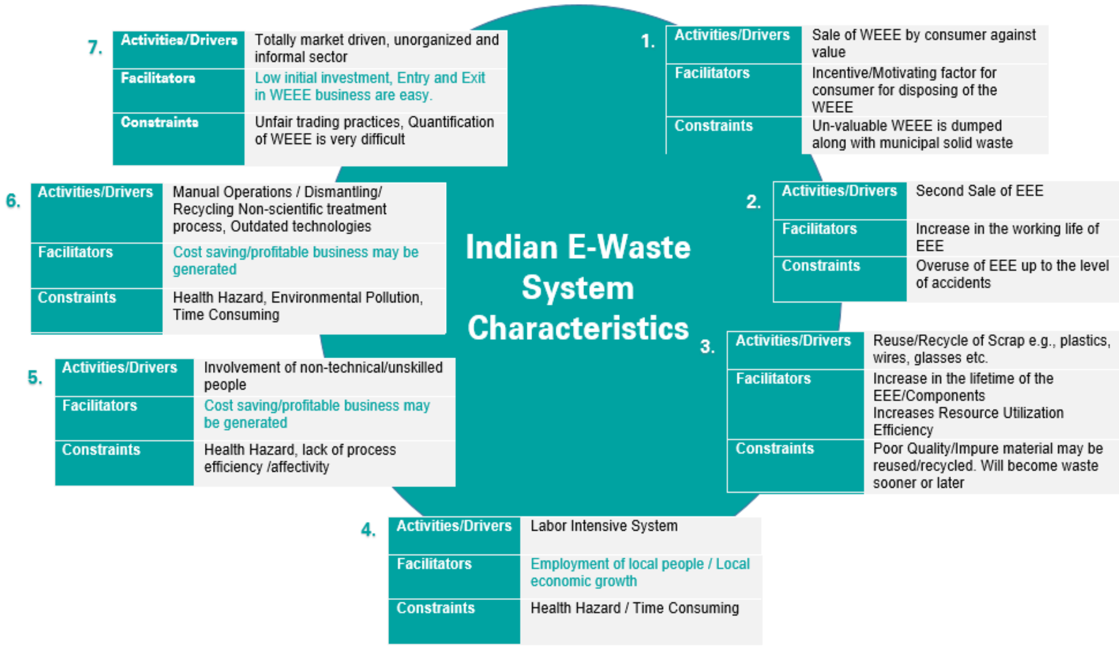
Panasonic developed a high-precision resin sorting system that automatically sorts and recovers plastic materials from residues. The system uses near-infrared rays to instantly identify specific plastic materials contained in the residues carried on a conveyor, and the plastic materials that are identified are shot down for recovery with compressed air. This system enables the sorting and recovery of plastic materials by type at purity of over 99%, and also enables the removal of plastic materials that contain bromine. The mass production equipment is compact in size, does not require the use of water, and has the potential to process 1,000 tons annually.

Extraction of Rare Earths from the Separated and Collected Rare Earth Magnets:

Hitachi through partnership with University of Tokyo's Institute of Industrial Science conducted experiments for extraction of rare earth materials from the magnets. These experiments were carried out using dry process instead of conventional method that is by using acids and other chemicals, and neodymium and dysprosium to separate the rare earths and extraction of materials from the other non-rare earth materials like iron in the rare magnets.

E–waste Management

The problem of E-waste has forced environmental agencies of many countries to innovate, develop and adopt environmentally sound options and strategies for E-waste management. The objective is to mitigate and control the ever growing threat of E-waste to the environment and human health. E-waste management is given the top priority in many developed countries, but in rapid developing countries like India, it is difficult to completely adopt or replicate the E-waste management system in developed countries due to many country specific issues viz. socio-economic conditions, lack of infrastructure, absence of appropriate legislations for E-waste, approach and commitments of the concerned, etc. **Figure** and **Table** below. Describe and lists characteristics, challenges and potential opportunities of e-waste management system in India.



