E-waste situation and current practices in Brazil

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16.1 Introduction

Brazil is a country with huge territory and a population of approximately 200 million people. It is considered the largest E-waste producer in Latin-America, with estimated 7 kg E-waste per capita (StEP, 2017), and also a receiver of illegal E-waste exports from other industrialized countries (Lundgren, 2012). Some aspects which influence E-waste generation in the country are the population consumption patterns, market prices and offers, and technological evolution of equipment with consequent obsolescence of others.

Considering the amount of E-waste in the country, the concerns with its potential hazardousness and the potential added-value with its recycling, Brazil has established in 2010 its National Solid Waste Policy (PNRS), which determines that E-waste take-back implementation in mandatory countrywide. Following the PNRS, there was an increasing tendency on the development of E-waste management specific Standard and licensing schemes, businesses in E-waste take-back and recycling, researches, and other initiatives regarding the implementation of E-waste management solutions. However, the growing discussion on this complex subject revealed several difficulties for adequate E-waste take-back implementation in the Brazilian context. This chapter aims at describing the Brazilian E-waste scenario, and discussing the existing difficulties and opportunities for a sound E-waste management in the country.

16.2 Brazilian legislation and regulation on E-waste

16.2.1 The national solid waste policy

The mark for E-waste management legislation in Brazil is the National Solid Waste Policy—PNRS (Law No. 12305), established in 2010. Before this law, there were environmental regulations for production and treatment of specific E-waste appliances, like batteries and lamps. For example, the Resolution No. 401/2008 from the National Environmental Council (CONAMA) established requirements and

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procedures for producers and importers of batteries, in order to promote environmentally sound management of their end-of-life products.

Another relevant mark prior to the PNRS is the Brazilian Standard no. 10004/2004, which defined the parameters to classify solid waste according to their hazardousness. Some kinds of E-waste, like lead batteries, mercurial lamps, and ashes from printed circuit boards (PCB) incineration, are specifically listed as hazardous, but the majority of E-waste types and components still need to be classified according to the procedures established in this Standard.

After the establishment of PNRS in 2010, take-back systems became mandatory for some kinds of special waste, including batteries; lamps; electrical and electronic equipment (EEE), and their components. Structuring and implementation of these take-back systems are an obligation of EEE producers, importers, distributors, and retailers.

The Decree 7404/2010, referred to the PNRS Law, defines that the instruments for implementation and operation of E-waste take-back systems are Sectorial Agreements (SA), regulations from the Government, and Terms of Engagement. The SA are contracts to be signed between representatives of EEE producers, importers, distributors and retailers, and the Government at all levels, focusing the implementation of shared responsibility for EEE life cycles. Some of the representatives currently engaged with E-waste SA in Brazil are ABINEE (Brazilian Association of EEE Industries); ABREE (Brazilian Association for EEE Recycling); and FECOMERCIO (State Federations for the Commerce of Goods and Services). Those representatives can create one or more E-waste management entities, who will be institutionally responsible for managing and contracting services for the implementation of the official E-waste take-back systems.

In 2013, the Ministry of Environment (MMA) opened a call for E-Waste Sectorial Agreement proposals, which should include, among others:

- Means for E-waste delivery and collection, defining: responsibilities, territorial coverage and delivery, collection, and recycling activities.
- Actions, criteria, and responsibilities over E-waste delivery points and transport activities.
- Procedures and responsibilities for operations of E-waste reuse, recycling, treatment and sorting; environmentally sound disposal of E-waste refuse.
- Possibility of hiring other entities, such as waste pickers' cooperatives.
- Progressive implementation targets, in terms of % of Brazilian cities.

Until mid-2018, the received proposals were still under discussion, negotiation, and revision between the signatories. According to the MMA, some of the most critical points that have hindered the reach for such agreement between the parties, mainly reflecting demands from EEE producers, importers, distributors, and retailers to the Government, are:

- The pecuniary participation of consumers in covering the costs of take-back systems: it should be clearly informed in the final price of purchased EEE, and free of taxes.
- The definition of E-waste as nonhazardous, prior to the modification of their physical or chemical properties: this should avoid high costs of treating all E-waste as hazardous in all steps of the take-back systems, to facilitate environmental licensing of E-waste

collection companies, and to avoid restriction of hazardous waste transport across some States with specific prohibitive legislation.
- Creation of a nationwide valid documentation of E-waste transport, for the registry of source and nature of the load, exempting the need for other waste transportation documentation.
- The recognition that E-waste delivery at take-back points implies in the loss of property of such goods by their owners: it could be solved with some documentation to be signed by the deliverers at the points, or the emission of a report stating such transfer of property after the delivery at the points.
- Who should be the responsibility for "orphan" products (illegal or fake EEE products that normally enters Brazilian market informally).
- The biding engagement of all EEE life cycle actors in the Sectorial Agreement, and not just its signatories: this issue was recently resolved by the Decrete 9177/2017, referred to the PNRS, which determines all producers, importers, distributors, and retailers acting in the country are responsible for what was agreed by signatories of the Sectorial Agreement.

