Environmental Research & Technology, Vol. 1(1), pp. 14-22, 2018

Turkish JournalPark ACADEMIC

Environmental Research & Technology

http://dergipark.gov.tr/ert

RESEARCH ARTICLE

Sub optimal e-waste management and the lost opportunity

Rakesh Tyagi [1], Priyanka Kaushal[2,*]

[1] Kampak Energy Solutions, 4515 Varsity Drive (NW), Calgary, Alberta T3A0Z8, CANADA
[2] Department of Energy and Environment, TERI University, 10, Institutional Area, Vasant Kunj, New Delhi 110070, INDIA

ABSTRACT

Electronic waste or e-waste is the waste generated from discarded and end of life electronic items. In recent times with change in lifestyle and improved purchasing capacity of people has accelerated the demand of new and improved electronic items, quick technology obsolescence,as a consequence the generation of e-waste has seen a huge rise. In year 2016, globally 93.5 tons of e-waste was generated, India, one of the leading producers of e-waste, produced 1.65 Milliontones of e-waste. Apart from domestic generation, a huge chunk of global e-waste was also dumped in India. 90 % of the e-waste is handled and managed by the unorganized sector. Hence there is a dire need to develop a mechanism to handle the enormous flux of e-waste in India.In this paper the e-waste sector has been reviewed. Also a detailed analysis of the material flow in the e-waste sector has been done. Results reveal that if mismanaged, e-waste can impose huge environmental penalty, however if it is regulated and handled scientifically it can become an asset for resource recovery whose carbon footprint is 70-80 % lower than its primary production.

Keywords: E-waste generation, stakeholders, policies, emission reduction

1. INTRODUCTION

With the arrival of new technology, growing income and change in lifestyle the rate of generation of e-waste has seen a steep rise, and this is a global phenomenon now. In year 2014 the world produced 41.8 Million tons of e-waste [1]. And it is expected to reach 130 million tons in 2018 from 93.5 million tons in 2016 [2].It is one of the fastest growing sectors in the world. India is the seventh-largest country and its population stands at 1.25 billion and is experiencing an annual growth rate of 1.2 per cent. In 2015, India's GDP was valued more than 2 trillion USD [3]. The demand for electronic products and systems in the country is estimated to reach US$ 400 billion by 2020 [4]. The estimated production will reach USD 104 billion by the year 2020, creating a gap of USD 296 billion in demand and production. This creates a unique market opportunity for businesses to look at India to cater to the domestic demand as well as act as an export-hub. As the demand for electronic products goes up, so will the generation of electronic waste. Electronic waste or e-waste or Waste Electrical and Electronic Equipment (WEEE) is the term used to describe old, end-of-life or discarded appliances using electricity as shown in Fig 1, it includes computers, mobile phones, television, refrigerator, air conditioner, medical equipment, printer, scanners etc. [5]. There are more than 1000 toxic substances [6] associated with e-waste, the more commonly reported substances are categorized in Table 1.

Table 1. E-waste material classification

Category	Material	Potential Environmental Impact
Hazardous	Cd, Cr, Pb, Hg CFCs, PAHs, PBDEs, PCDD/Fs	Negative
Non-hazardous	Cu, Se, Zn, Ag, Au, and Pt	Negative

India is witnessing a rapidly growth in the consumption of electrical and electronic products. This, accompanied with high obsolescence rates, has led to higher rates of e-waste generation. The Indian manufacturing segment alone contributed 110 million mobile devices during FY 2015-16, from 60 million in FY 2014-15, i.e. an increase of more than 80 % in a

Corresponding Author: priyanka.kaushal@teriuniversity.ac.in (Priyanka Kaushal)
Received 10 April 2017; Received in revised form 18 April 2017; Accepted 18 April 2017
Available Online 1 January 2018
Doi: ISSN:

year time [7]. Studies suggest that as much as 80% of the e-waste generated in developed countries sneaks into the grey market of developing countries like India, Bangladesh etc. [8]. In year 2014, e-waste produced, domestically, in India was 1.641 Mt [9] e-waste handling is a problem of increasing proportion, especially when crude methods are adopted for recovery of useful components from it. Literature suggests that the contamination due to the recycling of electronic waste in China and India is 80% higher than the rest of the world [10].

Fig 1. E-waste equipment in India

The impact of mismanagement of e-waste in India is reported in detail in the literature [11]. Fig 2 and Fig 3 show the sectorial contribution and the projection for e-waste generation in India.

