### Title

E-waste management in Brazil: Challenges and opportunities of a reverse logistics model




### Authors

Santos, Simone Machado
Ogunseitan, Oladele A



### Publication Date

2022-11-01

### DOI

10.1016/j.eti.2022.102671

Peer reviewed

Environmental Technology & Innovation 28 (2022) 102671

Contents lists available at ScienceDirect

Environmental Technology & Innovation

journal homepage: www.elsevier.com/locate/eti

# E-waste management in Brazil: Challenges and opportunities of a reverse logistics model

Simone Machado Santos [a,*], Oladele A. Ogunseitan [b]

[a] Núcleo de Tecnologia, Universidade Federal de Pernambuco, Caruaru, PE 55014-900, Brazil
[b] Department of Population Health & Disease Prevention, University of California, Irvine, CA 92697, USA

ARTICLE INFO

*Article history:*
Received 29 August 2021
Received in revised form 11 May 2022
Accepted 14 May 2022
Available online 25 May 2022

*Keywords:*
E-waste management
Legislation
Reverse logistics
Brazil

ABSTRACT

Brazil, the largest producer of e-waste in Latin America, recently enacted a new law for the reverse logistics of this waste. The implementation of the new regulation will require the integration of different stakeholders to overcome existing barriers including lack of awareness, data and technical expertise in e-waste management, as well as the existence on an illegal e-waste recycling market. A reverse logistics model is described as a potential solution to these barriers if the challenges to the model's implementation are resolved.



## 1. Background

The rapid pace of production and inherent short-term obsolescence of electronic products make the management of hazardous electronic waste (e-waste) a major challenge for regulatory policies designed to protect environmental quality and human health without compromising technological innovation, access to digital infrastructure, or employment opportunities associated with the international solid waste management enterprise (Schoenung et al., 2005; Ogunseitan et al., 2009; Awasthi et al., 2019). The international Global e-waste Monitor shows that 53.6 Mt (7.3 kg per capita) of e-waste was generated in 2019, but only 17.4% was properly recycled, and 82.6% of the generated e-waste has an unknown destination (Forti et al., 2020).

Some countries have developed policies for managing e-waste but encounter obstacles against implementation. Most policies are based on extended producer responsibility (EPR) (Davis, 2021). An EPR-based system involves subsidies, fees, or penalties targeting electronic manufacturers (Pathak et al., 2019). However, difficulties in implementing e-waste management regulations are common in developing countries. For instance, Imran et al. (2017) highlighted the lack of import regulation of e-waste as one of the most important in Pakistan. Wang et al. (2017) concluded that households' habit of selling e-waste to street vendors is an important barrier in Liaoning Province, China. Kumar and Dixit (2018) show that lack of public awareness and incoherent e-waste policies are barriers to e-waste management in India. Chen et al. (2020) noted that economic and financial restrictions are the main obstacles in Ghana.

Brazil is the second largest producer of e-waste in the Americas (2.14 Mt/ year and 10.2 kg/inhabitant), behind only the U.S. (6.9 Mt/ year and 21 kg/inhabitant) (Forti et al., 2020). The Brazilian government instituted the National Policy for Solid Waste (NPSW) (Brasil, 2020), with short, medium and long-term goals to be met by the government, private initiative and civil society. NPSW established as a goal in Article 33 the obligation of manufacturers, importers, distributors and traders of electronic products and their components, to structure and implement a process for managing post-consumer

* Corresponding author.
*E-mail addresses:* simone.machadosantos@ufpe.br (S.M. Santos), Oladele.Ogunseitan@uci.edu (O.A. Ogunseitan).

https://doi.org/10.1016/j.eti.2022.102671

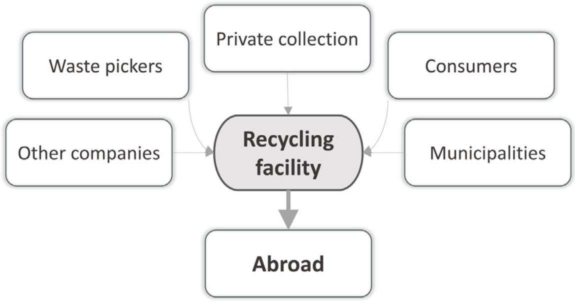


**Fig. 1.** E-waste recycling path in Brazil.

electronics independent of the public management of solid waste (Brasil, 2020). The resulting process is consistent with reverse logistics as defined by Hawks (2006), moving goods from their final destination for the purpose of capturing value, including remanufacturing and refurbishing, or proper disposal.

