A Comparative Analysis of Electronic Waste Management in India and China

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Abstract

Rapid technological advances such as artificial intelligence, robotics, 4G, and 5G have made high volumes of electronic trash or e-waste. China recycled this e-waste through circular economy to sustain its electronic manufacturing industries. This has made China the shining star in electronic manufacturing on the global map. India should work on the e-waste to combat Chinese advances in electronics manufacturing. India and China are the most populous countries which generate huge quantities of e-waste. Most of the literature on e-waste is concerned with environmental issues while this study treats e-waste as economic asset. This paper presents a comparative analysis which can be used to formulate a road map for India based on the practices currently used in China. This study suggests a future roadmap which may be utilized for achieving the objective for combating China's advancements in electronic industries. In the long run, India's Electronics Manufacturing Scheme 2.0 is expected to create a conducive environment to compete with its Chinese counterparts in electronic sectors. However, few additional suggestions have been made in this study.

Keywords: *Electronic waste, Economic perspective, Indian & Chinese strategies, comparative study, qualitative analysis*

Introduction

The rapid advent of technologies has reduced the life span of electronic gadgets, for instance, smartphones get an average life cycle of about 2 years, tablet 5 years, flat TV screen 7 years, laptop 11 years, and so on (average lifespan of consumer electronics and tech devices in 2015-2016). The average cost of such devices is also getting reduced day by day with the fact that more and more users are exposed to information and communication technologies (Koptyug 2020). In the last two decades, there has been an exponential increase in the production of electronic equipment all over the globe especially laptops and mobiles. All these reasons explain why there is an exponential increase in the obsolete electronic equipment in recent times. This trend is expected to get a new boom in the coming years due to Covid-19 outbreak followed by the inclusion of technologies like 5G, artificial intelligence, internet of things *etc*. The accumulation of obsolete electrical/electronic devices has become a serious matter of concern because it is causing adverse effects on human health and the environment. This kind of waste is more threatening than conventional municipal solid waste. The waste material that is created due to obsolete electronic gadgets, now popularly known as electronic waste or *e*-waste. In broader term, e-waste includes three main categories of obsolete materials, first large household appliances like refrigerator, washing machines, and air conditioners; second information and communication devices like personnel computers, laptops, and monitors; and third, consumer equipment like TVs, DVD player, mp3 player, mobile phones, and also electronic leisure-sporting equipment. These are all together called as electrical-electronics-equipment (EEE). Electronic obsolete materials include protective layer plastic, energizing batteries, motherboards or other circuit boards, cathode ray tubes, and lead capacitors come under the broader term of e-waste. The amount of e-waste generation has been huge and at an accelerating pace. In 2012, the United Nation Environment Program (UNRP) estimated

the average amount of e-waste generation globally which was 6.8 kg for every living person in the world (Perkins et al. 2014). The rise of population, urbanization and advent of technologies play an important role in the e-waste generation mechanism. More populated regions have led to the higher amount of e-waste generation at an accelerated pace. This is in contrast to the less populated regions where e-waste generation is only due to the advent of technology that too at a relatively constant pace. The two most populated countries are China and India. There are more similarities in the mechanisms of e-waste generation in these two countries. According to the UN, by 2050 India's urbanization will reach such a level which may not have any demarcation from rural areas (World Urbanization Prospects - Population Division - United Nations n.d.). The urban population settles mostly in metropolitan cities of India like Delhi-NCR region, and Mumbai-MMR region. These regions are more prone to heavyweight generation of electronic waste and also the place where higher middle class resides with the usual practice to buy new electronic gadgets just after the technological/hardware upgrade. Even though this practice may be taken care of by the refurbishment of electronic obsolete gadgets. The equilibrium state has not been achieved due to the uncivilized practice of throwing electronic products in usual municipal waste and the advent of technologies have made old devices unusable in newer interfaces with upgraded software. In rural areas, e-waste generation may get equilibrium and reusability due to illiteracy, backwardness, poverty, and lesser use of ITC technologies. But the futuristic urbanization in such areas may create e-waste generation problems as expected till the end of the 2040s. Covid-19 pandemic may play a catalytic role here and under the expectations of high use of technology soon in all regions. The situation is alarming because a large number of electronic gadgets have been used today and may not find any usage in the recent future. India, therefore, needs to have a proper roadmap as to how to address this problem of handling huge e-waste.

