Toxics Link
for a toxics-free world

LESS IS MORE

Strategies for minimization of Electronic waste

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 is "Working together for environmental justice and freedom from toxics". We have taken upon ourselves to collect and share both information about the sources and danger of poisons in our environment and bodies, and information about clean and sustainable alternatives for India and the rest of the world.

ACKNOWLEDGEMENT

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STUDY AND REPORT

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Strategies for minimization of
Electronic waste

LESS IS MORE

TABLE OF CONTENTS

01 BACKGROUND 06

Market Growth 8
Growing Electronics = Growing E-waste 9
Growing E-waste! No Recycling! But how does it impact us? 11

02 WHAT IS IN EEE? 12

Critical Elements 14
Hazardous Materials 15

03 TRIED STRATEGIES OF E-WASTE MANAGEMENT 16

Failed Collection System 17
Recycling Efficiency 18
Indian Scenario of Collection and Recycling 23
Unaccoutned Costs 25
Procurement of raw materials 25
Resources used in manufacturing 25
Transportation Costs 26
Packaging waste 26

04 NEED FOR MINIMIZING E-WASTE 28

Strategies for Reducing E-waste: In alignment with Sustainable Development Goals 29
Strategies for Reducing E-waste: In alignment with Circular Economy 30
Strategies used to kill repair and reuse 32
Right to Repair: A movement in making 33
Legislation on Reducing, Repair and Re-using E-waste 34
Initiatives taken by producers 37
Takeaway 37

05 RECOMMENDATIONS 38

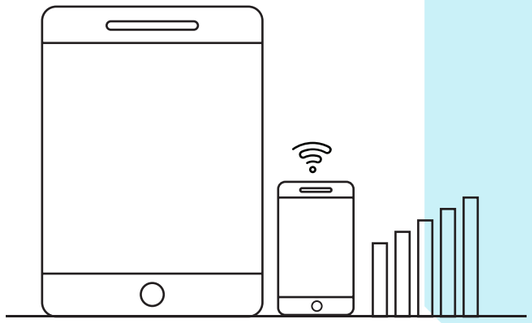
Going beyond Circularity 39
Regulatory Agencies 39
Producers 42
Consumers 43

ABBREVIATIONS

CE	Circular Economy
EC	European Commission
EU	European Union
EEE	Electrical and Electronic Equipment
EPR	Extended Producer Responsibility
EU	European Union
HREE	Heavy Rare Earth Elements. Group of elements called Terbium, atomic number 65 through Lutetium, atomic number 71, and also Yttrium, atomic number 39
LREE	Light Rare Earth Elements. Group of elements called Lanthanum, atomic number 57 through atomic number 64
PRO	Producer Responsibility Organization
PGM	Platinum Group Metal
REE	Rare Earth Elements
SDGs	Sustainable Development Goals
WEEE	Waste Electrical and Electronic Equipment

01

BACKGROUND



There could be nearly

50 BILLION NETWORK CONNECTED DEVICES BY 2020

Electrical and electronic equipment (EEE) represents an essential commodity in today's era and it is becoming increasingly difficult to imagine modern societies without these. The Electronics Industry has evolved tremendously and the sales have proliferated to reach even the remotest parts of the world, therefore the growth rate of this industry is at an ever-increasing pace. The major factors leading to the growth of this industry is increase in levels of individual income, country level development, growing urbanization and mobility, and industrialization. Another factor contributing to the success and growth of the Electrical and Electronic Equipment market is lowering cost owing to competition in the market and technological advances. Producers in countries like India and China are even promising lower prices (ITU 2016) as compared to the world market. This lowering price started attracting the emerging economies as well. The emerging economies with a low Purchasing Power Parity (PPP) have shown the fastest annual growth rates in EEE consumption[1]. Its easy availability and widespread use have enabled much of the global population to benefit with higher standards of living[2].

Figure 1: Key factors in growth of EEE market

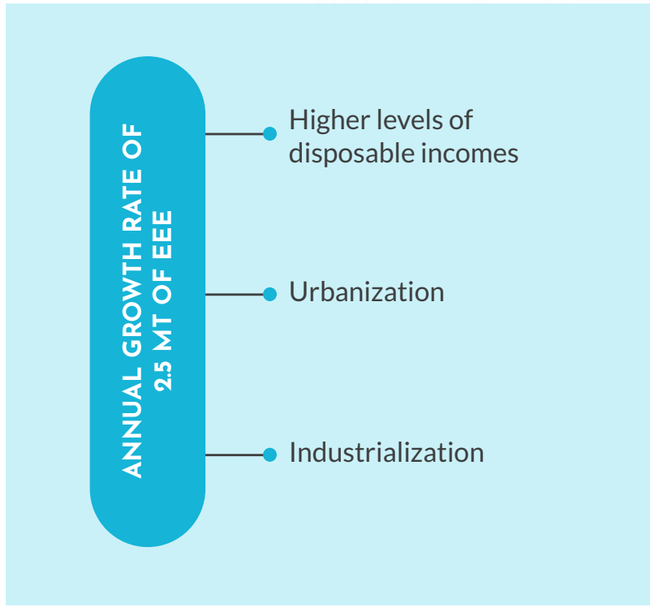


Table 1. Average annual growth rate of EEE per group of countries by Purchasing Power Parity

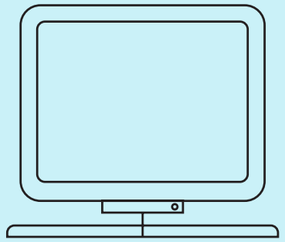
Purchasing Power Parity range (USD/ inh. 2016)		Average growth rate per year
Highest PPP	>34000	1.6%
High PPP	34000 - 15280	5.2%
Mid PPP	15280 - 6740	13%
Low PPP	6740 - 1700	23%
Lowest PPP	<1700	15%

1 Baldé, C.P., Forti V., Gray, V., Kuehr, R., Stegmann,P. : The Global E-waste Monitor – 2017, United Nations University (UNU), International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Vienna.

2 Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam.

MARKET GROWTH

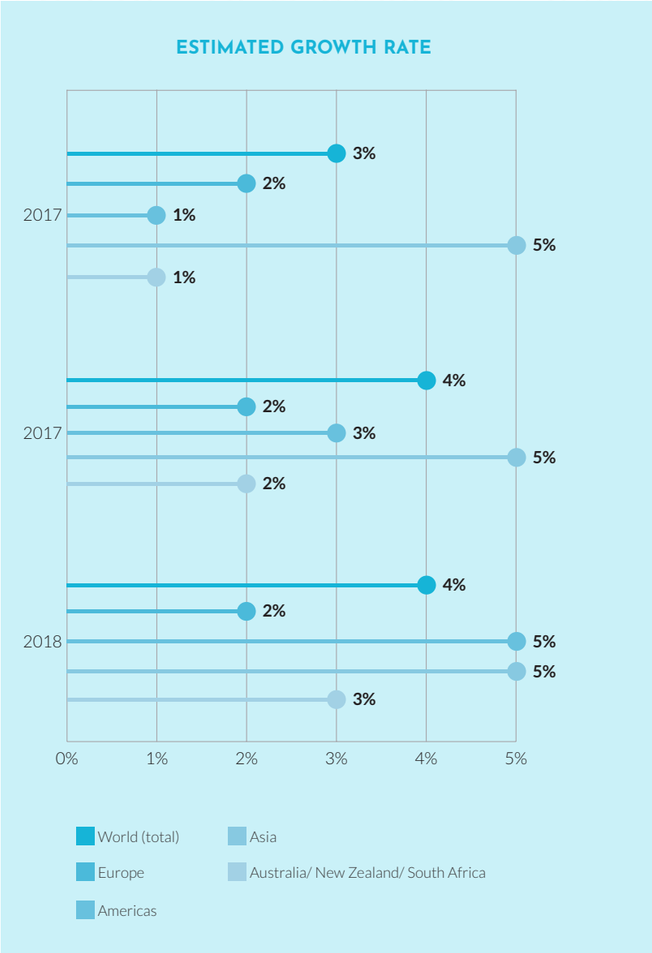
The Electronics market has shown tremendous growth in the last two decades and this growth is continuing even now. Though the growth rate was down in 2020, a COVID-induced effect, at -3% for the world -it is expected to rise up again to 6% in 2021. Revenue is expected to show an annual growth rate (CAGR 2020-2024) of 5.4%, resulting in a projected market volume of US$450,387m by 2024[3]. The consumer electronics market size was valued at US$ 1 trillion in 2019 and is estimated to grow at a CAGR of over 7% between 2020 and 2026[4]. User penetration of consumer electronics will be 22.3% in 2020 and is expected to hit 32.5% by 2024 globally. According to a report by Forrester Research, there were over one billion PCs in use worldwide by the end of 2008, and over 2 billion by the year 2015. Depicting the fast growth rate of electronics being sold, World Meters reports that over 23 million computers have been sold in 55 countries this year till date (as on 9th December), 2020 which includes desktop, notebook, ultra-portable and x86 Server[5].



According to **World Meters over 10 CR computers** have been sold in 55 countries **this year till June, 2020**

Amongst all regions Asia is predicted to experience the strongest growth[6] with 5% annual growth rate in 2018. The reason for this growth is availability of a new market due to emerging economies such as China and India which are also densely populated. The Indian Brand Equity Foundation (IBEF) reports that the Indian Electronics Industry is one of the fastest growing industries both in terms of production and export. In India the user penetration rate is lower than the global average at 17% and is projected to increase to 25% in 2024[7]. Considering the population of India, this means that 9.5 crore people will be added as new users in India. The figures are indicative of the fact that the Indian market has not yet saturated, and therefore still has immense potential of growing.

Figure 2: Estimated growth rates for the global electronics industry from 2016 to 2018, by region



3 https://www.statista.com/statistics/268396/estimated-growth-rates-for-the-electronics-industry-by-region/
4 Consumer Electronics Market Forecast 2026 | Global Report, Published-August 2020
5 https://www.worldometers.info/computers/
6 https://www.statista.com/statistics/268396/estimated-growth-rates-for-the-electronics-industry-by-region/
7 Ibid

GROWING ELECTRONICS = GROWING E-WASTE

An expanding market base or new markets is one of the key contributors to the rising EEE sales. But replacement sales or consumers who discard their old electronics to buy new ones, are also big contributors to this booming market. Falling prices and higher disposable income, coupled with forced aging of existing models is changing consumer behaviour and their disposal methods. Rapid change in technology incites or at times compels consumers to buy the latest models, discarding their functional EEE, making it probably one of the key reasons. One of biggest examples of obsolete technology rendering products useless is the shift in television industry, which shifted from big, bulky CRT to flat display LCD and finally LED monitors completely. A growing global middle-class with higher incomes often purchases a new product or device, replacing the old one, as this holds a status symbol and provides social recognition. Another reason is that repairing, which was popular earlier, has been 'made' difficult for the consumers, as electronic industry giants earn more profits by selling a new electronic device, and thus they make it difficult for consumers to upgrade or repair the gadgets.

The forced aging phenomenon is specially observed in smartphones, where the older models are not even supported by software updates, leaving the device unusable at times and forcing the consumers to change their phones. However, this is not restricted to phones. To benefit from the latest upgrades, higher speeds, and the latest technologies, consumers and businesses regularly change their laptops, PCs, routers, TV sets, and other devices. This is giving rise to a 'throwaway society'.

The pertinent question in such a scenario is, **WHAT HAPPENS TO THESE DISCARDED ELECTRONICS DEVICES?**

9.2 MT MORE E-WASTE GENERATED IN 2019 AS COMPARED TO 2014

- Higher consumption rates of EEE
- Design for Dump
- Few repair options

Recently an electronics company, anyway infamous for its recycling policies and bringing redundancy to its older models, introduced a "no charger" with USD $999 phone claiming that it would reduce packaging and many people already have chargers which are compatible. However, these new phones have rapid charging which is not supported by old chargers. So, if you want to avail this new technology then YOU WOULD HAVE TO BUY THE NEW CHARGER AS WELL, killing the entire point of saving the environment. This same company is notoriously known for changing the charger type and port every time it introduces a new model. This no-charger policy seems more like a money-making scheme than even remotely being related to the environment

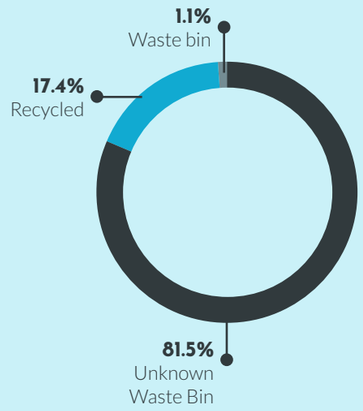
They become part of the **fastest growing waste stream** called **E-waste**

EEE becomes e-waste once it has been discarded by its owner as waste without the intent of reuse (Step Initiative 2014). According to EU WEEE directive 2012 'waste electrical and electronic equipment' or 'WEEE' means electrical or electronic equipment which is waste within the meaning of Article 3(1) of Directive 2008/98/EC, including all components, sub-assemblies and consumables which are part of the product at the time of discarding;

Global E-waste Monitor (2014) reported 41.8 Mt of E-waste being generated in 2014. Global E-Waste Monitor (2020) estimated that 53.6 Mt of e-waste was generated globally in 2019 which is expected to exponentially increase to 74.7 Mt in 2030- almost doubling in 16 years. The appalling factor is that out of the 53.6 Mt of E-waste generation the fate of 81.5% remains unknown. The collection and recycling rates are as low as 17.4% globally, as in 2019 the formal documented collection and recycling rate was only 9.3 Mt. If we look at the collection and recycling percentages closely, though E-waste has increased by 11.8 Mt worldwide in the period between 2014 to 2019, the amount of e-waste collected and recycled during this period increased only by 2.8 Mt. The recycling rate has an annual growth rate of 0.6 Mt, where the total E-waste generation had an annual growth rate of 2.8 Mt.

