

MAY 2016

# WEEE PLASTIC AND BROMINATED FLAME RETARDANTS

**A report on WEEE plastic recycling**



Toxics Link  
for a toxics-free world



## About Toxics Link

Toxics Link is an Indian environmental research and advocacy organization set up in 1996, engaged in disseminating information to help strengthen the campaign against toxics pollution, provide cleaner alternatives and bring together Groups and people affected by this problem. Toxics Link's Mission Statement - "Working together for environmental justice and freedom from toxics. We have taken upon ourselves to collect and share both information about the sources and the dangers of poisons in our environment and bodies, and information about clean and sustainable alternatives for India and the rest of the world"



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WRF is an independent non-profit international organization that serves as a platform connecting and fostering knowledge exchange on resources management amongst business leaders, policy-makers, NGOs, scientists and the public. ([www.wrforum.org](http://www.wrforum.org))



SRI builds capacity for sustainable recycling in developing countries. The programme is funded by the Swiss State Secretariat of Economic Affairs (SECO) and is implemented by the Institute for Materials Science & Technology (Empa), the World Resources Forum (WRF) and ecoinvent. It builds on the success of implementing e-waste recycling systems together with various developing countries since more than ten years. This report was written for the SRI country project in India, which addresses cross-contamination issues of recycled plastics with heavy metals and flame retardants. ([www.sustainable-recycling.org](http://www.sustainable-recycling.org))

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WEEE  
PLASTIC AND  
BROMINATED  
FLAME  
RETARDANTS

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**A report on WEEE plastic  
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# List of Abbreviations

ABS	Acrylonitrile butadiene styrene
BFR	Brominated Flame Retardant
BIS	Bureau of Indian Standards
CPCB	Central Pollution Control Board
EEE	Electrical and Electronic Equipment
EU	European Union
FR	Flame Retardant
HBCD	Hexabromocyclododecane
HIPS	High Impact Polystyrene
IT	Information technology
INR	Indian Rupee
Mt	Million Tonnes
NCR	National Capital Region
NGT	National Green Tribunal
OHS	Occupational Health & Safety
PBDE	Poly Brominated diphenyl ether
PC	Polycarbonate
PCB	Printed Circuit Board
PP	Polypropylene
PPE	Personal Protective Equipment
PPO	Poly (p-phenylene oxide)
PVC	Polyvinyl chloride
RoHS	Restriction of Hazardous Substances
TBBPA	Tetrabromobisphenol A
UNU	United Nations University
WEEE	Waste Electrical and Electronic Equipment

# Plastic recyc

*approx*

11 million  
tonne

*plastic consumption per year*



# lin g



## 1. Introduction

Plastic is one of the most used materials in the modern age. From toys to computers, from bottles to tanks, from pens to furniture, from clothes to vehicles, the list of products and processes where plastic is used is countless and still growing every day. It is also increasingly found in the environment due to inappropriate disposal and low to non-existent biodegradability. Plastic waste can be found in oceans, rivers, landfills, and roadsides etc., which causes pollution and contamination and poses risks to human health and the environment.

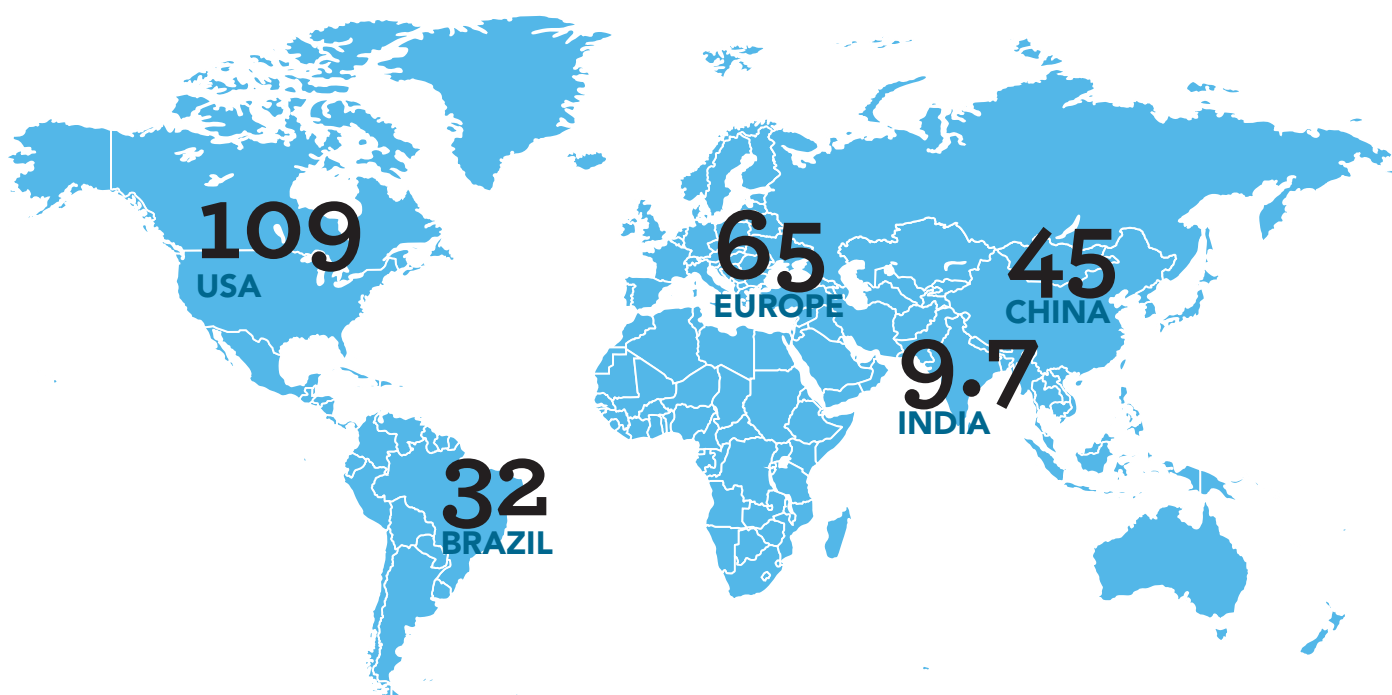
Plastics industry is one of the fastest growing industries in India. The country consumes about 11 million tonne plastic per year as against a global consumption of 275 million tonne per year<sup>1</sup>. However, a major challenge is in effective recycling of plastic waste which may contain many additives and contaminants. This report unravels such challenges and emphasises on the immediate need to have best practices and technology in place for safe and effective plastic waste recycling.

<sup>1</sup> Popular Plastics & Packaging; Dec 2013, Vol. 58 Issue 12, p14

## 1.1 Plastic use and waste in India

Worldwide, the plastics and polymer consumption is growing at an average rate of 10% per year. In India, the Plast India Foundation estimates that the demand for polymers will jump to 16.5 million metric tonnes by 2016-17, resulting in consumption rising by 10.8% per year<sup>2</sup>. India's per capita plastics consumption — estimated at 9.7 kilograms in 2012-13 — is far below the 109 kg level in the United States and 45 kg in China. Current per capita consumption level of plastic products in India as compared to developed countries suggests that their consumption will grow further.

**Figure 1: Per capita plastic consumption (kg/capita and year) in 2012-13<sup>3</sup>**



In India plastics waste is a significant portion of the total municipal solid waste. The Central Pollution Control Board (CPCB) estimates that 56 lakh tonnes of plastic waste is generated in India every year. Delhi contributes 2.5 lakh tonnes per year (689.5 tonnes/day). It is estimated that, out of the 15,342 tons of plastic wastes generated daily in India, about 60% are collected and recycled<sup>4</sup>, while the remaining fraction ends up in the environment.

Further, two main types of plastic polymers can be differentiated: Thermoplastic polymers soften when heated and can thus be mechanically recycled into new products. Thermoset polymers are irreversibly cured, they can only be ground and used as filler material. Thermoplastics, constitutes 80% and thermoset constitutes approximately 20% of total post-consumer plastics waste generated in India<sup>5</sup>. Most of this plastic is recycled in a crude manner in informal setups.

<sup>2</sup> [http://www.business-standard.com/content/b2b-chemicals/plastics-industry-to-witness-investments-of-10-billion-in-next-five-years-plastindia-113120200238\\_1.html](http://www.business-standard.com/content/b2b-chemicals/plastics-industry-to-witness-investments-of-10-billion-in-next-five-years-plastindia-113120200238_1.html)

<sup>3</sup> PlastIndia, Business Press, Research by Tata Strategic

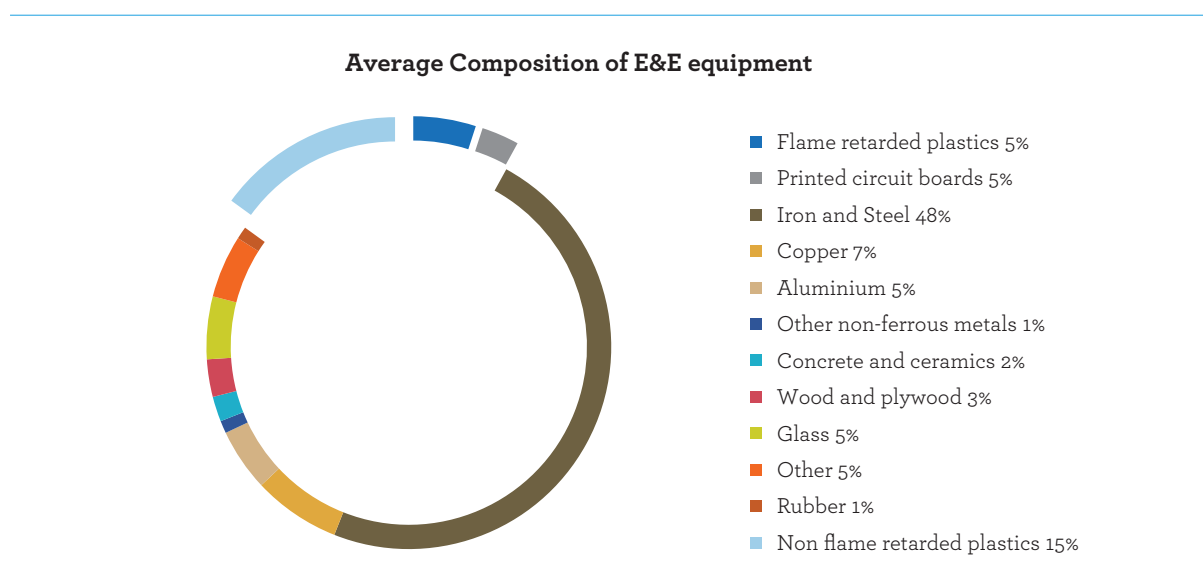
<sup>4</sup> [http://cpcb.nic.in/upload/NewItems/NewItem\\_155\\_FINAL\\_RITE\\_REPORT.pdf](http://cpcb.nic.in/upload/NewItems/NewItem_155_FINAL_RITE_REPORT.pdf)

<sup>5</sup> [http://www.cpcb.nic.in/divisionsofheadoffice/pcp/management\\_plasticwaste.pdf](http://www.cpcb.nic.in/divisionsofheadoffice/pcp/management_plasticwaste.pdf)

## 1.2 Plastic use in Electrical and Electronic Equipment (EEE)

The manufacturing of Electrical and electronic equipment (EEE) employs various materials. Besides the common metals like iron, copper and aluminium, EEE also contains precious metals such as gold, silver, platinum and palladium. Scarce metals like indium and gallium are also used in new technologies (e.g. flat screens and LEDs). Hazardous materials such as heavy metals lead, mercury, arsenic, and cadmium and flame retardants are used in the manufacturing of EEE. These hazardous materials become especially dangerous after EEE is disposed off as Waste Electrical and Electronic Equipment (WEEE).

**Figure 2: E&E equipment- composition<sup>6</sup>**



Plastics, are the second largest component of EEE, accounting on average for 25-35% of the weight<sup>7</sup>. The plastic content of different equipment categories varies considerably. Although the proportion of plastics in EEE has increased in recent times, the total weight of plastic contained currently put on the market has not grown at the same rate because of the decrease in the average overall weight of equipment.

**Table 1: Typical applications of Plastic Polymers in EEE<sup>8</sup>**

Polymer	Application
<b>ABS</b>	Housings and casing of phones, small household appliances, microwave ovens, flat screens and certain monitors Enclosures and internal parts of ICT equipment
<b>PS (HIPS)</b>	Components inside refrigerators (liner, shelving) Housings of small household appliances, data processing and consumer electronics
<b>PC</b>	Housings of ICT equipment and household appliances Lighting
<b>Epoxy Polymers</b>	Printed Circuit Board

<sup>6</sup> United Nations University, 2008, Review of Directive 2002/96 on WEEE, August 2007

<sup>7</sup> [http://www.ewasteguide.info/files/Waeger\\_2009\\_R'09.pdf](http://www.ewasteguide.info/files/Waeger_2009_R'09.pdf)

<sup>8</sup> Plastic Waste in the Environment, European Commission DG ENV, April 2011



Polymer	Application
<b>PP</b>	Components inside washing machines and dishwashers, casings of small household appliances (coffee makers, irons, etc.) Internal electronic components
<b>PPO (blend HIPS/PPE)</b>	Housings of consumer electronics (TVs) and computer monitors and some small household appliances (e.g. hairdryers) Components of TV, computers, printers and copiers
<b>PC/ABS</b>	Housings of ICT equipment and certain small household appliances (e.g. kettles, shavers)
<b>Polyurethane (Foam)</b>	Insulation of refrigerators and dishwashers

### 1.3 Plastic in Waste Electronic and Electrical Equipment (WEEE)

During the recycling of WEEE, plastics are the major components for which safe and sustainable recycling opportunities are currently quite limited. WEEE-plastics contain hazardous substances which get emitted during recycling if there is insufficient precaution, exposing the workers to danger and contaminating the environment.