This paper aims to suggest roadmap with two-fold opportunities. First, the roadmap will create a conducive environment in India to tackle China's supremacy in electronic import, second, it will suggest to make India a global player like China in electronic manufacturing. India has all ingredients and thrusts to capitalize on this opportunity. The ministry of electronics & information technology (MEIT) has announced the schemes worth Rupees fifty thousand crores ($6.65 billion) to push the domestic electronics manufacturing (Deep 2020). It is a package of three stimuli which aims to encourage domestic electronic manufacturing in India. These initiatives are under the names of production linked incentive plan (PLI). The scheme for promotion of manufacturing of electronic components and semiconductors (SPECS) and the modified electronics manufacturing clusters (EMC). The manufacturers' association for information technology (MAIT) welcomed this step stating it will help the mobile manufacturing industry to meet the targets laid down under National Policy on Electronics 2019. This scheme seems to have a long vision in terms of job creation and improving supply chains in India. The present study also covers how proper e-waste management will complement this long-awaited move.

E-waste as urban mine

Due to the outbreak of Covid-19 pandemic, the Tokyo Olympic 2020 was postponed by one year. It is considered to be the morale-booster as happened in the case of the 1948 London Olympics just after the World War II. Japanese had planned to honour the athletes innovatively as the medals of the athletes will have the symbolic desire to reduce environmental impact due to e-waste. About five thousand medals in the categories of gold, silver, and bronze were made from millions of smartphones, laptops, and other obsolete electronic gadgets which were donated by Japanese people (Signorelli 2019). A total of 47,500 tons of e-waste including 5 million smartphones were collected from Japanese people in less

than two years for this purpose. From this weight of e-waste, 28.4kg of gold, 3500kg of silver, and 2700kg of bronze have been extracted. It is to be noted that today's' smartphone contains around 34mg of gold, 34mg of silver, 15mg of palladium, 25g of aluminium, and 15g of copper. These extracted metals got converted to 30.3kg of gold medals, 3500kg of silver medals and 2700kg of bronze medals awarded in Olympic 2021. Japanese believe that e-waste is among the most damaging ecological challenges in the world today and also it is an unexploited mine for precious materials. They have successfully, sent an important message to the world community that e-waste needs to be properly managed for our sustainable development. According to a study by Blancco, most of the smartphones go into a new life cycle after these get discarded by their first users all over the world (McCarthy 2016). The study reports about 45% of smartphone users who plan to purchase a new device, either trade their old handset through online reselling or availing exchange offers. It is 22% of people present their older device to their near-dear ones and, 18% trade-in for an upgrade from the network operator. Only 5% of people plan to destroy their old phones soon after they purchase new ones. The expectation of managing electronic obsolete using the above methodology fails because all populations today have one or more than one smart device. The reselling or gifting an upgraded device put the older one to e-waste, hence the cyclic process begins. This cyclic procedure sustains no matter what the situation will be due to the constant up-gradation of software and hardware. Therefore, the creation of e-waste materials needs to be dealt accordingly to have sustainable development along with environmental harmony.