This makes it quite clear that recycling activities are not keeping up with the pace of E-waste being generated.

E-WASTE MANAGEMENT- WORLD STATISTICS

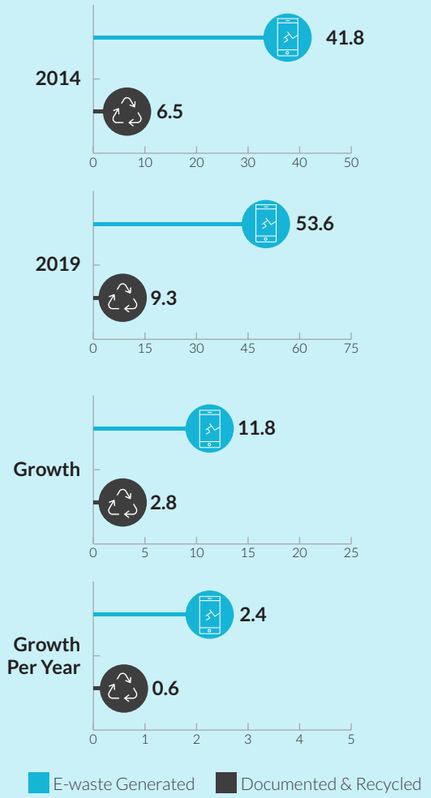


Since 2014, the number of countries that have adopted a national E-waste policy, legislation or regulation has increased from 61 to78 (as of October 2019). However regulatory advances are slow, enforcement is poor and policy, legislation or regulation does not yet stimulate the collection and management of e-waste due to lack of investment and political motivation[8].

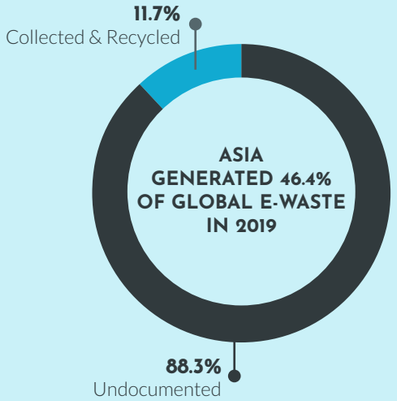
Asia as a region generated highest quantity of E-waste in 2019 at 24.9 Mt[9] accounting for 46.4% of total E-waste generated globally, as compared to 40.7% in 2016. Out of the E-waste generated in Asia, only 11.7% is documented to be collected[10], far behind Europe which has a collection rate of 42.5%.

India is the second highest generator of E-waste in Asia. India generated 3.2 Mt of E-waste in 2019. According to data available in the public domain in 2016 from ASSOCHAM India, the amount of E-waste that is collected and recycled in India is 0.03 Mt. E-waste Rules were first notified in India in 2011, with a more stringent form replacing it in 2016. The Rules were expected to increase the quantum of E-waste collected and recycled in India in formal recycling units. However, studies in India suggest that the majority of waste quantities are still handled in the informal sector and the formal recycling centres remain underutilized[11].

DIFFERENCE IN GROWTH BETWEEN E-WASTE GENERATED AND RECYCLED (MT)



E-WASTE MANAGEMENT - ASIA



GROWING E-WASTE! NO RECYCLING! BUT HOW DOES IT IMPACT US?

E-waste is a unique waste stream, with a mix of hazardous, precious and critical resources. On one hand, it contains several toxic additives or hazardous substances such as mercury, brominated flame retardants (BFRs), chlorofluorocarbons (CFCs), or hydrochlorofluorocarbons (HCFCs) and many other heavy metals and non- environmentally sound disposal and treatment of this waste stream can pose significant risks to the environment and human health. For example, currently 43.7 Mt of E-waste is not being handled in an environmentally sound way. This means approximately **50 Tonnes of mercury** and **71 Kilo tonnes of BFR** from plastics and **98 Mt of CO_2** from Hydrofluorocarbons (HCFs) are in the globally undocumented flows annually[12]. These elements are eventually leaching to the environment and many exposed workers, mostly informal, have several health impacts.

Electronic equipment also contains many critical elements which are present in a scarce quantity in the environment. In 53.6 Mt of E-waste there is **$57 billion worth of raw material**. These critical elements if not recovered are lost to the environment when the resources are not recovered.

A 2019 Cisco VNI report forecast that on a global basis, there will be **28.5 billion networked devices in use by 2022, up from 18.0 billion in 2017,** and 3.6 networked devices per capita **by 2022, up from 2.4 per capita in 2017.**

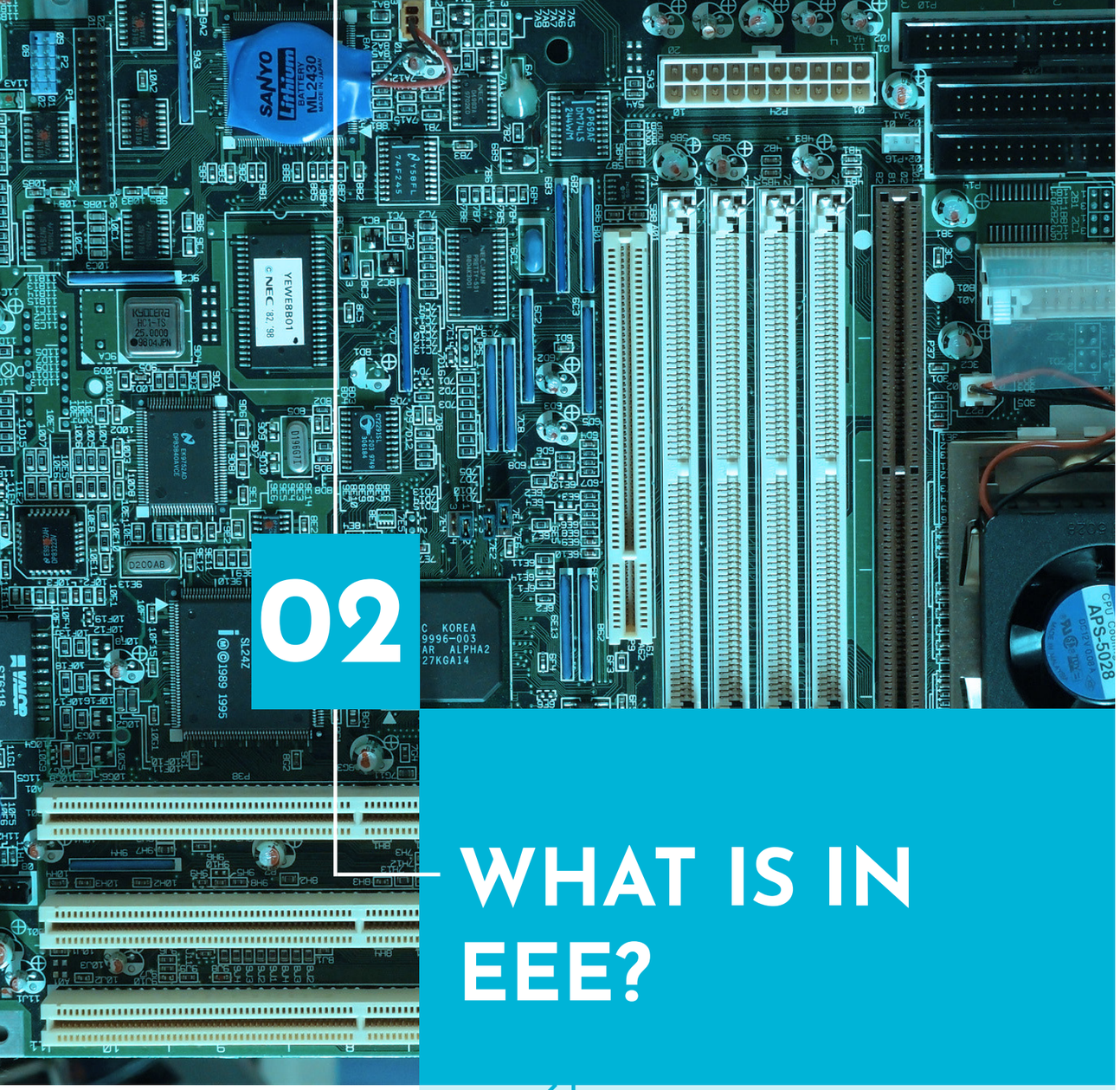
8 Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam.

9 Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam.

10 Ibid

11 Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam.

12 Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam.1



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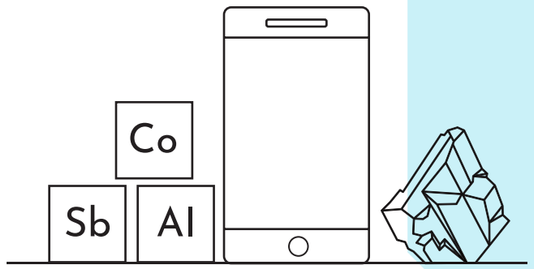
WHAT IS IN EEE?



More than 60 elements from the periodic table, including critical elements,

MAY BE FOUND IN ELECTRONICS

The electronic products contain many components which are made from a range of diverse and specific electro physical properties[13], anything from insulation to conductivity. The European Topic Centre on Sustainable Consumption and Production mentions that e-waste is commonly composed of steel and iron (about 50% of the weight), plastic (21%), various non-ferrous metals including precious ones (13%) and glass (5%). While these percentages may vary from product to product and may change with time (due to changing of the technologies), most of them undeniably have elements of value. The electronics market now consumes almost 80% of the world's demand of Indium (transparent conductive layers in LCD glass), over 80% of Ruthenium (magnetic properties in hard disks) and 50% of Antimony (flame retardants)- all rare metals available in limited quantities. A typical mobile phone can contain over 40 elements and smartphones can contain more than 60 including base metals like Copper (Cu) and Tin (Sn); special metals such as Lithium (Li), Cobalt (Co), Indium (In), and Antimony (Sb); and precious metals such as Silver (Ag), Gold (Au), and Palladium (Pd). The potential of E-waste recycling depends on the elements that are used in the Electrical and Electronic Equipments. More than 60 elements from the periodic table may be found in materials and components which are used[14] and can be classified into four main groups.

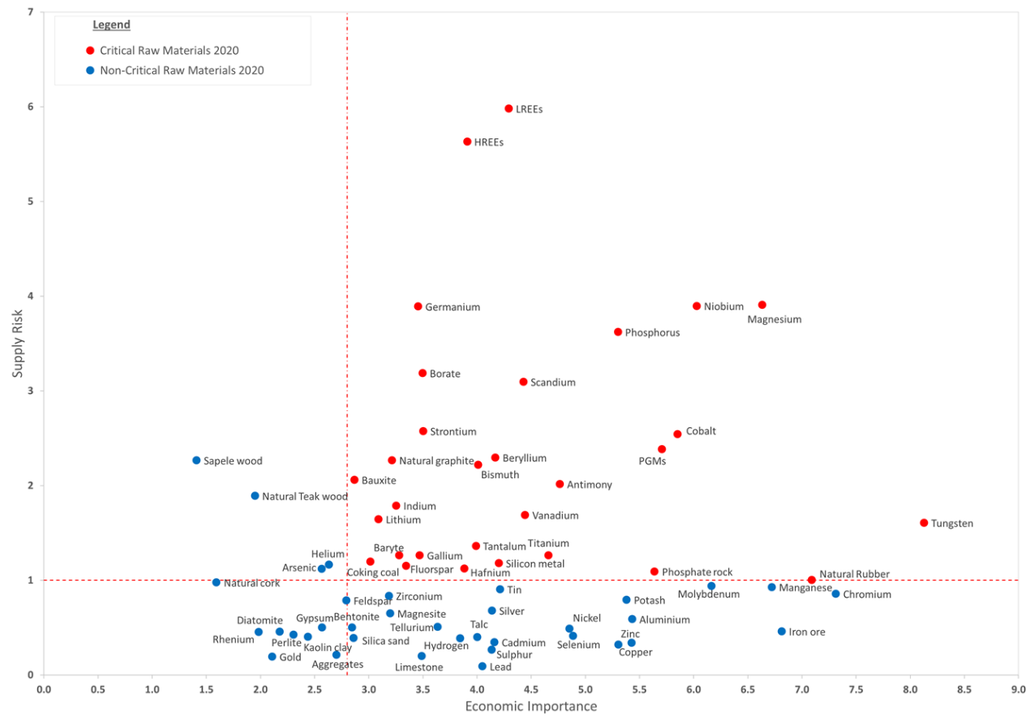
1. METALS

Many different metals could be found in electronic products. Steel and iron are the ones that account for about 50% of the products' weight. Other common and well-known materials are aluminium and copper, used for their high conductivity and malleability (good characteristics for shaping and mashing). Several other metals, such as nickel, chromium, lead, silver, gold or tin are used in resistors, capacitors and transducers. The majority of the other metals are used in much smaller amounts.

2. RARE-EARTH ELEMENTS

Rare-earth elements (REEs) are a group of Lanthanides series, Scandium and Yttrium (17 elements in total). REEs are usually used in small or very small amounts, but they are vital for many high-tech applications, for instance, permanent magnets, batteries, lasers and phosphors[15].

Figure 4 Critical and Non critical elements recognised against the parameters of supply risk and economic importance as identified by European Union



13 Miliute-Plepiene J. et al. 2019. E-waste and Raw Materials: From Environmental Issues to Business Models. IVL Swedish Environmental Research Institute.
14 Ibid
15 Ibid

3. PLASTICS AND OTHER PETROLEUM-BASED MATERIALS

Plastics are the second largest group of materials used in electronic products and constitute about 20% of e-wastes by weight[16]. Plastics are mainly used in electronics for their insulating and heat-resistant characteristics.