The characteristics of e-waste management system in India and its implications
(Source: Adapted from Wath et al. (2010), Heeks et al. (2015); Reference 5 & 1)

Chapter 4
Business Opportunities

Business Opportunities

Material wastes have become extremely significant over the past decade. Now and into the future we are seeing an increased reliance on critical materials, rare earth and precious materials. With innovation, the demand for these materials has increased, but the supply is not increasing at the same rate as the demand. There is a limited supply in the world for certain types of materials and it is crucial that industries operating in electronic equipment and other sectors look at new ways of recycling, new ways of improving material resource efficiency, and implementing the idea of circular economy in order to recover valuable waste from these products so that they can be purified and rooted back into the supply chain. New industry will be emerging to tap into this growing market, which is growing at a rate of three to five percent every year internationally. It's not going to go away in the near future.

Potential Opportunities for Indian E-Waste System
(Source: Reproduced from Wath et al. (2010); Reference 5)

Scientific	**Engineering**
▪ Eco-friendly Recovery Solutions o Precious Metals o Base Metals	▪ Integrated /Distributed processing facilities o Unorganized to Organized o Involvement of SME's and NGO's
▪ Value addition to recyclables for reuse o Plastics o Glass and other recyclables	▪ Scientific Collection, transport, handling, segregation and disposal of e-waste
▪ Disposal of Process Waste and Residues o Size Reduction o Toxic Reduction	▪ Feasible Techno-Economical Solutions o Processing o Recycling o Recovery
Organizational	
▪ Inventorization of E-Waste generation, import and its characterization ▪ Organization and structuring E-Waste management system ▪ Training and Awareness on Safety, Health and Environment	

Case: End Processing of LCD /LED Panels and recovery of precious metals

Recycling hundreds of millions of LCDs will create new job opportunities. The new equipment and tools will be tested by e-waste recyclers, and field data will be collected. The initial stage will involve removal of monitor's housing, detaching circuit boards and metal frames, then polarizing filters, glass, liquid crystals, and the mercury-containing backlight unit will be separated.

An LCD monitor includes the front frame, back cover, metal frame, circuit boards, the liquid crystal subassembly with a driver circuit and the backlight unit. Electrode patterns are made of a layer of indium tin oxide, or ITO. The backlight unit includes a frame, fluorescent tubes, a prism, a "diffuser," a reflector, and a protective layer. The liquid crystal subassembly's drive circuit has a gold coating.

The gold is a high value component and the drive circuit may contain 1-2 grams of gold. In the past several years, increasing demands from LCD and thin-film solar cell manufacturing have led to the price of indium running from less than $100 per kilogram in 2003 to more than $600 per kilogram in 2011.Therefore, recovering the ITO-coated glass makes business sense.

Chapter 5
Job Potential Estimates

Estimating demand in terms of Job Potential (Considerations)

Currently, 90 per cent of recycling activities related to e-waste in India is performed in the unorganized sector. Across various cities, these activities are concentrated in slums or dump-yards, where laborers manually dismantle, burn or collect the waste, exposing themselves directly to substances like cadmium, lead oxide or mercury, causing heavy metal poisoning, lung diseases, limb damage and even death. The job creation potential is driven by the larger number of jobs created per ton of material recycled as compared with material landfilled or disposed. For Example: while waste collection and landfill disposal creates less than 1 job per 1000 tons managed; the collection, processing and manufacturing of products with recycled materials as feedstock creates 6 – 13 more jobs per 1000 tons depending on the material (Reference: From Waste to Jobs, NRDC Report, March 2014).

The rapidly growing e-waste can be utilized as source of recyclable and recoverable materials and enormous employment opportunities can be explored *via.* This profession. Bulk of the jobs would come from manufacturing, which is more labor intensive per ton of material than collection or processing.