In 2016, the Brazilian Association of Electric and Electronic Industry (ABINEE), a non-profit civil organization established the Green Eletron management system for logistics of electronic equipment and created the Institute for Research and Technological Development of the Electrical and Electronic Complex (IPD Eletron) (ABINEE, 2020). On October 31, 2019, the implementation of NPSW advanced through signing of a sectoral agreement for reverse logistics of electronics products and their components. The sectoral agreement was signed by the Brazilian government, represented by the Ministry of the Environment, and representatives of entities linked to the sector of electronic equipment such as ABINEE, Green Eletron, the Brazilian Association for Distributing Information Technology (ABRADISTI) and the Federation of Associations of Brazilian Information Technology Companies (ASSESPRO). The sectoral agreement aims at structuring, implementing, and operationalizing the reverse logistics system for household electrical and electronic products, placed on the domestic market (Sectorial Agreement, 2019).

In this article, we assess: (i) the current status of e-waste recycling in Brazil, (ii) modifications that will be necessary after signing the sectoral agreement for reverse logistics, and (iii) some of the challenges that must be expected for the implementation of a reverse logistics system.

## 2. E-waste management practices and policies in Brazil

In Brazil, the disposal of e-waste in the same receptacles as general recyclable waste is a very common practice (Araujo et al., 2017; Moura et al., 2017; Oliveira et al., 2020). However, some e-waste is also discarded with ordinary garbage. Therefore, the largest share of e-waste is ultimately sent to domestic landfills (Souza et al., 2016). According to Dias et al. (2018), there are few e-waste recycling facilities in Brazil, most of them (89%) only undertake the dismantling process and receive the waste in the following ways: (i) through partnerships with other companies; (ii) private collection service performed by the recycler; (iii) voluntarily delivered by the consumer; (iv) sold by waste pickers (often, e-waste pickers use rudimentary and unsafe processes to dismantle products); and (v) partnerships with municipal programs. After dismantling, sorting and grinding, the material is exported to international recycling facilities. Fig. 1 summarizes the current e-waste recycling path. In the current management model, the e-waste recycling flow occurs independently of the action of manufacturers, importers and distributors, and the inspection of the government. Although the NPSW is strongly connected with the EPR principles, it does not detail the structure necessary (stakeholders and their roles, funding sources, system monitoring, etc.) for reverse logistics to work. The existing reverse logistics is due to an informal market in which waste pickers play a fundamental role (Oliveira et al., 2020; Guarnieri et al., 2016; Ghisolfi et al., 2017). As a result, despite the entry of 2792 Mt/yr (13.3 kg/inhabitant) of electronic products in the Brazilian market (Forti et al., 2020), the rates of formal collection and recycling of e-waste are very low, 0% (Forti et al., 2020) and 3% (Green Eletron, 2021), respectively.

The Decree No. 10,240, issued on February 12, 2020, subsidizes compliance with the NPSW establishing rules for the implementation of a mandatory reverse logistics system for household electrical and electronic products and their components (Brasil, 2020). The decree requires manufacturers and importers to recycle or properly dispose all e-waste received through the reverse logistics system. The new model requires collaboration among stakeholders and the development of new regulatory instruments (Fig. 2).

According to Decree 10,240, each stakeholder is responsible for implementing and operating the reverse logistics system. Manufacturers and importers should establish and finance a legal management entity to design, implement and operate the reverse logistics system. The entity should establish a performance monitoring group to monitor and report performance indicators to the Ministry of Environment. Consumers should sort e-waste separately from other types of waste and remove private information and data before disposal at specific locations in the reverse logistics system. The cooperatives and associations of waste pickers should be legally constituted to integrate the reverse logistics system.