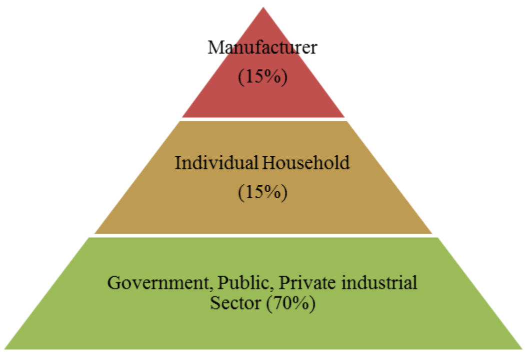

Fig 2. Pyramid form showing sector's share in e-waste in India

With government of India migrating towards e-initiatives, where in the idea is to digitize the services the rate of volume of e-waste in this sector has gone up considerably.

2. E-WASTE IN INDIA

India's approach to manage waste is based on the following principles: (a) precaution i.e. economic develop but no damage to environmental (b) Penalty i.e. polluter must bear the costs for the environmental damages. The journey and major milestones India has achieved in order to manage waste is as follows.

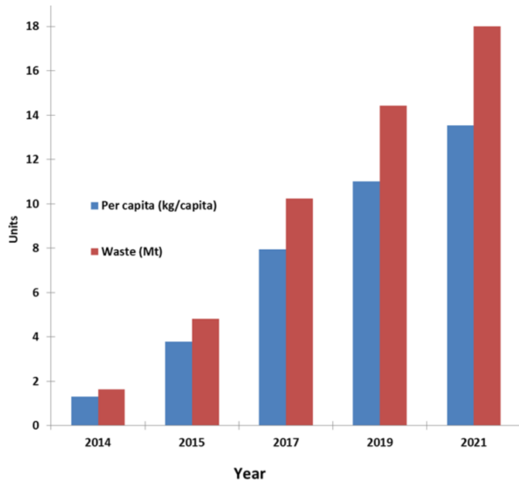

Fig 3. E-waste generation in India

2.1. *Policy & Regulation*

In 1986, The Environment (Protection) Act 1986 was passed by an Act of the Parliament of India. The purpose of the Act was to implement the decisions of the United Nations Conference on the Human Environments [12]. In 2006 came, The National Environment Policy. This policy was more comprehensive; it encompassed Legal Liabilities, Legislative Reforms, and Environment Impact Assessment. It also talked about the threats due to genetically modified organisms, challenges of Coastal regions and environmentally sensitive area. In 1989, came The Hazardous Wastes (Management and Handling) Rules. This was a document that laid down the foundation to deal with the hazardous wastes. It identified the various central and state players like MOEF, CPCB, PCC etc. and their corresponding duties and responsibilities. The rules are notified to ensure safe handling, processing, treatment, package, storage, transportation, use, reprocessing, collection, conversion, destruction and disposal of Hazardous Waste. These Rules have been amended later in the years 2000, 2003 and 2008 [13]. This was followed by E-waste (management and handling rules), 2011; and E-waste (management) rules, 2016 [14] These policy and regulation encouraged reuse and recycling, established system for assortment and recycling of materials to recover resources, produce guidelines for Environmentally safe disposal of residues, put e-waste under hazardous waste, regulation for trans-boundary movement. Despite the regulations, e-waste is handled in pseudoscientific means that contaminates soil air and water [15]. Policy makers are proactive and routinely revise and update the rules and regulations. To this end, GoI, under E-waste (Management) Rules, 2016, has, additionally brought under its horizon the management of the waste generated from disposal of different mercury containing lamps. Though the responsibility to implement these rules lies with the state governments, new economic instruments such as `exchange' and `deposit refund' can act as incentives for consumers to adopt the waste management strategies.

Waste management policy formulation and regulation is a work in progress and is evolving. Though the new rules have laid down the responsibilities of various stakeholders in clear terms it has not included the informal sector, a sector that handles more than 95 per cent of e-waste generated in the country. It is essential that any long-term policy on e-waste integrates the informal sector by including them under the stakeholder-umbrella and then slowly faze them out by integrating them into the mainstream.

2.2. E-Waste Handling

The main stakeholders in e-waste management are the manufacturers, distributors, importers, consumers, collectors, recyclers, policy makers and policy implementers.

The informal sector, also known as unorganized sector, is part of a very well-organized hierarchy and structure, as elaborated in various studies and reports [16]. It is interesting to view this structure and understand the waste flows. The waste collectors locally known as "kabadiwalas" are the most important link in this waste flow and are responsible for the collection of waste from all consumers and manufacturers [17]. There is another set of operators, waste traders with better financial capacity, who bid for larger volumes of waste being discarded by companies and organization through auctions. The waste then flows down to scrap dealers, who recovers the functional component and then pass on the remaining waste to the dismantlers. It is here that the waste is further separated and then broken down to individual components and materials. The waste then finally reaches the recycler by materials as glass, plastics, metal and circuit boards for material recovery. The recyclers in a particular cluster are generally engaged in a specific set of activities and operations. For other equipment like refrigerators, washing machines or air conditioners, the segregation is more material-based and plastic and metal parts are separated and treated in specific streams. Some useful components such as power supplies or motors are taken out for further use if possible. Since most electronic and electrical products have a value at the end of their useful life, the informal sector is able to pay the consumer to acquire this waste. The formal sector, because of its larger infrastructure and operational costs, finds it hard to compete with the informal sector.