Given the hazardous nature of certain WEEE-plastics, some of it should not be recycled, rather properly disposed off, while other parts should only be reused in safe applications. The disposal and recovery of plastics from WEEE is thus of considerable importance, especially from an environmental perspective.

**Table 2: Plastic concentration in WEEE<sup>9</sup>**

Equipment Category	Ferrous metals	Non-ferrous metals	Glass	Plastics	Other
<b>Large household Appliances</b>	61%	7%	3%	9%	21%
<b>Small household appliances</b>	19%	1%	0%	48%	32%
<b>IT equipment</b>	43%	0%	4%	30%	20%
<b>Telecom</b>	13%	7%	0%	74%	6%
<b>TV, Radio, etc.</b>	11%	2%	35%	31%	22%

The processing generally consists of successive steps, e.g. pre-treatment, sorting and recycling. But it is difficult because of the following reasons:

- Numerous resin types are used in different types of equipment
- Plastic parts are not labelled according to their type and
- Presence of hazardous additives in some of the plastics which require protective measures for workers employed in operations where these plastics are shredded or heated.

<sup>9</sup> Waste from Electrical and Electronic Equipment in Ireland: A Status Report, May 2001

Thus, while there is potential in WEEE-plastic recycling, the release and spreading of toxic substances from WEEE-plastic recycling also needs to be considered.

## 1.4 Hazardous additives in WEEE-plastic

The polymers used in plastics are rarely used in pure form. In almost all commercial plastics, they are compounded with ingredients to improve their processing and end-use performance. These additives include reinforcing fibres, fillers, coupling agents, plasticizers, pigments, stabilizers, biocides, processing aids, flame retardants and others. Of these, brominated flame retardants (BFRs) and heavy metals used as pigments and stabilizers are the most problematic additives in WEEE-plastic.

### Brominated Flame Retardants (BFRs)

All organic polymers undergo thermal degradation if exposed to sufficient heat. Flame Retardants (FRs) are added to make the polymer formulation less flammable. This enables plastics to be used close to heat-generation and ignition sources common in EEE, such as housings and covers of appliances and machines, printed circuit boards, wiring and electric power distribution equipment.

The relatively high price of FRs ensures that they are only used where required, and most plastic encountered does not contain flame retardants. The types of flame retardants used are magnesium and aluminium hydroxides, BFRs, antimony compounds, phosphorus and nitrogen-based compounds<sup>10</sup>. It is estimated that flame retarded plastics make up around 5.5% of WEEE by weight, or 25% of all plastic used in EEE (Hedemalm *et al*, 1995). Of these flame retarded plastics, approximately 80% are treated with brominated flame retardants (ENEA, 1995). These are mainly used in printed circuit boards, components (such as connectors), plastic covers, and cables.



BFRs are a family of chemical substances with different properties, characteristics and performance. Notable BFRs include TetrabromobisphenolA (TBBPA), the family of Polybrominated diphenyl ethers (PBDEs) and Hexabromocyclododecane (HBCD). TBBPA is the most widely used BFRs today and is employed in two forms. In its main use, TBBPA is reactively bound to the polymer in when used in epoxy – fibre glass composites such as in printed circuit boards. In a significant secondary use, TBBPA is used as an un-reacted additive in housings of EEE. Of the PBDEs, only the fully brominated DecaBDE is still used in significant amounts, with the less brominated variants being banned in all sectors by the Stockholm convention and the “Restriction of Hazardous Substances” (RoHS) provisions for EEE, as implemented in India by the e-waste (management and handling) rules, 2011 (for detail-see section 1.8). HBCD was an additive also sparingly used in EEE, but included recently by the Stockholm convention.

To render plastic fire-resistant, BFRs are typically added in concentrations of a few percent<sup>11</sup>. For high fire-resistance, (v0 grade), typical Br concentrations are 10% for HIPS, 4.5% for PC and 9.6% for ABS.

<sup>10</sup> Segev, O., Kushmaro, A., Brenner, A., Environmental Impact of Flame Retardants (Persistence and Biodegradability), Int. J. Environ. Res. Public Health, 2009 (<http://www.mdpi.com/1660-4601/6/2/478/htm>)

<sup>11</sup> Flame Retardants for Plastics and Textiles, Practical Applications. Hanser. Eds. Weil and Levchik ISBN 978-3-446-41652-9

For lower fire resistance, (v2 grade), these concentration are 6% for HIPS and 6.8% for ABS. PC is itself partly fire resistant and reached a v2 grade without any flame retardants.

Since the 1970s, the electronics industry has been one of the largest consumers of polybrominated diphenyl ethers (PBDEs), about 40% of PBDEs are used in the outer casings of computers, printers and televisions and by far the largest volume of the PBDE mixture used as a flame retardant has been Deca-BDE<sup>12</sup>.

The major BFRs associated with the three main resins used in EEE (HIPS, ABS and Epoxy resins) are Decabromodiphenyl ether (DecaBDE) in light electronic consumer durables such as TVs, radios, digital media players, and computers (also known as brown goods) and Tetrabromobisphenol-A (TBBPA) in data processing and office equipment, and in printed circuit boards.

Apart from these heavy metals are also in use. Details of the heavy metals are given in the following section.

## Heavy Metals

Elements such as lead, cadmium, chromium, mercury, bromine, tin and antimony are or have been added to polymers as pigments, fillers, UV stabilizers, and flame retardants<sup>13</sup>. The e-waste (management and handling) rules restrict the use of lead, mercury, cadmium and Hexavalent Chromium in new EEE (for details- see 1.8). Of the four heavy metals, only cadmium and lead have been found in concerning concentrations. Heavy metals in plastics, notably cadmium, have been highlighted as a concern<sup>14</sup>.

## Cadmium

Cadmium sulphide and cadmium sulphoselenide are utilized as bright yellow to deep red pigments in plastics<sup>15</sup>. Both compounds are well known for their ability to withstand high temperature and high pressure without chalking or fading, and therefore are used in applications, where high temperature or high pressure processing is required, such as ABS, PA, PC or HDPE (International Cadmium Association, 2010). Another possibility for an import of cadmium into plastics, especially PVC, is the use of mixed barium and cadmium carboxylates as stabilizing agents. Cadmium pigments are usually incorporated in plastics in proportions of 0.01 to 0.75 per cent by weight<sup>16</sup>.

## Lead

In plastics, lead compounds are applied as pigments and, as carboxylates, stabilizing agents. In a study for EEE, the share of lead containing plastics was exceptionally high with 30%, which was caused by the use of lead additives in the PVC isolation of cables. Lead was not only found in yellow, orange and red plastics, which can contain lead pigments, but also in plastics of (all) other colours<sup>17</sup>. Lead is still used today as stabilizer mostly for PVC, where typical concentrations are in the range of 0.1-1% Pb are used.<sup>18</sup>

12 Sinha, S., Mahesh, P., Sharma, V., 2011, Brominated Flame Retardants Spreading the Fire, Toxics Link

13 <http://mie.esab.upc.es/ms/informacio/miscellanea/Heavy%20metals%20in%20plastics.pdf>

14 RoHS substances in mixed plastics from Waste Electrical and Electronic Equipment. Patrick Wäger, Mathias Schluep and Esther Müller

15 Harant, M., 2002. Umweltrelevante Inhaltsstoffe in Elektro- und Elektronikgeräten, Bayerisches Landesamt für Umweltschutz, Augsburg.

16 International Cadmium Association ([http://www.cadmium.org/pg\\_n.php?id\\_menu=13](http://www.cadmium.org/pg_n.php?id_menu=13))

17 Hohl, C. and Randegger-Vollrath, A., 1995. Cadmium, Blei und Chrom in Kunststoffen: Resultate einer schweizerischen marktüberwachung, Bundesamt für Umwelt, Wald und Landschaft, Bern.

18 Handbook of Vinyl Formulating, Wiley. Ed. Richard F. Grossmann, ISBN 978-0-471-71046-2



## 1.5 BFR - Concerns

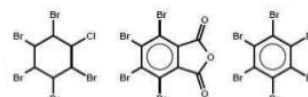
Brominated flame retardants (BFRs) are found in numerous household, healthcare, and consumer products. However, they are also ubiquitous in our environment. In the past decade, scientists have detected BFRs in human and wildlife tissues, as well as in house dust, sediments, sewage sludge, air, soil, and water samples in the United States, Canada, northern Europe, Taiwan, and Japan. PBDEs and HBCD have been found in air samples of remote regions such as the Arctic and in marine mammals from the deep seas, indicating long range transport of BFRs<sup>19</sup>. Researches, over the years, have made it increasingly evident that BFRs are similar to PBBs and another category of banned persistent, bio-accumulative toxicants—polychlorinated biphenyls (PCBs).

In most materials, BFRs are incorporated as additives, leading to a release of these substances during service life and recycling processes of waste, as these are not chemically bound to the polymer matrix. Due to this, BFRs can move into the environment. Hence, when these products reach the end of their useful lives, disposal or recycling operations can release the bromine in other hazardous forms into the environment.

Brominated Flame-Retardants (BFRs), especially PBDEs' capacity to bio-accumulate in fatty tissue and bio magnify up the food chain, in combination with their persistence and toxicity make this class of chemicals of high concern to the environment and human health<sup>20</sup>. Several BFRs, including certain PBDEs and HBCD, which are known for their toxic properties, are highly resistant to degradation in the environment. Some are now widespread and regarded as environmental pollutants, with higher levels generally being found in the atmosphere and rivers close to urban and industrialized areas<sup>21</sup>. Rapidly increasing levels of BFRs measured in sediments, marine animals and humans indicate significant potential for damage to ecological and human health.

The entire life cycle of BFRs contributes to their distribution in the environment. Industrial facilities that produce BFRs and manufacturing facilities that use BFRs in consumer products, release these chemicals during polymer formulation, processing, or manufacturing practices. Disintegration of foam products, volatilization (especially under conditions of high temperature), and leaching from products during laundering or use results in the release of BFRs from products. Finally, disposal of products, including combustion and recycling of waste products, as well as leaching from landfills, is the final route of entry for BFRs into the environment.

### BROMINATED AND FLAME RETARDANTS



- **used for fireproof (flame retardent)**

- **persistent and bioaccumulative chemicals in environment**



The scientific evidence available on PBDEs to date indicates that these chemicals share many common traits with PCBs, including animal studies linking them to immune suppression, cancer,

<sup>19</sup> [http://noharm.org/lib/downloads/bfrs/BFRs\\_Rising\\_Concern.pdf](http://noharm.org/lib/downloads/bfrs/BFRs_Rising_Concern.pdf)

<sup>20</sup> <http://www.mri.com.au/plastic-recycling.shtml>

<sup>21</sup> <http://www.greenpeace.org/international/Global/international/publications/toxics/2011/Achievements%201-%20Guide%20to%20Greener%20Electronics.pdf>

endocrine disruption and neurobehavioral and developmental effects. PBDE levels now present in some humans are close to the levels shown in animals to have negative effects.

The biggest challenge is to control PBDE in articles and the recycling streams. Developing countries or economy in transition countries are a challenge where state of the art recycling plants with monitoring capacity do not exist and measurement capacity is not established<sup>22</sup>. In India, since most plastics get recycled, especially in unmonitored space, it needs to be ensured that hazardous chemicals including POPs, other persistent toxic substances including heavy metals are controlled and phased out and do not end up in sensitive recycled plastic products like children toys or household goods.