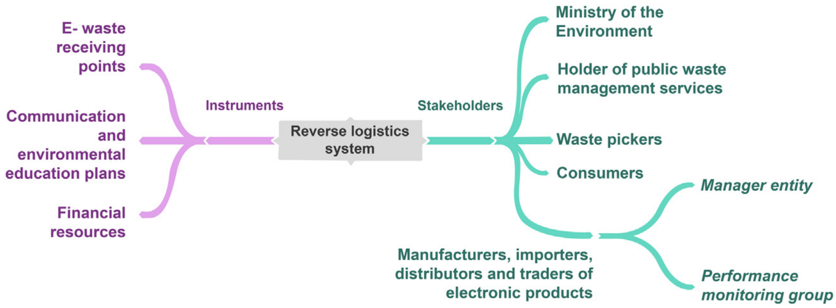


**Fig. 2.** Reverse logistics system: stakeholders and instruments.

**Table 1**
Stakeholders and immediate actions to implement the reverse logistics system.

| Stakeholder | Action |
|---|---|
| Consumers | Availability to pay a higher price for the electronic product to subsidize the reverse logistic system. |
| Waste pickers | Training to segregate and dismantle e-waste to protect health and the environment. |
| Manufacturers, importers, distributors and traders of electronic products | Search for qualified professionals to compose the manager entity and a performance monitoring group. |
| Holder of public waste management services | Evaluation of the possible benefits arising from public awareness of the importance of separating e-waste: (i) cost reduction with collection and final disposal; (ii) reduction of illegal recycling activities and consequent minimization of pollution; others. |
| Ministry of the Environment | Creation of a professional committee to monitor the performance of the reverse logistics system. |

**Table 2**
Barriers to implementation of e-waste reverse logistic system.

| Barrier | Description |
|---|---|
| Lack of awareness | Few consumers are aware of the dangers of e-waste and often dispose of it together with ordinary waste or even as recyclable common waste in selective collection (Oliveira et al., 2020). Another common behavior is the storage of obsolete or damaged electronic equipment in homes, making it difficult to recycle and circularize the materials. Campaigns for proper separation and disposal of e-waste will be necessary for the good functioning of the reverse logistics system. |
| Illegal e-waste recycling market | Due to the high value of electronic components in the recycling market, e-waste is sought by collectors who dismantle it in places inappropriately and without environmental security (Ghisolfi et al., 2017; Oliveira et al., 2020). |
| Lack of data and research | Data on e-waste are scarce. Annually, ABINEE publishes sales, import and export performance indicators for some electronic equipment. Due to the scarcity of data, few studies examine e-waste production estimates as Araújo et al. (2012), Neto et al. (2016) and Araujo et al. (2017). |
| Lack of technical expertise in E-waste recycling | The variability of e-waste requires advanced technologies for the recovery of critical materials and rare earth elements. Due to the lack of technologies and investments, Brazil only undertakes the dismantling process (Oliveira Neto et al., 2017). Recycling processes that recover critical metals and/or rare earth elements, which are in high demand worldwide should be assessed as an economic opportunity. |

Financial incentives may accrue through a point-of-sale invoice. Manufacturers and importers of electronic products must properly recycle or dispose e-waste collected through the system. Public waste management services may voluntarily perform parallel campaigns or programs for the environmentally appropriate management of electronic products.

## 3. Challenges and prospective

The e-waste reverse logistics system can only work with the integration and engagement of stakeholders who should immediately recognize their roles to achieve the policy objectives. In Table 1, we describe some immediate actions necessary for the implementation of the reverse logistics system. The implementation will be a challenge for Brazil's relatively weak solid waste management, as described in Table 2.

A major challenge will be to integrate each stakeholder into a single process, considering that the current system is very decentralized. Considering that the waste picker is an important player in Brazilian waste management, the country can start by taking the experiences of e-waste management in China and India as an example. According to Awasthi and Li (2017), in these countries, policies in addition to focusing on EPR, also focused on formalizing informal recycling to achieve their goals. Awasthi and Li (2017) also conclude by proposing measures to increase recycling capacity and reduce e-waste production in these two countries. More research on e-waste management in China and in India can be found at: Chen et al. (2018), Zeng et al. (2017), Cao et al. (2016) and Garlapati (2016).