In case of large companies and PSUs, the flow is a little different. As the quantity is large and auctioned through tenders to highest bidders, only waste dealers with large financial capacities can participate in this trade. At times the dealers jointly bid for the scrap and share the total waste among them for further processing. Most dismantling and recycling units are owned by individuals who make good profit, but the workers employed in these facilities earn less than minimum wages.

2.3. Informal Sector

The processing of e-waste in India is largely carried out in an informal backyard setup, which is unregulated and does not follow the prescribed environmental norms for handling hazardous substances [11]. Some of the processes and activities practiced by the informal sector have serious environment and social impacts (use of toxic chemicals, poor working conditions, child labor, etc.). The recycling chain of e-waste consists of two sets of processes, as shown in Fig 4, one being dismantling and segregation of components and the other being material recovery.

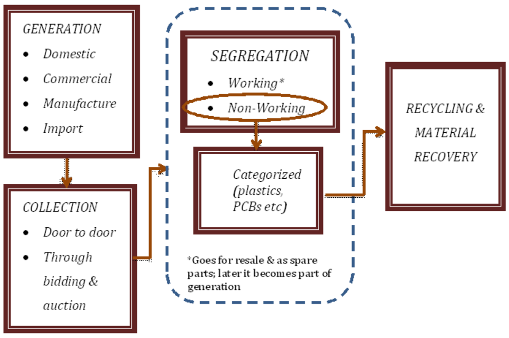

Fig 4. Waste flow chain in India

The first stage of waste processing involves cannibalization of serviceable parts and refurbishment of components and products. All unserviceable components and products are then shifted to dismantlers. Individual products such as monitors, keyboards or CPUs are then dismantled and broken down to individual components using bare hands and basic tools such as hammers and screwdrivers. Blowtorches and heaters are used to loosen solders to remove the components attached to the circuit boards. Printed circuit boards are placed directly above the heaters, allowing the solder to melt and drop. The process of dismantling is carried out in unventilated rooms without any semblance of housekeeping or concern for occupational health. These segregated components are sorted by their material composition and then shifted for material recovery. 95% of e-waste is handled by informal sector. And this is alarming. The informal sector uses primitive [18]. All these processes cause environmental degradation and sickness to the poorly paid employees. With the alarmed rate of rise of e-waste in India, correct formal handling and registered recyclers have become the highest priority for the country. In India most of the e-waste utilization facilities are registered with Central Pollution Control Board (CPCB). As on 2015, 149 recycling units were registered with CPCB, their cumulative capacities as shown in Fig 5 and Fig 6, is around 410,000 MTA.

3. E-WASTE & RESOURCE RECOVERY

Industries are growing at a rapid pace and so are the emissions related to it. Mining industry-extracting metals from their ores and processing it, is energy-intensive and generate significant direct greenhouse emission (GHG) emissions, together with carbon dioxide. Environmental impacts will be impaired because it becomes tougher to extract metals and minerals. Also rising fuel prices, water constraints, and environmental regulation can place downward pressure on profit margins in this trade. Mining metals like iron and copper is energy-intensive, requiring six fold additional energy to supply every ton of metal in comparison to mining industrial materials like phosphate, stone, sand, and gravel [19, 20].

1, 00,000 MTA – 50,000 MTA   20,000 MTA – 10,000 MTA
50,000 MTA – 20,000 MTA   10,000 MTA – 500 MTA

Fig 5. States with registered recycler under CPCB in year 2015

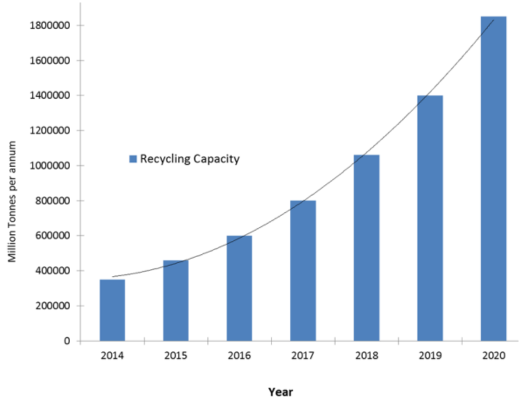

Fig 6. Recycling capacity of registered recyclers in India

Electronic waste products mainly contain a thin deposit of a metal on a substrate [21]. As a whole, electronic waste consists of:

1. Plastics: (C-H-O polymers like polyesters, polyethylene, polycarbonates),
2. Metals: classified further as base metals and precious metals. Copper, Iron, Zinc, Aluminum, Tin, Lead, Nickel are the base metals. The precious metals are Gold, Silver and Palladium.
3. Refractory oxides: silica, alumina, alkaline and alkaline earth oxides.