## 1.6 Other sources of contaminated plastics

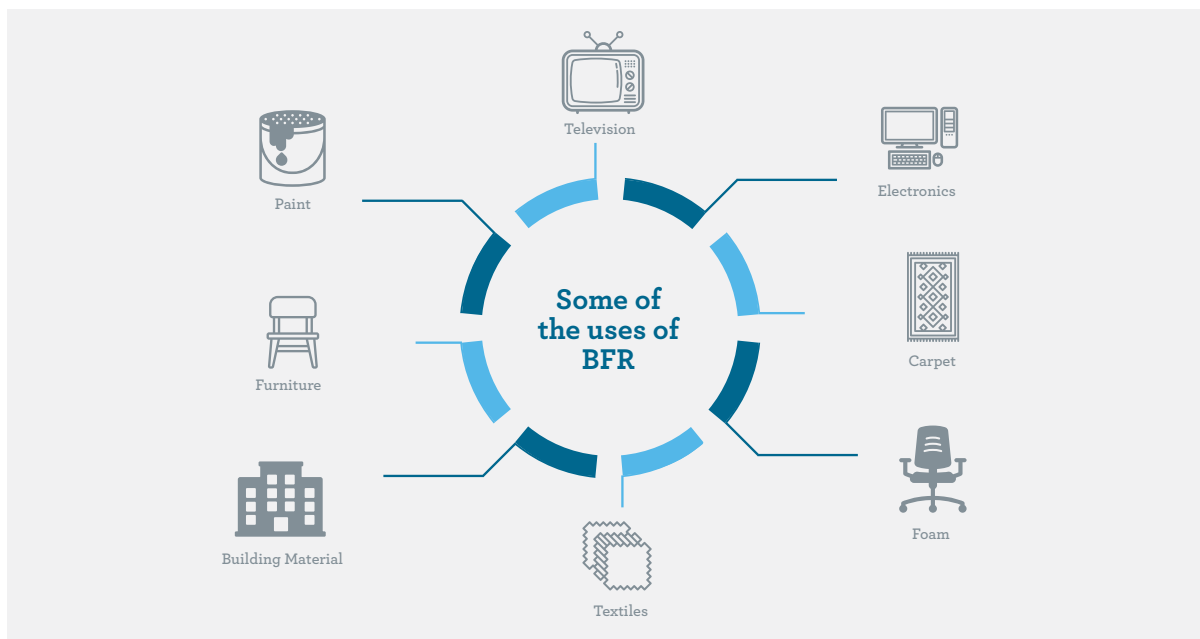
The hazardous additives BFRs and heavy metals are not only used in EEE. Given that heavy metals can be used for many different reasons, they can be expected to have been or be used quite frequently in many different products. The case is similar for BFRs, although their applications are much more limited to specific applications. The main applications of hazardous BFRs other than EEE have been in foam and insulation used in the construction and automobile sectors and in the textile sector.

**Table 3: Uses of BFRs<sup>23</sup>**

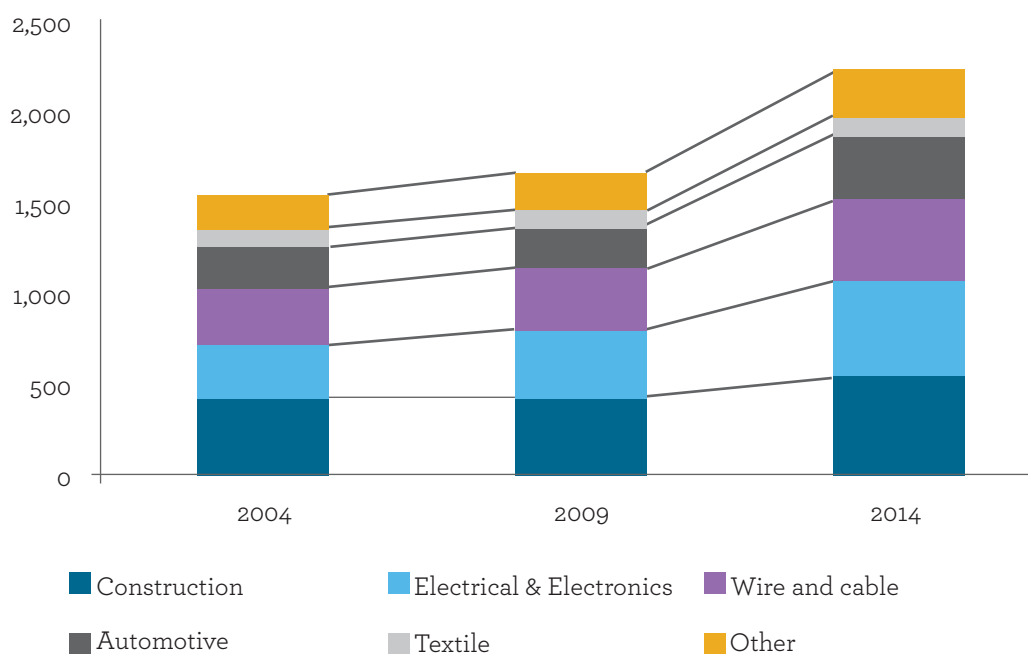
Chemical Name	Typical Products
<b>Pentabromodiphenyl ether (Penta-BDE, PBDE, or Penta)</b>	Polyurethane foams: mattresses, seat cushions, other upholstered furniture and foam packaging. Also: carpet padding, imitation wood, paints, sound insulation panels, small electronic parts, fabric coatings, epoxy resins, conveyor belts
<b>Octabromodiphenyl ether (Octa-BDE, OBDE, or Octa)</b>	Acrylonitrile-butadiene-styrene (ABS) plastic: housings for fax machines, computers and other electronics. Also: automobile trim, telephone handsets, kitchen appliance casings, small electronics parts, audio/video equipment, remote control products
<b>Decabromodiphenyl ether (Deca-BDE, DBDE or Deca)</b>	High-impact polystyrene (HIPS) plastic: housings for televisions, computers, stereos and other small electronics. Also: mobile phones Various plastics: polycarbonates, polyester resins, polyamides, polyvinyl chloride, polypropylenes, terephthalates (PBT and PET), and rubber. Also: upholstery textiles (sofas, office chairs, backcoating), paints, rubber cables, lighting (panels, lamp sockets), smoke detectors, electrical equipment (connectors, wires, cables, fuses, housings, boxes, switches), stadium seats
<b>Tetrabromobisphenol A (TBBP A)</b>	Reactive flame retardant: epoxy and polycarbonate resins. Also: printed circuit boards in electronics (96%), office equipment housings Additive flame retardant: various plastics, paper and textiles. Also: housings of computers, monitors, TV, office equipment, adhesive coatings in paper and textiles
<b>Hexabromocyclododecane (HBCD)</b>	Various plastics: Polystyrene (EPS, XPS), HIPS, polypropylene. Also: textiles and carpet backing, television and computer housings, textiles in automobiles, building materials (insulation panels, construction blocks, thermal insulation, roofs), upholstered foam, latex binders

<sup>22</sup> Sindiku, Babayemi, J., Osibanjo, J., Schlummer, M., Schluep, M., Weber, R., Assessing POP-PBDEs and BFRs in E-Waste Polymers In Nigeria

<sup>23</sup> Janssen, S., 2005, Brominated Flame Retardants Rising Levels of Concern, Page 2, Health Care Without Harm ([http://noharm.org/lib/downloads/bfrs/BFRs\\_Rising\\_Concern.pdf](http://noharm.org/lib/downloads/bfrs/BFRs_Rising_Concern.pdf))



**Figure 3: Flame Retardant market**



## 1.7 Previous research

In a study done by Toxics Link in 2011, 41% of the samples collected from informal units in Delhi were found to be contaminated with BFRs. Heavy metals like lead and cadmium were also found in almost all samples. Presence of these unintended chemicals pointed towards a possibility of cross contamination.



The 2011 study by Toxics Link titled “Brominated Flame Retardants - Spreading the Fire” was a preliminary research on the presence of BFRs in recycled plastics. It was found that there were no occupational and environmental safety norms being observed during the recycling processes in the unorganized sector. Recycling of BFR contaminated plastics might be leading to BFR exposure. The use of high temperature during pellet making process may lead to formation of brominated dibenzofurans, which are known to be carcinogenic. Out of 10 recycled plastic pellets tested under the study, 5 of them contained BFRs. All three plastic resins included in this test, namely HIPS, ABS and PC, were found to be contaminated with PBDEs. No processes were being used to remove BFR during plastic recycling in the informal sector. Thus there was a risk of cross contamination as these recycled plastic pellets are used to manufacture new products.

Another study by Toxics Link and EMPA titled “Improving Plastic Management in Delhi – A report on WEEE plastic recycling” (2012) aimed at studying the WEEE plastics recycling process in Delhi, investigate and identify the possibility of cross contamination of the material supply chain with BFRs, identify gaps in the recycling processes, identify environmental concerns on account of recycling practices and options for policy engagement if any.

It was found that no procedures to decontaminate the plastic or prevent cross contamination was in use in the plastic recycling units in both formal and informal sector. Presence of BFRs like PBDEs and PBBs and heavy metals like lead and cadmium in lab analysis clearly pointed towards the increasing risk of absence of such decontamination.

## 1.8 Regulatory Framework

In India, though there are no specific legal frameworks to address the plastic fractions from WEEE, there are regulations which impact them indirectly.

### Plastic Waste (Management and Handling) Rules, 2011

India’s Ministry of Environment adopted new rules governing the management and disposal of plastic waste in 2011. The new rules include an extended producer responsibility system. These Rules do not lay down any standards or guidelines to recycle plastic and does not have any provisions mentioned for plastics with flame retardants or other hazardous chemicals.



## Guidelines on recycling of plastic waste

The Bureau of Indian Standards (BIS), New Delhi has issued guidelines on recycling of plastics waste, including code of practices for collection. However, while formulating Indian standard specifications for various plastic products, used for critical applications like plastic piping system, water-storage tanks, packaging for food articles, a clause is included which reads “no recycled plastics waste shall be used”. Again there is no specific mention of critical additives like BFRs.



## E-Waste (Management and Handling) Rules, 2011

E-waste rules were notified in May 2011 and looks at both upstream and downstream aspects of waste arising from EEE.

The rules call for the reduction in the use of hazardous substances in the manufacture of EEE. Every producer of equipments listed in schedule 1 of the rule namely, information and telecommunications equipment and consumer electrical and electronics shall ensure that their products do not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, and polybrominated diphenyl ethers above a specified threshold. The threshold for cadmium is 0.01% by weight; for all other substances, the threshold is 0.1% by weight. The list of concerned appliances is given in Annexure 1. The rules also apply to products imported into India. The reductions had to be achieved by May 2014, two years from when the rules applied.

Currently, both the Plastic waste Rules and E-waste Rules are being revised. The draft Rules have been notified, with no mention of recycling of plastic with contaminants like BFRs.

## Implementation of E-Waste Rules 2011, Guidelines

The E-waste guideline was notified in 2011 and recognises the BFR issue. It states- ‘Plastics and printed circuit board contains brominated flame retardants (BFRs). BFRs can give rise to dioxins and furans during incineration. Recoveries of these non-ferrous/precious/semi-precious metals from e-waste, if not done in a scientific and environmental friendly manner, will result in large emissions of hazardous substances into the environment. In view of this, environmentally sound recycling of e-waste is a must.’ However, the guidelines further do not elaborate on any process or procedure to be followed for recycling BFR contaminated plastics.

## Stockholm Convention

Polybrominated diphenyl ethers (PBDEs) were the first brominated persistent organic pollutants (POPs) listed in the Stockholm Convention.<sup>24</sup> Commercial pentabromodiphenyl ether (c-PentaBDE)

<sup>24</sup> Stockholm Convention on Persistent Organic Pollutants is a global treaty to protect human health and the environment from POPs. [www.pops.int](http://www.pops.int)

and certain congeners of commercial Octabromodiphenylethers (c-OctaBDE) were added to Annex A of the Stockholm Convention.<sup>25</sup> Therefore these listed PBDEs (POP-PBDEs) are officially recognised as persistent organic pollutants (POPs) under the Stockholm Convention which prohibits production, use, import, and export with some defined exemptions. Furthermore Article 6 of the Convention requires that wastes containing POPs has to be managed in a manner protective of human health and the environment. This listing requires signatory parties to take appropriate measures to reduce or eliminate releases of POP-PBDEs from stockpiles and wastes.

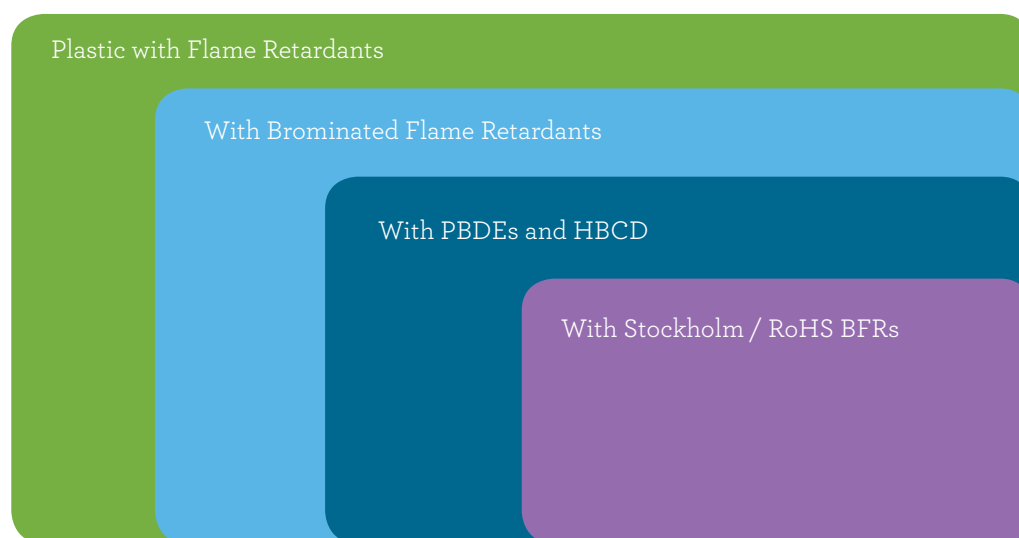


The listing of PBDEs, unlike the original Stockholm POPs, includes specific exemptions allowing for recycling and the use in articles of recycled materials containing these chemicals. In details, materials containing POP-PBDEs may be recycled if

- Both recycling and final disposal is can be guaranteed to be carried out in an environmentally sound manner.
- The regulated chemicals are not recovered (i.e. concentrated) for their reuse.