The experiences of countries with more advanced e-waste management consider that the implementation of the reverse logistics system will depend on the construction of a complex cooperation network that integrates all those who participate in the entire life cycle of electronic products.

## CRediT authorship contribution statement

**Simone Machado Santos:** Conceptualization, Writing – original draft, Writing – review & editing. **Oladele A. Ogunseitan:** Supervision, Writing – review & editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgments

The authors would like to thank the Universidade Federal de Pernambuco and the World Institute for Sustainable Development of Materials (WISDOM), University of California, Irvine.

## References

ABINEE, 2020. Panorama Econômico e Desempenho Setorial 2020. http://www.abinee.org.br/abinee/decon/decon40.htm (in Portuguese).
Araújo, M.G., Magrini, A., Mahler, C., Bilitewski, B., 2012. A model for estimation of potential generation of waste electrical and electronic equipment in Brazil. Waste Manag. http://dx.doi.org/10.1016/j.wasman.2011.09.020.
Araujo, D.R., Oliveira, J.D., Selva, V.F., Silva, M.M., Santos, S.M., 2017. Generation of domestic waste electrical and electronic equipment on Fernando de Noronha Island: qualitative and quantitative aspects. Environ. Sci. Pollut. Res. http://dx.doi.org/10.1007/s11356-017-9648-3.
Awasthi, A.K., Li, J., 2017. Management of electrical and electronic waste: A comparative evaluation of China and India. Renew. Sustain. Energy Rev. http://dx.doi.org/10.1016/j.rser.2017.02.067.
Awasthi, A.K., Li, J., Koh, L., Ogunseitan, O.A., 2019. Circular economy and electronic waste. Natu. - Electron. http://dx.doi.org/10.1038/s41928-019-0225-2.
Brasil, 2020. Decree no 10.240, February 12, 2020. Regulates the implementation of a reverse logistics system for electrical and electronic products and their components for domestic use. http://www.planalto.gov.br/ccivil_03/_Ato2019-2022/2020/Decreto/D10240.htm. (Accessed March 2020) (in Portuguese).
Cao, J., Lu, B., Chen, Y., Zhang, X., Zhai, G., Zhou, G., Schnoor, J.L., 2016. Extended producer responsibility system in China improves e-waste recycling: Government policies, enterprise, and public awareness. Renew. Sustain. Energy Rev. http://dx.doi.org/10.1016/j.rser.2016.04.078.
Chen, D., Faibil, D., Agyemang, M., 2020. Evaluating critical barriers and pathways to implementation of e-waste formalization management systems in ghana: a hybrid BWM and fuzzy TOPSIS approach. Environ. Sci. Pollut. Res. http://dx.doi.org/10.1007/s11356-020-10360-8.
Chen, M., Ogunseitan, O.A., Duan, H., Zeng, X., Li, J., 2018. China E-waste management: Struggling for future success. Resour. Conserv. Recy. http://dx.doi.org/10.1016/j.resconrec.2018.08.006.
Davis, J.M., 2021. A model to rapidly assess informal electronic waste systems. Waste Manag. Res. http://dx.doi.org/10.1177/0734242X20932225.
Dias, P., Machado, A., Huda, N., Bernardes, A., 2018. Waste electric and electronic equipment (WEEE) management: A study on the Brazilian recycling routes. J. Cleaner Prod. http://dx.doi.org/10.1016/j.jclepro.2017.10.219.
Forti, V., Baldé, C.P., Kuehr, R., Bel, G., 2020. The global E-waste monitor 2020. Available at: http://ewastemonitor.info/. (Accessed May 2021).
Garlapati, V.K., 2016. E-waste in India and developed countries: Management, recycling, business and biotechnological initiatives. Renew. Sustain. Energy Rev. http://dx.doi.org/10.1016/j.rser.2015.10.106.
Ghisolfi, V., Chave, G., Siman, R., Xavier, L.H., 2017. System dynamics applied to closed loop supply chains of desktops and laptops in Brazil: A perspective for social inclusion of waste pickers. Waste Manag. http://dx.doi.org/10.1016/j.wasman.2016.12.018.
Green Eletron, 2021. Tudo o que você precisa saber sobre o lixo eletrônico. Green eletron, 28 de Julho de 2020. Available at: https://greeneletron.org.br/blog/tudo-o-que-voce-precisa-saber-sobre-o-lixo-eletronico/. (Accessed July 2021).
Guarnieri, P., Silva, L.C., Levino, N.A., 2016. Analysis of electronic waste reverse logistics decisions using strategic options development analysis methodology: A Brazilian case. J. Cleaner Prod. http://dx.doi.org/10.1016/j.jclepro.2016.06.025.
Hawks, K., 2006. What is reverse logistics? Reverse Logist. Mag. 1 (1), 12–15.
Imran, M., Haydar, S., Kim, J., Awan, M., Bhatti, A., 2017. E-waste flows, resource recovery and improvement of legal framework in Pakistan, resources, conservation and recycling. http://dx.doi.org/10.1016/j.resconrec.2017.06.015.
Kumar, A., Dixit, G., 2018. An analysis of barriers affecting the implementation of e-waste management practices in India: A novel ISM-DEMATEL approach. Sustain. Prod. Consump. http://dx.doi.org/10.1016/j.spc.2018.01.002.
Moura, J.M., Pinheiro, I.G., Licheski, D., Valle, J.A.B., 2017. Relation of Brazilian institutional users and technical assistances with electronics and their waste: What has changed? Resources. Conserv. Recy. http://dx.doi.org/10.1016/j.resconrec.2017.08.022.
Neto, J.Cabral., Silva, M.M., Santos, S.M., 2016. A time series model for estimating the generation of lead acid battery scrap. Clean Technol. Environ. Policy http://dx.doi.org/10.1007/s10098-016-1121-3.
Ogunseitan, O.A., Schoenung, J.M., Saphores, J., Shapiro, A.A., 2009. The electronics revolution: From E-Wonderland to E-wasteland. Science http://dx.doi.org/10.1126/science.1176929.