Minerals and non-metallic materials

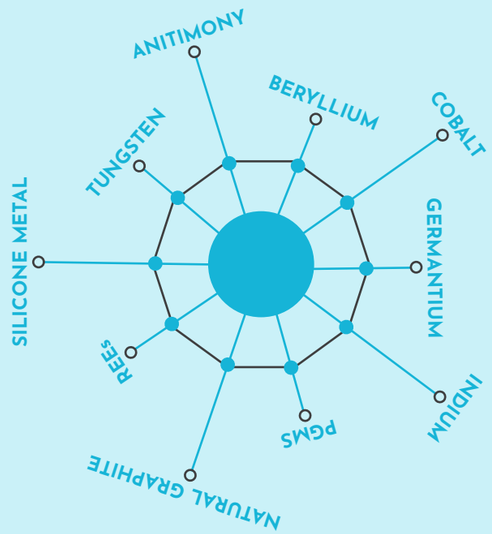
Some metalloid (or semi-metal) materials, such as Silicon, are also used in e-products, enabling many of their key technical features. Silicone and its derivatives are the main substrate material in the production of microchips and semiconductors. Other non-metal or semi-metal materials are Antimony, Bismuth, Cobalt, Fluorite, Garnet, Magnesium and Talc. Other materials like Ceramics are also used for their insulation characteristics. Certain clays, glasses, calcium and carbon (in various forms) are also often used.

CRITICAL ELEMENTS

Some of the above-mentioned materials are used in small or even trace quantities but they have severe environmental impacts. A few of these materials are defined as critical due to increasing mismatch between supply and demand, high price volatility or politically - induced limitations of supply[17]. In 2017 the EU released a list of materials defined as "critical". The criticality of these materials is defined by its importance in the economy and high supply risks. Many of these critical materials such as Antimony, Beryllium, Cobalt, Germanium, Indium, PGMs, natural graphite, REEs, silicon metal and Tungsten are used in EEE products. Though these exotic materials were not required much in the past, of late there has been a sudden increase in their demand[18]. Albeit crucial , they find their usage in EEE in small quantities,.

Table 2 List of elements included in the critical raw material list by European Commission

Antimony	Fluorspar	LREEs	Phosphorus
Baryte	Gallium	Magnesium	Scandium
Beryllium	Germanium	Natural graphite	Silicon metal
Bismuth	Hafnium	Natural rubber	Tantalum
Borate	Helium	Niobium	Tungsten
Cobalt	HREEs	PGMs	Vanadium
Coking coal	Indium	Phosphate rock	



Critical elements being used in electronic products, these represent **37%** of the total critical elements listed out

HAZARDOUS MATERIALS

The importance of focusing on E-waste management is not just because of the critical and rare elements in electronic products but also the hazardous elements in E-waste. Most electronic products contain heavy metals such as mercury, lead, cadmium, chromium, and many others[19] . Other hazardous substances include, for instance, brominated flame retardants used in plastics, which have similar negative effects. These hazardous elements if leached out to the environment can cause severe harm to environment and human health by entering into human food chains and ecosystems and bio-accumulating in living tissues. The highest risks of exposure and harmful health effects are often due to improper management/recycling of e-waste, which, for example, can directly affect workers at waste management sites or indirectly affect society at large by leaching into the soil and water, harming microorganisms, disrupting ecosystems and entering into food chains though complex bio-accumulation mechanisms[20]. As it has been established, currently 80% of E-waste is being either dumped in a landfill or managed in the informal sector, therefore these hazardous elements are being currently lost to the environment.

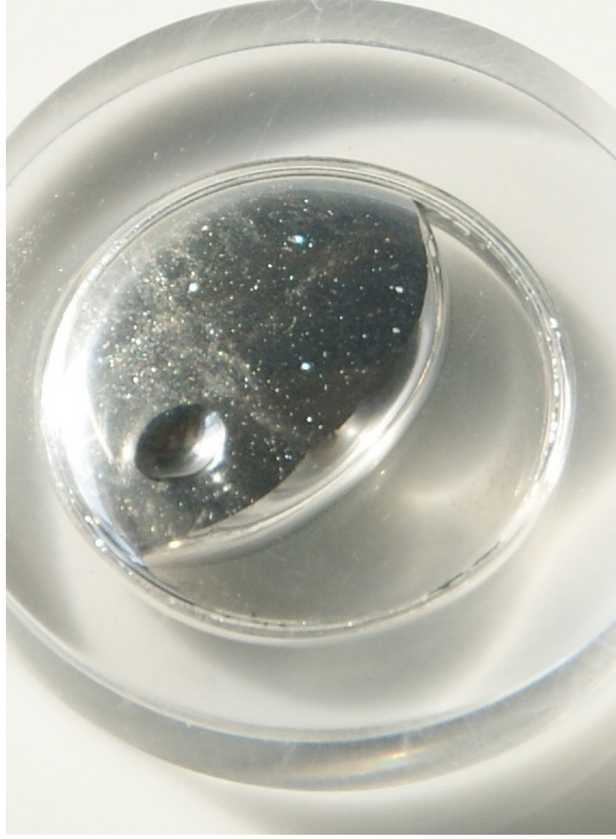


Table 3 Hazardous Elements in E-waste their impacts

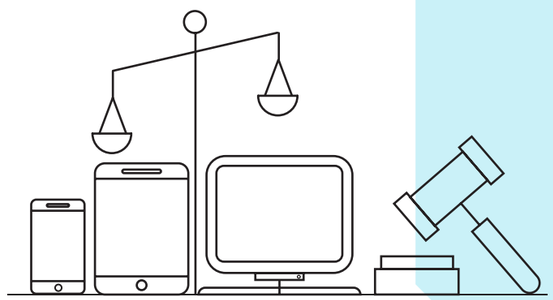
Elements	Usage	Impact
Lead (Pb)	Used in the glass of CRT monitors (both TV and computer), circuits, solder in printed circuit boards, lead acid batteries	Carcinogenic, neurotoxic, reprotoxic, endocrine disruptor and persistent, bio-accumulative. The effects are most damaging in-utero and to children.
Mercury (Hg)	Used in fluorescent light tubes, flat screen monitors, tilt switches, cell phones.	Carcinogenic, neurotoxic, reprotoxic effects, persistent toxin, endocrine disruptor, bio-accumulativecharacteristics. Exposure to Hg isvery damaging to foetuses and small children.
Cadmium (Cd)	Mostly present in Ni-Cd batteries, light-sensitive resistors, and corrosion-resistant alloys for marine and aviation environments	Carcinogenic, repro and neuro-toxic, mutagenic, endocrine disruptor.
Brominated Flame Retardants (BFR)	Used to reduce the flammability of plastics in most e-products. Includes polybrominated biphenyls (PBBs), polybrominated diphenyl ether (PBDEs) decabromodiphenyl (DecaBDE) and octabromodiphenyl (OctaBDE) ethers.	Endocrine disruptor, persistent, Bio-accumulative and toxic. Effects Include impaired development of the Nervous system, thyroid problems and Liver problems

16 Ibid
17 Bakas, I., et al. (2016). Critical metals in discarded electronics. Mapping recycling potentials from selected waste electronics in the Nordic region. Denmark, Nordic Council of Ministers.
18 Miliute-Plepiene J. et al. 2019. E-waste and Raw Materials: From Environmental Issues to Business Models. IVL Swedish Environmental Research Institute.

19 Baldé, C.P., Forti V., Gray, V., Kuehr, R., Stegmann,P. : The Global E-waste Monitor – 2017, United Nations University (UNU), International Telecommunication Union (ITU) & InternationalSolid Waste Association (ISWA), Bonn/Geneva/Vienna.
20 Miliute-Plepiene J. et al. 2019. E-waste and Raw Materials: From Environmental Issues to Business Models. IVL Swedish Environmental Research Institute.

03

TRIED STRATEGIES OF E-WASTE MANAGEMENT



78 COUNTRIES AND 71% OF THE WORLD'S POPULATION

are currently covered under some form of e-waste regulation

The strategies applied globally in managing the enormous amount of E-waste focuses on an end-of-life system, through setting up collection mechanisms and facilitating recycling operations. It is believed that a robust collection system, followed by an efficient recycling system is the solution to this problem. The following section tests this claim against the waters of facts available in the public domain.

FAILED COLLECTION SYSTEM

Is Regulation the solution for this humongous problem?

> Each product has different material content, is disposed of and recycled in different ways, and is harmful to the environment and human health if not managed in an environmentally sound manner (Global E-waste Monitor, 2020)

E-waste includes various types of equipments; information and communication devices like computers, printers and mobile phones, large household gadgets like televisions, refrigerators, air conditioners etc, small devices like grinders, microwaves, lighting etc. These are generated in different kinds of establishments, including offices, factories, educational institutions and households etc. The foremost challenge seen in managing e-waste was its dispersed generation and setting up a collection mechanism for the same. The way taken for achieving this was national regulatory frameworks and implementation of the same. The logic followed was that increasing the collection capacity and making it more efficient will be the solution. 78 countries and 71% of the world's population are currently covered under some rule, policy and regulation but there are still lower rates of collection and recycling. As we have stated earlier, only 17.4% of the total E-waste generated is being collected and recycled in a formal setting globally. These dismal collection numbers do indicate the lackadaisical attitude of national authorities in implementing the regulations, but more importantly clearly show the failure of a stand-alone regulatory tool to bring back end-of-life products into collection systems. This has led to an enormous amount of E-waste going undocumented. Most of this undocumented waste ends up in landfills or ends in the informal sector, especially in developing countries. The processes used in the informal sector yields a lower recycling efficiency[21] and critical as well as toxic, hazardous elements are lost out to the environment.

Hence, the assumption that legislation will automatically lead to higher collection rates and will help in managing E-waste, is really in question. But this challenge also leads us to an even bigger one. If hypothetically one were to assume 100% collection, will that solve all the concerns?

21 Chi, X., Streicher-Porte, M., Wang, M. Y. L., & Reuter, M. A. (2011). Informal electronic waste recycling: A sector review with special focus on China. Waste Management, 31(4), 731–742.

RECYCLING EFFICIENCY

E-waste management has also assumed huge importance because of the resources it contains and it is now being often seen as a secondary mine for valuable materials, and therefore recycling is deemed to be of much importance. The Electronics Industry consumes many precious, rare and critical elements. Precious heavy metals like gold, silver, which are in EEE, make recycling of E-waste a business opportunity and a secondary mine for recovering valuable metals. E-waste management entails various steps, but at the heart of the process is the separation of materials. E-waste components or parts are manually dismantled and segregated by materials to facilitate recycling or physically shredded before sorting and separation of plastics from metals and components. Magnets are then used to separate ferrous metals from other elements, and these iron and steel fragments can thereafter be resold as recycled steel.

Hydrometallurgical processes are used to separate metals; printed circuit boards are dissolved into leaching solutions consisting of sulfuric acid, hydrochloric acid, nitric acid, aqua regia, and alkalis. The desired metals can then be recovered via a number of processes, including electrorefining, precipitation and solvent extraction etc. Processes like pyrometallurgical and bio-metallurgical processing are also used for recovering metals. While these processes are effective to some extent, theycan be expensive, in terms of the actual economic cost incurred in the method, as well as the ecological cost to carry out each process. What is also overlooked is the resource not recovered or lost. The tables and figures below show the recycling efficiency that has been achieved in recycling some of the end-of-life equipment and the amounts which will be lost during recycling. Efficient collection is seen as one of the biggest hurdles in e-waste management. So, even if the channels of collection are made 100% efficient, the recycling efficiency of E-waste is never 100% and hence this loss.

The improper handling of e-waste is resulting in a significant loss of scarce and valuable raw materials, of resources, some of which are non-renewable.