16.2.2 States legislation

As in the national level, some Brazilian States already had specific legislation for some kinds of E-waste, prior to the PNRS, or created particular State Laws after it. Most of this legislation has been tracked in the StEP E-waste World Map (StEP, 2017). For example, before the PNRS, States like Espírito Santo (ES) and São Paulo (SP) already had specific Laws for the correct management of E-waste (SP Law No. 13576/2009) or waste containing mercury and heavy metals (ES Law No. 9163/2009). There were also some municipal Laws on this regard, as in the city of Cascavel, State of Paraná (Law No. 4726/2007). Many of these were moved by the previous countrywide discussions that resulted in the PNRS in 2010.

Other States and municipalities developed specific E-waste legislation after the PNRS. For example, the Rio de Janeiro State (RJ) created, in its State Law no. 8030/2018, the E-waste take-back Program for all of its territory. This Law determines that all administrative buildings of the State Government, as well as their autarchies, foundations, and entities of the indirect public administration, must make available E-waste delivery points to the external public, with visual communication referring to the risks related to E-waste. In accordance to the PNRS, the collected appliances must be forwarded to EEE producers, importers, distributors, or retailers, and the municipalities can be hired to promote E-waste collection within the take-bake system under their direct responsibility.

Some States, like São Paulo (SP), are ahead in the regulation and implementation of E-waste take-back schemes in their territories. In 2015, the State Environmental Secretary (SMA-SP) issued a Resolution (No. 45/2015) determining that this Secretary and the State Environmental Company (CETESB) can celebrate Terms of Engagement for monitoring and implementation of take-back systems (in line with the aforementioned PNRS Decree No. 7404/2010). In 2017, such Term was signed between the following parties: SMA-SP; CETESB; and Green Eletron, a take-back management entity created and represented in this Term by ABINEE

and FECOMERCIO-SP. In addition, in order to tackle some of the already discussed critical issues regarding the E-waste SA, CETESB issued in 2016 a Decision (No. 120/2016/C) in which it determined that E-waste can be classified as nonhazardous in operations that do not involve separation of components, and therefore do not promote exposition to potential hazardous constituents—except final disposal. Furthermore, in 2018 CETESB issued another Decision (No. 076/2018/C), establishing the required conditions for environmental licensing of take-back activities, what, among other definitions, limits the Operation Licensing of all producers, importers, distributors, and retailers in the State, to the approval of a take-back plan for their related end-of-life products.

16.2.3 Brazilian standardization on E-waste take-back systems

The Brazilian Association for Technical Standards (ABNT) has published, in 2013, a Standard on Requisites for E-waste Reverse Manufacturing (ABNT, 2013). This is the reference Standard for E-waste management implementation in Brazilian companies. It establishes requisites for the implementation, maintenance, and continuous improvement of an E-waste management system, which is based in other Standards such as ISO 9000 series and ISO 14001.

According to this Standard, the E-waste management system to be implemented in Brazilian companies includes:

- An environmental policy.
- Planning, comprehending: environmental and health and safety aspects; legal requisites; objectives, targets, and programs.
- Implementation and operation aspects, such as: resources, functions, responsibilities, authorities, competences, training, awareness, communication, documentation, and its controlling, operational controlling, preparation, and response to emergencies.
- Verification aspects like monitoring and measurement, compliance assessment and others, corrective and preventive measures, registry controlling, and internal auditing.
- Administration analysis, focusing diagnosis, and opportunities for improvement.

Although this Standard is still not certifiable, it has been guiding the implementation and enhancement of organizational maturity of many E-waste businesses in the country. Some of its main contributions to Brazilian E-waste management companies regard the creation of standardized documentation for mass balance control along operational steps like E-waste reception, storage, dismantling, and commercialization; the standardization of operational procedures; adequate management of hazardous components; E-waste traceability from reception to final destination; and reporting to clients and environmental authorities.

16.3 E-waste generation in Brazil

Brazil is still far from having a fully controlled scheme to manage E-waste. Therefore all figures related to E-waste generation in the country are based on

estimation methods. A highly referenced estimate is 7 kg/capita in 2014 (StEP, 2017), or a total of 1.4 Mt in that year, what was calculated based on a correlation with Purchase Power of the Population (PPP). One study developed by request of the Federal Government, to assess the feasibility of possible E-waste take-back schemes in Brazil, estimated a range of 4.79 − 7.19 kg E-waste/capita (ABDI, 2012), based on a correlation with the GDP per capita of some European countries, as previously presented by Huisman et al. (2008). Other Brazilian studies estimated E-waste generation per capita as 3.77 kg in 2008 for seven types of appliances (Araújo et al., 2012) and 4.8 kg in the city of São Paulo (Rodrigues et al., 2015). These latter studies adopted estimation methods like the Market Supply and the Time-Step, that rely on variables like amount of EEE products put on market each year, the EEE in stock (in use), and average lifespans for each kind of appliance.

Those estimates are much necessary in order to support the planning of take-back schemes in the country. However, all of them have downsides due to uncertainties and adopted approaches. For example, the correlation with PPP and GDP per capita depends on previous data with real E-waste generation accounting in a considerable sample of places, which could be comparable to the country under study. In this case, a correlation based on European countries from 10 + years ago may not be reliable to estimate E-waste generation in Brazilian context nowadays. Another restriction is the dependence on data such as average lifespan of products, what may also vary according to social-economic contexts in each place, to the period under study, and the evolution of technologies. On this regard, all of the aforementioned Brazilian studies adopted average lifespans from the international literature in previous years, what may not reflect the patterns of Brazilian consumers. Finally, most of these studies adopted methods that depend on the amount of EEE products put on market in different years. Such data, when available, usually reflects the EEE consumption countrywide. Thus, the E-waste generation estimates represent an average of the country population, what does not reflect the specific social and economic contexts in the different regions (e.g., according to IBGE (2015), the estimated GDP per capita in the country was R$ 29k in 2015, but varied from as much as 43.5k in the State of Sao Paulo to 11.4k in Maranhão).