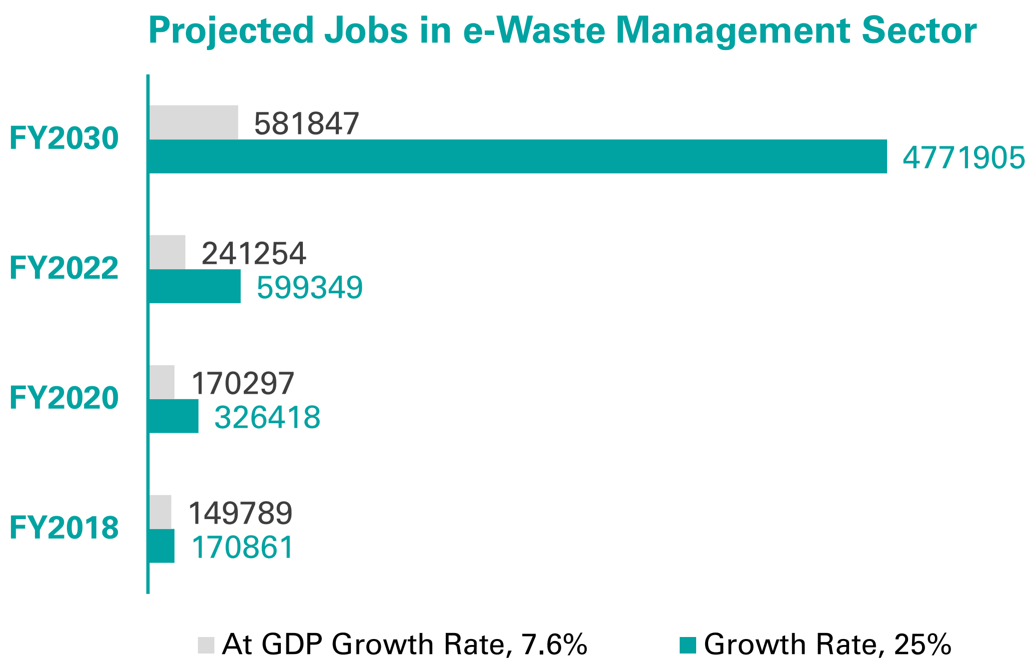
Reuse and remanufacturing are particularly labor intensive with job production estimates of over 7 jobs per 1,000 tons for several material/product categories and around 20 jobs per 1,000 tons for metal products.29 Such high job production estimates for reuse and remanufacturing reflect the significant labor required for disassembly, inspection, repair/refurbishment, reassembly and testing.

Job Production Factors by Material and Management Activity (Jobs per 1000 Tons)
(Reference: NRDC, 2014 and Stakeholder consultations)