Table 5: Amount of Recoverable Elements in Personal Computer (CRT Monitors)

Personal Computer (CRT Monitors)[22]				
Elements	**Content (% of total weight)***	**Content (kg)***	**Recycling efficiency (%)***	**Recoverable weight of element (kg)#**
Plastics	23	6.63458	20%	1.326916
Lead	6	1.73076	5%	0.086538
Aluminum	14	4.03844	80%	3.230752
Germanium	0.0016	0.000462	0%	0
Gallium	0.0013	0.000375	0%	0
Iron	20	5.7692	80%	4.61536
Tin	1	0.28846	70%	0.201922
Copper	7	2.01922	90%	1.817298
Barium	0.0315	0.009086	0%	0
Nickel	0.8503	0.245278	0%	0
Zinc	2	0.57692	60%	0.346152
Tanialum	0.0157	0.004529	0%	0
Indium	0.0016	0.000462	60%	0.000276922
Vanadium	0.0002	5.77E-05	0%	0
Terbium	0	0	0%	0
Beryllium	0.0157	0.004529	0%	0
Gold	0.0016	0.000462	99%	0.000456921
Europium	0.0002	5.77E-05	0%	0
Tritium	0.0157	0.004529	0%	0
Ruthenium	0.0016	0.000462	80%	0.000369229
Cobalt	0.0157	0.004529	85%	0.003849499
Palladium	0.0003	8.65E-05	95%	8.22111E-05
Manganese	0.0315	0.009086	0%	0
Silver	0.0189	0.005452	98%	0.005342856
Antinomy	0.0094	0.002712	0%	0
Bismuth	0.0063	0.001817	0%	0
Chromium	0.0063	0.001817	0%	0
Cadmium	0.0094	0.002712	0%	0
Selenium	0.0016	0.000462	70%	0.000323075
Niobium	0.0002	5.77E-05	0%	0
Yttrium	0.0002	5.77E-05	0%	0
Rhodium	0	0	50%	0
Mercury	0.0022	0.000635	0%	0
Arsenic	0.0013	0.000375	0%	0
Silica	24.8803	7.176971	0%	0

22 *UNEP E-waste Inventory Assessment Manual (2007) #Recoverable weight calculated against the average weight from:Forti et al.2018. United Nations University

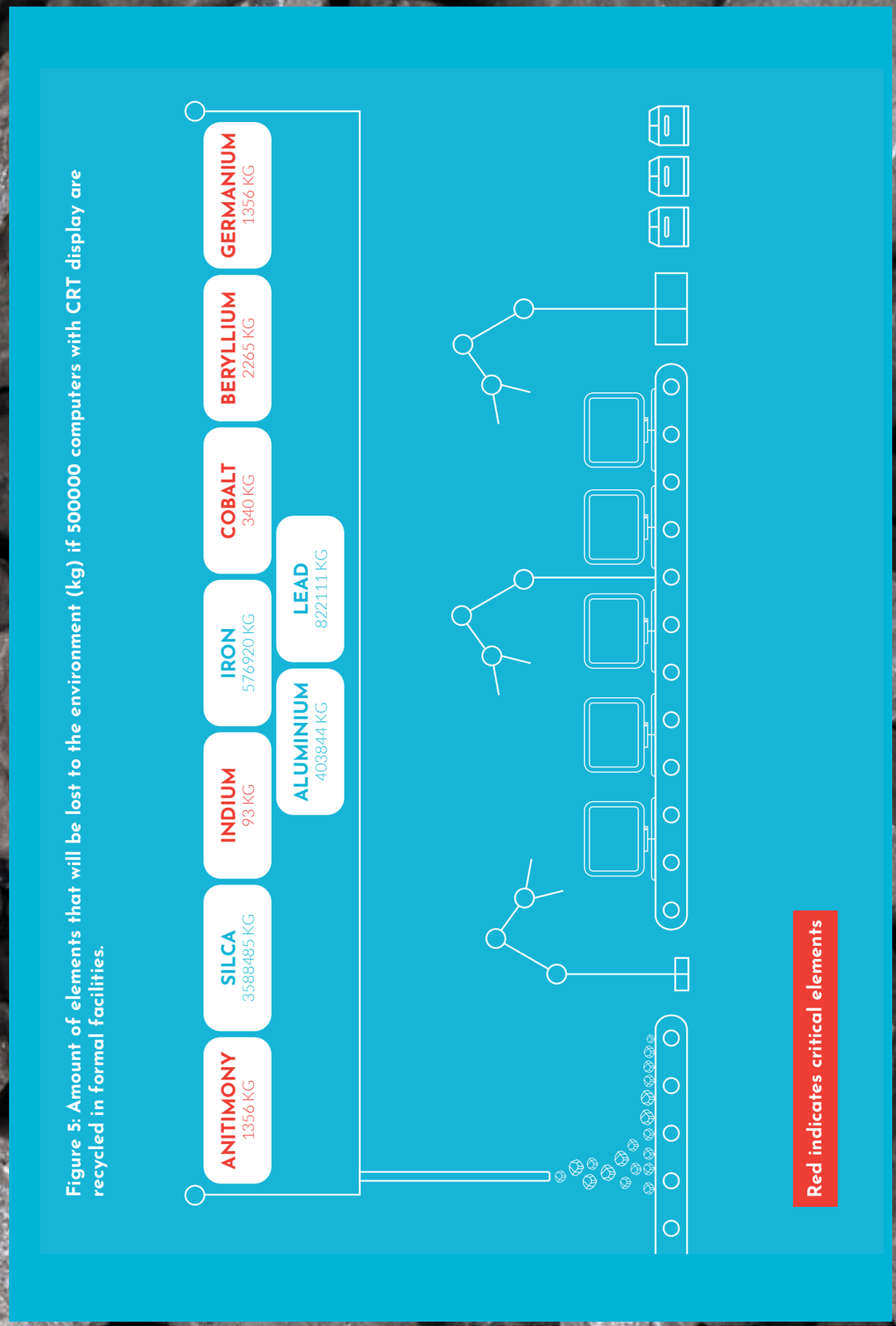


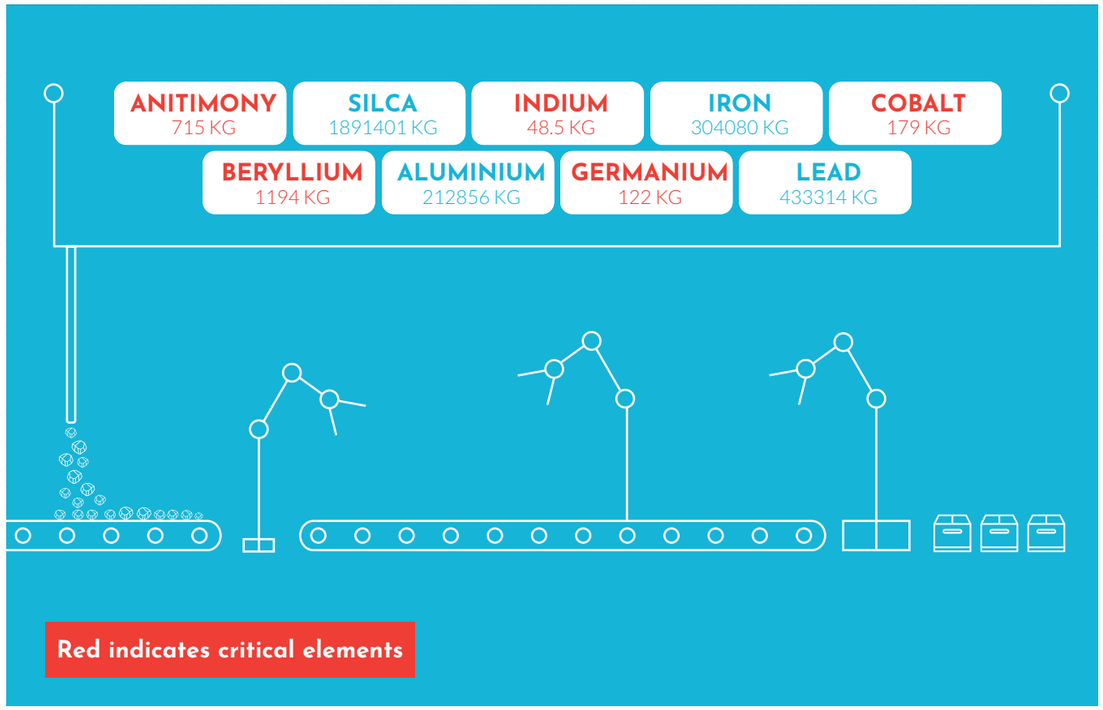
Figure 5: Amount of elements that will be lost to the environment (kg) if 500000 computers with CRT display are recycled in formal facilities.

Table 6 Amount of Recoverable Elements in Personal Computer (Flat Display Monitors)

Personal Computer (Flat Display Monitor)[23]				
Elements	**Content (% of total weight) ***	**Content (kg)***	**Recycling efficiency (%)***	**Recoverable weight of element (kg)#**
Plastics	23	3.49692	20%	0.699384
Lead	6	0.91224	5%	0.045612
Aluminium	14	2.12856	80%	1.702848
Germanium	0.0016	0.000243	0%	0
Gallium	0.0013	0.000198	0%	0
Iron	20	3.0408	80%	2.43264
Tin	1	0.15204	70%	0.106428
Copper	7	1.06428	90%	0.957852
Barium	0.0315	0.004789	0%	0
Nickel	0.8503	0.12928	0%	0
Zinc	2	0.30408	60%	0.182448
Tanialum	0.0157	0.002387	0%	0
Indium	0.0016	0.000243	60%	0.000146
Vanadium	0.0002	3.04E-05	0%	0
Terbium	0	0	0%	0
Beryllium	0.0157	0.002387	0%	0
Gold	0.0016	0.000243	99%	0.000241
Europium	0.0002	3.04E-05	0%	0
Tritium	0.0157	0.002387	0%	0
Ruthenium	0.0016	0.000243	80%	0.000195
Cobalt	0.0157	0.002387	85%	0.002029
Palladium	0.0003	4.56E-05	95%	4.33E-05
Manganese	0.0315	0.004789	0%	0
Silver	0.0189	0.002874	98%	0.002816
Antinomy	0.0094	0.001429	0%	0
Bismuth	0.0063	0.000958	0%	0
Chromium	0.0063	0.000958	0%	0
Cadmium	0.0094	0.001429	0%	0
Selenium	0.0016	0.000243	70%	0.00017
Niobium	0.0002	3.04E-05	0%	0
Yttrium	0.0002	3.04E-05	0%	0
Rhodium	0	0	50%	0
Mercury	0.0022	0.000334	0%	0
Arsenic	0.0013	0.000198	0%	0
Silica	24.8803	3.782801	0%	0

23 *UNEP E-waste Inventory Assessment Manual (2007)#Recoverable weight calculated against the average weight from:Forti et al.2018. United Nations University

Figure 6: Amount of elements that will be lost to the environment (kg) if 500000 computers with flat display are recycled in formal facilities.



In a formal e-waste recycling structure, toxic elements like lead have only a 5% resource recovery potential and many metals like Germanium, Gallium, Barium, Nickel, Vanadium, Terbium, Manganese, Chromium and Cadmium have 0% resource recovery potential. And that would mean all the critical elements, valuable materials going down to landfills or lost and the hazardous materials and chemicals being released into the environment.

Unfortunately, this is not the only problem associated with recycling of E-waste. Another key point to be kept in mind is that proper and safe recycling often costs more money than the materials are worth, especially when the cost of collection and reverse logistics is added to the same. And hence, many components are not recycled and are just dumped, like in case of mercury-containing lamps. The process of recycling is labour intensive and often does not make sense in countries with high labour costs[24]. It is also more profitable if environment safety is compromised. For these reasons, e-waste is often subject to illegal shipments into developing countries for recycling[25]. Here e-waste is often dismantled and semi-recycled illegally using low-tech solutions with poor or no protection from the associated risks. Many hazardous and toxic materials are released during improper dismantling or recycling operations, which inevitably enter into food chains and pose risks to human health.

> Toxic elements like lead in E-waste only have 5% resource recovery potential and many metals like Germanium, Gallium, Barium, Nickel, Vanadium, Terbium, Manganese, Chromium and Cadmium have 0% resource recovery potential.

With the changing technology and upgrading, the products are also becoming lighter, more compact; resulting in more complex designs and difficult to recycle at the end-of-life. In many devices, such as smartphones, tablets, or smart watches, components are integrated into the design and hence harder to separate. Components are often sealed, so even removing a simple battery can be a time-consuming challenge, making end-of-life recycling efforts both tedious and expensive. Many a times, even removing simple labels take a lot of time, making recycling unviable, especially in countries with high labour cost. Further, as devices get smaller, the material value of electronic devices is getting smaller; also, there is reduced usage of precious metals, which means the recovery value is lesser and hence recycling is economically not so viable.

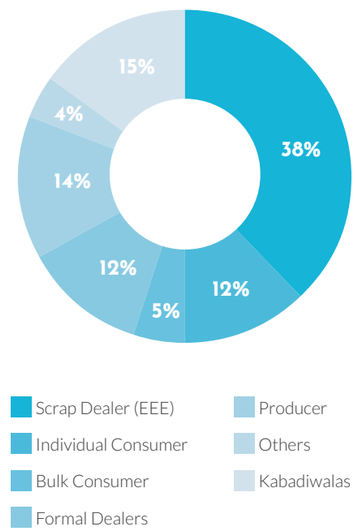
24 Ibid
25 Miliute-Plepiene J. et al. 2019. E-waste and Raw Materials: From Environmental Issues to Business Models. IVL Swedish Environmental Research Institute.

INDIAN SCENARIO OF COLLECTION AND RECYCLING

Producers are mandated by E-waste (Management) Rules, 2016, under the purview of EPR, to set up a collection and recycling mechanism. Eight years after the first rule that came in 2012 and 4 years since the revised rules, the situation on ground is still a problem, with major EEE brands not having an effective take-backmechnism in the country[26].

The Informal sector recycling of E-waste continues to be a flourishing and profitable business in India. A study by Toxics Link[27] which tracked Informal E-waste hotspots in Delhi, estimated 5000 units functioning in the city, over 50000 workers involving themselves in collection, international and regional trading, dismantling, segregation of components, repairing, refurbishing and metal recovery. Most of the practices of dismantling were rudimentary and manual. After manual separation material-specific recovery processes are applied. Generally, these processes show low recovery efficiency [28] and do not abate environmental emissions. Furthermore, when it comes to recycling of precious metals, the efficiency of recycling and extraction of metals in the informal sector lags behind completely. Recycling efficiency of Gold, Silver, Platinum, Palladium and Lead in the informal sector is approximately 20%-30%[29]. Also, none of these units had health and environment protection measures. In the Toxics Link study one of the most shocking results was that 14% of waste inflow of EEE was from the producers itself (Figure 5).