An attempt to reduce those uncertainties was done by Abbondanza and Souza (2018), by using surveys to collect data for the Market Supply E-waste estimation method. These surveys were applied to a sample population with 5% margin of error, which is representative of different city zones of the city of São José dos Campos, State of São Paulo, Brazil. The interviewed households informed data as the number of appliances acquired in past years, number of appliances currently in use, and the age of appliances lately discarded as E-waste. With this, the estimated E-waste generation in this city was 4 kg/capita in 2017. The observed lifespans varied considerably in comparison to those adopted by the aforementioned studies. For example, adopted lifespans of mobile phones ranged from 2 to 4 years in those studies, whilst in this case the observed average was 1.98 year (smartphones) to 2.5 years (nonsmartphones). The study found the average lifespan of 7 years for a washing machine, compared to 7−11 from the previous studies. Another advantage of this study was to produce lifespan distributions, rather than just averages, what

does not restrict the E-waste generation projections to a discrete lifespan value. It also represented those lifespan profiles by regions of the city, thus seeking to represent the social-economic contexts. For example, the probability of a smartphone becoming E-waste in the city was around 45%, but this varied from 40% to 55% depending on the zone of the city. Such information can be useful to support planning of E-waste take-back systems in the country, especially because, as seen in Section 16.2, such implementation in the country must be progressive and cities are the basic units for the systems.

16.4 Currently known E-waste routes in Brazil

As mentioned before, in Brazil there is still very few control on E-waste generation and destinations, because a countrywide formal take-back system is still in its very early steps. Based on empirical evidences and previous literature, the known current routes for E-waste in the country are summarized in Fig. 16.1, and further discussed.

A particular issue in Brazil regarding E-waste management is that most adequate systems, or the more specialized operations within the take-back routes, tend to be located in the Southeast (SE) and South (S) regions on the country, the most developed ones, but as far as 3.500 km from poorer regions like North (N) and Northeast

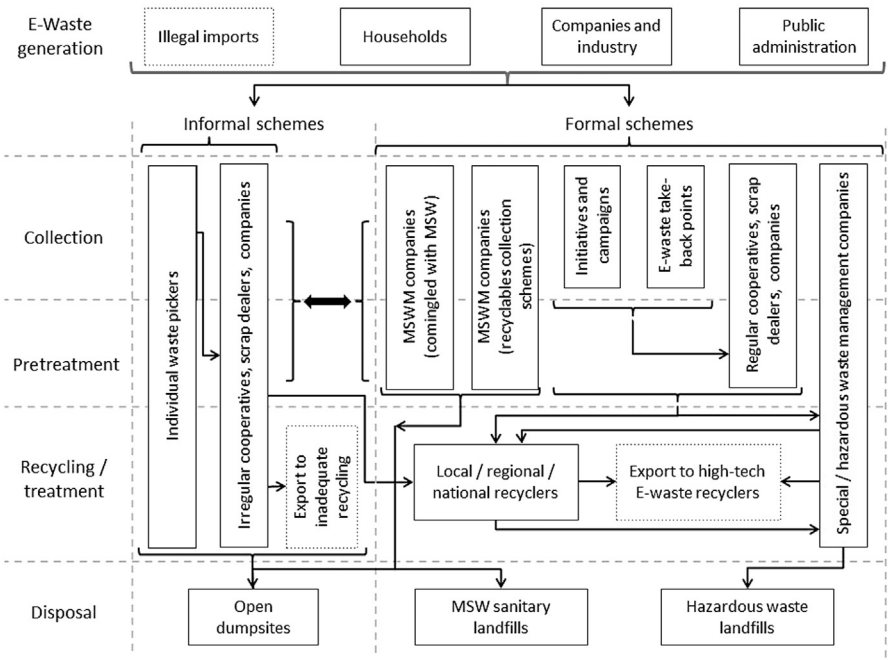

Figure 16.1 Currently known E-waste formal and informal chains in Brazil.

(NE). The study by ABDI (2012) identified, in 2012, 94 E-waste recyclers in the country, of which 50 were located in the SE region (37 just in SP State) and 34 in the South region, compared to 4 in the NE and 3 in the North regions. Considering that Brazil is a continental country in terms of its territory, and that its logistical infrastructure is highly dependant on road transport, this poses a huge logistical challenge that hinders the feasibility of E-waste take-back systems countrywide. The concentration of E-waste take-back activities in southern regions, particularly in the São Paulo State, can be illustrated with data collected from a Brazilian database of waste management companies (CEMPRE, 2017). Late in 2017, there were 150 cooperatives registered in this database that were doing business with E-waste, from which 63 were located in the SP state. Regarding scrap dealers, 87 registered companies were doing business with E-waste, 49 just in SP. And concerning recycling companies, 129 were registered for E-waste business, 60 of these in SP.