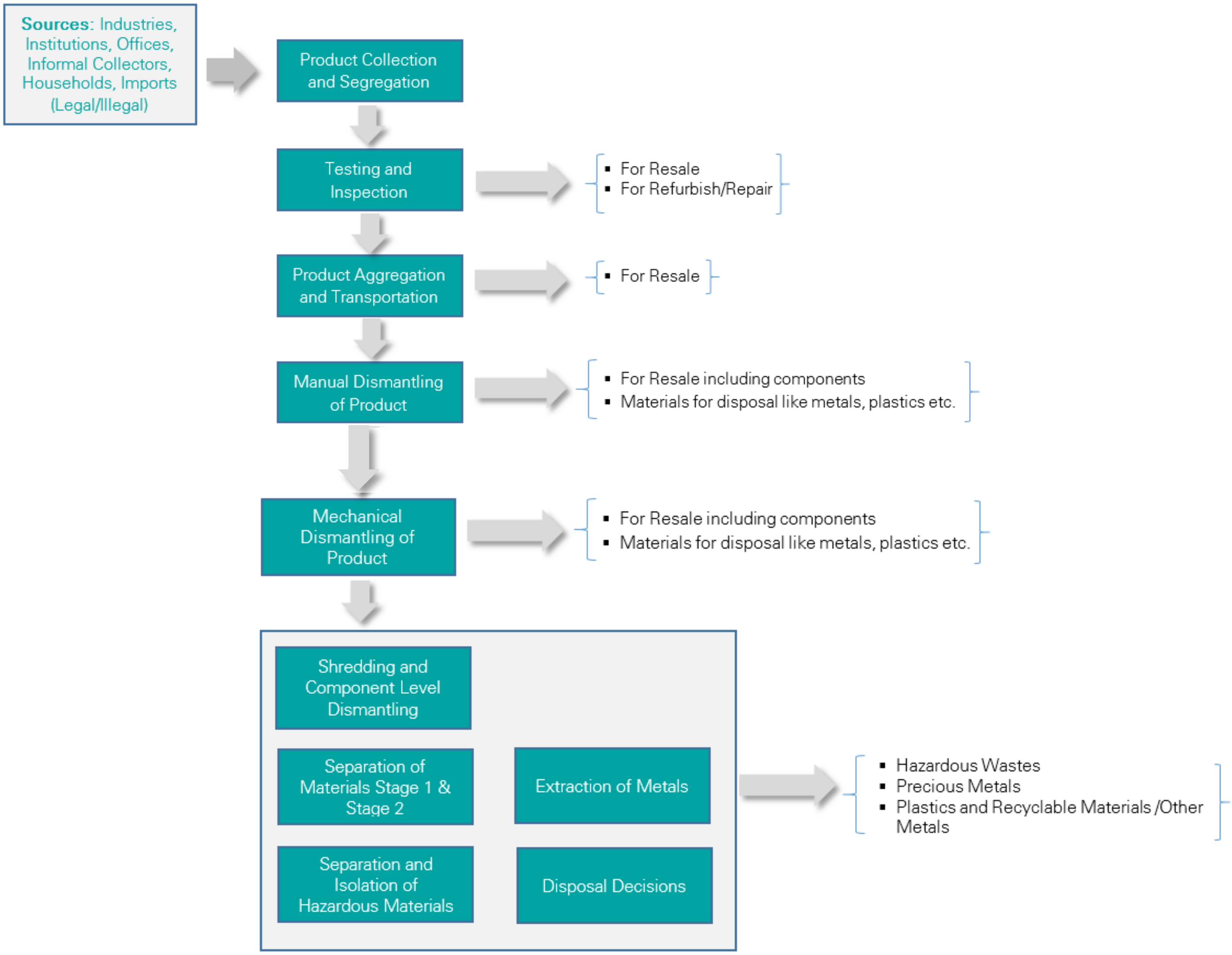
Type	Diverted Waste (Jobs per 1000 Tons)				Disposed Waste (Jobs per 1000 Tons)		
	Collection	Processing	Manufacturing	Reuse and Manufacturing	Collection	Landfill	Incineration
Materials	1.23	2					
Paper and Paperboard	1.23	2	4.16	NA	0.56	0.1	0.1
Glass	1.23	2	7.85	7.35	0.56	0.1	0.1
Metals	1.23	2					
Ferrous	1.23	2	4.12	20	0.56	0.1	0.1
Aluminum	1.23	2	17.63	20	0.56	0.1	0.1
Other (Non-Ferrous)	1.23	2	17.63	20	0.56	0.1	0.1
Plastics	1.23	2	10.3	20	0.56	0.1	0.1
Rubber & Leather	1.23	2	9.24	7.35	0.56	0.1	0.1

Number of Jobs 1 (Recycling Side) = Volume of Waste × Demand (Formal Waste Processing Demand) × % of Constituent in the Waste Stream × Standard Job Production Factors (Diverted Waste).

Number of Jobs 2 (Disposal Side) = Volume of Waste × Demand (1-Formal Waste Processing Demand) × % of Constituent in the Waste Stream × Standard Job Production Factors (Disposed Waste).


Projected Jobs in e-Waste Management Sector
FY2030
581847
4771905
FY2022
241254
599349
FY2020
170297
326418
FY2018
149789
170861
At GDP Growth Rate, 7.6%
Growth Rate, 25%