Figure 7 Inflow of WEEE to the informal sector. A study by Toxics Link in the Informal E-waste situation in Delhi. http://www.toxicslink.org/docs/Informal%20E-waste.pdf



26 http://toxicslink.org/docs/Time%20to%20Reboot%203.pdf
27 http://www.toxicslink.org/docs/Informal%20E-waste.pdf
28 Chi, X., Streicher-Porte, M., Wang, M. Y. L., & Reuter, M. A. (2011). Informal electronic waste recycling: A sector review with special focus on China. Waste Management, 31(4), 731–742. https://doi.org/10.1016/j.wasman.2010.11.006
29 Ibid

Table 9 Environmental Impacts of Informal recycling sector in E-waste management in India (Wath, Dutt et al., 2011)

E-waste Component	Process Used	Potential Environmental Hazard
Cathode ray tubes (used in TVs, computer monitors, ATMs, video cameras and more)	Breaking and removal of yoke followed by dumping	Lead, Barium and other heavy metals leaching into groundwater and release of toxic Phosphor
Printed circuit board	De-soldering and removal of computer chips; open burning and acid baths to remove metals after chips are removed	Air emissions and discharge into rivers of Glass dust, Tin, Lead, Brominated Dioxin, Beryllium, Cadmium and Mercury
Chips and other gold-plated components	Chemical stripping using nitric and hydrochloric acid and burning of chips	Polycyclic Aromatic Hydrocarbons (PAHs), heavy metals, brominated flame retardants discharged directly into rivers acidifying fish and flora. Tin and Lead contamination of surface and groundwater. Air emissions of brominated dioxins, heavy metals, and PAHs
Plastics from printers, keyboards, monitors, etc.	Shredding and low temp melting to be reused	Emissions of brominated dioxins, heavy metals, and hydrocarbons
Computer wires	Open burning and stripping to remove copper	PAHs released into air, water, and soil.

As it has already been established E-waste is one of the fastest growing waste streams in India and with increasing purchasing power parity this stream has been projected to grow even further. With informal structures handling majority of the E-waste, considering it is not following any safety protocols which is what makes it profitable, the environmental impacts (Table 9) of it are profound. Therefore, it is important for a developing country like India to focus on managing E-waste.

The presence of critical elements and losses during the recycling process of EEE does warrant us to reconsider our approach in managing E-waste. But the big question is if it is possible to develop technology which will make recycling 100% efficient and economically feasible and even if that happens, will it solve all the problems?

All EEEs use lot of resources, apart from the ones contained in them. The energy used in manufacturing, transportation and packaging have their environmental impact as well.

UNACCOUNTED COSTS

Even if 100% recycling efficiency is achieved, can the environmental and social impacts be offset?

The EEE sector is associated with multiple environmental and social problems through its entire life cycle. This section looks at the entire journey, from mining to manufacturing to disposal, to assess the holistic impact of EEE.

Procurement of raw materials

Mining and extraction of raw materials is one of the most important sources of environmental and human health problems associated with lifecycle of e-products. Extraction of many raw materials is highly material and energy intensive and may cause significant impacts from toxic pollution[30]. Extraction of 1kg of raw copper generates 310 kg of mining waste while extraction of 1g of gold generates 1-5 tonnes of mining waste. Mining the specialty materials used in electronic products often takes place in politically unstable regions and conflict-prone economically underdeveloped countries with weak regulatory systems, ineffective governance structures and inadequate technological means to ensure the sustainable extraction of natural resources (MIT 2016). As mining takes place in politically unstable regions technologically it is sub-optimal and polluting. Due to sub-optimal technology mineral extraction is poor which depletes the available resources. Though efficient recycling can help in getting back some of the materials, the impact of extraction of minerals for EEE is profound and the effects cannot be mitigated easily.

> The extraction of 1kg of raw copper generates 310 kg of mining waste while extraction of 1g of gold generates 1-5 tonnes of mining waste.

Resources used in manufacturing

After extraction of elements comes the manufacturing stage of EEE products. The production of many electronic components (especially semiconductors and microchips) are highly material and energy intensive[31]. It takes 16000 litres of water, 1.6 kg of fuel and 0.7 kg of chemicals to make a single microchip. A computer requires 240 kg of fuel, 22 kg of chemicals and 1500 litres of water to get manufactured[32]. The greatest energy impact of an electronic device occurs during its manufacturing process and not through its use. The energy needed to produce a single microchip is more than the average energy used by a computer over three years of use. According to information available in the Technological Liberal Conflict[33] one has to use their computer for 33 to 89 years to offset the greenhouse gas emissions before we decide to get a new one.

30 Miliute-Plepiene J. et al. 2019. E-waste and Raw Materials: From Environmental Issues to Business Models. IVL Swedish Environmental Research Institute.
31 Ibid
32 https://www.tecnologialibredeconflicto.org/en/environment/
33 https://www.tecnologialibredeconflicto.org/en/environment/

Figure 8 Source: https://www.tecnologialibredeconflicto.org/en/environment/

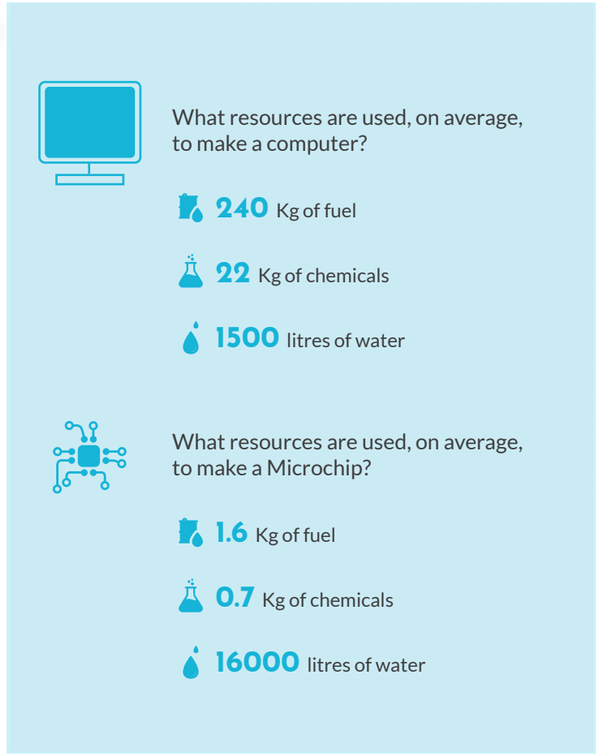
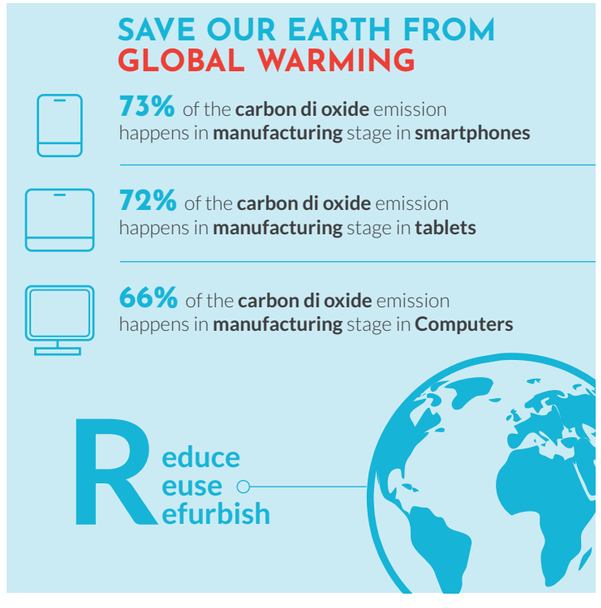


Figure 9 Source: https://19january2017snapshot.epa.gov/sites/production/files/2015-06/documents/smart_phone_infographic_v4.pdf



One should also keep in mind that most of the manufacturing of electronics of major electronic giants is located in developing or under developed countries in the South East Asian region because of the not-so-stringent environment and labour laws. So, there are many social and environmental considerations which are not even reported and documented.

Transportation Costs

After the product is manufactured it needs to be packed and transported. Packaging consumes paper from trees, plastic from crude oil and aluminium from metal ore and transportation requires fossil fuels, which can contribute to global climate change as well. The transportation and environmental cost is high because it is getting manufactured in giant hubs in South Asian Countries and getting consumed worldwide.

Packaging waste

Another issue which comes along with buying new electronics is packaging material. That box your computer came in, the blister pack your battery was packaged in and so forth. Because of the delicate nature of many of these products, they are packed in multi layers- not just to avoid physical damage but also to prevent any electrostatic discharge. Foam and thermoformed plastic are both used extensively in the packaging of electronic products. So every time one buys new devices, there is packaging waste generated, many of which is not recyclable and ends up in landfills.

Takeaway

The life cycle approach indicates that there are profound losses which occur during the extraction, manufacturing and disposal of Electronics which cannot be just mitigated by improving collection, treatment and recycling efficiency at the end-of-life. If the principles of circular economy have to be applied in managing E-waste, then strategies such as reduce, repair and reuse have to be included in order to have a holistic solution to the mounting E-waste, because only they can reduce the environmental and social impacts of manufacturing EEE.

Figure 10 Source: https://www.tecnologialibredeconflicto.org/en/environment/

WHAT ABOUT PACKAGING AND TRANSPORTATION?

Packaging consumes:

Paper from Trees

Plastic from Crude Oil

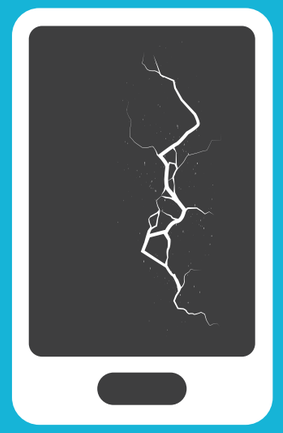
Aluminium from Metal Ore

Transportation requires fossil fuels, which can contribute to global climate change.

Globally there is focus on E-waste management and recycling in alignment with the sustainable development goals; good health and well-being, clean water and sanitisation, decent work and economic growth, sustainable cities and communities, responsible consumption and production; life below water. However, these goals also aim towards a circular economy where "reduce", "re-use" and "repair" are the essence yet these are often ignored concepts. But one cannot be just dependent on recycling as it is just one aspect of the solution. The sustainable development goals if coupled with the concept of circular economy, can take us to a direction where reduction through green design, reuse and repair comes to the forefront in strategies of handling E-waste effectively and towards a sustainable future.

From Smart to Senseless

The Journey of Smartphones



In less than 10 years more than
10 BILLION
Smartphones have been produced

Between 2007-2016 the energy footprint of smartphone is
968 TWH

The average life of mobile phones has decreased from
5-10 YEARS TO 15-24 MONTHS

60%
of the phone sales are replacement

90%
of which are still functioning when they are discarded

2 OUT OF 3
people aged 18-35 own a smartphone globally

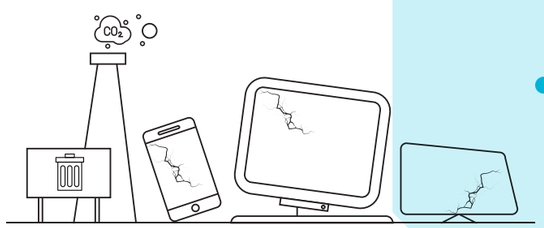
The current business model is driving significant human impacts in the supply chain including
OCCUPATIONAL HAZARDS

More than
60 ELEMENTS
are used in manufacturing advanced electronics as smartphones

Source:
Paiano, A., Lagioia, G., & Cataldo, A. (2013). A critical analysis of the sustainability of mobile phone use. Resources, Conservation and Recycling, 73, 162–171. https://doi.org/10.1016/j.resconrec.2013.02.008
Jardim, E. (2017). From Smart to Senseless: The Global Impact of Ten Years of Smartphones. Greenpeace Inc., March, 16. https://www.greenpeace.org/usa/wp-content/uploads/2017/03/FINAL-10YearsSmartphones-Report-Design-230217-Digital.pdf
https://en.reset.org/knowledge/ecological-impact-mobile-phones

04

NEED FOR MINIMIZING E-WASTE



50 MILLION TON

of e-waste generated every year-

EQUIVALENT

to throwing out 1000 laptops every single second

It has been established in the section before that the most predominant strategy of managing E-waste, which is collection and recycling, has failed in providing a holistic solution towards sustainability. The world simply hasn't found a way to responsibly deal with the volume of waste that is being created. With recycling efficiency not optimal, there are concerns about the availability and supply of new materials for electronics and electrical devices in the future. Rising commodity prices have highlighted risks. While one cannot abandon collection and recycling as a method because E-waste generated cannot be reduced to zero in today's era it is clear that it has to be combined with other strategies for sustainable use of electronics and overall a sustainable lifestyle. In alignment with the sustainable development goals and a circular economy, the other key strategy that should be incorporated by national and international bodies, manufacturers and consumers should be towards reducing the amount of E-waste being generated.

Reduction as a strategy does not imply that we stop using electronics, as its usage has tremendous benefits as well. Hence, we need to look at other aspects which could be applied in achieving the same-

- **Reducing at source:** Strategies involving reducing the amount of EEE being consumed.
- **Repairing:** Building a conducive environment for repair of electronics instead of promoting a culture of buying new products
- **Refurbishing:** Building a conducive environment for refurbishing old electronics and selling them instead of just sending them for recycling

STRATEGIES FOR REDUCING E-WASTE: IN ALIGNMENT WITH SUSTAINABLE DEVELOPMENT GOALS

The United Nations and all Member States adopted the 2030 agenda for Sustainable Development in September 2015. The agenda identified 17 SDGs and 169 targets to end poverty, protect the planet and ensure prosperity for all over the next 15 years. The accountability has been put on governments, businesses and civil societies to pursue a sustainable path. Though e-waste has not been mentioned specifically in SDGs and targets, it has a direct bearing on e-waste management. Increasing amount of e-waste generation across the world, unsafe management and handling, and disposal through incineration or in landfills pose significant challenges to the environment and human health, and to achievement of SDGs. And hence reducing the amount of E-waste generated is also intertwined with these SDGs.

Working towards reduction and management of E-waste will contribute towards achieving several goals of the 2030 agenda of sustainable development. Active data collection and comprehensive understanding will help address the SGDs related to environmental protection and health.

E-waste is closely linked to Goal 3(Good health and Well-being), Goal 6(Clean water and sanitation), Goal 8 (Decent Work and Economic Growth) Goal 11 (Sustainable Cities and Communities), Goal 12(Responsible Consumption and Production) and Goal 14 (Life Below Water).