Independent studies conducted by Beijing and Sydney universities estimated that one ton of electronic waste contains about 350g of gold compared to 5-6g extracted from a ton of mined raw material. The United Nations (UN) estimated that about 320 tons of gold and 7200tons of silver combined worth of about 200 billion Euros which were thrown away in the year 2018. However, the Dell Company had also attempted to make gold jewellery from

recycled motherboards. The company has taken the pledge to complete the recycling of 100 million pounds of e-waste by the current year. The estimation studies indicate that one can extract about 100 times more gold from e-waste, as could be achieved through gold ore of the same weight (Mahesh and Mukharjee 2018).E-waste is now regarded as urban-mine since it contains a huge secondary source of precious materials. This is one of the fast-growing economies in recent times that have reached $62.5 billion in the formal sector in 2018 (He et al. 2020). That is three times more than the annual output of the world's silver mines. The improper handling of *e*-waste material causes significant loss of precious valuable raw materials like cobalt (found in batteries), indium (found in LCD, TV, monitors), and neodymium (found in motors' magnets). The proper recycling for these materials is missing in the current situation as the target most of the time is for gold and silver. These materials may be used as raw material for electronic manufacturing as some of these are limited on earth-crust and others are difficult to extract from natural resources.

Current e-waste management: China vs. India

The life cycle of any product involves three main stages such as production, consumption, and disposal. The material flow analysis (MFA) is a useful tool used by developed countries to manage resources and waste in harmony with the environment (Islam and Huda 2019). The concept of MFA was elaborated by Brunner et al (Brunner and Rechberger 2016) who described MFA as *a* "systematic assessment of flows and stocks of materials within a system defined in space and time? It connects the sources, the pathways, and the intermediate and final sinks of as material". Very diverse nature of e-waste because it contains all types of materials, both valuable and toxic chemicals, makes it to constitute flow in the number of directions. In most of the developing countries like India, e-waste is considered as a mean of getting paid by local collectors. In developed countries, however,

the management of e-waste is under strict regulations. Moreover, in these countries, e-waste materials flow is such that it restricts illegal dumping and trade. This situation leads to the flow of e-waste materials into countries like China and India either through legal or through illegal routes. There is a need to have a comprehensive investigation for the identification of e-waste material flows all over the globe for resource conservation, country-to-country movement, and health-environmental issues.

The highly saturated markets for EEE are the countries belonging to the organization for economic cooperation and development (OECD). These countries are mainly responsible for e-waste generation on a global map (Widmer et al. 2005). These countries show a high rate of consumption in terms of EEE so it is reflected as a high rate of domestic generation of e-waste. Basel convention restricts the transboundary transfers of e-waste material. In fact, developing countries import a considerable amount of e-waste. India and China are among those countries who fight against the illegal import of e-waste especially from the USA and other western countries. About 50-80% of e-waste gets exported from the USA to China and India through sea routes. Even though both countries have changed the rules to combat this illegal import but intensions to get a material cycle for getting raw materials from e-waste cannot be denied. The main thrust in e-waste generation is on the domestic side due to highly populated urban areas rather than imports from the USA and European countries. A study on MFA practices for e-waste is done for many countries in the world (Islam and Huda 2019). It indicated that China and India have many similarities in terms of e-waste generation but the basic difference is due to the management of these waste materials.

Indian practices in managing e-waste

As discussed, e-waste contains thousands of hazardous chemicals and materials which cause serious environmental and health concerns. In addition to hazardous materials, e-waste also contains non-hazardous materials. For instance, if we consider a typical personal computer CRT monitor waste, it contains about 43.7% metal, 23.3% plastics, 17.3% electronic components, and 15% glass. From a broader perspective, it contains plastics, glass, printed circuit boards (PCBs), ceramics, ferrous and non-ferrous metals, rubber, elements like lead, mercury, cadmium, silver, gold, and platinum etc. There are many non-hazardous materials found in e-waste like glass, gold, silver, copper, and platinum can be recycled for further use. These precious materials which attract informal recyclers in India. The typical four stages, life-cycle of electronic electrical equipment (EEE) in India are depicted in the schematic shown in Figure 1.