India has signed the initial Stockholm convention in 2006. However, the country has also stipulated that any amendments to the list of banned substances will not enter into force automatically but only upon the deposit of its national instrument of ratification or approval.<sup>26</sup> So far, India has not ratified any new amendments to the Stockholm convention and thus BFRs are not covered under the current legislation.<sup>27</sup>

**Figure 4: WEEE-Plastic and Flame Retardants**



25 Sindiku, O, Babayemi, JO, Osibanjo, O, Schlummer, M., Schluep, M., Weber, R., Assessing POP-PBDEs and BFRs In E-Waste Polymers In Nigeria, <http://chm.pops.int/Portals/o/download.aspx?d=UNEP-POPS-NIP-GUID-ArticlePaperPBDEInv-6.En.pdf>

26 <http://chm.pops.int/Countries/StatusofRatifications/PartiesandSignatories/tabid/252/Default.aspx>

27 <http://chm.pops.int/Countries/StatusofRatifications/Amendmentstoannexes/tabid/3486/Default.aspx>



## 2. Objective and Methodology

Given the extent to which WEEE and BFRs are harmful to both environment and life and the absence of appropriate recycling methods in India and gaps in legislation this study is of great importance.

With electronic equipment and gadgets being the fastest growing waste stream in many countries, dealing with so-called 'e-waste' is probably one of the most pressing environmental problems in the near future. Though in recent times, this waste stream has been viewed as an urban mining opportunity, the toxicity of this stream is a cause of concern for many.

### 2.1 Rationale of the study

Plastic, which is one of large constituent of e-waste, has huge recycling potential and has fuelled a large recycling industry within the country, especially in the informal sector. But WEEE-plastic often contains contaminants like Brominated Flame Retardants (BFRs), especially PBDEs, some of which are known toxins. The contaminated material should be removed before recycling.

The legislation on e-waste in India was introduced in 2011 (effective from 2014) which restrict use of concerning BFRs. While new WEEE will not contain any more of these toxics substances, WEEE-plastic will still be contaminated with toxic BFR for a long time, unless it is contained separately.

As a response to the legislation, several formal e-waste recyclers have sprung up, but it is the informal sector which still controls most of e-waste and plastic recycling. These sectors are tightly linked, with WEEE-plastic being directly recycled. In a previous study in Delhi, Toxics Link found that plastics



containing BFRs were rarely segregated or disposed off as required. Rather they were deliberately mixed with clean plastic. With the rapid growth of e-waste and the revised legislation, we carried out another study to document the changes, if any, in WEEE-plastic recycling.

The current study attempts to understand the existing recycling practices and look at the material closely. It also aims to understand the possible hazards, both in terms of health and environment, caused by recycling operations of plastic waste in the informal recycling sector in Delhi, India. The city of Delhi is among the largest metropolises in the country and provides a useful example of growth driven urban centres in the country faced with increasing urban waste problems. It is also one of the largest recycling hubs in the country.

The scope of the research is limited to the study of informal recycling of WEEE plastics in Delhi. We have also limited ourselves to study the common thermoplastics of WEEE (ABS, PC, HIPS) and PVC, and not look at epoxy thermosets (in printed wiring boards) and PU-foam (insulation in white goods).

The study aims at

- Examining existing data on e-waste volumes in India and quantify the WEEE-plastic volumes generated in India and Delhi, especially plastics containing BFRs.
- Study the flow of CRT plastic in more detail as one of the main sources of BFRs in the recycling.
- To study the WEEE-plastic recycling practices and processes and describe the organisation and material flow in the sector
- Identify gaps in the recycling processes if any
- Identify environmental and occupational concerns.
- Study the economics of plastics waste in the informal recycling sector

## 2.2 Methodology

A review of existing literature was performed to estimate the WEEE-plastic volumes in India, Delhi in particular. While unstructured interviews with plastic recycling workers were conducted to get an understanding on the economic flow, structured interviews were conducted with around 50 workers on the health and safety conditions using a questionnaire (see Annexure 2). Health and safety information





from these interviews was supplemented with observations (e.g. on noise levels) during the visit of around 25 grinding, 20 pellet making and 10 moulding units. In addition to this methodology, exploratory surveys, site visits to markets and trading hubs and photo documentation were also used. Experiences from earlier studies of Toxics Link in Delhi were used to plan this study.

**Figure 5 Number of Units visited for the survey**

No. of Units Visited				
Dismantling	Trader/Scrap Dealer	Grinding	Pellet Making	Moulding
15	10	25	20	10

## 2.3 Limitations

- The study was limited in nature as the field visits were confined to Delhi and its adjoining areas.
- The informal recycling sector essentially denotes entrepreneurs or operators who do not have valid licenses or approvals from a designated authority to perform such activities. The study relied on information collected from the informal sector operators. Most respondents were not very forthcoming, especially on information related to quantities costs and profit margins. Their reluctance to respond to any query from outside agencies stems from their apprehensions about losing their livelihood.
- There is very limited information on BFRs in India, hence there exists is low interest among stakeholders and a constraint in getting information from stakeholders.

# Global e-waste

in the year 2014



Lamp

1%



Screens

6.3%



Small IT

3%



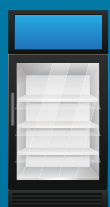
Small equipment

12.8%



Large equipment

11.8%



Cooling and freezing equipment

7%

# 3. Findings

Findings from both literature review and filed study are presented in the following section.

## 3.1 Review of Literature

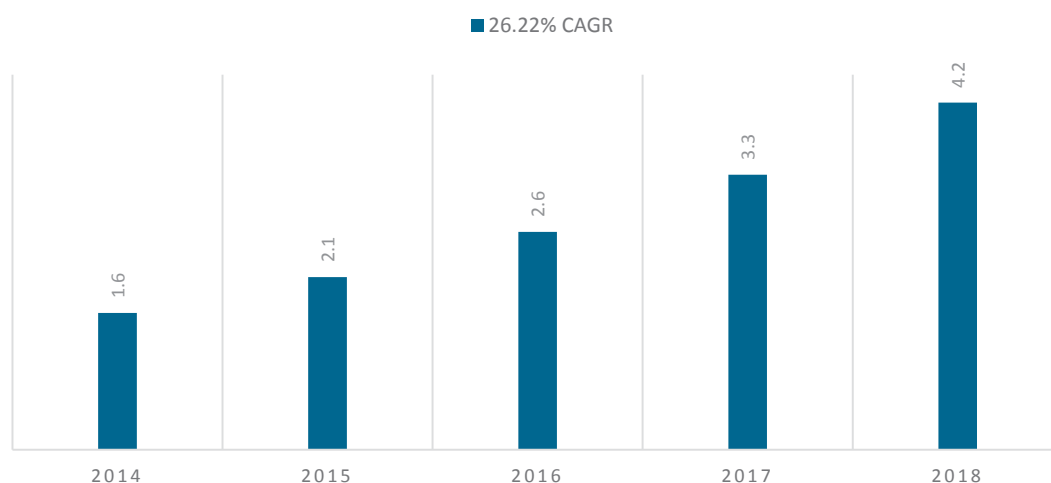
Globally E-waste is considered to be one of the fastest growing waste streams. In a recent study by UNU, it is estimated that around 42 million tonnes of WEEE was generated worldwide in 2014. It is forecasted to increase to 50 million tonnes of e-waste in 2018 with an annual growth rate of 4 to 5 per cent.

This graph on e-waste comprises of 1.0 million tonnes (Mt) of lamps, 6.3 Mt of screens, 3.0 Mt of small IT (such as mobile phones, pocket calculators, personal computers, printers, etc.), 12.8 Mt of small equipment (such as vacuum cleaners, microwaves, toasters, electric shavers, video cameras, etc.), 11.8 Mt of large equipment (such as washing machines, clothes dryers, dishwashers, electric stoves, photovoltaic panels, etc.) and 7.0 Mt of cooling and freezing equipment (temperature exchange equipment).

Asia being the largest continent, contributed close to 16 million tonnes or 38% of global e-waste generated in 2014. This, in spite of the fact that the average per capita e-waste generation in the continent is only 3.7kg/year.



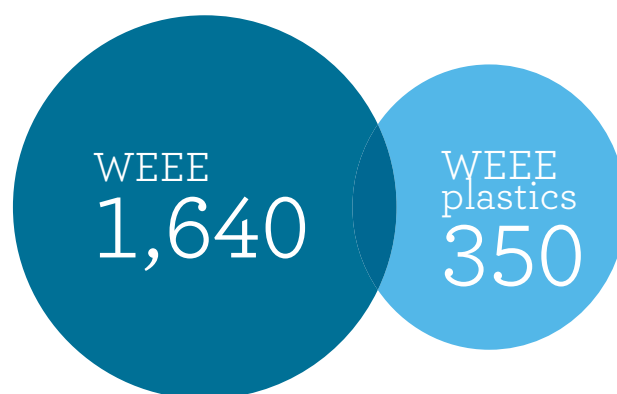
**Figure 6: E-waste Growth in India (in million tonnes)**



As per the UNU study, with a per capita e-waste generation of 1.3 kg, India generated approximately 1.6 million tonnes of e-waste in 2014. The growth rate for e-waste in India for 2015-2019 has been estimated at 26%,<sup>28</sup> which is much faster than the average global growth rate. According to this growth rate, e-waste quantities in India will increase to 4.2 million tonnes by 2018.

As indicated earlier, while the weight of the equipment is getting smaller with newer technologies, the percentage of plastic fraction is on the increase. According to Plastics Europe, WEEE consisted of 21.1% plastic in Europe in 2001.<sup>29</sup> The longer lifetime of EEE in India means today's e-waste in India will have a similar composition. Thus, approximately 350'000 tonnes of WEEE-plastic were generated in 2014 which will increase to 879'000 tonnes in 2018.

**Figure 7: WEEE plastic volumes in India in 2014 (in thousand tonnes)**



Of these, 21.1% plastic in WEEE, 5.3% are flame-retarded and 15.8% are not.<sup>30</sup> Hence around 25% of the WEEE plastic contains flame retardants. Using these figures, flame-retarded WEEE-plastic in 2014,

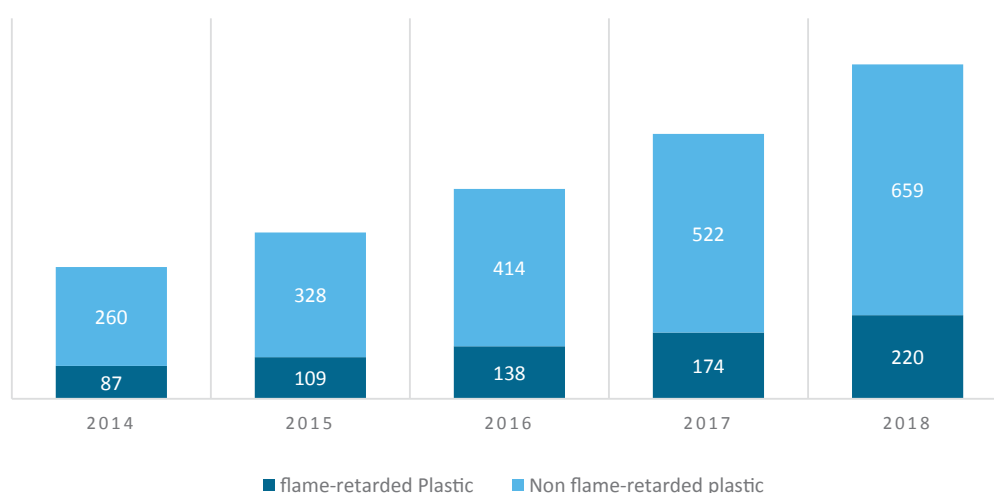
<sup>28</sup> E-Waste Market in India 2015-2019, TechNavio

<sup>29</sup> Cited as APME (2001) in Huisman, J., Magalini, F., Kuehr, R., Maurer, C., Ogilvie, S., Poll, J., Delgado, C., Artim, E., Szlezak, J. and Stevels, A., 2008. 2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment (WEEE), United Nations University. ([http://ec.europa.eu/environment/waste/weee/pdf/final\\_rep\\_unu.pdf](http://ec.europa.eu/environment/waste/weee/pdf/final_rep_unu.pdf))

<sup>30</sup> APME (2001)

which would amount to almost 87'000 tonnes, grows to approximately 220'000 tonnes in 2018.

**Figure 8: WEEE-plastic growth in India (in 1000 tonnes)**



Approximately 80% of flame retardants found in WEEE are bromine-based.<sup>31</sup> If we go by these estimations, it would mean that 69'000 tonnes of BFR plastic has reached recyclers in 2014, which corresponds to 190 tonnes /day.