Market penetration, replacement market and high obsolescence rate makes e-waste one of the fastest growing waste streams globally [13]. This new kind of waste is posing a serious challenge in its disposal and recycling. The dumping of e-waste, particularly computer waste, into India from developed countries, primarily because of economic benefits, has further complicated the problems with waste management in India [22].

Studies so far reveal that the e-waste generation in India in 2015 is approximately 1.67 million tones .The projected growth for e-waste generation for India is about 34% per annum [23]. Besides the domestic e-waste generated, an additional 50,000 MT a year is illegally imported into the country [24]. Fig 7 has mapped the global source and dump sites for e-waste.

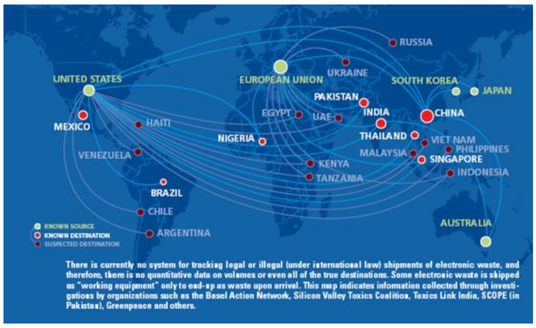

Fig 7. Known and suspected route for e-waste dumping
Source: BASEL ACTION NETWORK; UNEP

3.1. Emission Reduction Potentials from e-waste

As a consequence of continuous modifications of function and design of EEE, WEEE is a highly heterogeneous mix of materials. The precious metals are mainly found in printed circuit boards (PCBs). The concentration of precious metals in PCBs is usually much higher than their ores. Mined ores for the extraction of gold and palladium contain less than 10 g t^{-1} of precious metals where as in PCB it is 250 g t^{-1} & 110 g t^{-1} for gold and palladium respectively [25]. Hence the temptation to recover precious and expensive metals from electronic waste becomes obvious. Also mining by its very virtue is complex (it involves land acquisition, resettlement etc.) and has upfront negative environmental impacts. The environmental impacts of the secondary production in state-of-the-art operations are much lower than primary production [26]. Besides environmental protection and legislative pressure, recycling also serves the economic interests. Precious metals contribute to more than 80% of the materials' market value of obsolete personal computers, despite their small quantity [27]. Secondly, the limited availability of precious metals reserves provides additional impetus to improve the recovery of precious metals from WEEE [28].

4. MATERIALS AND METHOD

Waste, especially e-waste is a new form of waste. As reported earlier, 95% of e-waste (includes both domestic production and international dumps) in India are handled by informal sector and as of now, no information, particularly on e-waste is captured in any of the national surveys. However to generate data and to understand the system, the research team has visited and interviewed the owner (proprietor) and the workforce in the e-waste handling clusters in Delhi only. The informal sector is very well aware of the fact that the work carried out in their backyard is not legal they were reluctant for any interaction let alone information, However after repeated visit and networking some confidence was established before they shared information with us. The information, is called primary data in the study, was not complete for analysis purposes. To bridge the missing information secondary sources of data like newspaper articles, journal articles, open source data, were extracted. With this an attempt has been made to formulate an inventory of metals and plastic content in consumer electronic waste i.e. for television, mobile phone and personal computer. These items are the fastest growing sector in India as shown in Fig 8.

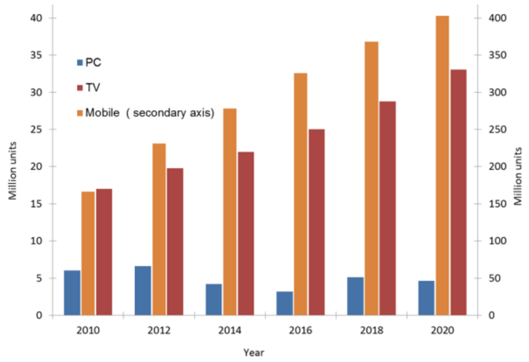

Fig 8. Growth of consumer electronic in India [29]

In India market penetration rate for TV is, 3 times of refrigerator, and an order of magnitude higher than other consumer electronics like AC or washing machine. As on 2016, India had 1250 million populations and it had around 330 million mobile phones. In the consumer electronic category, mobile phones, TV and PC together hold more than 85 % sales [29]. They also hold the highest rate of discard probability [1]. Therefore this study is limited to these three product category only.

Emission reduction calculation is done as per the general guidelines for the selected small scale (SSC) clean development mechanism (CDM) methodologies given by UNFCCC. Fig 9 is the schematic of the methodology.