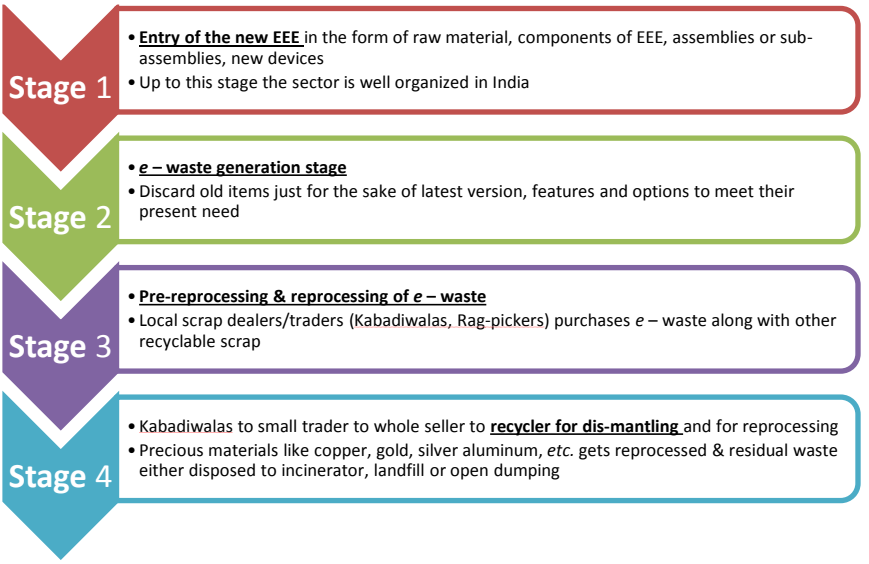

Figure 1: Typical life cycle of Electrical-Electronic-Equipment (EEE) in India

A major part of *e*-waste management in India is done through an unorganized sector with a handful of organized *e*-waste recyclers. More than 95% of *e*-waste is treated and processed in the majority of urban slums. In this unorganized sector, untrained workers carry out dangerous procedures without any personnel protective equipment. Such procedures are not only detrimental to their health but also the environment. The rough methods used by the unorganized sector which involves the open burning of plastic waste to extract metals, exposure to toxic solders by hammering, and open acid baths. This recovers saleable materials and components from *e*-waste with little or no safeguards to human health. This procedure also pollutes the environment - the land (disposal in landfill), air (open burning of e-waste), and water (due to river dumping of acids) and general widespread dumping (Husain et al 2019). The untrained and uneducated workers working in this field putting their lives at risk. There is a huge amount of *e*-waste generated in India and this is increasing at an accelerating pace. For instance, a recent study for the Chandigarh region shows that this region itself generates about 4112tons of e-waste per annum (Ravindra and Mor 2019). According to ISRI, India process 2.7 million tons of e-waste every year mainly through the unorganized sector and seventy percent of e-waste comes from 10 major cities (Awasthi and Li 2017). The fact of the illegal import of e-waste from developed countries is also another issue that needs to be mentioned. Government regulations were introduced on this matter for the first time in 2011, then it got superseded in 2016 and amended in 2018. The rapid changes in Govt. policies indicate the complex nature of e-waste management in India.

China's practice in managing e-waste

China's situation is somewhat similar to India as far as e-waste generation is concerned but its approach to deal with it is different. A recent case-study in terms of the smartphone has discussed this situation. The smartphones have become indispensable,

irreplaceable, and an essential part of daily human life which is evident from the fact that the total number of mobile phones in the world today has crossed the world's human population. China being the most populated country is world's largest mobile phone market. It is also world's largest smartphone manufacturing country. In 2017, the global mobile subscriptions reached 7.38 billion units and out of that 1.32 billion units were brought new through China's manufacturing. A high volume of obsolete mobile phones gets generated in China which is taken as a source of high-tech minerals (HTMs). HTMs contain various precious materials which are limited on earth crust including rare earth materials and platinum group metals. The emerging Chinese national strategic industries treat HTMs as raw materials for the development of high-end equipment. This had been proven beneficial as compared to processing virgin ore due to economic and technical constraints. The sustainable supply of HTMs enabled the smooth development of such industries which might have been hit due to mining HTMs from natural deposits. Hence, China has taken urban mining as an alternative to natural mining for precious metallic requirements in electronic manufacturing. The schematic to represent China's latest go about the e-waste is depicted in the schematic shown in Figure 2.