Goal 3, Goal 6 & Goal 14

In Goal 3, Target 3.9 talks about substantially reducing the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination. This target is directly related to impacts of electronic waste when mishandled or processed in the informal sector. In Goal 6, Target 6.1 talks about achieving universal and equitable access to safe and affordable drinking water for all. This can be assured by preventing leaching of chemicals and heavy metals while processing E-waste. Target 6.3 talks about improving water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally. This can also be achieved by ensuring proper handling and management of end-of- life EEE. Goal 14 Target 14.1 talks about preventing and significantly reducing marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution. If E-waste is not handled in proper recycling channels then it might end up in the informal sector or landfills. The leachate from E-waste which contains toxic elements if not handled properly, might find its way to aquatic systems. Currently as reported by the Global E-waste Monitor the amount of E-waste being recycled stands at 17.4%. Therefore, reducing the amount of E-waste being generated aligns with this goal and in the current situation as well where waste is not being handled and managed in proper recycling channels.

Goal 8

Goal 8 of SDGs Target 8.4 is to improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on Sustainable Consumption and production, with developed countries taking the lead. In the context of E-waste this can be achieved by product design innovation in EEE for lower obsolescence rate and greater longevity.

Goal 11

Similarly, Goal 11 Target 11.6 talks about reducing the adverse per capita environmental impact of cities by paying special attention to air quality and municipal and other waste management. Target 11.b mentions about resource efficiency as well.

Goal 12

Goal 12, Target 12.4 also talks about environmentally sound management of chemicals and all wastes through their life cycle and Target 12.5 talks about substantially reducing waste generation through prevention, reduction, recycling and reuse.

STRATEGIES FOR REDUCING E-WASTE: IN ALIGNMENT WITH CIRCULAR ECONOMY

Circular economy (CE) is a closed-loop economic system in which raw materials, components and products retain their value as much as possible, for as long as possible, with the use of renewable energy. Systems thinking is at the core of CE. Circular economy is the opposite of the current "take, make, dispose of" linear economic model of materials and products that strain our current resources. A circular economic model "is restorative or regenerative by intention and design". The European Union defines circular economy as a model of production and consumption, which involves sharing, leasing, reusing, refurbishing, repairing and recycling existing materials and products as long as it is possible to extend the life cycle of products[34]. Circular Economy has been gaining attraction as an approach for achieving local, national and global sustainability. It is viewed as an alternate strategy to seek low rate of consumption of resources by circulating them in the market. Circular Economy is closely related to SDG 12; responsible consumption and production; it is not specifically mentioned in the SDG agenda. However, the circular economy practices and principles are transversal and its adoption in necessary to achieve multiple targets under SDG[35].

The history of circular economy can be divided into three phases[36] . The first phase which lasted from 1970-1990 refers to dealing with the amount of waste that was being generated. Circular economy phase II which lasted from 1990s-2010 spoke about connecting input and output in strategies for eco-efficiency. Phase III refers to the era after 2010 where the focus is on maximizing value retention in the age of resource depletion[37].

While the rhetoric still stresses economic gains, ultimate threats to survival of the human race, in the light of seemingly insurmountable sustainability challenges, are linked to population growth and results in renewed attention to resource depletion and retaining value of resources. This is from the fear that we cannot consume endlessly and that other nations should not catch up with the Western level of exploiting nature – at least not through the same growth path and with similar rebound effects. Against this context, the allegedly newly developed idea of CE gets celebrated for its potential of decoupling growth from resource use[38].Thereby, it is phased as a way out of the 'resource trap'. This phase focuses on not just recycling but also on repair and reuse of materials. The era of circular economy embodies the spirit of reducing as an importing strategy in curbing the amount of waste being generated at an initial stage. This also means introducing green design solutions in order to reduce toxicity at source and increasing longevity of the products which is applicable in the case of managing Electronic waste as well.

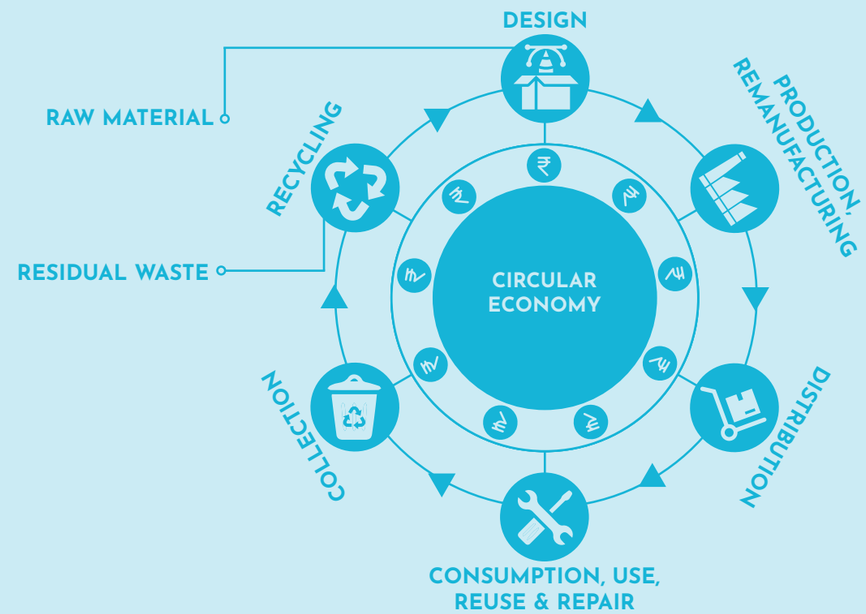


Figure 12 Phases of circular economy

FIRST PHASE
- 1970 - 1990
- Focused on dealing with the amount of waste being generated

SECOND PHASE
- 1990 - 2010
- Focused on connecting input and output in strategies for eco-efficiency

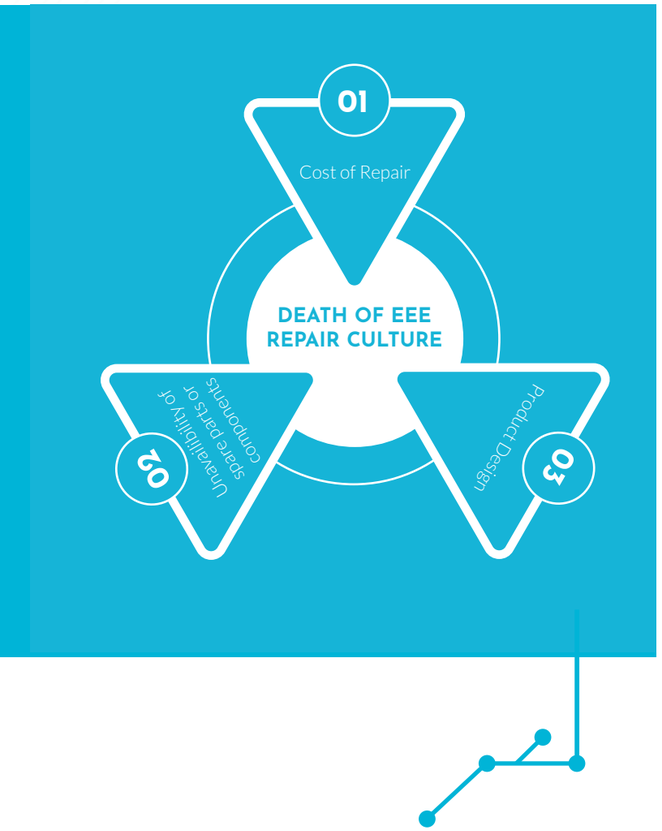
THIRD PHASE
- 2010 - till now
- Focuses on maximizing value retention in the age of resource depletion

34 https://www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy-definition-importance-and-benefits
35 Schroeder et al. 2018. Circular Economy and SDGs. Yale University. DOI: 10.1111/jiec.12732 Editor managing review: Nancy Bocken.Volume 23, Number 1
36 Reike, D., Vermeulen, W. J. V., & Witjes, S. (2018). The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. Resources, Conservation and Recycling, 135(August), 246–264. https://doi.org/10.1016/j.resconrec.2017.08.027
37 Blomsma, F., Brennan, G., 2017. The emergence of circular economy: a new framing around prolonging resource productivity. J. Ind. Ecol. 21 (3), 603–614. http://dx.doi.org/10.1111/jiec.12603.
38 Crul, M., Diehl, J., Ryan, C., 2009. Design for Sustainability-A Step-by-step Approach.UNEP, Paris, France.

The concept of circular economy is being increasingly used to reduce the amount of waste being generated. Using this approach for handling and managing E-waste is becoming crucial because the impact of mismanagement of this waste stream can have dire consequences on human health and environment. Using a circular approach with EEE, one can create a sustainable model that benefits individuals, organizations, and communities everywhere. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems, and business models" and this definition makes it directly applicable to E-waste management – shifting the focus from recycling.

Reducing the amount of E-waste being generated, through Reduce, Repair and Refurbishment aligns with the concepts of circular economy and SDGs.

Figure 13: Reasons behind dying repair culture



STRATEGIES USED TO KILL REPAIR AND REUSE

In economics and industrial design, planned obsolescence (also called built-in obsolescence or premature obsolescence) is a policy of planning or designing a product with an artificially limited useful life or a purposely frail design, so that it becomes obsolete after a certain pre-determined period of time upon which it detrimentally functions or suddenly ceases to function, or might be perceived as unfashionable[39]. Planned obsolescence has probably been used by the Electronics Industry in the most effective manner, with frequent product launches, and upgradation of software and hardware which are non-compatible with the earlier versions. This means that the possibility of repair reduces considerably and results in replacement with a new product. Meanwhile, the companies continue to profit from steady sales.

The EEE industry has been a clear user of 'Designed for the Dump' strategy. The ultimate result of such design are single-use versions of durable gadgets such as disposable cameras, which are meant to be thrown away after using them a single time or products which are often designed to be impossible to service or repair; for example, a digital watch which may have a casing which is sealed in the factory or a mobile phone with a sealed battery and no possibility of removing and replacing it when it drains out. Manufacturers also make replacement parts either unavailable or so expensive that it makes the product uneconomic to repair. For example, if you try and replace the screen of a phone, in the same cost you may be able to buy a brand new phone. Companies also use design features to frustrate repairs, such as tamper-resistant pentalobe screws used by an IT giant. Pentalobe screws are sometimes referred as "Evil Proprietary Tamper-Proof Five Point Screw" (or the EPTP5PS). It is designed to make it impossible for anyone but the company to service their phones or computers. Front loading washing machines often have the drum bearing - a critical and wear-prone mechanical component - permanently moulded into the wash tub, making it impossible to renew the bearings without replacing the entire tub. The cost of this repair may exceed the residual value of the appliance, forcing it to be scrapped.

39 Bulow, Jeremy (November 1986). "An Economic Theory of Planned Obsolescence" (PDF). The Quarterly Journal of Economics. Oxford University Press.

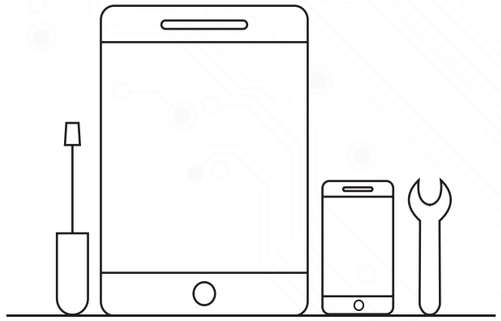
RIGHT TO REPAIR: A MOVEMENT IN MAKING

Repair is one of the most important aspects of a circular economy. Right to Repair is a movement that started in America within the automotive industry. With electronics becoming more complex, manufacturers use this complexity to prevent independent repair shops by only maintaining an "authorized" network of repair shops. Joining this network of repair shops is difficult and expensive, while this practice in itself may be viewed as based on a legitimate concern for quality control, it becomes more troubling when manufacturers couple it with obscure repair information and a refusal to supply replacement parts in the open market[40]. In addition to this some manufacturers utilize their intellectual property rights to tighten their control over the repair market for their products[41]. Many of these authorized repair shops do not actually offer repair but replacement of an entire part of the device which is not just expensive but also a wastage of resource.

Consumer frustration with this interference into their personal autonomy is apparent. This is what leads to the rise of Right to Repair in the electronics industry. This movement has several branches- one branch is pushing on "Right to Repair" or "Fair Repair" through state legislatures. These Right to Repair laws would require manufacturers of consumer electronics (defined rather broadly) to enable consumers and independent repair shops to repair consumer products. Towards this goal, the legislation would require manufacturers to make available, on fair and reasonable terms, repair information, parts and tools.

The Right to Repair movement's aim is towards the following-

1. Consumers and product owners should have the right to decide who repairs their products.
2. Creating an economy around extending the lifespan of manufactured goods will create local jobs.
3. Repairing and maintaining electronics requires information, parts and tools from the product designers. As manufacturers add electronics to more and more products, it is shutting out independent repair organizations. Right to Repair will prevent the same from happening
4. The knowledge and tools to repair and refurbish products should be distributed as widely and freely as the products themselves are. In contrast to centralized manufacturing, reuse must be broadly distributed to achieve economies of scale.
5. Extending the lifespan of manufactured goods will benefit the environment, easing the demand on natural resources and keeping electronics out of landfills.



In India the repair and resell culture has traditionally been quite popular and an accepted norm. Once upon a time, it was a thriving business. Even now, in the capital city of Delhi there are seven Electronics markets, namely Gaffar, Wazirpur, Palika Bazar, Lajpat Rai, Nehru Place, Bhagirath Palace and Janpath, which have bustling repair shops. Similarly, all major cities have repair markets such as Lamington Road in Mumbai, Ritchie Street in Chennai, SP Road in Bangalore, Madan Street in Kolkata. However, as the purchase parity is increasing, the middle class and higher class society of India, which are the largest buyers of electronics, go to authorized service centres over the unauthorized ones or more often prefer to buy new products and dump repairable equipment. In our high consumerist disposable culture, the resource-draining turnover of electronics has become normalised, taken for granted and as a result, almost invisible.