## 3.2 WEEE and WEEE-plastic volumes in Delhi

A recent study has indicated that Delhi-NCR generates close to 55000 tonnes of WEEE annually and this is expected to grow at 25% to reach 95000 tonnes by 2017.<sup>32</sup> Considering these figures, the amount of flame retardant WEEE-plastic generated in Delhi-NCR will be close to 2950 tonnes in 2014 (8 tonnes/day) and would reach around 5035 tonnes in 2017 (13 tonnes/day).

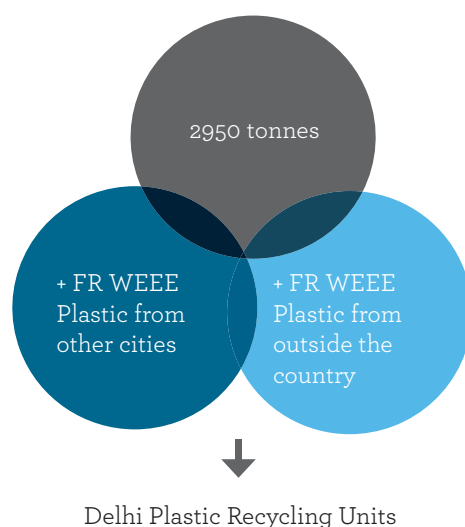
Delhi is the largest recycling hub in India, possibly also one of the largest in the world as waste flows into the city from other states and also from other countries. The volumes estimated for the WEEE fractions in Delhi does not include waste illegally dumped in India.

<sup>31</sup> <http://www.environ.ie/en/Publications/Environment/Waste/WEEE/FileDownLoad,1341,en.pdf>

<sup>32</sup> <http://assochem.org/newsdetail.php?id=4633>



**Figure 9: Flame Retardant Plastic processed in Delhi**



CRT plastic also follows the same process and flow as flame retardant plastic.

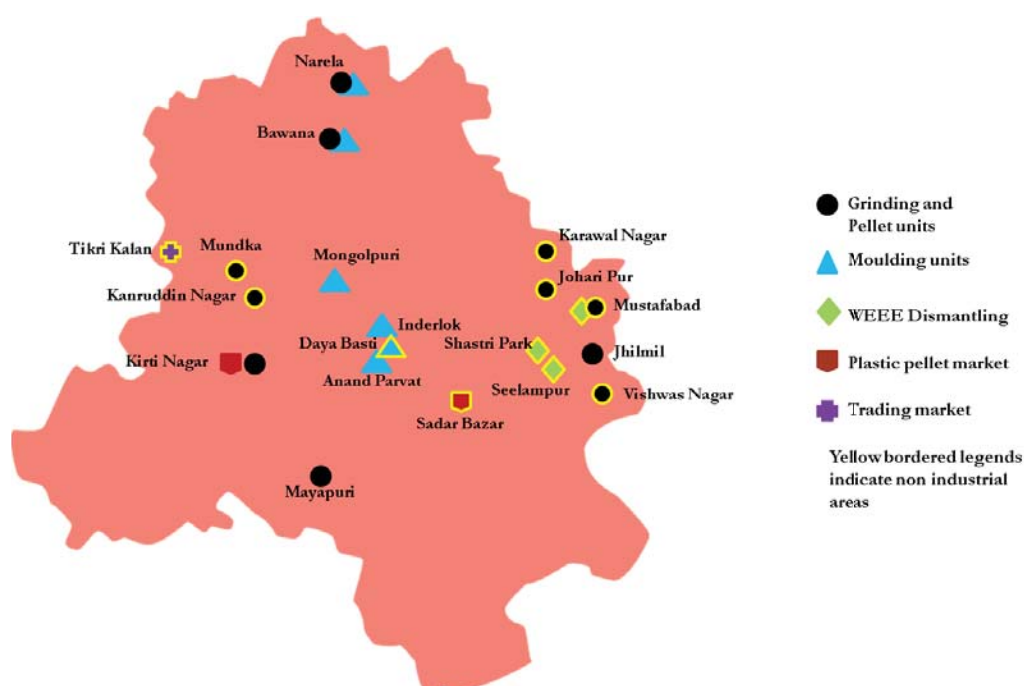
### 3.3 Markets and hotspots of WEEE-plastic recycling

The plastic waste trade and processing units are widely spread across Delhi. The WEEE plastic, as mentioned above, is not just from local domestic generation but the city also receives such plastic from outside the city. Migrants from poorer states often come to the capital city in search of livelihood and find work in the fast growing recycling sector.

During the study, many of the WEEE-plastic processing sites were visited along with the e-waste dismantling sites. As dismantling is the starting point of the plastic recycling value chain, it was important to map those areas as well.



**Figure 10: Plastic recycling hotspots in Delhi**



Most of the e-waste dismantling areas are concentrated towards the eastern part of Delhi. Areas such as Shastri Park, Old Silampur and Old Mustafabad are big centres for e-waste pre-processing. Once, e-waste is dismantled and plastic is separated, it is picked up by the plastic traders, who further sell it to grinding units. Areas like New Seelampur and Beta Hazirpur specialize in wire stripping to separate copper and the PVC plastic, which is then sold to the plastic traders situated in other parts.

The plastic processing units are spread across the city with most of them located in the eastern, northern and western part. Depending on the spread and market availability, each area has around 1000-4000 units with around 5-15 workers working in these units. Areas like Mundka, Narela and Bawana are the largest plastic recycling hubs. The other areas include Vishwas Nagar, Jhilmil Industrial Area, Kirti Nagar, Mayapuri, Karawal Nagar and Joharipur. These areas mostly had grinding and pellet making units.

Mundka is one of largest plastic scrap hubs in the city, with estimated more than 4000 units in the area, engaged in sorting, cleaning, trading and processing of plastic waste. This includes registered and unregistered units. There are no units engaged in moulding or making new plastic products in this area. These 4000 units are spread along a 4 km stretch and deal with all kinds of plastic scrap. Among these, around 3800 units are mainly engaged in sorting and cleaning operations. These sorting operations are mainly in open plots, each plot shared by multiple units. Massive fires have been reported in the plastic market many times in last few years, destroying material worth crores and probably also emitting huge quantities of toxins.

Bawana, the industrial area on the outskirts of Delhi, houses many clusters of units engaged in reprocessing plastic waste. The plastic reprocessing units in Bawana are larger units engaged in the operation of grinding, pellet making and moulding.

Another major plastic re-processing hub in Delhi is Narela, which is around 4-5 km from Bawana. This is one of the earliest recognized industrial areas in Delhi, notified in 1978, with around 3300 planned

plots. Around 1000 units in this area process plastic, among which 500 deal with plastic scrap. These units are also mainly grinding, pellet making and moulding. Thirty industrial units in Narela zone had been sealed by the North Municipal Corporation for allegedly illegally storing and recycling plastic in 2014. The action was taken with help from local police in pursuance of an order of the National Green Tribunal regarding plastic collection and burning in Mundka and Nangloi areas. Also, notices were sent, directing the owners or occupants of such units to stop unauthorised activities (storing, segregating, recycling and burning of plastic or rubber waste). These activities are unauthorised in the areas Nangloi, Mundka, Tikri Kalan and Ghevra, among others, the North Corporation said in a statement then.

Moulding units were mostly concentrated in areas like Anand Parvat, Daya Basti, Inderlok, Mongolpuri, Narela and Bawana. In Bawana, out of 1000 plastic processing units, only 25% were moulding units and rest were either involved in grinding or pellet making.

Another important area in the plastic recycling business is Sadar Bazaar, being one of the largest wholesale markets in the city, dealing mainly with household items. This market is subdivided into various sub markets, specializing in various products or items. Kirti Nagar is other similar market which deals with all kinds of fresh and recycled pellets, different resins, colours and quality, can be bought here in huge quantities.

Most of these activities are concentrated in residential areas making them informal in nature. Out of 19 plastic recycling areas visited, 8 were in authorized industrial areas and 11 were either in residential or village areas.

**Figure 11: Plastic Units in Industrial Area**



Also, even the units which were in the industrial areas, it was not sure if they were authorized registered units or not. While interviewing the industrial associations, it seemed that the plastic recycling units within the industrial areas are usually registered and have obtained permissions under orange category (non-hazardous).

The field study also indicated some linkages between formal and informal plastic recycling units. This is likely also because of their co-existence in the same areas. The material from the plastic units in the informal sector was at times picked up by the formal recycling units directly for pellet making or for moulding. Also, the pellets from the informal recycling units were sold in the common market like Sadar, from where they could be picked up by formal or informal recycling units. The reverse seemed unlikely as the costs in the formal units are expected to be higher.

## 3.4 Recycling Sector- Actors

The informal sector of the plastic reprocessing business constitutes different players at different stages of waste management. This is similar to any waste stream hierarchy.

In most cases, informal waste recycling is carried out by poor, disadvantaged, vulnerable and/or marginalised social groups such as rural migrants, illiterates and religious minorities who often resort to waste business. The socio-economic and socio-demographic characteristics (level of income, gender, age distribution) of people in recycling work differ from location to location. It is also difficult to estimate the number of people engaged in recycling as the informal sector is not usually included in the census. Therefore, no reliable data on the number of individuals engaged in waste collection is available. The informal sector is characterised by small-scale, labour-intensive, adapted technology, low-paid, unorganised/unplanned, and unregistered/unregulated work. Individuals and family groups within the sector do not usually possess trading licences, do not pay taxes, and are not included in the government insurance, social welfare or funding schemes. But this workforce is skilled and have over the years acquired expertise, especially in terms of identifying materials, segregation etc.

**Table 4: Value add**

Informal Sector- Plastic Recycling Value added	
Collection	Identification and picking of items or collecting mixed waste allows the sector to acquire the waste and turn it into a resource. Also huge network means a large reach.
Sorting	Main process that increases the value of the waste recovered. The deeper the sorting differentiation, the higher the value of waste. For instance, if plastic is grouped into one major category, its value is lower than when it is further separated into sub-categories of hard and soft, then HDPE, PET, LDPE, etc. Sorting according to colour, size, shape and potential use or re-use of the materials so as to meet the end-users quality specifications.
Accumulation of volume	Volume adds value. Larger volumes command higher per-unit prices. The greater the quantity, the better bargaining power the trader has.
Pre-processing	For instance: washing, changing in shape-cutting, granulating, compacting. Low operational costs keep the overall material costs lower
Market intelligence	Proximity to markets where informal recyclers and traders conduct business allows for the flow of information which allows decisions to be made on accurate market prices, competitors etc.
Trading	In informal or formal markets. Links to the secondary materials network are crucial. Has the forward and backward linkages that enable wastes to be recovered for recycling purposes.

**Rag pickers (locally also called 'Kachrawala')** – Rag pickers or waste pickers constitute the bottom layer of waste recycling in Delhi and form the base of the large informal recycling pyramid. Pickers collect waste just by picking it up from public places such as garbage dumps, streets or landfills and earn their livelihood by selling collected and sorted waste to higher levels. Among the recyclables, plastic is a relatively significant material for waste picking. Occurrences of finding WEEE plastic in public places, except wires at times, are rare and hence rag pickers are not really big players in the WEEE plastic pyramid.

**Waste Collectors (locally also called 'Kabaddiwalas')** – The collectors are also at the bottom of the waste pyramid, but their operations are different from the Rag pickers. The collector goes to the generators of waste, for example households, small offices, shops etc., and purchases their waste by paying cash. In contrast to rag pickers, they need to have some operating capital to buy material. They earn profit by selling it to actors at the higher level in the pyramid. Only males are known to be in this occupation in Delhi (in India). The collectors, mostly, have access to better material constituting of metal, plastic and paper. WEEE plastic does reach the collectors, as they collect small WEEE from generators.

**Figure 12: Waste Hierarchy in the informal sector for WEEE plastic in Delhi**



**Kabaddi or Junk shops** – There are two different levels of Scrap shops or Kabaddi shops, small and large. The small Kabaddi shops are spread across the city and have presence in almost all localities. They buy materials from many local 'Kabaddiwalas' and then sell them further to a larger Kabaddi shop. The larger Kabaddi shops are limited in number and in addition to small Kabaddi shops, also receive sorted waste from other sources. They also pick up waste directly from offices or establishments. At both these levels WEEE and WEEE plastic are dealt with. The large Kabaddi shop may receive EEE as a whole which he will sell to specific traders dealing with that or may receive plastic parts, from repair shops or other places, which he collects and sells to a plastic trader. There are around 4-5 workers in these kind of junk shops.

**Trader/Dealer/Wholesaler-up** – Till the level of Kabaddi shops, all players deal with all kinds of recyclables. At the trader or dealer level it becomes specialized. A plastic waste dealer purchases waste from junk shops, institutions, shops and industries. The trader also has direct linkages and can pick up material from imports or buy from auctions. A plastic dealer will directly put the plastic in the material chain which includes sorting, cleaning, grinding and pellet making whereas an EEE dealer will sell it to a dismantler who separates the plastic to put it in the plastic chain. Traders also tend to sell working EEE to those who refurbish and get more money in this.

**Dismantler** – Non-working WEEE equipment are usually bought by dismantlers, who break open the equipment and separate the components. Working components might be cannibalized, but plastic scraps are usually collected and sold in the plastic chain. The dismantlers mostly separate different plastic resins before selling them, as they fetch a better price.