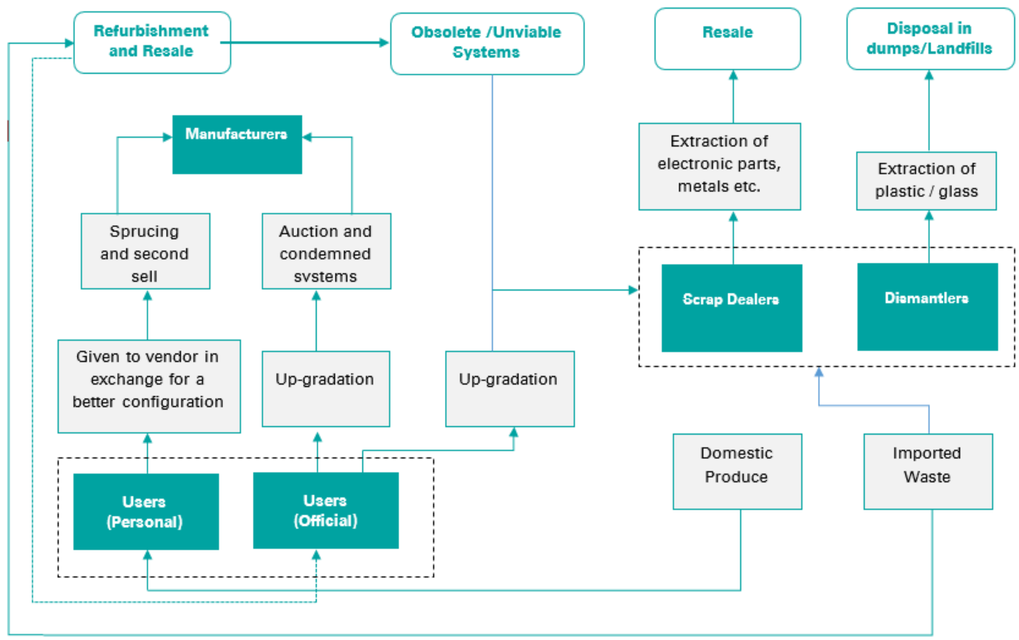
Chapter 6
Process Mapping



Sources: Industries, Institutions, Offices, Informal Collectors, Households, Imports (Legal/Illegal)
Product Collection and Segregation
Testing and Inspection
For Resale
For Refurbish/Repair
Product Aggregation and Transportation
For Resale
Manual Dismantling of Product
For Resale including components
Materials for disposal like metals, plastics etc.
Mechanical Dismantling of Product
For Resale including components
Materials for disposal like metals, plastics etc.
Shredding and Component Level Dismantling
Separation of Materials Stage 1 & Stage 2
Extraction of Metals
Separation and Isolation of Hazardous Materials
Disposal Decisions
Hazardous Wastes
Precious Metals
Plastics and Recyclable Materials /Other Metals

Production/Disposal Pathway

Production-Disposal pathways of e-waste in India highlighting key players viz., manufacturers, scrap dealers, dismantlers etc. (especially IT items) is shown below: *(Adapted from Premalatha et.al, 2014)*



<table>
<tr><th>Stage</th><th>Steps in the Value Chain</th><th>Key Activities</th></tr>
<tr><td rowspan="2">1: Generation</td><td>1A: Manufacturing of Electrical and Electronic Equipment</td><td rowspan="2">Sources of E-Waste:
o Domestic
o Import

Domestic Sources:
o Households and Small Businesses
o Large businesses / Organizations / Industries / Institutions
o Original Equipment Manufacturers (OEM)

Import of e-waste:
o Legal
o Illegal</td></tr>
<tr><td>1B: Generation of Waste Electrical and Electronic Equipment</td></tr>
<tr><td>2: Collection</td><td>2A: Product Collection</td><td>E-Waste collection through any of the following scenarios:
Scenario 1: Official Take Back
Scenario 2: Disposal along with mixed residual waste
Scenario 3: Collection outside official take back
Scenario 4: Informal collection and Recycling

Activities associated with the scenarios:
[1] Setting-up of Collection Channels
[2] Allocation of financial mechanism for collection of WEEE/E-waste from private households.
[3] Allocation of responsibility for collection, treatment, recovery, recycling & disposal of WEE/E-waste from private household deposited at collection points.
[4] Allocation of financial mechanism for collection of WEEE/E-waste from private households.
[5] Transportation of waste from waste storage depots/ transfer stations for processing/ disposals: The key sub steps under collection and transport are as under:
(5A) Pilot Survey: Study the consumer behavior for the best used option for collection point i.e. retailer take back collection center, municipal collection center or others
(5B) Calculation of WEEE/E-waste collection systems.
(5C) Calculate the WEEE/E-waste haulage capacity
(5D) Calculate the number of trucks/ trailers of different capacities required to transport the WEEE/ E-waste
(5E) Optimize the route and frequency of collection based on accessibility of the collection site.</td></tr>
</table>