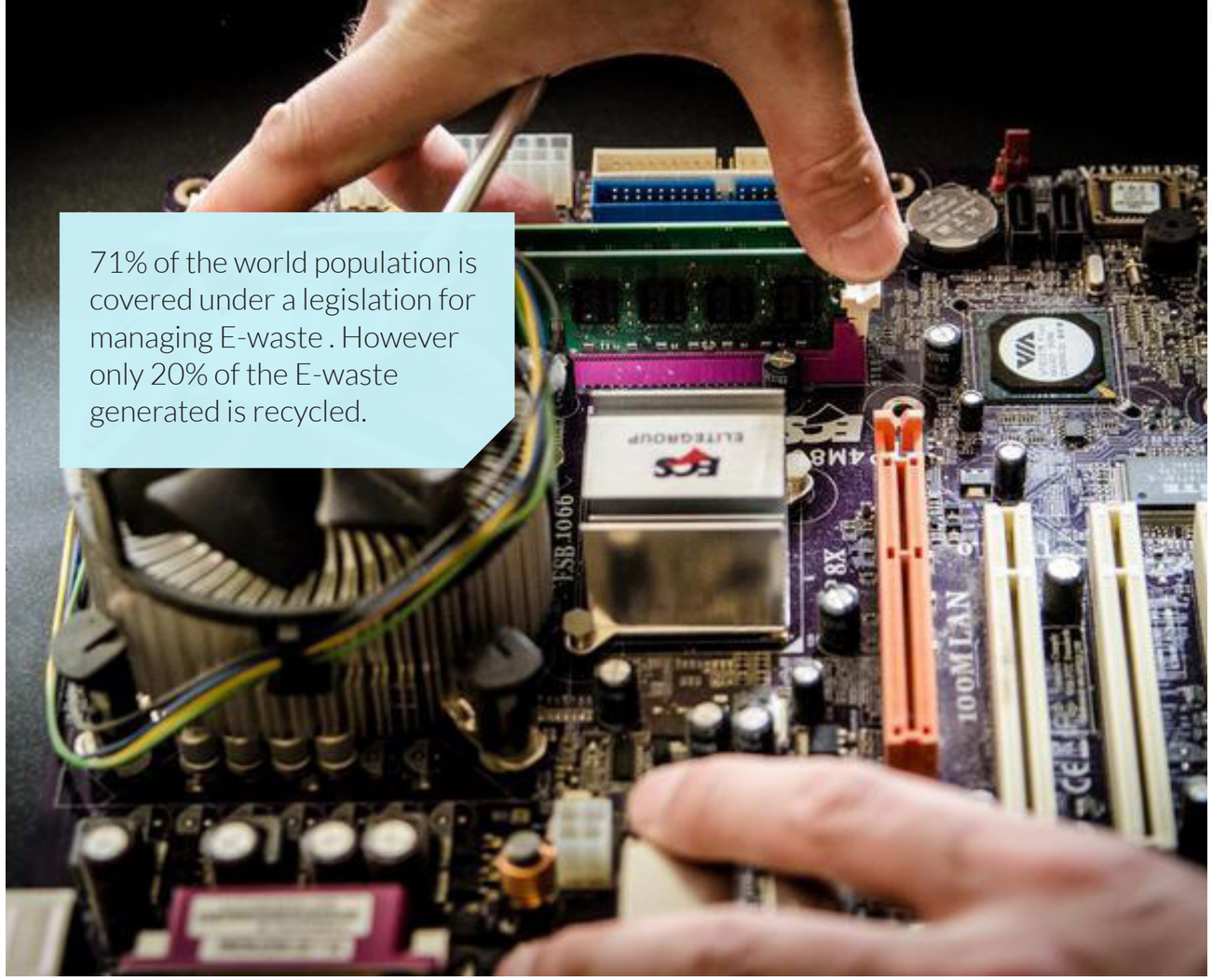
40 Grinvald, L. C., & Tur-Sinai, O. (2019). Intellectual Property Law and the Right to Repair. SSRN Electronic Journal, 63–128. https://doi.org/10.2139/ssrn.3317623
41 Ibid

LEGISLATION ON REDUCING, REPAIRING AND REUSING E-WASTE

As documented in the Global E-waste Monitor report 2020, 71% of the world population is covered under some legislation on E-waste. However, most countries legislations are still focusing on End – of – Life management of E-waste, recycling and therefore concentrating on setting up an effective system for the same[42].

However, as it has been established in the previous sections, recycling does not provide a holistic solution for managing E-waste in alignment with SDGs and circular economy principles. It is a fact even if 100% collection rate is achieved along with 100% recycling efficiency (which is something far from reality). Therefore, it is important for countries to start thinking about other strategies for management of E-waste. Reduce, Repair and Reuse. This in combination with recycling provides a sustainable solution, where reduce, repair and reuse comes before recycle. This section explores the national policies of countries which have included the above-mentioned principles.

Extended Producer Responsibility is a tool most popularly used in E-waste management. It was supposed that EPR would organically lead product design initiatives and achieving of high utilization rates by Producers. However, such a phenomenon has not been observed, because of a combination of reasons including the regulation itself which is not stringent, lack of enforcement on ground and absence of any incentives for producers who followed the path. Product design initiative has become a voluntary exercise, except for reducing hazardous substances in electronics.



71% of the world population is covered under a legislation for managing E-waste . However only 20% of the E-waste generated is recycled.

CHINA

In 2007 China brought a policy by the name of Measures for the Control of Pollution from Electronic Information Products which provided restrictions on the use of six toxic and hazardous substances, requirements for eco-design, mandatory provision for producers to provide information on components, hazardous substances and recycling about their products. They also introduced The Circular Economy Promotion law (2008), Collection and Treatment Decree on Waste Electrical and Electronic Equipment in 2011 in order to prevent pollution caused by the storage, transport, disassembly, recycling, and disposal of e-waste and stipulated that e-waste should be collected through multiple channels and recycled by licensed recycling enterprises.

The Circular economy promotion law lays responsibility on enterprises and public institutions shall establish a sound management system and take measures to reduce resource consumption and the generation and discharge of wastes, and improve their level of recycling and resource recovery. The law also encourages and guides citizens to use products and recycle products featuring energy, water and material conservation, and ones that are conducive to environmental protection, and thereby reduce the generation and discharge of wastes. The citizens are entitled to report activities of wasting resources and damaging environment, have the right to access official information on circular economy promotion and give opinions and suggestions in this regard.

JAPAN

In 2000 Japan in its policy titled law for the promotion of effective utilization of resources (LPUR) aimed to establish a recycling-based economic system by reusing parts of collected products such as computers, strengthening collection methods, introducing new measures to reduce wastes and extending product life span.

Japan has always been highly dependent on natural resource imports for industrial raw material inputs. In order to optimise material use, and thus decrease import dependency, the Law for Promotion of Effective Utilization of Resources promotes the 3 'Rs': Reduce, Reuse, and Recycle. It encourages the utilisation of recyclable resources, reusable materials and product parts at the producer level. The law forms a legal framework covering the entire life span of products from the plastic, electronics, paper, packaging, automobile and raw material processing industries, both upstream and downstream. It sets standards for producers in terms of the generation of by-products and under this law, producers are obliged to use specified amounts of recycled resources and reusable parts in the production of new products. Violators of these standards, following a first public warning, may incur a financial penalty. The national government, however, is responsible for facilitating the enforcement of the law by funding necessary implementation measures and by providing subsidies to private business operators. Additionally, the government promotes research and development activities, implements educational and publicity programmes, and uses their procurement power to stimulate the use of recyclable resources and reusable parts. In addition to the national law, local governments are also required to promote and implement the law in accordance with local situations.

AUSTRALIA

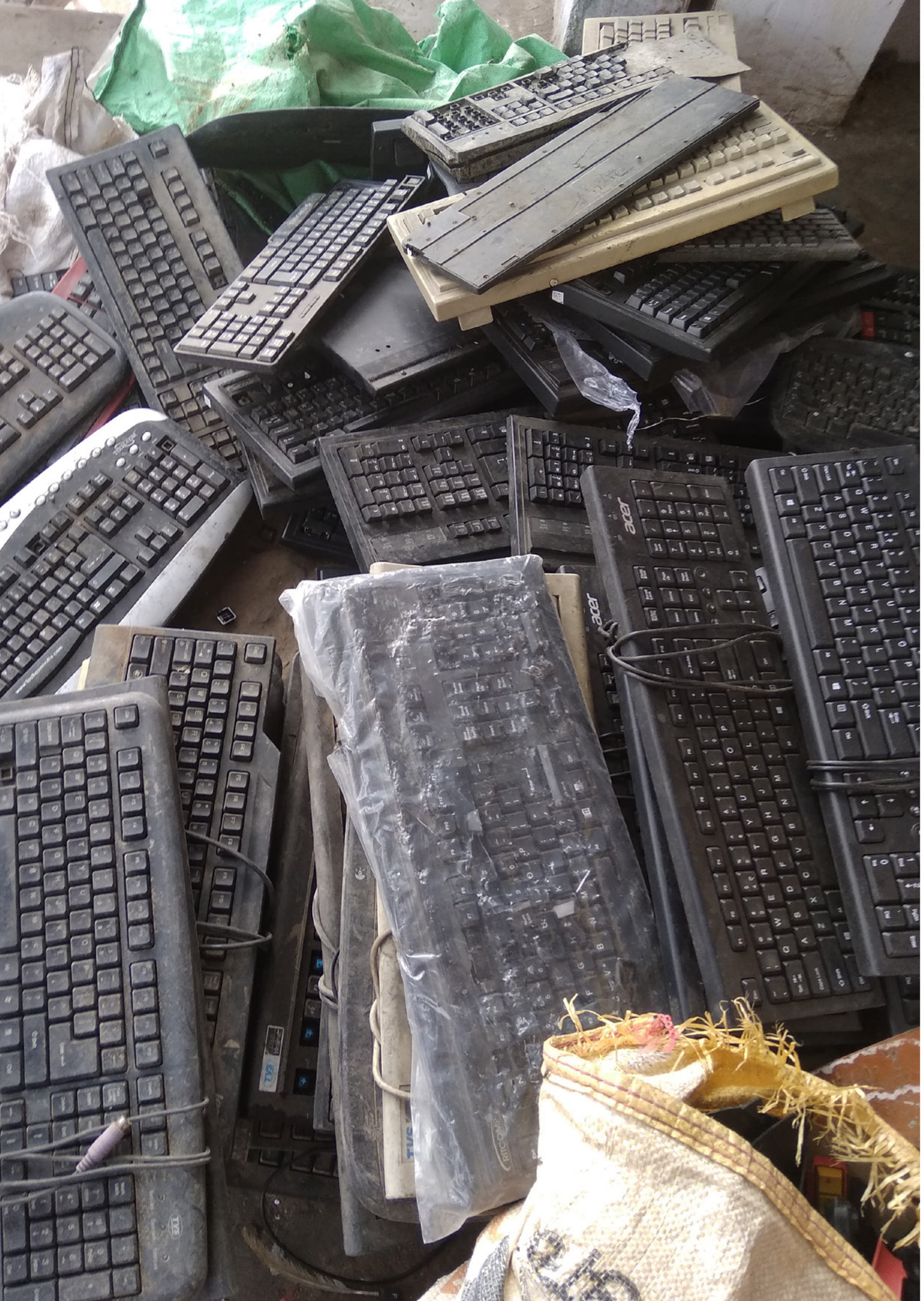
They introduced National Waste Policy in 2009 and revised it in 2018 with the aim to reduce the amount of waste (including hazardous waste) for disposal, manage waste as a resource, ensure that waste treatment, disposal, recovery and reuse are undertaken in a safe, scientific, and environmentally sound manner, and contribute to the reduction in greenhouse gas emissions, energy conservation and production, water efficiency, and the productivity of the land.

They apply the principles of circular economy to reduce the amount of waste by following 14 strategies which includes green design, economic incentives for producers to put greener products in the market and support recovery and recycling schemes (such as packaging, batteries, electric and electronic equipment and vehicles), product stewardship, sustainable procurement by governments, businesses and individuals.

INDIAN SCENARIO

Following the introduction in the Basel Convention, e-waste first came under the regulatory framework in India in the year 2003 as part of the Hazardous Waste (Management and Handling) Amendment Rules, 2003. These rules specified the waste from electronic industry as hazardous and their handling and the disposal shall be the responsibility of the generator ensuring no adverse effects. Also, electronic assemblies and their scraps were restricted for import. The first precise rule on e-waste in the country came into effect from 2012 as E-waste (Management & Handling) Rules, 2011. This rule introduced the concept of Extended Producer's Responsibility (EPR) for the producers to manage their end-of-life electrical and electronic products. This rule was further replaced by the E-waste (Management) Rules, 2016 (which came into effect from October, 2016) mandating targeted collection responsibilities to the producers and the maintenance of national registry. These rules aimed to ensure effective implementation and clear delineation of the role of producers. Manufacturer, dealer, refurbisher and Producer Responsibility Organization (PRO) have been introduced as additional stakeholders in the rules with specific roles. Compact Fluorescent Lamp (CFL) and other mercury containing lamps were brought under the purview of rules for the first time. The Rules set responsibilities for consumers & bulk consumers, collection centres, dismantlers, recyclers and regulatory agencies (SPCBs/PCCs) for effective compliance/implementation of these rules as well. The rules were further amended as E-Waste (Management) Amendment Rules, 2018 with relaxation in the EPR plan by reducing E-waste collection targets for industries. Though the Rules do have a mandate to reduce certain hazardous materials from EEE, there is no focus on Reduce or Reuse. There is no focus on reducing of the amount of E-waste being generated.