It is also worth mentioning that those identified E-waste recyclers can only process some types of E-waste and components at a limited capacity. This is going to be discussed further in this section.

16.4.1 Informal schemes

The informal sector in Brazilian waste management is widely known and observed in all regions, bus still very few data are available, and especially concerning E-waste. However, we can consider that informality plays a huge role in waste management recycling chains in the country, and this also applies for E-waste. The adequate E-waste recycling rate in Brazil is estimated at 2% (Araújo et al., 2012). E-waste corresponds to 2% of all waste collected by recyclables collection schemes (CEMPRE, 2016), what is far from being widespread in the country, as discussed further.

16.4.1.1 Individual waste pickers, irregular cooperatives, scrap dealers, and companies

It is estimated that in 2008 around 70.5k waste pickers were acting in urban areas, 18% of those in the State of São Paulo, and 5.5k being children under 14 year old. Out the 5760 Brazilian cities, 27% acknowledged the presence of waste pickers in their municipal solid waste (MSW) disposal sites (Silva et al., 2013).

There are evidences that waste pickers and scrap dealers handle E-waste in the country (Ongondo et al., 2011), what is also highly supported by empirical experience. Some of these were found to make rough acid leaching of PCBs, as well as open burning of components like cables (Lundgren, 2012; Souza, 2014).

A very common scene in Brazilian cities, especially in the poorest areas, in presented in Fig. 16.2. It clearly represents the activity of individual waste pickers, who collect E-waste from households or businesses, dismantle the appliances, separate the most valuable components for commercialization (usually to scrap dealers), and leave the less valuable parts at open dumps, like vacant lots, green areas, or public parks.

Figure 16.2 Informal dismantling and dumping of CRT TVs in a Brazilian city.

The activity of cooperatives or scrap dealers who are not formally licensed to process E-waste is also very common. Because E-waste has a considerable market value in the recycling business, those actors also apply irregular processing in order to separate valuable materials for commercialization. Fig. 16.3 shows the working area of a recyclables cooperative, where some dismantled or to-be-dismantled E-waste can be seen directly over the ground, and exposed to weather.

In some cases, the informal E-waste sector is already involved with organized crime schemes. For example, it was reported in the city of Belo Horizonte a significant shift in the stealing of electrical cables from public traffic lights. From January to June, 2018, the municipal administration reported the stealing of 64 km of cables from traffic lights, against 5 km in the same period in 2017. In the city of Sao Paulo, in the first semester of 2018, 32 km of cables were reportedly stolen, in a total of 1000 occurrences. Such crime is also widespread in the country, with other cases affecting systems as federal roads, water supply, and healthcare facilities. So far, identified receivers of such stolen cables are scrap dealers, who have paid for the material either in cash or with alcoholic drinks (dia Brasil, 2018).

Some of these informal actors go further into irregular E-waste processing, searching to extract valuable metals. Acid leaching seems to be a very common activity within the E-waste informal sector, despite no formal data are available. In the city of São José dos Campos (SP), we could identify at least one small company, not licensed for WEEE, who not only crashed CRT tubes to reduce volume but also applied acid leaching of PCBs. This company provided a simple recipe for this process, consisting of acid leaching of PCBs with *acqua regia*, followed by filtering, heating on hot plate, and precipitation of gold using a reagent. It is also very easy to find Brazilian videos on YouTube, where this process is homemade by informal actors. As it can be observed in these cases, the informal process does not make use of adequate laboratory conditions, and neither health and safety cares like the use of adequate personal protective equipment.

Figure 16.3 E-waste irregularly stored and processed by a recycling cooperative.

16.4.1.2 Open-dumping

Besides the prohibition of open dumping by PNRS, in Brazil most of the municipal solid waste management (MSWM) systems still rely on comingled waste collection and inadequate disposal, open dumpsites being a very common final destination. According to ABRELPE (2015), about 60% of Brazilian cities had open dumps or

controlled (not sanitary) landfills as final MSW disposal. Besides the open dumpsites that accumulate all mixed MSW of many Brazilian cities, including E-waste, there are also uncountable smaller open dumping areas, like those mentioned in Section 16.4.1.1 and illustrated in Fig. 16.2. This situation is also enhanced by the lack of coverage of MSW collection schemes, especially in the North and Northeast regions (around 80% coverage, according to ABRELPE, 2015), provoking people either to dispose of their waste at open dumps, or open burn them.

16.4.2 Formal schemes

16.4.2.1 Municipal solid waste management systems and landfills

In addition to the widespread informal E-waste schemes, another very common destination of E-waste in Brazil are the MSWM systems. Because of lack of information or lack of adequate delivery points in most cities, citizens have regularly disposed of their E-waste mixed with MSW.

Besides MSWM systems can be considered formal schemes, this is still not an adequate situation, especially considering the Brazilian scenario. Only 18% of Brazilian cities have some implemented separate recyclables collection scheme (CEMPRE, 2016), meaning that in most cases MSW is collected without previous sorting. Moreover, 42% of Brazilian MSW is destined to inadequate landfills or open dumps. This corresponds to the largest share of Brazilian cities (60%), consisting mostly of small and medium cities, and more concentrated in the North, Northeast, and Midwest regions, the poorest in the country.