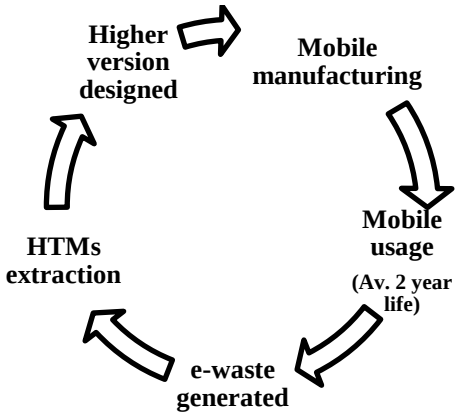

Figure 2: Typical life cycle of Mobile waste materials in China

It is predicted that by 2030, the value of precious material that will be extracted from e-waste in China will worth about US$ 23.8 billion by urban mining (Rick 2019). The circular economy is depicted in Figure 2 will present a huge opportunity to generate growth. China is all set to exploit its unique position to fulfill the demands of consumer electronics by large scale manufacturing of advent devices. The three key areas in making sustainable circular economy i.e., supply of electronic goods, demand for recycled materials, and transportation of these materials. These are in abundance in China. The fund balance analysis modelling is used to evaluate MFA in China which indicates the future sustainability of formal recycling industries (Yifan et al 2017). The Chinese government motivates the circular economy as a national policy since 2005. Since then, China has the ambitions to develop waste resource utilization industries with the aim to get economies of scale for secondary resource recycling. China has utilized the recycling of waste materials for resource recoveries with environmental protection. The policies are so adopted that average profits in recycling companies guarantee the circular economy for sustainable growth.

Opportunities and Suggestions for India

If we compare the e-waste management procedures for India and China, there are huge similarities with minor differences. For instance, both the countries have high population to generate a huge amount of e-waste. They import of e-waste from western countries and have overtaken domestic generation of e-waste as compared to import. Moreover, both the countries have legal and illegal recycling units and they suffer from weak regulations/enforcement of e-waste laws. China and India are facing environmental and health concerns due to e-waste. The global compound annual growth rate (CAGR) for e-waste generation is anticipated to be 23.5%. On the other hand, the CAGR for India between 2015-2019and for China between 2013 and 2018

are predicted to be 26% and 19.45% respectively (Awasthi and Li 2017).

The difference lies in the fact that even though both countries thrive to deal with the informal e-waste market. But in the case of India, this is on a higher side as high as 95%. These informal operators are not green but exploitative involving the poorest population with their livelihood depends on this sector. A significant contribution is given by these people through the chain of collection-dismantling-refurbishment of e-waste. But when they try to dispose of the residue by traditional ways of solid waste, it creates a loss in two fronts one environmental other one economic. The high-value precious material (HTMs) gets lost due to improper disposal of residue of e-waste. A strategic approach is required in India to make this situation an opportunity by ensuring HTMs preservation and then use. The open system of e-waste management as depicted in Figure 2 should be replaced by a close-mechanism followed in China as depicted in figure 3. The aim should be to get maximum HTMs from e-waste to act as an exporter of these precious recyclable materials. This will create an opportunity for the Indian industry (either in manufacturing or recycling), new job creation, and help to tackle the environmental-health issues and prove to be a new battleground for China. India may look forward to being a new global player in electronic manufacturing and e-waste disposal ground. India already has a solid foundation laid to achieve this objective.