Oliveira, J.D., Oliveira Neto, J.F., Silva, M.M., Santos, S.M., 2020. E-waste mistakenly disposed of as recyclable waste: A case study from Brazil. Clean - Soil Air Water http://dx.doi.org/10.1002/clen.202000115.

Oliveira Neto, G.C., Correia, A., Schroeder, A.M., 2017. Economic and environmental assessment of recycling and reuse of electronic waste: Multiple case studies in Brazil and Switzerland. Resour. Conserv. Recy. http://dx.doi.org/10.1016/j.resconrec.2017.08.011.

Pathak, P., Srivastava, R.R., Ojasvi, 2019. Environmental Management of E-Waste, Electronic Waste Management and Treatment Technology. Elsevier Inc., http://dx.doi.org/10.1016/B978-0-12-816190-6.00005-4.

Schoenung, J.M., Ogunseitan, O.A., Shapiro, A.A., 2005. Adopting lead-free electronics: Knowledge gaps and policy differences. J. Ind. Ecol. http://dx.doi.org/10.1162/1088198043630496.

Sectoral agreement for reverse logistics of electronics products, 2019. agreement http://consultaspublicas.mma.gov.br/eletroeletronicos/wp-content/uploads/2019/08/NewAS_LR_EEE_Completo_30_07_2019-compactado.pdf (in Portuguese).

Souza, R.G., Clímaco, J., Sant'Anna, A., Rocha, T., Valle, R., Quellas, O., 2016. Sustainability assessment and prioritisation of e-waste management options in Brazil. Waste Manag. http://dx.doi.org/10.1016/j.wasman.2016.01.034.

Wang, W., Tian, Y., Zhu, Q., Zhong, Y., 2017. Barriers for household e-waste collection in China: Perspectives from formal collecting enterprises in liaoning province. J. Cleaner Prod. http://dx.doi.org/10.1016/j.jclepro.2017.03.202.

Zeng, X., Duan, H., Wang, F., Li, J., 2017. Examining environmental management of e-waste: China's experience and lessons. Renew. Sustain. Energy Rev. http://dx.doi.org/10.1016/j.rser.2016.10.015.