Even where there are sanitary landfills, E-waste is regularly being landfilled mixed with MSW. This is the case, for example, of Rio de Janeiro, the second biggest city in the country. The E-waste share within commingled MSW has shifted from 0.2% in 2010 to 0.48% in 2016, what varies significantly depending on the MSW collection areas (COMLURB, 2016). Considering the average MSW generation of 1.39 kg/capita in the city in 2016, and the estimated population of 6,476,631 inhabitants in the same year (IBGE, 2017), the E-waste amount landfilled in 2016 can be estimated in 9k tonnes.

16.4.2.2 Initiatives and campaigns

There are several and an increasing number of initiatives for the collection and adequate destination of E-waste in Brazil. In many cases, delivery points are made available by the municipalities, in partnership with take-back and recycling companies, in determined periods of a year. There are also several initiatives for the collection of E-waste by delivery points placed at universities and schools.

Some cities have established specific services for the door-to-door collection of E-waste under demand. This is the case, for example, of the “e-lixo” (E-waste) service in the city of São José dos Campos. This city also has several delivery points for recyclables and special MSW, including E-waste. From both systems,

the E-waste collected is destined to a cooperative (Coopertech) specialized in E-waste dismantling.

One example in the city of Rio de Janeiro is a partnership of the companies Tech Trash and Zyklos, who installed dozens of E-waste delivery points at shopping centers and several partner shops along the city. Those companies also provide door-to-door collection under a fee.

A reference E-waste take-back initiative at universities is the Centre for Discard and Reuse of IT Waste (CEDIR), at São Paulo University (USP). This center has a partnership with recyclers, promoting the adequate E-waste destination. Most of the biggest Brazilian universities have already installed special E-waste collection points. Some of them, like the Federal University of Rio de Janeiro (UFRJ), also have a sorting area, operated by a partner cooperative, where E-waste can be sorted and dismantled, before promoting the correspondent adequate destination to each fraction.

A well-structured initiative is a pilot project implemented in the Lapa neighborhood in the city of São Paulo, called "Descarte ON" ("Discard ON"). This initiative aimed at testing a small-scale take-back system, to be a further model for the E-waste take-back implementation in Brazilian cities. E-waste delivery points were placed at large shops and supermarkets, and the collection, pretreatment, and recycling are operated by partner companies. Such initiative is the result of a partnership between the Japan International Cooperation Agency (JICA), the Brazilian Federal Government, the São Paulo Municipality, and representative associations and federations for Brazilian EEE industry and commerce, and E-waste recyclers.

16.4.2.3 Formal E-waste take-back systems

Many of the cases mentioned in the Section 16.4.2.2 can be considered formal E-waste delivery systems, especially those consisting of initiatives and programs by the municipalities. However, those systems still cannot be considered official under the framework of the PNRS legislation, municipalities can only operate E-waste take-back processes under a contract and payment by the E-waste management responsible entities, as defined in the Sectorial Agreement (which is still not formalized, as previously discussed).

A pioneer initiative in the country was the signature of a Term of Engagement in the State of São Paulo (see Section 16.2.2), with the creation of a Management Entity for the E-waste take-back system to be implemented in this State. This Entity, called Green Eletron (www.greeneletron.org.br), was created by ABINEE, and is a signatory of the São Paulo Term of Engagement. The system under management of Green Eletron in the State is still expanding since the signature of the Term of Engagement, and up to August 2018, had installed 35 standardized delivery points (Fig. 16.4) at partner shops and commerce representatives, having collected a total of 98t of E-waste. As seen in Fig. 16.2, those delivery points allow for E-waste collection in separate drawers for IT equipment (computers, printers, tablets); mobile phones; and screens (bottom drawer). This system is operated by two hired companies: GM&CLOG and Sinctronics (see Section 16.4.2.5), who are

Figure 16.4 E-waste delivery point installed by Green Eletron and Sinctronics.

responsible for all operational steps from collection to processing and final destination.

Besides those systems that focus the final consumers, there are also formal take-back schemes implemented by specific companies to recover their end-of-life products. Brands like Dell, HP, and Lexmark have their own take-back schemes, operated by partners like Sinctronics (see Section 16.4.2.5), after the demand by consumers willing to deliver their spent equipment, who request the service by phone of by filling a form in their websites.

16.4.2.4 Regular cooperatives and companies

A growing number of cooperatives and small companies are developing capacity and getting authorization to adequately handle E-waste. In general, the largest amount of E-waste collected by such businesses comes from large companies and the public administration, who regularly upgrade their computers and other IT appliances, and dispose of their old equipment in batches.

In São Paulo, the cooperative Coopermiti has a partnership with the municipality, and promotes E-waste dismantling and adequate destination. This cooperative collects E-waste from the municipal MSW delivery points, and by demand. Their management system is certificated with ISO 9001 and ISO 140001.

In Rio de Janeiro, the cooperatives COOPAMA and Céu Azul are good examples of such kind of institution. They have been trained in adequate E-waste dismantling and management, and authorized by the municipality to operate in this business. COOPAMA (Fig. 16.5A) has a team of 11 trained staff in E-waste dismantling, and has been processing tonnes E-waste/month, after a partnership with large retailing networks. Another example is in São José dos Campos, where Coopertech (Fig. 16.5B) is also working in partnership with the municipality, and collecting E-waste mainly from the municipal E-waste special collection service, and from large companies and public agencies—an average of 5 ton/month. In particular, this cooperative has been implementing the requisites for the Brazilian Standard on E-waste (Section 16.2.3), aiming at being the one of the first cooperatives which satisfies such Standard.