4.1. UNFCCC methodology

Emission reduction was estimated by calculating the difference between

(i) the energy used for production of metals and plastics from virgin materials (i.e. baseline emission)
(ii) the production of the same metals and plastics from e-waste recycling(i.e. Project activity emission)

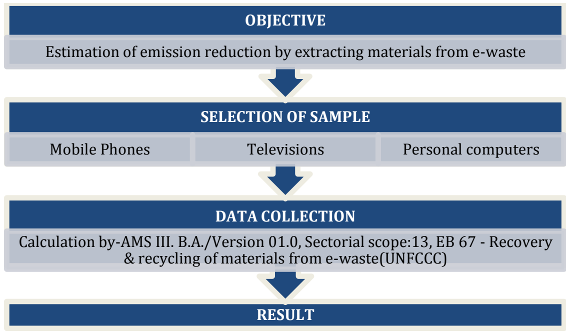

Fig 9. Methodology for Emission reduction calculation [30]

The baseline emissions were calculated using following equations;

$$BE_y = BE_{m,y} + BE_{p,y} \quad (1)$$

$$BE_{m,y} = \sum_i (Q_{i,y} * B_i * SE_i) \quad (2)$$

$$BE_{p,y} = \sum_i (Q_{i,y} * L_{p,i} * B_i * (SEC_{Bl,i} * EF_{el,y} + SFC_{Bl,i} * EF_{FF,CO2}) \quad (3)$$

The project activity emissions were calculated using following equations;

$$PE_y = PE_{r,y} + PE_{p,y} \quad (4)$$

$$PE_{r,y} = \sum_i (EC_{i,y} * EF_{el,y} + FC_{i,y} * NCV_{rec,ff,y} * EF_{rec,ff,CO2,y}) \quad (5)$$

$$EC_{i,y} = EC_y * \frac{Q_{i,y} * \$_{i,y}}{\sum_r Q_{r,y} * \$_{r,y}} \quad (6)$$

$$FC_{i,y} = FC_y * \frac{Q_{i,y} * \$_{i,y}}{\sum_r Q_{r,y} * \$_{r,y}} \quad (7)$$

$$PE_{p,y} = \sum_i (Q_{i,y} * EFP_i * EF_{el,y}) \quad (8)$$

$$ER_y = BE_y - PE_y - LE_y \quad (9)$$

It was also assumed that there was no leakage due to the project activity. The details of the methodology are given elsewhere [31].

5. RESULTS & DISCUSSION

Suboptimal management: For efficient management of e-waste the whole trade chain must be acutely monitored and the responsibilities should be distributed among all the stakeholders, as illustrated in Fig 10.

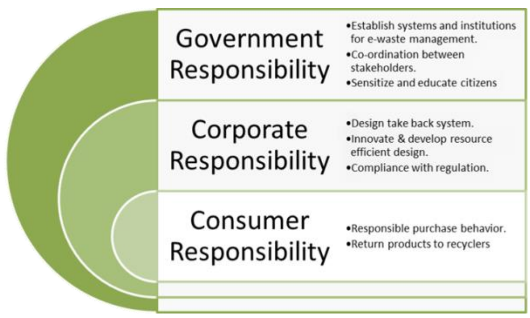

Fig 10. Stakeholder participation in e-waste management

Lack of infrastructure capacity: Even though the recycling rate of the CPCB registered recyclers are growing but it can be clearly projected that by the year 2020, the percentage of recycled e-waste is very negligible (Fig 11). This also highlight that the government policy and initiatives are not in sync with the realities. India would face rising environmental damage and health problems if e-waste recycling is left to the vagaries of the informal sector. The lack is in the infrastructural facility only; there is no dearth of experienced human resource. This is also an opportunity to mainstream the workforce, who is currently engaged in the illegal informal sector. They have the experience and skillset to take up. With little training they will integrate seamlessly in to the formal sector of e-waste recycling.

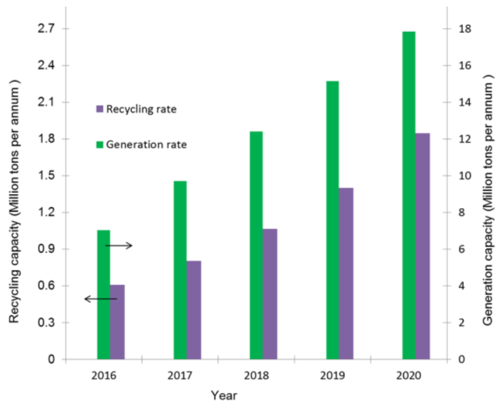

Fig 11. Generation and recycling rate of recyclers in India

Emission reduction: As shown in Fig 12, if India had managed (or is willing to manage), its e-waste efficiently and extracted metals from top three contributor of e-waste (i.e. mobile phones, desktop and television) in FY year 2015/16 then the emission reduced would have been 1.1 million tons of CO_2 equivalent. As shown in the Figure, the emission reduction potentials are also increasing at a CAGR of 14-15 %.