42 Forti V., Baldé C.P., Kuehr R., Bel G. The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam.



and reusing part as a way to implement the same. No country makes it mandatory for producers to manufacture green design and get rid of their Designed for the dump strategies, which would reduce the waste at source. Mining of elements is still occurring in politically unstable regions and the manufacturing process remains highly energy-intensive. There is another tool which could be used by states in order to control the amount of e-waste being produced and to introduce Right to Repair legislations, as manufacturers utilize their intellectual property rights to tighten their control over the repair market for their products. Many states in USA have introduced the legislation in the parliament but it is far from being passed as a law. The European Union is on its way to introduce Right to Repair law by 2021. More efforts need to be made in order to implement circular economy in managing E-waste holistically.

INITIATIVES TAKEN BY PRODUCERS

The producers of electric and electronic products are one of the most important stakeholders in influencing the environmental impact of the electronic products. However, what has been observed till now is that the producers in a quest to generate more profits have been designing the electronic products for dumping. This has come under severe criticism and producers have started to take some initiatives in order to reduce their footprints by specially introducing design innovation. One such example of product design innovation is launching dual sim phones by producers for people who want to separate their personal and professional life but would not have to buy multiple phones. The section below assesses the voluntary initiatives taken by producers towards Reduce, Reuse and Repair.

Voluntary Initiatives

Dell is launching new efforts to shrink its carbon footprint and cut down on e-waste. The sustainability targets were unveiled at a summit in Austin, Texas, alongside other initiatives on diversity, inclusion. By 2030 the company plans to reuse or recycle an equivalent product for every device that a customer buys. It is also pledging that, by then, at least half of all the materials used in its products will be "recycled or be renewable"

Apple is trying to pack more renewable materials into its latest iPhones. The new iPhone series will use recycled tin in their logic boards, preventing 10,000 tons of tin ore from being mined per year. The phones will also use 35% post-consumer recycled plastic in their speaker enclosures, and 32% bio-based plastic for the frame around the cover glass.

Samsung in addition to the e-waste goal, has set a goal to recover one billion pounds of recycled materials including plastic by 2030.

Fairphone, a Dutch social enterprise, says it is committed to having a positive impact on the electronics industry by paving the way for more ethical sourcing. The company builds smartphones with responsible and sustainable materials, including recycled plastic, copper and tin as well as fair trade-certified gold. Their definition of "fair" is strongly influenced by the working conditions of the people mining the materials. Fairphone has set a goal to responsibly source 70 percent of these eight materials – tin, plastic, gold, tungsten, copper, cobalt, lithium and neodymium – by the end of 2020.

Since 2016, HP has been drawing attention to the impact of e-waste. HP says it has used over half a million pounds of ocean-bound plastic in their products, and more than 80 percent of HP ink cartridges and 100 percent of HP LaserJet toner cartridges are manufactured with recycled content. The company also supports events designed to inspire new ideas to push the circular economy forward. Recently, HP hosted a Massachusetts Institute of Technology event focused on moving away from the traditional approach of making electronics as take, make and dispose. Innovators were brought together to brainstorm solutions that could enable a shift in supply chains from linear to circular, helping to reduce waste and improve lives along the way. Organizers of the event say new solutions will be presented later this year.

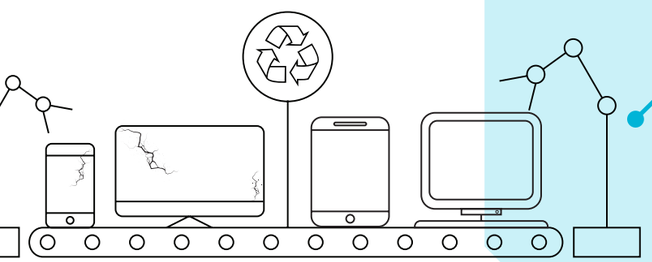
TAKEAWAY

These voluntary initiatives taken by Producers of EEE are in the direction of reuse, the elements recovered from old electronics or reducing the hazardous elements at source. They are still relying on recycling and just fulfilling their national responsibilities as mandated by a state. No producer is talking about reducing the amount of E-waste being generated. Repair still remains a challenge in many developed countries where replacing seems like a cheaper alternative. Most manufacturers are against the Right to Repair movement claiming intellectual property rights[43]. "Designed for the dump" and obsolescence still seems to be at the core of the producers though they are talking about sustainability.

43 Grinvald, L. C., & Tur-Sinai, O. (2019). Intellectual Property Law and the Right to Repair. SSRN Electronic Journal, 63–128. https://doi.org/10.2139/ssrn.3317623

05

RECOMMENDATIONS



WITH ONLY 17.6% OF E-WASTE BEING RECYCLED

we need to close the loop with reduction strategies

GOING BEYOND CIRCULARITY

The environmental impact of a product is caused throughout its life cycle, from the acquisition of raw materials and production to consumption and waste management. Though the electronics industry seems to have projected that e-waste recycling can solve all the problems associated with e-waste, it is far from the truth. It is clear that recycling alone cannot provide a holistic solution to problems associated with E-waste and in order to mitigate its environmental impact changes have to be made at every level. There is a need to not just move from linear cycle to circular but to look beyond that. To tackle the challenges brought about by e-waste worldwide, which range from pollution to health risks to lost value, governments and businesses need to not only find more effective waste collection, handling and recycling programs but also reduce the number of discarded electronic devices. At the heart of the issue is a technology sector whose profits are driven by planned obsolescence. And hence one of the key solutions entails manufacturers to design products that are more durable rather than disposable and also design it in a way that at their end-of-life, they can be safely and easily recycled. Such measures require different strategies and support from all stakeholders. Only the extension of the life of the devices currently in circulation, through their maintenance, refurbishment, and repair, can have a meaningful effect on their environmental impact.

> Minimizing e-waste helps to conserve resources and reduces the amount of energy we take from the earth.

REGULATORY AGENCIES

Governmental actors, international, national and local authorities play a significant part in directing the management of electrical and electronic products and waste to a more sustainable system through the implementation of legislation and policy instruments. With only 17.6% of electronic waste being recycled and a massive electronic industry growth rate the time has come to focus on reducing of E-waste by bringing the following under the purview of the legislation –

- **Bringing Right to Repair regulations**
- **Product Design Innovation to increase longevity**
- **Standardization of second hand market of electronics**
- **Utilization rate of Electronics**

In their environmental responsibility report, Apple concedes that 77% of the carbon footprint of their electronics comes from their manufacture, versus the 17% that comes from its actual use. The environmental impact of replacing a device, even if it is recycled later, remains significant.

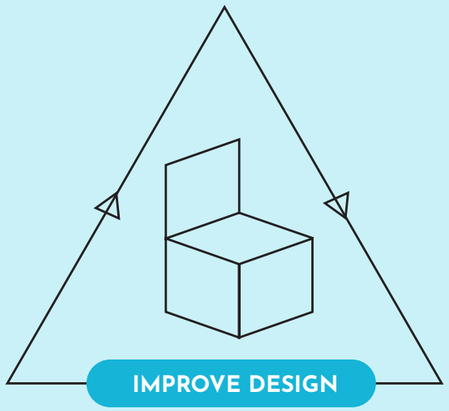
Source: https://www.forbes.com/sites/vianney-vaute/2018/10/29/recycling-is-not-the-answer-to-the-e-waste-crisis/?sh=6574c5a87381

The need of the hour is to shift focus from just recycling to other aspects of a circular economy such as reducing the amount of E-waste being generated in order to solve the fastest growing waste problem which will soon become unmanageable at its current rate of recycling. These discussions should not be just at a national level but on international platforms because of the globalised nature of electronic products, where elements are extracted in some other country, manufactured somewhere else, assembled in some other part of the world, sold everywhere and disposed in developing or underdeveloped countries.

PRODUCER

Manufactures should switch from designing for the dump to green design. Embracing durable designs will mean that electronic devices are kept in circulation for longer. One such example of green design is a universal adapter for both phones and computers that would also reduce the amount of E-waste being generated. Mostly wires go unaccounted for in the E-waste legislations as well, and thereby even more difficult to manage. Changing the charger type with every new model introduced, along with the headphone jack leads to unsustainable ways of keeping the profit margins high. A converter has become a necessity for AC-type jack with every new product one buys.

The producers need to get semblance not just within their own products but also with others, which is



currently lacking on all fronts. In alignment with the polluter pays principle, it is important for the producers to own up to their responsibilities by not just following the government mandate but also by making product design innovations to increase the utilization rate.

It is also important for Producers to engage in ethical sourcing of raw materials to mitigate the impact caused during mining and extraction processes

Producers should switch to completely recycled material, manufacture using renewable energy promoting slow replacement (product being repairable and upgradable). Cleaning the loop is also very important by reducing the number of hazardous chemicals in the electronics products.

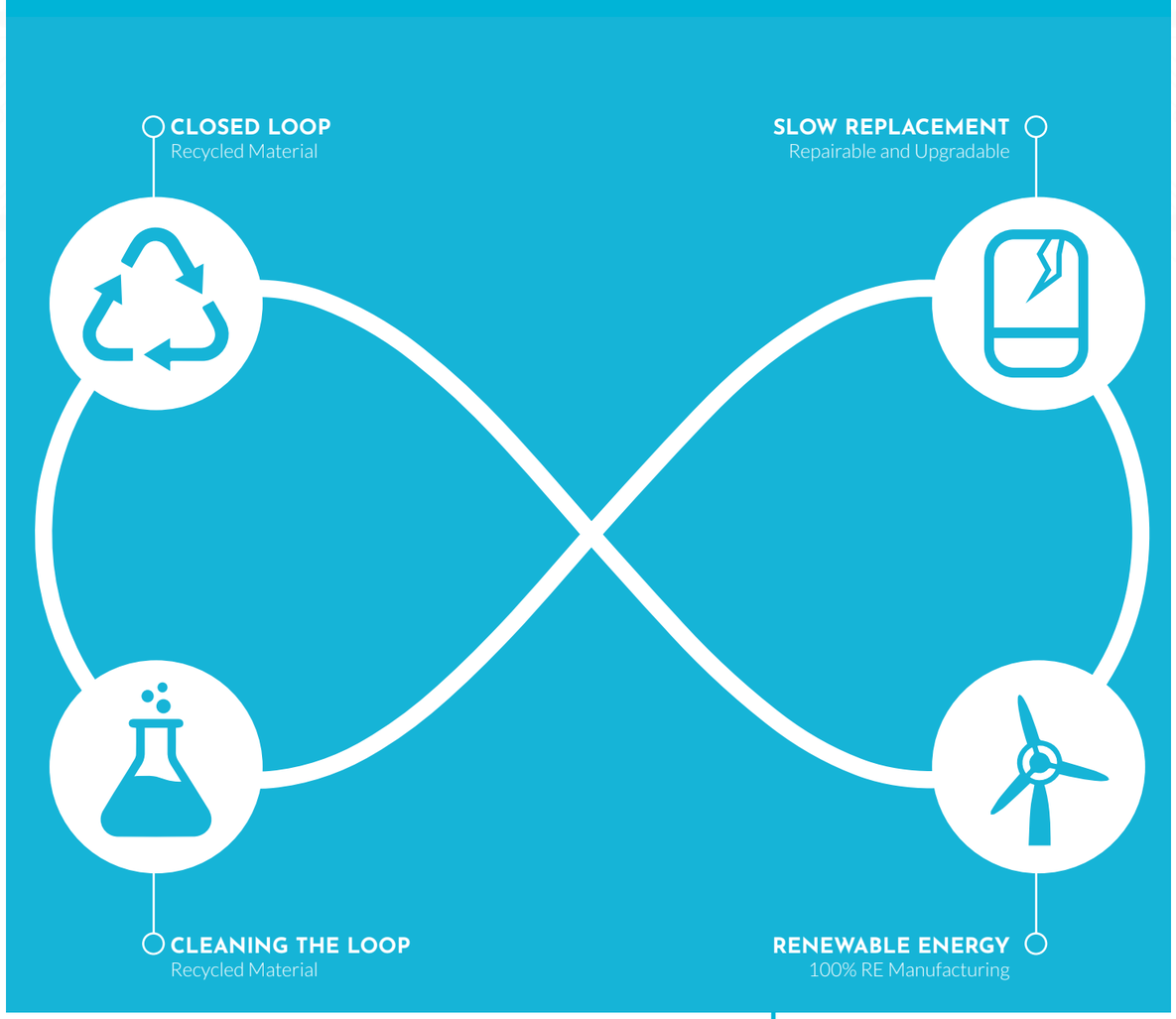


Figure 14 Source: Jardim, E. (2017). From Smart to Senseless: The Global Impact of Ten Years of Smartphones. Greenpeace Inc., March, 16. https://www.greenpeace.org/usa/wp-content/uploads/2017/03/FINAL-10YearsSmartphones-Report-Design-230217-Digital.pdf

CONSUMERS

Demand is what causes the supply, it is not of little importance what the consumer decides to purchase. This goes for both individual and bulk consumers. The consumption of home electronics is increasing, and the environmental impact of these products are greater than the environmental impacts of many other products[44]. It is therefore important to think about the alternatives before buying new products.

In management of E-waste the pyramidal structure explains the fact that we should first concentrate on reducing production, then reusing the product, then repairing and after the EEE product has been rendered completely useless it should be recycled in order to extract the resources.

What can YOU do?

RESIST your Urge to Upgrade

REPAIR your Broken Stuff

RESELL your old electronics

And finally **RECYCLE**

44 Miliute-Plepiene J. et al. 2019. E-waste and Raw Materials: From Environmental Issues to Business Models. IVL Swedish Environmental Research Institute.

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