3: Pre-Processing	3A: Test / Sorting	[1] Initial Equipment Evaluation [2] Evaluation of individual components [3] Separation of Re-usable Parts
	3B: Disassembly	[1] Evaluation of equipment/Individual components: Evaluation occurs at dismantling stage to determine which components are suitable for reuse after refurbishment repair or material recovery and which are to be dismantled. [2] Disassembly (Manual/Mechanical): Materials evaluated to have no continuing value through refurbishment and no remaining valuable working components will be taken apart, manually or mechanically, and separated into steel, plastics and circuit boards.
4: End-Processing	4A: Re-sale / Re-Use Product from 3A and 3B.	[1] Technical Evaluation [2] Up-gradation/Replacement (Hardware parts, software up-gradation etc.), Cleaning, labelling and distribution (Refurbishment is done for whole equipment's or /and also for individual component parts) [3] Evaluation of the final product value [4] Setting-up a sales criteria / Issue of tenders [5] Vendor identification [6] Inspection of the vendor processing/product refurbishing facility/ Potential business plan [7] Shortlisting and entering legal agreement on Re-sales and dispatch. Intent: Bringing a useful computer or component back on the market for continuing use. Depending on the type of component or part, those that cannot be repaired or reused will be sent to either dismantling or recovery.
	4B: Size Reduction	[1] Manual Dismantling (Hammering, chiseling, drilling, cutting, burning) [2] Mechanical Dismantling o Coarse Shredding o Medium Shredding o Fine Shredding

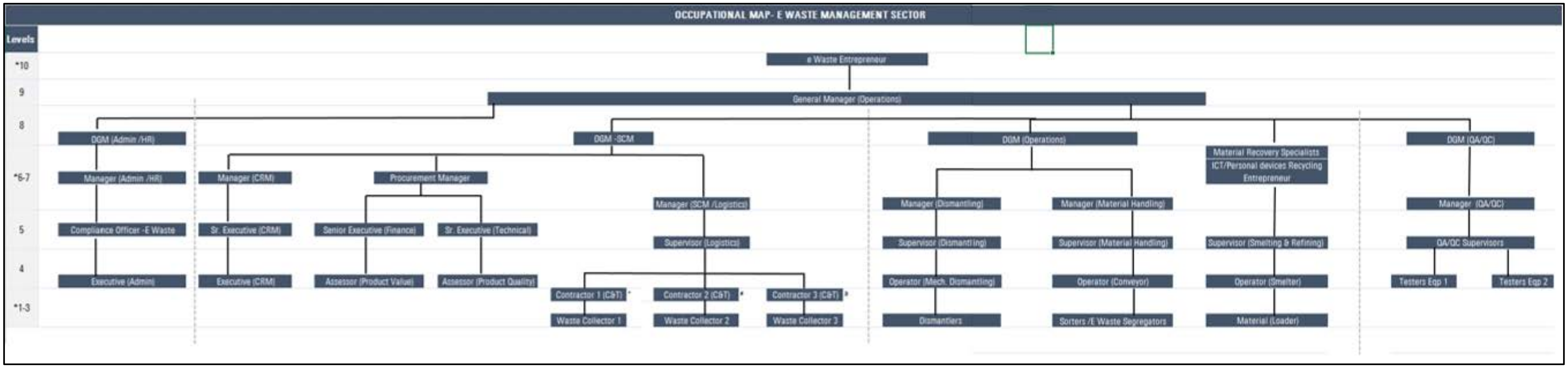
	4C: Separation by Materials	[1] Sorting (Material into batches) [2] Consolidation (for specialized material recovery) [3] Separation through various processes: o Magnetic Separation: Separation of Ferrous Metals o Eddy Current Separation: Separation of non-ferrous metals o Density Separation: Separation of plastics o Air Separation: Separation of Films, Labels [4] Resin Identification [5] Extrusion [6] Pellerizing
	4D: Recovery	[1] Identification of appropriate treatment chain for individual consolidated batches; [2] Feeding of separated batches of materials into specialized processes in series: [3] Specialized processes may include High temperature processes: Smelting, pyro-metallurgical processes / Very strong chemicals: hydro-metallurgical processing by acids or cyanides Examples: o Circuit Boards: Copper Recovery > Specialized refining of Residues to recover other metals o Engineered Thermoplastics: Size Reduction > Granulation Examples of treatment options for hazardous fractions: o Mercury containing components > recovery o Batteries and accumulators > recovery (non-recoverable batteries treatment, recycling and disposal as hazardous waste) o PCB-capacitors > thermal treatment o Electrolyte capacitors > recovery or thermal treatment o Printed circuit boards with components > dismantling of components or thermal treatment o Picture tube coatings and screen coatings resp. glass parts and broken glass with screen coatings > treatment, recycling and disposal as hazardous waste o Liquid crystal displays > treatment, recycling and disposal as hazardous waste
5. Disposal / Recycle/Other Options	5A: Re-sale / Re-Use Product from 4C.	[1] Evaluation of the final product value [2] Setting-up a sales criteria / Issue of tenders [3] Vendor identification [4] Inspection of the vendor processing/product refurbishing facility/ Potential business plan [5] Shortlisting and entering legal agreement on sales and dispatch.