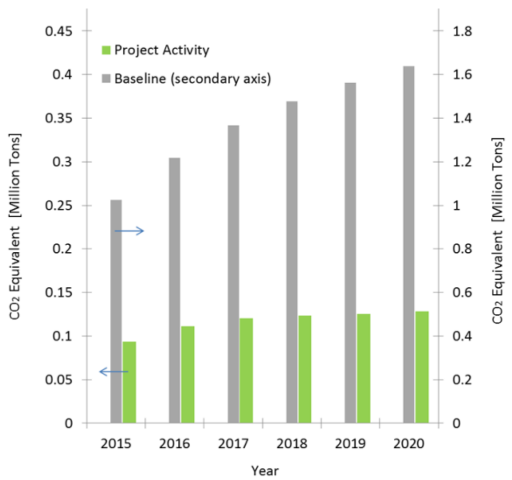

Fig 12. Emission reduction potentials by extracting materials from e-waste in India

5.1. Challenges

In India, few immediate challenges and concern in the e-waste sector are as follows:

Fast growing stream: A UN-report predicted that by 2020, e-waste from old computers only would jump by 500 per cent on 2007 levels in India and e-waste from discarded mobile phones would be about 18 times higher than 2007 levels [18]. Hence, there is an urgent need for strategic planning for handing and management of e-waste in India. Also, the rules, regulations and laws, that govern the e-waste sector, that are very well documented need to be practiced.

Hazardous materials: If not handled safely the hazardous e-waste will leak into the eco-system; they have very high carcinogenic potency. For example, mercury from electronics has been cited as a leading source of mercury in municipal waste [32]. Similarly, brominated flame retardants that are commonly added to plastics used in electronics, if not handled safely, they release toxic fumes during incineration; and post combustion if the ash is dumped either at landfill site or otherwise it contaminates the ground water.

Data Security: It is also very important that agencies engaged in the e-waste management do not have facilities to access the data (if any) in the e-waste. Data storage devices and media contain critical personal, financial, legal, technical, operational, and classified information. Though it is the prime responsibility of the consumer to sanitize the goods before discarding, however, it is rational to have second level of data security too.

Feedback mechanism: On the national or state level, the government currently has no mechanism or information management system to determine the number or volume of equipment put into the market. Similarly, there is no data or information about the e-waste. For planning purposes all data is generated on normative basis. Currently e-waste is dealt by the informal sector. In the absence of any information management system for the informal sector, the e-waste flow goes unreported. There is no legitimate source of primary data available on the quantity collected, re-used, refurbished and recycled in the informal sector. There is a critical requirement to develop an information management system to track e-waste flows along the value chain for its sound management. The problem of imported e-waste is another threat.

5.2. Way forward:

Merger of formal and informal sectors: The informal and formals sector needs to be integrated. The collection and the physical sorting of e-waste can be done by the informal sector and post segregation the e-waste should be passed on to the formal facility for recycling and resource recovery (Fig 13). It is also important to monitor and ensure the performance of the unit adheres to the resource recycling and recovery guidelines.

Some ways by which e-waste management can be improvised are:

Improved efficiencies: On a holistic level one way to reduce waste is to "generate less waste". Therefore Indian industries engaged in manufacturing should move to 'precautionary principle' by employing waste minimization techniques and by a sustainable product and service design. Globally this concept is receiving lots of attention of late [33, 34].

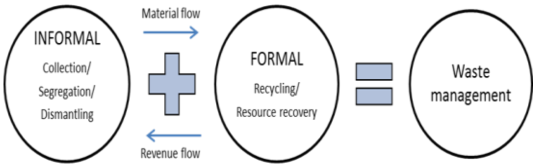

Fig 13. Proposed e-waste management model

Awareness and sensitization: The current awareness regarding the existence and dangers of e-waste are extremely low, partly because the e-waste being generated is not as large as MSW and hence public as a whole do not perceive it as a menace. Secondly, the consumer has no information about the recycling and resource recovery potential in the electronic goods they possess. They are equally unaware of the impacts it might bring to environment if the electronic waste is not disposed of scientifically. Urgent measures are required to address this issue. To this end it is important that the agencies involved in waste management should plan sensitization activities.

6. CONCLUSIONS

Despite positive outcomes, the reins of e-waste handling and management, in India, is in the hands of informal sectors and it is limited to (1) insufficient collection (2) nonscientific resource recovery (3) passive participation from implementation agencies and (4) illegal import of e-waste from the developed economies. All together they pose serious health risks to human and environment. India needs urgent approach to manage e-waste by technical and policy-level interventions and implementation. Data analysis also showed that India should build infrastructural capacities to handle high flux of e-waste in near future. Secondly, the country is committed to scale down its emissions intensity per unit GDP by 33% to 35 % below 2005 by 2030. With the tons of emission reduction by extracting materials from e-waste, it will contribute constructively to achieve the emission reduction target.