An example of a small company in the Brazilian E-waste business is Zyklos (mentioned in Section 16.4.2.2). This company operates in Rio de Janeiro, collecting and dismantling E-waste from large and medium partner companies. Their operational area has a capacity to process 20 + tonnes of E-waste per month (Fig. 16.5C), depending on the type of appliance. Currently they have processed an average of 8 ton/month. Their main operational processes are E-waste collection, dismantling, sorting for reuse, recycling, and destination of hazardous components, and repairing. The E-waste collection is subcontracted to authorized companies, and the destination of hazardous components is to a specialized company which makes coprocessing or adequate landfilling. A network of recyclers purchases the recyclable components.

Some challenges for the financial sustainability of such small business are the fluctuations in prices and in the E-waste supply, also influenced by the large competition in this business; and the large amount of less valuable E-waste that they have to collect under demand of their suppliers-clients. For example, a huge issue in the country in the 2010s decade was the large number of CRTs discarded as E-waste. This was shifted not only by the technological evolution of TVs and monitors, but also after a National policy to quit analogic TV signal and implement digital signal countrywide. CRTs have been a critical component to be recycled or disposed of, because of the large volumes of such E-waste generated in the 2010s. Because of its volume and weight, this waste can represent a major cost if destined to hazardous waste treatment by E-waste generators or dismantlers. However, the E-waste collection and dismantling companies are very often pressured to receive such material as a share of a full batch of E-waste, containing also the more valuable appliances (e.g., IT) that make the service worth.

Besides those cooperatives and companies whose business is focused in E-waste collection and dismantling, there are also specialized companies in providing logistical services for the E-waste recycling business. This is the case, for example, of

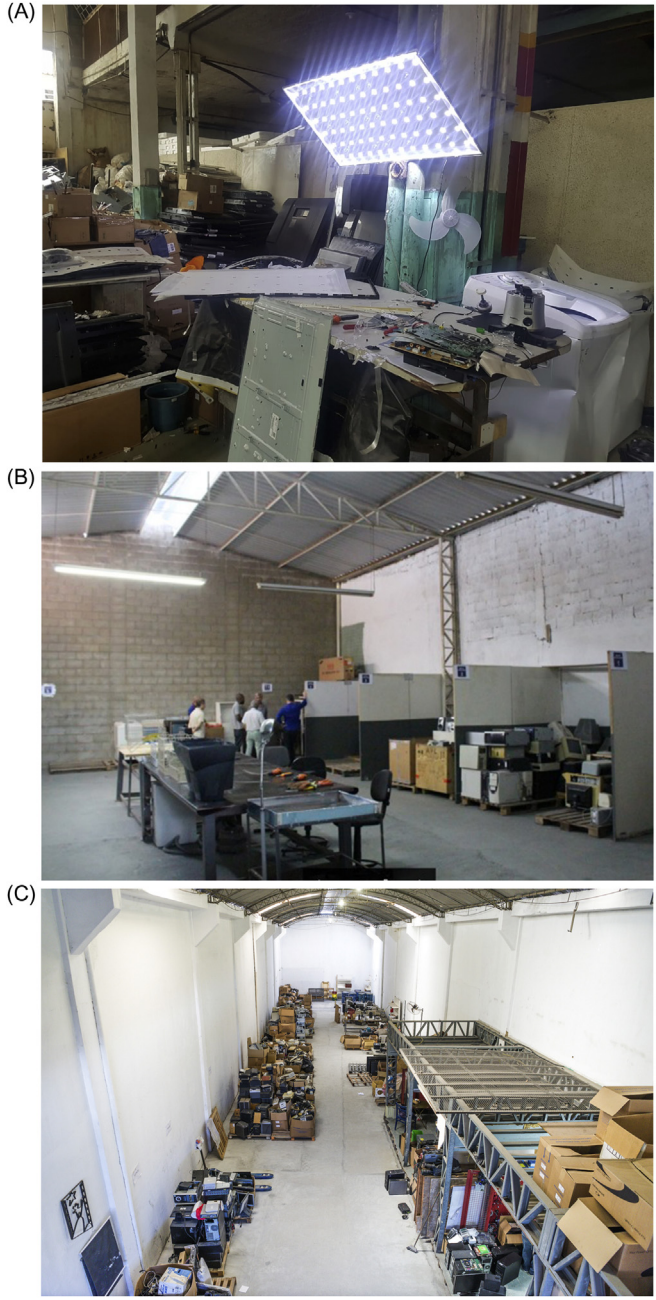

Figure 16.5 (A) E-waste dismantling station at COOPAMA, lightened by reused parts of a LED TV; and the production lines of (B) Cooperative Coopertech; and (C) Zyklos.

GM&CLOG, who is one of the logistical operators for the system implemented in São Paulo State, after the Term of Engagement explained above.

16.4.2.5 Brazilian recyclers

Although E-waste recycling is a growing business in Brazil, as previously mentioned, most of the recycling companies are concentrated in the SE and S regions, the most industrialized in the country. Most E-waste components can be recycled in the country, even those considered hazardous, but still no large-scale technology is installed to recover precious metals from PCBs.