	5B: Waste to Energy (WTE) and Others	[1] Qualitative and Quantitative Checks on end-components batches. [2] Technical Evaluation and Sorting [3] Process feeding [4] Disposal of Residue

Note: *The stages are defined based on consultations with stakeholders*

Chapter 7
Occupational Mapping

Occupational Map



List of Job Roles in Occupational Map

Administrative / HR/Leadership	**Designation**	**NSQF Level**
	E-waste entrepreneur	9-10
	DGM (Admin/HR)	8
	Manager (Admin/HR)	6-7
	Compliance Officer- E waste	5
	Executive-Admin	1-3
Customer Relationship	**Designation**	**NSQF Level**
	DGM (Admin/HR)	8
	Manager (Admin/HR)	6-7
	Compliance Officer- E waste	5
	Executive-Admin	1-3
Supply Chain / Product Purchase /Procurement	**Designation**	**NSQF Level**
	DGM (Supply Chain Management (SCM))	8
	Procurement Manager	6-7
	Manager (SCM/Logistics)	6-7
	Executive-Finance	5
	Executive-Technical	5
	Supervisor-Logistics	5
	Assessor-Product Value	4
	Assessor-Product Quality	4
	Contractor 1: Collection and Transportation-ICT /Personal Devices	3
	Contractor 2: Collection and Transportation-White /Brown goods	3
	Contractor 3: Collection and Transportation-CFL/Fluorescent tubes etc.	3
	E Waste collector & Segregator	1-2
Operations	**Designation**	**NSQF Level**
	GM (Operations)	9
	DGM (Operations)	8
	Material Recovery Specialists	7
	ICT/Personal Devices Recycling Entrepreneur	7
	Manager (Dismantling)	6
	Manager (Material Handling)	6
	Supervisor (Dismantling)	5

	Supervisor (Material Handling)	5
	Supervisor (Smelting & Refining)	5
	Operator (Mechanical Dismantling)	4
	Operator (Conveyor)	4
	Operator (Smelter)	4
	Dismantlers	1-3
	Sorters (E Waste Segregators)	1-3
	Loader	1-3
Quality Assurance and Quality Control	**Designation**	**NSQF Level**
	DGM (QA/QC)	8
	Manager (QA/QC)	6-7
	Supervisor (QA/QC)	5
	Equipment Testers	4