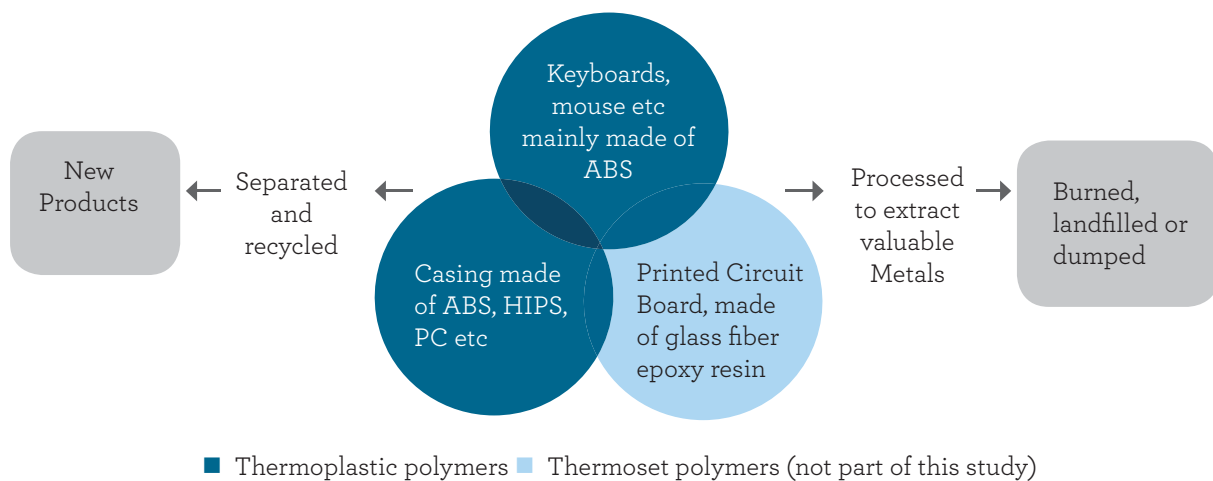


**Plastic Recyclers** – The recycling chain of plastic consists of several traders, waste sorters, grinders and pellet makers. After material trading at a commission basis (most times more than once), plastic usually ends up with waste sorters who separate different types of plastic, based on their experience and some indigenous methods. After sorting, these are sold to grinders who do a further segregation and cleaning before the cutting and grinding process. These are then channelized to pellet makers. The pellet makers receive waste from dismantlers and traders directly they also have linkages in other cities and receive waste from there. The sorted and grinded pellets then go through the extrusion process for making pellets. The recycled pellets are either sold directly to the moulding units in the city or are sold to traders in the city dealing in plastic. The recycled pellets are also sold to plastic traders in the other cities.

### 3.5 Plastic Processing in the informal sector

WEEE-plastic recycling constitutes various processes. The different steps in recycling of plastics in the informal sector are sorting, grinding/shredding, melting, granulation and moulding.

**Figure 13: Plastic separation in WEEE dismantling unit**



### Dismantling

In the first step, E-waste is dismantled manually. WEEE-plastic is separated and sold to a plastic dealer/trader by weight. The plastic from WEEE are mainly segregated in three separately traded categories, casings, keyboards and mouse etc., and printed circuit boards.

The printed circuit boards (PCBs) are usually not sold along with the other plastic as it contains a lot of valuables and precious metals and hence processed separately.

The PVC wires that generally come to WEEE dismantling units are dealt separately. These were earlier burnt to recover the copper as there was no demand for this plastic, but now since there are takers for the PVC plastic, the wires are stripped to separate copper (or other metals like aluminium) and PVC.

Mostly women, young children and elderly people are only involved in stripping work.

## Sorting

Next, plastic is sorted manually using visual methods and judgments. Plastic is usually sorted according to the type of plastics and recycled plastic is sold first to fetch the best prices. At times, these are additionally segregated colour wise. This helps to achieve a uniform colour of the recycled plastic but more importantly it ensures uniformity of the scrap being recycled.

In grinding units with included sorting facilities, they also try to segregate the FR plastic because of economic reasons. The methods used are rudimentary like burning, and smell) and may not be very accurate.



## Grinding

Once the plastics are sorted depending on demand, these are put in the grinding machine for shredding and size reduction. Usually separation of FR and non-FR plastic takes place after the grinding process but few units separate the FR and non-FR plastic prior to the grinding as well. This largely depends on the volume of FR-plastic available with them and their hands on experience on identifying it. If the grinding unit has FR-plastic in small quantities, they mix it with the non-FR plastic. Some of the units indicated that they mix it in the ratio of around 10:1, indicating deliberate contamination. The demand for FR-plastics from recyclers manufacturing radio transistor casings and similar products can also drive the process of separating FR and non-FR plastics.

In Delhi, only few units were found to be practicing separation of FR and non-FR plastic. The FR plastic was not further separated into Br and non-Br FR-plastic. FR and non-FR plastic is separated using density separation (salt water technique, see box). According to these units it is more profitable to separate the FR and non FR plastics as the clean non-FR plastic had a higher market value. The reason most units do not separate FR-plastics seems to be due to a lack of know how on the available technology or the convenience of selling mixed plastic. After separation, the grinded plastic is sun dried and sold to pellet manufacturing units.

### Salt water technique:

Few units visited by the research team found the sorters/recyclers meticulously following the process of using a salt water bath for separating FR and non FR plastics. These units use the salt water flotation for carrying out this separation. They prepare a salt water solution and pass the shredded plastics through this solution of salt water. FR plastic sinks and settles at the bottom of the tub and non FR plastics floats upwards, which is then separated. The concentration of salt water solution is also prepared based on their experience and they do not follow a prescribed norm or percentage of water to salt. During the process of floatation, salt is additionally added to the mixture whenever there is any addition of water, to maintain the appropriate concentration of the solution. There could be some errors in following this process but by and large the units consider this process effective in separating these plastics.



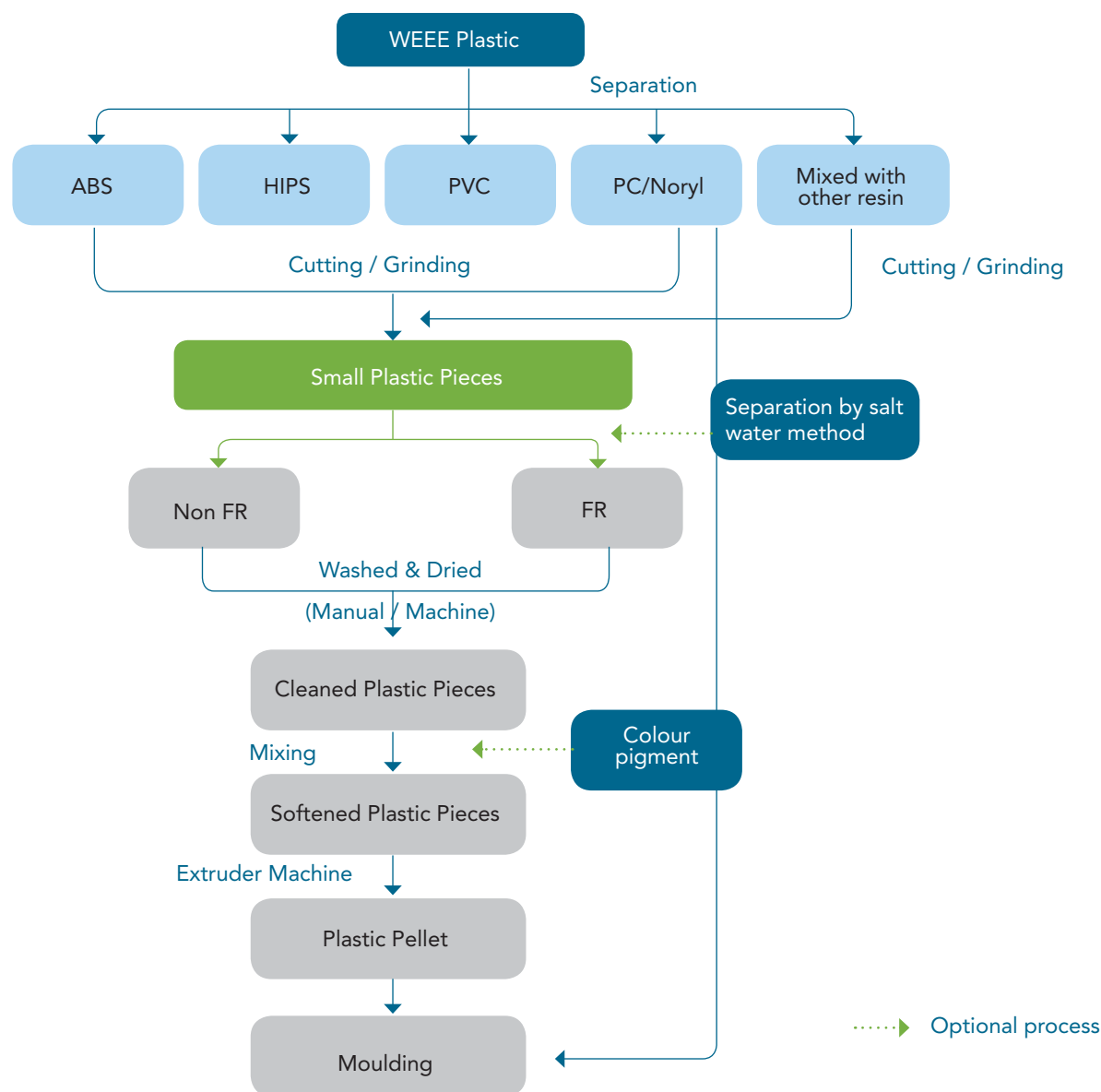
### Pelletization

After grinding, the plastic granules or shredded plastic are washed and cleaned to remove impurities like dust. The cleaned pieces are dried in a dryer or in the open, after which they are treated in a mixer. In the mixer, the heat generated due to friction makes the material soft and pliable. Chemicals are also added to enhance the sheen or the gloss of the material. Colour is usually also added at this stage if required.

After preliminary processing, the plastic is mixed and formed in the extruder. The material enters through the feed throat (an opening near the rear of the barrel) and comes into contact with the screw. The rotating screw forces the plastic pieces forward into the barrel which is heated to the desired melt temperature of the molten plastic. Most units rely on experience to control the temperature as the heating devices may or may not have temperature recording devices. Few units which have temperature recording devices attached achieve around 150-250°C, depending on plastic variety. The outputs are strings of plastic which are passed through a cooling tank. The strings are then cut into granules, danas or pellets by the use of a cutter.

The PVC follows the same route of grinding followed by Pelletisation. The interesting bit to note here is that PVC dealers and processors are usually very specialized and deal with only that resin type.

**Figure 14: Processing Flow**



## Mixing and Moulding:

In the final stage, the pellets are used to produce new products. The recycled pellets are put into a mixer to soften them and colour can be added if required. Virgin material is often added to improve the quality of the desired product. The virgin material (FR and non-FR) is thereby mixed with all types of recycled plastic (FR, non-FR and mixed).

The softened pellets are then put through a moulding machine. Most of the surveyed units used injection moulding. The product finishing and colouring is done before the products are ready to be packed and dispatched.



## 3.6 Impacts of Recycling

As mentioned above, plastic recycling is primarily done in informal set ups. In India, there has been little work done to study the health risks on workers in various occupations, especially in the informal sector and since recycling is mainly carried out in the unorganized or informal sector, its risks are mainly unknown.

### 3.6.1 Occupational Concerns

Though plastic recycling units in India are located in industrial as well as residential areas, most of them do not follow any safety norms. Although informal workers are sometimes organized in cooperatives, their working conditions remain extremely precarious and unsafe. There is inadequate research and statistics of the ergonomics, safety and health problems linked to the sorting, grinding, pellet making and moulding processes.

Inadequate safety and health standards and environmental hazards are particularly evident in these informal recycling operations. Some of the most prevalent problems are: poor lighting, lack of ventilation, excessive heat, poor housekeeping, inadequate work space and working tools, lack of protective equipment, exposure to hazardous chemicals and dust and long hours of work.