ACKNOWLEDGEMENT

The authors would like to thank TERI University for the support.

LIST OF ABBREVIATIONS

AC	Air Conditioner
CAGR	Compounded Annual Growth Rate
CDM	Clean Development Mechanism
CFCs	Chloro Fluoro Carbons
CPCB	Central Pollution Control Board
CPU	Central Processing Unit
EEE	Electrical and Electronic Equipment
FY	Financial Year
GDP	Gross Domestic Product
GHG	Green House Gas
GoI	Government of India
MTA	Metric Tons Annually
MOEF	Ministry of Environment and Forestry
PAH	Poly Aromatic Hydrocarbon
PBDE	Poly Brominated Diphenyl Ethers
PC	Personal Computer
PCBs	Printed circuit Board
PCC	Pollution Control Committee
PCDD	Poly Chlorinated Dibenzo Dioxins
PSUs	Public Sector Undertakings
SSC	Selected Small Scale
TV	Television
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USD	US Dollar
WEEE	Waste Electrical and Electronic Equipment

REFERENCES

[1]. M. Abbas, "Web page on The Economics Times", [online]. Available: http://economictimes.indiatimes.com/industry/telecom/mobile-phones-among-most-dangerous-e-waste-contributors-assocham/articleshow/52570256.cms. 2016

[2]. C.P. Baldé, F. Wang, R. Kuehr and J. Huisman, "The global e-waste monitor – 2014", 1st Ed., Bonn, Germany: United Nations University, Available: https://i.unu.edu/media/unu.edu/news/52624/UNU-1stGlobal-E-Waste-Monitor-2014-small.pdf. 2015.

[3]. S.Haridas, "Confedration of Indian Industries SME Policy Roundtable on "Emerging Business Opportunities for Indian MSMEs in Electronic System Design and Manufacturing (ESDM) Sector" – *Confedration of Indian Industries*, Discussion Document, 2015.

[4]. World Bank, Web page on The World Bank. [online] Available: http://www.worldbank.org/en/country/india, 2016.

[5]. C.H. Lee, S.L. Chang, K.M. Wang and L.C. Wen, "Management of scrap computer recycling in Taiwan," *Journal of Hazardous Materials*, Vol. 37(3), pp. 209-220, 2000

[6]. J. Puckett and T. Smith, "Exporting harm the high-tech trashing of Asia," *In: Coalition, The Basel Action Network (BAN) & Silicon Valley Toxics Coalition (SVT)*, Available: http://svtc.org/wp-content/uploads/technotrash.pdf, 2002.

[7]. ASSOCHAM, "India`s e-waste growing at 30% per annum,": *ASSOCHAM-cKinetics study,* Available: http://www.assocham.org/newsdetail.php?id=5725. 2016.

[8]. UNEP, *Web page on United Nations Environment Programme*. [Online] Available: http://www.grid.unep.ch/products/3_Reports/ew_ewaste.en.pdf, 2005.

[9]. R. Agarwal and A. N. Mullick, "E-WASTE management in India-The corporate Imperative," *YES BANK-TERI BCSD Report*. Available: http://cbs.teriin.org/pdf/researchreports/EWasteManagementReport.pdf, 2014.

[10]. K. Brigden, I. Labunska, D. Santillo, and M. Allsopp, "Recycling of electronic wastes. In: China and India," *Greenpeace Research Laboratories, University of Exeter, UK. Technical Note 09/2005 (section 1)* Available: http://www.greenpeace.org/austria/Global/austria/marktcheck/uploads/media/report_recycling_electronic_waste_2005.pdf. 2005.

[11]. M.N. Mundada, S. Kumar and A.V. Shekdar, "E-waste: a new challenge for waste management in India," *International Journal of Environmental Studies*. Vol. 61 (3), pp. 265-279, 2004

[12]. UN Report, "Report on the United Nations Conference On The Human Environment," Stockholm. A/CONF.48/Rev.1, 1972 Available: http://www.un-documents.net/aconf48-14r1.pdf.

[13]. CPCB. Hazardous Waste Web page on CPCB. [online]. Available: http://cpcb.nic.in/Hazardous_waste.php, 2016.

[14]. B.Sinha.. Government of India, Notification webpage on MOEF. Available: http://www.moef.gov.in/sites/default/files/EWM%20Rules%202016%20english%2023.03.2016.pdf. 2016.

[15]. S. Chatterjee, and K. Kumar, "Effective electronic waste management and recycling process involving formal and non-formal sectors," *International Journal of Physical Sciences*, Vol. 4 (13), pp. 893-905, 2009

[16]. M. Dwivedy and R.K. Mittal, "An investigation into e-waste flows in India," *Journal of Cleaner Production*, Vol. 37, pp. 229-242, 2012.