In China, there are about 109 registered e-waste recyclers that can recycle about 133 million units per annum. India, on the other hand, has a higher number of formal recyclers at present about 178. China's current regulations facilitate recycling e-waste with environmentally sound technologies which are well supported by the infrastructure required for this purpose. Indian policies at present, just focuses on extended producer responsibility (EPR) with limited capacity, technological, and logistic support. Indian policies seem to get inspired by developed/western countries like

the EU, USA, and Japan without taking note of ground reality. Every country has its unique circumstances and culture so the policies must be made keeping the local scenario in perspective rather than blindly follow. E-waste handling is now becoming a monumental task in India in the absence of an integrated approach to deal with it. The coordination between e-waste scrap collectors, dismantlers, and recycler is needed in India as is practiced in China. The adoption of EPR legislation without any financial incentive causes the inefficient implementation of policies about formal recycling. India needs to adopt policies similar to that followed in developing countries rather in developed countries. Better collection methods should be devised similar to China's integrated recycling plants. The integrated mobile collection methodology is practiced by China, a similar approach may be adopted in India to improve the initial task of collection of e-waste. Both China and India are in the transitionary stage with a mix of formal and informal sectors dealing the e-waste. India and China, both have the challenges in the enforcement of regulations and lack of public awareness towards the hazardous-preciousness in e-waste. China has succeeded early by taking a good systematic approach to improving the recycling of e-waste, while India needs to step-in. The Chinese government has adopted an incentive-based approach in dealing with e-waste which results in proper channelization of e-waste materials to formal enterprises. The annual formal collection rates are increased in China reaching up to 64% in the formal sector. The better implementation of 3R (reduce, reuse, recycle) policies in China proven to be a learning for India who seemed to have practicing ineffective EPR models. China's better position in terms of regulations, recycling rates needs to be appreciated and better SWOT-approach may be used to draw a roadmap for India in the field of e-waste management. The main suggestions for India may be drawn from the discussion so far as follows.

1. *Electronic manufacturing:* China is, no doubt, the world's largest supplier of electronic goods but at the same time it is the largest importer of e-waste. This proves the point how China made

itself independent of the raw material supply chain. India is focused on the electronic assembly units of imported electronic parts and manufacturing is restricted to few semi-conductor devices. The electronic industry in India is more oriented to designing rather on manufacturing. The suggestion is that policymakers should encourage more electronic manufacturing industries. The recent National Policy on Electronics (NPE-2019) is the first step in this direction but a proper target-based approach is required to achieve the objectives in time otherwise China's primacy may prevail in the future too. The Ministry of Electronics and Information Technology (MEIT) on June 2, 2020 announced the much-awaited Electronics Manufacturing Scheme 2.0. This scheme aims to promote production not only for domestic markets but also for global export. This scheme aims to manufacture electronics goods including smartphones, laptops, etc. worth Rs. 8 trillion, while generating employment for about 1 million people within the next five years (Alawadhi 2020). This will be the grass root step in tackling the imbalanced Indo-Chinese electronic trade. Indian import of electronic goods in the year 2019 was US$ 19.97 according to Nations COMTRADE database on international trade (India Imports from China of Electrical, electronic equipment - 1988-2019 Data | 2020 Forecast 2020).

2. *Rules & Statues:* Indian rules to monitor e-waste management are based on extended producer responsibility (EPR) but this approach is somewhat failed as state regulators have no monitoring policy on EEE-producers. There are expensive establishment requirements for recyclers under the environmental and health constraint. China, on the other hand, used innovative ways to formalize e-waste collection and recycling (Srivastva and Pathak 2020). The suggestion is to make new rules to achieve conducive atmosphere for formal e-waste recyclers with the incentive to collect e-waste material through local rag-pickers. The role of informal e-waste collectors will be very important both due to their poverty

levels and due to their reach to local households. The need is to make a system of organized recycling that should be facilitated by local rag-pickers who can help in the collection of e-waste material. The initial higher incentives may help in creating an atmosphere of trust between the informal collector and formal recyclers.