**Table 5: Key health hazards identified in recycling units**

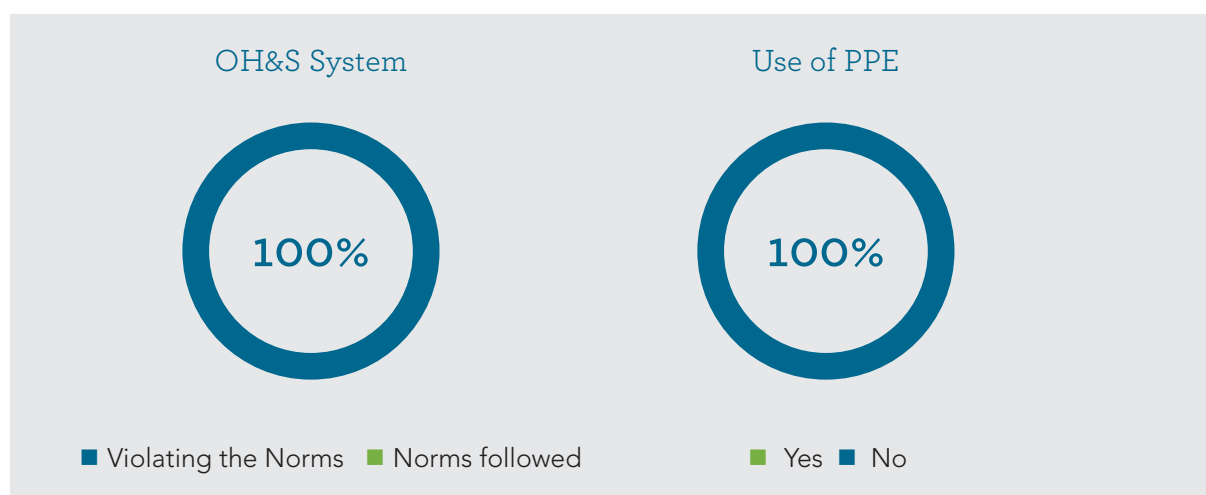
Health Hazards	Description
Physical	Insufficient lighting, high noise levels, lack of ventilation, irregular floor surfaces or damaged floor, lack of roof cover or damaged roof and water leaks. Breathing problems due to dust from materials and processes
Chemical	Chemicals and additives added at various stages
Accidents	Accidents during handling of materials or operating machinery, cuts due to sharp instruments used in operations. Unsafe work layouts.
Ergonomic	Improper posture due to lack of correct infrastructure in the collection, separation and processing of material, insufficient lightning, unsafe work organization
Hygiene	Lack of hand washing areas or proper toilets.

### 3.6.2 Occupational Health and Safety System

None of the units visited during the study were found to have an OHS system. All the workers interviewed stated that they did not receive any occupational safety and health training. According to the information provided by the workers as well as our observation, there was no injury log kept in the companies to report for any accident. Non-availability of even basic first aid kits in the units pointed towards total apathy to workers safety. None of the workers had received any protection equipment or were wearing any Personal Protective Equipment (PPEs).



**Figure 15: Worker Safety**



### 3.6.3 Physical Hazards

The informal recycling units visited during the research were of varying sizes, depending mainly on the kind and magnitude of operations. The sorting units for plastic waste are shared by a number of operators, with small sections having temporary roofs. All sorts of plastic waste are strewn around in these units, with a large number of women, sitting on the ground and carrying out segregation and sorting processes mostly with their bare hands. The grinding operations also takes place in open areas, with only a small roofed portion provided. The grinding machine is placed in this covered part, with no provision for any exhaust to throw out the dust particles generated during the process.

The pellet making and moulding units, visited during the field research, were mostly in enclosed areas. These operative units generate heat due to the mixing and extrusion processes, the mixing process also generates a lot of dust particles. The units have no ventilation system, resulting in high



temperature and dust within the unit. The layouts of the units are unplanned and hence most units have hardly any space to move around swiftly.

Most units have irregular floor surfaces and are only dimly lit. Noise levels were generally not satisfactory in units. While plastic sorting does not generate much noise, plastic sorters are often exposed to noise originating from grinders in combined units. The noise levels of machines used in grinding, pellet making and moulding units were high and it was often difficult to hear anyone standing in the vicinity.

### 3.6.4 Chemical Hazards

The colorants and other additives used during the recycling are often powders. As such, they are part of the dust present in the closed units. Given the lack of ventilation, the exposure levels may be very high. Carbon black, an often used colorant, tends to deposit in the whole unit. Caustic soda and other cheap detergents are used for cleaning.

### 3.6.5 Accidents

Probabilities of accidents in these units are very high. Firstly the layout of the units is haphazard, with the storage of materials, machine operating areas, and sorting area within small spaces. Cuts and injuries due to cut pieces coming out at high velocity while grinding are common. Burns due to frequent contact with heated machines or particles also occur. Skin irritation, injuries and cuts at the time of washing and drying flakes are routine. Risks due to open wires, carrying heavy loads on uneven surfaces etc. are also present.

### 3.6.6 Ergonomic

Plastic sorting processes is often carried out by women in the units. Often the sorting is performed with the material spread on the floor, forcing the workers to remain squatting or sitting on a small stool or box or ground. During this phase, the workers have to perform repetitive movements and sometimes lift weights. We observe a risk of development of skeletal muscle problems such as repetitive strain injuries and spine injuries.

In the plastic processing units, due to high production demands and poor work organization, the tools and facilities used for lifting and transporting materials are often inadequate. This, linked to repetitive working movements, carrying of heavy loads and awkward postures, provokes a physical workload which may reach unacceptable levels causing unnecessary strain on the workers and fatigue, contributing towards injuries.

The insufficient lighting in these areas could also result in ergonomic risk as the workers are bending or sitting in improper postures for hours.

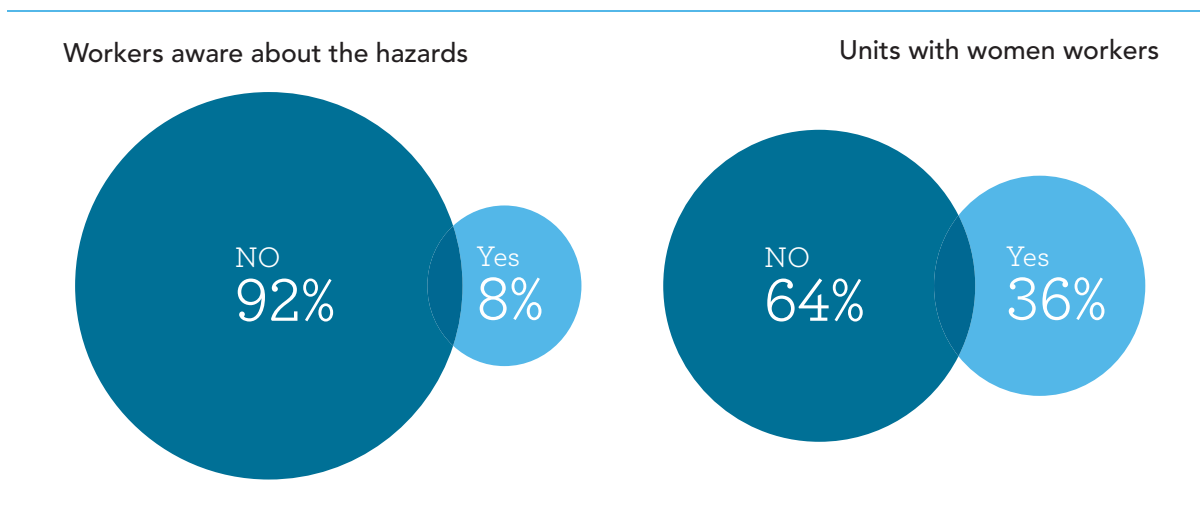
### 3.6.7 Hygiene

Further, the sanitary conditions in these work environments are unsatisfactory. The workers are usually sitting within the piles of waste and other harmful materials even for their meals. There is no proper facility for hand washing before or after the meals. The workers also wear the same clothes back to their home and might be carrying the toxics as well.

### 3.6.8 Workers knowledge

The workers employed in these units are mostly very poor and uneducated. Though, over time, they do acquire skills related to this industry, their knowledge on health concerns is almost non-existent. In some cases, they do face certain discomfort during the operations, but they don't attach any major health impact and hence do not take any precautions. There are no personal protective equipment used by the workers. During grinding, at times, the workers cover their nose and mouth with a piece of ordinary cloth.

**Figure 16: Plastic Processing units- Workers**



### 3.6.9 Environmental Concerns

Recycling is generally considered a key strategy for alleviating the environmental concerns related to huge volumes of plastic waste generated globally. A variety of environmental justifications for plastic recycling exist: recycling processes reduce demand for energy for fresh production, result in less water pollution and air emissions and mitigate the problem of solid waste disposal. In particular, recycling plastic reduces the pressure on landfills and also curbs the pollution caused by burning it.

But recycling plastic in improper manner can also lead to environmental pollution. This study looked at the possible points of environmental concerns in the processes and practices documented in this study.

The washing and cleaning process is the major source of generation of effluents. Wastewater is generated during the recycling process when the plastic scrap is cleaned. The quantity and characteristics of wastewater generated cannot be generalized. The soap solutions used for cleaning are reused several times before disposing it into open drains. This water should be treated before releasing it into open drains.

It was also observed during the field visits that the optimal temperature for pellet making is often not achieved consistently. This could lead to formation of dioxins and furans. Dioxins are unintentional persistent organic pollutants (POPs), formed and released from thermal processes involving organic matter and chlorine as a result of incomplete combustion or chemical reactions. Dioxin is a known human carcinogen.



Many of the plastic processing processes could also lead to emissions of toxic chemicals which have been added as additives in the products, the concerns are mainly due of presence of heavy metals and flame retardants.

## 3.7 Economics of plastic recycling

### 3.7.1 Prices along the value chain

Recovery and recycling of plastic in India is mainly a market driven phenomenon with a comprehensive domestic trade market system. Delhi is one of the largest plastic recycling markets in the country. Availability of raw material and cheap labour has made plastic recycling a lucrative business. The huge spread and the number of units indicate that the business is economically viable and also has profits for each sector involved in this business, from traders to sorters, from grinder to pellet making units. There is a huge market for the products made out of the recycled pellets, as it is usually cheaper to use the recycled polymer.

Since the study is focused on understanding the recycling concerns related to BFR contaminated WEEE-plastic and possible solutions to separate this toxic waste stream, it is important to understand the economics of the entire plastic market, especially the contaminated plastic from WEEE.

The traders work on a cost difference of around 10-30% whereas the pellet making units sell at a difference of 40-70% depending on the quality and type of plastic. The table below indicates some costs.

Traders usually get plastic from e-waste dismantling units and then further trade it to the grinding units. Cost incurred at each level has various components such as labour, machinery, transportation etc. The margin is usually decided taking into accounts all these factors which were not shared by the workers or units owners in the informal setup. Almost all transactions/trade are based on weight, where the material is sold and bought in kilograms (kgs) or tons. There are few exceptions like in the case of keyboards, where the initial trader sells it to a dismantler on a piece cost.





The informal recyclers have some knowledge about plastics with flame retardants due to its economic value. Since in EEE, ABS is primarily the resin which has flame retardants, some try to use means to separate them. They use salt water floatation process to separate these plastics; the plastics that float in salt water are termed as plain and the plastic that sink are termed as FR Plastics. Salt water separation is practiced by few recyclers and is demand driven and separating FR and non FR plastics can be financially beneficial for the recyclers as these separated fractions usually fetch higher price as compared to mixed plastics. On close examination it indicates that the floatation process is not very efficient as plastics with other impurities can also be part of FR plastics and it can also be on account of inaccurate density of salt water. The percentage of sinking plastic (possible FR containing) is with 70% higher than the values used for calculating the amounts of FR plastic.

The plastic costs are determined by plastic category, for example PC recycled plastic pellets are sold at an average of around 140 INR/kg; whereas PVC recycled pellets would cost around 52 INR/kg. Within a particular plastic category as well, at time the costs vary, owing to the fact that the few grades of a particular type of plastic are of better quality and have high demand.

The costs usually follow a similar trend in FR variety as well. PVC plastic with FR would cost lowest, whereas PC FR plastic would cost highest. Dismantlers sell their WEEE-plastic at roughly Rs 20-30 per kg. PVC from wire stripping plastic is sold at a rate of Rs 15-25 per kg.