[17]. S. Sinha, P. Mahesh, E. Donders, W. Van Breusegem, "Waste electrical and electronic equipment. The EU and India: sharing best practices," J. Bentinck, P.R. Holmes and S. Das, Ed. Available : http://eeas.europa.eu/archives/delegations/india/documents/eu_india/final_e_waste_book_en.pdf, India, 2011.

[18]. Rajya Sabha Secretariat, E-waste in India webpage on Rajyasabha. [Online]. Available: http://rajyasabha.nic.in/rsnew/publication_electronic/E-Waste_in_india.pdf, 2011.

[19]. SASB. Research Brief on Metals and Mining webpage on SASB. [Online]. Available: http://www.sasb.org/wp-content/uploads/2014/06/NR0302_MetalsMining_2014_06_24_Industry_Brief.pdf, 2014.

[20]. M. Fischedick, J. Roy, A. Abdel-Aziz, A. Acquaye, J.M. Allwood,J.P. Ceron, Y. Geng, H. Kheshgi, A. Lanza,D. Perczyk, L. Price, E. Santalla, C. Sheinbaum, K. Tanaka. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2014

[21]. UNIDO, "Guidance on best available techniques and best environmental practices for the recycling and disposal of articles containing polybrominated diphenyl ethers (PBDEs) listed under the Stockholm Convention on Persistent Organic Pollutants," Available: https://www.unido.org/fileadmin/user_media/Services/Environmental_Management/Stockholm_Convention/Guidance_Docs/UNEP-POPS-GUID-NIP-2012-BATBEPPBDEs.En.pdf, 2012.

[22]. K.K. Wankhede Webpage on Toxiclink, Available: http://www.toxicslink.org/art-view.php?id=75. 2005.

[23]. A. Borthakur, "Generation and Management of Electronic Waste in India An Assessment from Stakeholders' Perspective," *Journal of Developing Societies*, Vol. 31(2), 220-248 , 2015.

[24]. V.N. Pinto, "E-waste hazard: The impending challenge," *Indian Journal of Occupational and Environmental Medicine*, Vol. 12(2), pp. 65–70, 2008.

[25]. P. Chancerel, C.E.M. Meskers, C. Hageluken and V.S. Rotter, "Assessment of Precious Metal Flows During Preprocessing of Waste Electrical and Electronic Equipment," *Journal of Industrial Ecology*, Vol. 13(5), pp. 791-810, 2009.

[26]. R.U. Ayres, "Metals recycling: economic and environmental implications," *Resources, Conservation and Recycling*, Vol. 21, pp. 145–173, 1997

[27]. M.S. Porte, R. Widmer, A. Jain, .H.P. Baderd, R. Scheidegger and S. Kytzia, "Key drivers of the e-scrap recycling system: Assessing and modelling e-scrap processing in the informal sector in Delhi," *Environmental Impact Assessment Review*, Vol. 25(5), 472-491, 2005.

[28]. S. Behrendt, M. Scharp, L. Erdmann, W. Kahlenborn, M. Feil, C. Dereje, R. Bleischwitz, R. Delzeit, "Rare Metals. Measures and Concepts for the Solution of the Problem of Conflict-Aggravating Raw Material Extraction – The Example of Coltan. Research," *Report 363 01 124. 2007. Federal Environmental Agency (Umweltsbundesamt)*, ISSN 1862-4804, 2007.

[29]. Ernst & Young, "Study on Indian electronics and consumer durables segment," Available: http://www.ey.com/Publication/vwLUAssets/EY-study-on-indian-electronics-and-consumer-durables/%24FILE/EY-study-on-indian-electronics-and-consumer-durables.pdf, 2015.

[30]. UNFCCC, "Indicative simplified baseline and monitoring methodologies for selected small-

scale CDM project activity categories," Available: https://cdm.unfccc.int/Panels/ssc_wg/meetings/036/ssc_036_an01.pdf, 2012.

[31]. UNFCCC, "General guidelines for ssc cdm methodologies," EB 69 Report, Annex 27. 2005. Available: https://cdm.unfccc.int/Reference/Guidclarif/ssc/methSSC_guid25.pdf, 2005.

[32]. H. Cheng and Y. Hu, "Mercury in Municipal Solid Waste in China and Its Control: A Review," *Environmental Science and Technology*, Vol. 46 (2), pp. 593–605, 2012

[33]. I. Bereketli, M.E. Genevois, and H.Z. Ulukan, "Green Product Design for Mobile Phones," *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering* , Vol. 3(10), pp. 1850-54, 2009

[34]. S. Edwards, "The Lowell Center Framework for Sustainable Products," Available: http://www.sustainableproduction.org/downloads/LowellCenterFrameworkforSustainableProducts11-09.09.pdf 2009.