For example, a few industries are able to recycle batteries collected by take-back schemes and companies such as those mentioned in Section 16.4.2.4. These recyclers apply either chemical or thermal processes after shredding the batteries, in order to recover metals.

Regarding CRTs recycling, only one company in the country, located in the State of São Paulo, is known to recycle CRT glasses, producing ceramic glazes. Because of the large demand on this company, many times they could not absorb the full amount of CRTs they have been offered by E-waste dismantlers. However, the peak generation of CRT E-waste was around 2015−16, and such kind of waste is now decreasing in volume.

A good benchmark for Brazilian E-waste recycling is Sinctronics, a company owned by the Flextronics International group. Sinctronics is another operator of the São Paulo State E-waste take-back system. Besides an efficient E-waste dismantling line (Fig. 16.6A), the company also has technology to separate cooper from cables, and to recycle E-waste plastics (Fig. 16.6B), including thermoset polymers like ABS. A particular market niche for this company is the recycling of plastics from printer cartridges and tonners, what are often discarded as hazardous waste. The recycled plastic products range from handles for new printers' boxes, ecological plastic wood (Fig. 16.6C), and other resins that are turned into new EEE parts (e.g., printers, air conditioners). Their whole production line implements lean manufacturing principles.

16.4.2.6 Large waste management companies

Besides a large number of relatively small companies working in the E-waste business, as mentioned in Section 16.4.2.3, there are also some few large companies who are very active in Brazilian waste management systems, especially those offering hazardous waste treatment and MSWM services. Because of their operational capacity, territorial coverage, and financial conditions, these companies are also large players in the E-waste business. Mostly, those companies purchase valuable E-waste components, or offer treatment and disposal of hazardous E-waste parts. Regarding the PCBs market, these companies usually separate and shred the cards to export to large PCB recyclers in the international market. At least one of these large MSWM companies had a unit for metals recovery from waste, based on hydrometallurgy, but it is know that this unit has been inactive for large periods because there was no sufficient E-waste amount reaching the system to make its operation feasible.

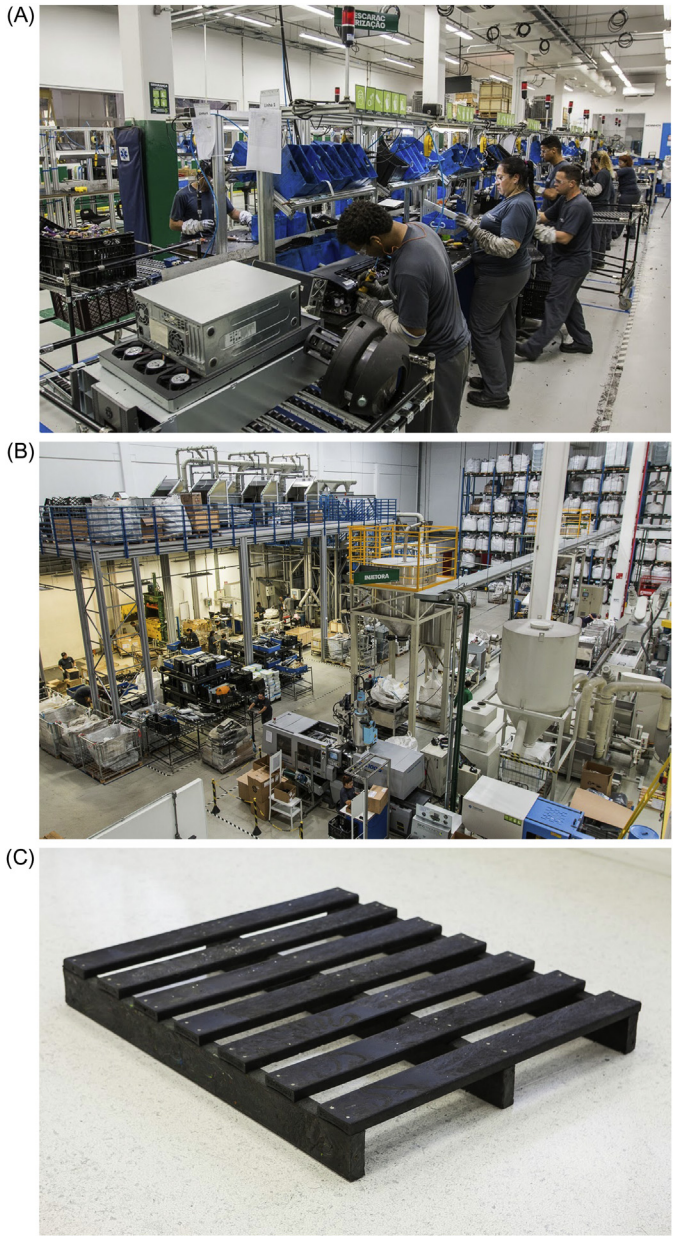

Figure 16.6 Sinctronics production: (A) E-waste dismantling line; (B) plastics recycling plant; and (C) E-waste plastic recycled products.

16.5 Brazilian research and projects on capacity building

It is known that some of the large waste treatment companies cited in the Section 16.4.2.6 are investing and making partnerships to develop technologies to extract precious metals from E-waste. This is the case, for example, of the Rematronic project, in which a biohydrometallurgic technology is being developed by the Renato Archer IT Institute (CTI) for the extraction of gold and other precious metals.