**Table 6: Economics of plastic processing: prices in informal recycling (INR / kg)**

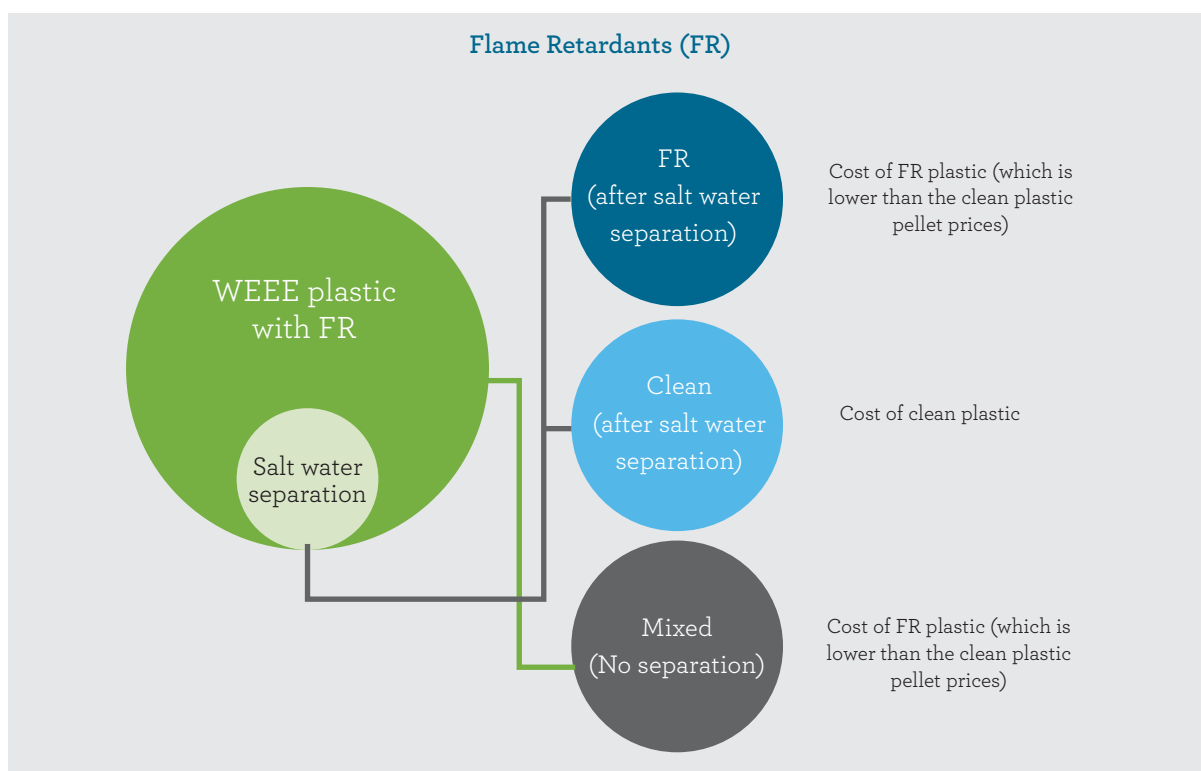
Plastic Category	Waste Plastic Trader		Grinding Unit		Pellet Unit	
	Cost Price	Selling Price	Cost Price	Selling Price	Cost Price	Selling Price
ABS (non-FR)	47.67	55.00	55.00	60.33	61.00	83.33
ABS (FR)	33.33	40.00	40.67	47.50	47.50	66.67
HIPS (non-FR)	32.67	37.67	41.00	47.00	50.50	68.33
HIPS (FR)	29.00	31.67	31.67	40.00	40.00	68.33
PVC (non-FR)	21.67	25.67	26.67	35.00	36.00	51.67
PVC (FR)	18.67	24.33	22.00	--	--	31.00
PC (non-FR)	80.00	95.00	95.00	120.00	120.00	145.00
PC (FR)	35.00	42.33	42.33	45.33	45.67	70.00

### 3.7.2 Prices in the plastic market

Besides the recycling markets, pellets can also be procured directly from the plastic pellet markets such as Sadar Bazar and Kirti Nagar. Both fresh and recycled FR and non-FR plastics are found in these markets. Usually this is not the sunken fraction from the salt separation method, as there is no surety of the concentration or type of FR used in those.

FR plastic in the market costs 50-100 INR/kg more for virgin and 20-70 INR/kg more for recycled plastic than non-FR plastic. VirginFR plastic is prepared ondemand according to the requirement of the buyer. Information on whether these traders get their FR plastic made in formal or informal units was unavailable.

**Figure 17: FR Separation**



### 3.7.3 Salaries of the workforce

The workers in these units are usually paid according to their skill levels, for example in a unit in Bawana, we found that the salary is divided in three categories helper Rs. 4500/-, skilled labour Rs.6000-6500/- and supervisors Rs.7000/-per month. The units usually work in two shifts each being of 12 hours duration. There are many workers in these units who are also paid daily wages, ranging from 100-150 rupees.

Male workers were involved more in the grinding process and were paid a salary of Rs 6000-8000 per month depending on their experience.



## 3.8 Business prototypes

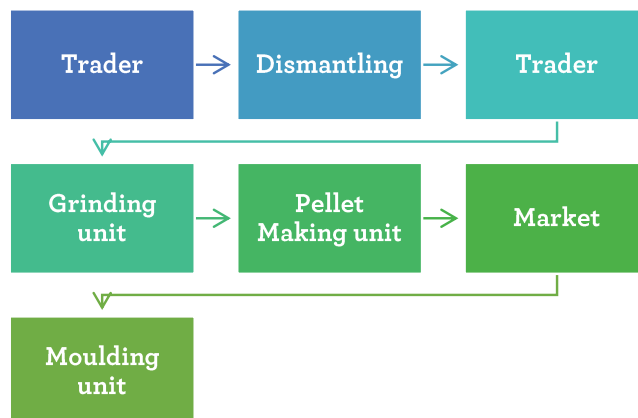
The plastic reprocessing business in Delhi operates using different prototypes. It is important to consider this as it helps us in understanding the diverse flows and the possibility of contamination at various levels. The only variation that was found in the prototypes from the last study was that during the last study, there were few units which had grinding, pellet making and moulding within the same premises. The previously described units have changed their business model or disappeared.

Mentioned below are different types observed in the field, which are also represented figuratively. The boxes in red are essentially e-waste stage of the business, whereas the blue marks plastic business.

**Type 1:** In this business prototype, each step of the operation is carried out by a different player (fig 20), meaning a trader picks up e-waste from different sources like an auction or small collectors or from import. This waste is then sold to a dismantler who breaks it open to remove parts and segregate them. The separated plastic is then sold further to a trader, who specializes in plastic and sells it to a grinding unit. In most of the locations the grinding unit also goes through segregation or a sorting process, whereby the bought plastic is separated resin wise and ground separately to get better

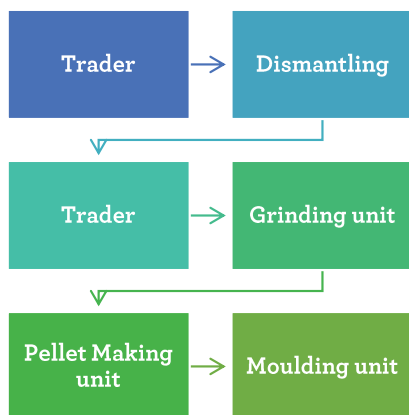
prices. This ground plastic is then sold to a pellet making unit, which processes it through an extruder machine to get recycled plastic pellets. The plastic pellets are ready to be sold to traders/shops in the market where they are sold to moulding units, completing the whole business chain.

**Figure 18: Business Prototype- Type 1**

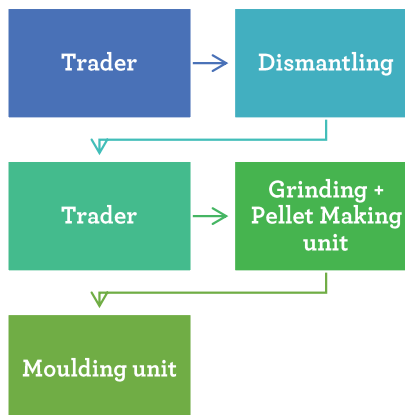


**Type 2:** This type is similar to Type 1, where each operation or activity is carried out by a different player/company. The only difference in this type is that the recycled pellets are directly sold to moulding units instead of the intermediate market trader or shop (fig 19). The pellet making units have either a regular arrangement with the moulding units or the moulding units visit directly, scouting for the kind of resins they require.

**Figure 19: Business Prototype- Type 2**



**Figure 20: Business Prototype- Type 3**



**Type 3:** This is a slight variation from the earlier versions, as the grinding and pellet making processes are carried out by a single operator. Though the figure below (fig 20) depicts that the pellets going directly to the moulding units, there can be also a small variation whereby the pellets are picked up by traders who in turn sell it to the moulding units.

**Type 4:** This final business prototype looks at some operations (mainly in areas like Old Mustafabad) where the grinding unit is attached to the dismantling unit. These units essentially buy WEEE and separate the plastic to grind it. These units also buy plastic from other small dismantlers. The other recovered materials from WEEE are sold to traders specializing in those and plastic, after grinding, is sold to pellet making units (fig 21). In this type also, a small variation is possible, where there is an intermediate trader between the pellet making unit and moulding unit.



**Figure 21: Business Prototype- Type 4**



### 3.9 New products

Reprocessed plastic is used by various industries but especially by low cost manufacturers. Plastic recycled for the first time can be used to make the same product again by adding virgin plastic. After repeated recycling, the grade of the plastic decreases and can then only be used to manufacture low cost goods with low quality requirements- The type of plastic described here can be recycled approximately 4 times.

## 4. Conclusion and Recommendations

India has seen significant growth in plastic consumption in the last couple of decades. Though the per capita plastic consumption in India, which stands at around 9 kgs, is much lower than many developed countries, the >1 billion population means enormous amounts of plastic being used and eventually discarded or thrown. 'We are sitting on a plastic time bomb,' the Supreme Court, the highest judiciary body of India, said last year, as India generated 56 lakh tonnes of plastic waste annually. 60% of this waste plastic is recycled with some 3,500 recognised recycling units and unlimited number of units in the unorganised sector, spread all over India.

Plastic recycling can be a concern, especially with the presence of contaminants and additives which are added for different purposes. Plastic from EEE have additives like Brominated flame retardants (BFRs) added to inhibit the fire catching ability. A lot of work and knowledge is available internationally on the topic of BFRs and its environmental and health impacts. By including some BFRs in the Stockholm convention, the international community has signalled strongly that BFRs are global pollutant and the need for knowledge exchange between developed and developing economies can be extremely beneficial.

The current E-waste rules, as notified by the MOEFCC have clearly identified BFR as hazardous material, and placed it under the category RoHS (Reduction in the use of Hazardous Substances) restricting its usage. However, the Rules or the accompanying guidelines for implementation do not give any specific suggestions on how to segregate and properly manage BFR-containing plastics. This report shows that there is a high volume of e-waste plastics containing BFRs in India which is not properly managed.

The informal recycling sector is recycling large quantities of plastic in Delhi. It has developed its own low-cost techniques for sorting the different plastic wastes, even as far as to separate BFR from non-BFR plastic. But BFR containing plastic is separated only if there is enough demand or if it makes economic sense. The occupational and environmental safety or the issue of cross contamination is not in consideration. Thus the contaminated plastic is mixed with other 'clean' plastic- leading to contamination of the much larger quantities and more importantly unmarked plastic which contains this restricted chemical.

The current practices of plastic recycling do suggest that there is need to find safer ways or alternatives to deal with such material. The following recommendations are put forth to improve plastic management, especially hazardous fractions.-

- With the adoption of the new e-waste rules, changes have to be implemented in the accompanying guidelines. The guidelines should contain specific suggestions on how to segregate BFR-plastics and clarify the proper management of BFRs. The guidelines will support both formal and informal recyclers to improve their processes.
- There is a need for a guideline for environmentally safe disposal of BFR containing plastics./ recycling of plastics containing BFR to ensure such plastic are recycled with better environment and safety norms
- Manufacturers have to assume their responsibility for this hazardous material.





- Trainings for the informal sector have to be developed and implemented; spreading technologies to further improve the segregation of BFR-plastics and EHS standards in facilities handling these materials.
- Recycling units should have OHS system in place which provides workers with occupational safety and health training. There is an urgent need to generate awareness among plastic recyclers on harmful impacts of toxics used in plastics.
- Preventing the mixing and contamination of a high quantity of plastic, as documented in the study, can be achieved by creating demand for BFR-plastics.
- Products should be labelled with the chemicals which would help to differentiate products containing BFR and would prevent their contamination into the clean plastic being recycled.
- In India, little information is still available on the prevalence of BFRs in plastics other than from e-waste. Internationally, automobiles and the construction sector have been important users of BFRs. In addition, little information is available how plastic (including foams) from these sectors are recycled and disposed. There is a need to produce an inventory of BFRs still existing in the country and include their management in the National Implementation Plan for Stockholm Convention.

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# Annexure

## Annexure 1

Schedule I, E-Waste (Management & Handling) Rules, 2011

Categories of Electrical and Electronic Equipment	
i	<b>Information Technology and Telecommunication Equipment:</b> <ul style="list-style-type: none"><li>a. Centralized data processing,</li><li>b. Mainframes, Minicomputers,</li><li>c. Personal computing,</li><li>d. Personal computers (Central processing unit with input and output devices),</li><li>e. Laptop computers (Central processing unit with input and output devices),</li><li>f. Notebook computers,</li><li>g. Notepad computers,</li><li>h. Printers including cartridges,</li><li>i. Copying equipment,</li><li>j. Electrical and electronic typewriters,</li><li>k. User terminals and systems,</li><li>l. Facsimile,</li><li>m. Telex,</li><li>n. Telephones,</li><li>o. Pay telephones,</li><li>p. Cordless telephones,</li><li>q. Cellular telephones,</li><li>r. Answering systems</li></ul>
ii	<b>Consumer electrical and electronics</b> Television sets (including sets based on (Liquid Crystal Display and Light Emitting Diode technology), Refrigerator, Washing Machine, AirConditionersexcludingcentralizedair conditioning plants.

## Annexure 2

### Questionnaire

1. Kind of activity, the worker is engaged in?

- Sorting
- Grinding
- Pellet making
- Moulding
- Loading and Unloading

2. Do you deal with BFR plastic?

Yes

No

3. Can you recognize BFR plastic?

Yes

No

4. Do you know BFR is hazardous?

Yes

No

5. Do you use any kind of preventive measures?

Yes

No

6. Have you received any kind of occupational health and safety training?

Yes

No

7. Do you have a log book to report accidents or injury:

Yes

No

8. Is there a first aid kit or box available for cuts or small injuries?

Yes

No







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