References

1. Richard Heeks, Logakanthi Subramanian & Carys Jones. Understanding e-Waste Management in Developing Countries: Strategies, Determinants, and Policy Implications in the Indian ICT Sector. Information Technology for Development 2015; 21:4; 653-667.
2. M. Premalatha, Tabassum-Abbasi, Tasneem Abbasi & S. A. Abbasi. The Generation, Impact, and Management of E-Waste: State of the Art. Critical Reviews in Environmental Science and Technology 2014; 44:14, 1577-1678.
3. Pooja Pandey & Madhav Govind. Social repercussions of e-waste management in India: a study of three informal recycling sites in Delhi. International Journal of Environmental Studies 2014; 71:3, 241-260.
4. Sushant B. Wath, P.S. Dutt, Tapan Chakrabarti. E Waste scenario in India: Its Management and Implications. Environ Monit Assess 2011; 172:249–262.
5. Pia Tanskanen. Management and recycling of electronic waste. Acta Materialia 2013; 61:1001-1011.
6. Mahesh C. Vats, Santosh K. Singh. Status of E Waste in India-A Review. International Journal of Innovative Research in Science, Engineering and Technology 2014; Volume 3, Issue 10.
7. Kausar Jahan Ara Begum. Electronic waste (E-Waste) Management in India: A Review. IOSR Journal of Humanities and Social Science 2013; Volume 10, Issue 4.
8. Rolf Widmer, Heidi Oswald-Krapf, Deepali Sinha-Khetriwal, Max Schnellmann, Heinz Bőni. Global perspectives on e-Waste. Environmental Impact Assessment Review 2005; 25: 436-458.
9. Maheshwar Dwivedy, R.K. Mittal. Estimation of future outflows of e-waste in India. Waste Management 2010; 30:483-491.
10. Suthipong Sthiannopkao, Ming Hung Wong. Handling e-waste in developed and developing countries: Initiatives, practices and consequences. Science of the Total Environment 2013; 463-464:1147-1153.
11. Sushant B. Wath, Atul N. Vaidya, P.S. Dutt, Tapan Chakrabarti. A roadmap for development of sustainable e-waste management system in India. Science of the Total Environment 2010; 409: 19-32.
12. Martin Streicher-Porte, Rolf Widmer, Amit Jain, Hans-Peter Bader, Ruth Scheidegger, Susanne Kytzia. Key drivers of the e-waste recycling system: Assessing and modelling e-waste processing in the informal sector in Delhi. Environmental Impact Assessment Review 2005; 25; 472-491.
13. Devin N. Perkins , Marie-Noel Brune Drisse, Tapiwa Nxele and Pater D. Sly. E-Waste: A Global Hazard. Icahn School of Medicine at Mount Sinai. Annals of Global Health 2014; 80: 286-295.
14. Shelly De. The Role of informal Economy in Management of E-Waste in Kolkata. International Journal of Advance and Innovative Research 2015; Volume II, Issue 2 (II).
15. J. Hazra, Abhijit Sarkar, Vishal Sharma. Article: E-Waste Supply Chain in India: Opportunities and Challenges. IIM-Bangalore. Link: http://tejas.iimb.ac.in/articles/87.php.
16. Mahesh C. Vats, Santosh K. Singh. Status of E-Waste in India –A Review. International Journal of Innovative Research in Science and Technology 2014; Volume 3, Issue 10.
17. UNEP. Assessment Manual E–Waste-Volume-I: Inventory Assessment Manual, E-Waste Volume-II: Management Manual, E-Waste-Volume-III: WEEE/E-waste “Take Back System” 2007.
18. UNEP. Basel Convention-Revised guidance document on the environmentally sound management of used and end-of-life computing equipment (PACE) 2013.
19. United Nations University. White Paper-Solving the e-waste problem (StEP), Recommendations for standards, Development for Collection, Storage, Transport and Treatment of E-Waste 2014.
20. United Nations University. Publication-The Global E-Waste Monitor-Quantities, Flow, Resources 2014.
21. E-Waste (Management) Rules, 2015. Ministry of Environment and Forests, India.
22. Waste Electrical and Electronic Equipment (WEEE) Directive (2002/96/EC) of European Union (EU).
23. Basel Convention on the Control of Trans-boundary movement of hazardous wastes and their Disposal, 1989.
24. Waste to Wealth, ASSOCHAM, Ministry of New and Renewable Energy, QCI
25. NRDC Report. From Waste to Jobs 2014.
26. UNEP, StEP. “Sustainable Innovation and Technology Transfer Industrial Sector Studies, Recycling-From E-waste to Resources”; 2009.

Annexure A

Occupational Map