Besides the CTI Institute, several Brazilian universities and research centers have developed a growing number of studies focusing the E-waste analysis and development of recycling technologies. Analyzing the publications indexed in Scopus, until mid-2018, the leading research institution in this area is São Paulo University (USP), followed by the Federal University of Rio Grande do Sul (UFRGS), Federal University of São Carlos (UFSCar), and Federal University of Rio de Janeiro (UFRJ).

Some of these studies have focused the chemical analysis of E-waste, considering either the organic and inorganic components for further recycling or treatment (Santos et al., 2011; Yamane et al., 2011; Aquino and Pereira-filho, 2015). An interesting study analyzes efficient techniques for E-waste disassembly (Duflou et al., 2008). Other studies have analyzed techniques to extract metals from E-waste, like copper (Rubin et al., 2014; Calgaro et al., 2015; Silvas et al., 2015) and silver (Dias et al., 2016).

Besides the growing number of Brazilian researches, there are also many funded projects aiming at capacity building for sound E-waste management in Brazil. Some funding schemes by large private companies and public agencies (like the Banco do Brasil Foundation) have supported specific initiatives from companies and cooperatives in the E-waste sector. Other projects are focused in a wider range of targeted public, and in developing knowledge and capacity for an adequate and efficient E-waste management. An example of such projects is Ambientronics by the aforementioned CTI, which as a public scientific institute linked to the Ministry of Science, Technology and Innovation. Started in 2006, this Project aims at the capacity building for sustainability in the Brazilian EEE complex. It also has the goal of developing and implementing Brazilian Standards on E-waste and Restriction of Hazardous Substances (RoHS). It was under this initiative that CTI played a leading role in the development of the Brazilian E-waste Standard (Section 16.2.3). This Project has also offered several training courses on E-waste management the respective Standard requisites, to small companies and cooperatives in the State of São Paulo. They have also supported the creation of E-waste commercialization networks to empower those companies and cooperatives, aiming at a better feasibility for these businesses.

Another example of capacity building project focusing Brazilian E-waste management is LaWEEEda—Latin-American-European Network on Waste Electrical and Electronic Equipment Research, Development and Analyses. This Project started in 2016 with the support from Erasmus + funding scheme by the European

Commission, and includes 11 partners—universities and E-waste business partners—from 5 countries—Austria, England, Germany, Brazil, and Nicaragua. This Project offers a series of training courses in relevant E-waste management topics, from practical dismantling techniques, to chemical analysis, business planning, recycling and treatment techniques, and others. The targeted public are not only companies and cooperatives acting in the Latin-American E-waste business but also technicians from environmental agencies, municipalities, and a strong focus in university students. The courses are offered in four adequately equipped Training Centers established in Brazil and Nicaragua.

16.6 Challenges and further steps for sound E-waste management in Brazil

Observing the scenario described in this chapter, there are still many challenges, but also opportunities, for the implementation of a sound E-waste management in Brazil:

- *Implementation of the Sectorial Agreements*: as previously discussed, there are still several tangles until the responsible entities reach an agreement on how the Brazilian take-back scheme must be structured, and what are the respective responsibilities and implementation solutions. Once the Sectorial Agreement is established, the country will be able to shift the velocity and adequacy of E-waste take-back implementation.
- *Environmental licensing and formalization of the businesses*: the creation of new E-waste businesses, and the licensing of new and existing ones, still face many difficulties concerning the involved bureaucracy. Environmental agencies of some States have established standards and procedures to enable such businesses, but in most cases it is still rather unclear, even for the governmental bodies, what should be the adequate procedure to formalize these businesses. This is also true concerning the tributary and fiscal aspects, what pose many burdens for the E-waste businesses. Some of these difficulties could be relieved by the creation and revision of Federal environmental laws, as well as of the tributary and fiscal rules.
- *Capacity building for adequate and efficient E-waste management*: many E-waste businesses have been created as a response to a new market opportunity in the country. However, in many cases, and especially when it comes to waste pickers' cooperatives, it is necessary to develop a basic level of knowledge regarding legislation, E-waste take-back operation, business management, and others. With this, the emerging companies can manage their businesses more effectively and efficiently.
- *Expansion of recycling capacity in the country:* the Brazilian recycling capacity is still pretty much concentrated in the South and Southeast regions, and especially in the Sao Paulo State. This causes a complex logistical challenge for the E-waste take-back from farthest regions, what is increased by the existing transport infrastructure issues. It is also necessary to develop feasible technology for the recycling of a wider range of E-waste components, especially PCBs. Furthermore, the country needs to establish financial and tributary incentives for the expansion of the E-waste recycling businesses countrywide.
- *Inclusion of capacitated cooperatives:* the existence of a large number of waste pickers' cooperatives is a particular scenario in Brazil, which could be explored and is stimulated

by the PNRS, concerning their inclusion in the E-waste take-back systems. Such potential can only be explored once these cooperatives have adequate training, working conditions, licensing, and financial incentives, what is still the reality of very few cases. Working on the aforementioned challenges would also foster the expansion of E-waste management cooperatives countrywide, favoring the wider coverage of implemented take-back systems. This is also true for small E-waste management companies.

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