3. *Awareness:* Public awareness is required in managing e-waste. The suggestion is that such awareness programs may be run through electronic retails and these retail shops may also act as formal e-waste collection points. The good initiatives named "Greene" from the Ministry of Electronics and Information Technology (MEIT) (Greene n.d.) have already started. Such programs should be taken up by higher education institutions as it will not only spread awareness among the young generation but also to the public at large. The public should also learn the importance of segregation as it is beneficial at this point both on the economic front and Indo-Chinese battlefield.

4. *New Business model:* Because of the high cost of labour, transportation, and electric power, e-waste recycling is no longer a viable business in western countries. Technology and infrastructure are developed in developed countries, but labour, transportation, processing, etc. are cheaper in developing countries like India. As India's non-formal recyclers deal with the bulk of e-waste, any formal approach is likely to affect the entire value chain associated with e-waste management. The new business model, hence needed for e-waste collectors that may encourage them to earn maximum without having to use burning and chemically exposing methods to extract gold, silver, etc. If there is a mix of informal and formal sectors, with the informal sector handling collection and reuse while the formal sector is responsible for dismantling and recycling.

5. *Financial constrains:* In China, pilot projects were launched with an aim to test new formal recycling methods in place of informal recycling. In most cases, these projects fail to collect enough e-waste because informal recyclers pay consumers for their waste and pilot programs don't. One policy proposal entails sharing financial responsibility between consumers, manufacturer and government. An incentive is provided to consumers for donating e-waste to the system in the form of a deposit.

6. *New Policy making:* As e-waste crosses borders and is currently exported to developing countries at an alarming rate, the implementation of EPR in these countries has become essential due to the lack of recycling and waste disposal infrastructure in these countries. For effective management of e-waste in developing countries, governments must change their attitude, appropriate legislation must deal specifically with e-waste, controls on electronic waste dumping must be enacted, EPR must be implemented and technology transfer must take place on sound recycling of e-waste.

7. *New Techniques:* By replacing conventional and traditional e-waste management practices with future-oriented eco-friendly approaches such as chelation, injection of ionic liquids, integrated processes, hybrid technologies, micro-factories, photo catalysis, and green adsorption, we may to be able to significantly bridge the shortfall in the current e-waste management.

8. *Self-motivation for environment protection:* We can conserve resources by minimizing e-waste and reduce energy consumption by lessening the amount of e-waste we generate. If we really need a new gadget, then we should find one that can serve multiple purposes. We should buy a case, keep the device clean, and avoid overcharging the battery. Consider products that are Energy Star-certified or that have been

evaluated by the Electronic Product Environmental Assessment Tool.

Conclusions

The current thrust in India to tackle Chinese infringement through economic war front was the subject matter of present study. It has been found that China and India both had similar platforms on e-waste management front, but better decisions and implementations of policies over last one decade made China to get an upper hand. China encashed the situation very well in past 15 years or so during the evolution of ICT technologies. It was first to judge the opportunity in e-waste rather than taking it as environmental problem. This led to its current solid position in electronic manufacturing on global map. The close Indo-Chinese geographical positioning makes India to learn lessons and combat China appropriately. However, Chinese global grip on electronics is hard to break, but systematic discussion presented in this paper proves the point that proper management of e-waste in India as is practiced by China, will help in making India an electronic manufacturing hub. That will not only counterbalance Indo-Chinese electronic economics but also give India a global exposure. The roadmap so suggested may bring harmony in issues pertaining to electronics in terms of environment, health, poverty, and economics. The present outbreak of Covid-19 has given new origin for old scenario with the expected boom in technologies and sell of advent electronic gadgets to get imbedded into all fields. This is the golden chance that India need to encash to get better avenues in electronic economic through proper management of e-waste.

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