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Improvements in the regulation and implementation of extended producer responsibility systems: analysis from the e-waste case study in the State of São Paulo from 2012 to 2021

Avanços na regulação e implementação dos sistemas de logística reversa: análise baseada no estudo de caso dos resíduos eletroeletrônicos no estado de São Paulo de 2012 a 2021

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ABSTRACT

The strategy adopted for the implementation of the extended producer responsibility (EPR) in the State of São Paulo was conceived in three phases, the first and second of which have already been completed, while the third is in progress. The aim of this paper is to evaluate the response of EPR systems to the advancement of regulation, based on the case study of waste electrical and electronic equipment in the State of São Paulo. An evaluation of the behavior of these systems was carried out from 2012 to 2021, between the first and second phase of EPR implementation, considering the following variables: established goals, participating companies and results achieved, with two approaches: a) comparative analysis between the two engagement agreements established with entities in the electronics sector, signed, respectively, in the first and second phase; b) analysis of the aggregate results of the systems whose reverse logistics plans were presented to the state environmental agency in compliance with the regulation, between 2018 and 2021. Advances were noted from the first to the second phase, regarding the variety of waste covered, quantity and diversity of actors in the production cycle involved, significance of goals, geographic scope of waste collection points and quantities collected. From 2018 to 2021, the total number of collection points increased 37.4 times, and the amount collected almost quadrupled. The decisive factor for this advance was the publication of an innovative regulation between the two phases, binding the compliance with the EPR to environmental licensing at the state level.

Keywords: extended producer responsibility; waste electrical and electronic equipment management; environmental licensing.

RESUMO

A estratégia de implementação da logística reversa no estado de São Paulo foi concebida em três fases de 2011 a 2025, das quais a primeira e a segunda já foram concluídas e a terceira está em andamento. O objetivo do artigo é avaliar a resposta dos sistemas de logística reversa ao avanço da regulação, com base em um estudo de caso dos resíduos de equipamentos eletroeletrônicos no estado de São Paulo. Foi realizada a avaliação do comportamento desses sistemas no período de 2012 a 2021, entre a primeira e a segunda fase de implementação, adotando como variáveis as metas estabelecidas, empresas participantes e resultados alcançados, com dois enfoques: a) análise comparativa entre os dois termos de compromisso estabelecidos com entidades do setor de eletroeletrônicos e firmados, respectivamente, na primeira e na segunda fase; b) análise dos resultados agregados dos sistemas de logística reversa cujos planos de logística reversa foram apresentados ao órgão ambiental estadual em atendimento à regulação, entre 2018 e 2021. Foram constatados avanços da primeira para a segunda fase quanto à variedade de resíduos abrangidos, quantidade e diversidade de atores do ciclo produtivo envolvidos, alcance das metas, abrangência geográfica dos pontos de entrega e resíduos coletados. De 2018 a 2021, o total de pontos de entrega aumentou 37,4 vezes e a quantidade coletada quase quadruplicou. O fator decisivo para esse avanço foi a publicação de regulação inovadora entre as duas fases, vinculando o cumprimento da logística reversa ao licenciamento ambiental em âmbito estadual.

Palavras-chave: responsabilidade estendida do produtor; gestão de resíduos de equipamentos elétricos e eletrônicos; licenciamento ambiental.

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Introduction

Waste electrical and electronic equipment (WEEE) originates from a wide range of products, differing by characteristics such as volume, composition, lifespan, economic value and potential impact on the environment and health. These differences are reflected in the particularities of post-consumption management for each group, which involves steps such as collection, segregation, logistics, disassembly and recycling, as well as in consumers' attitudes at the time of disposal (Forti et al., 2020; Rodrigues et al., 2020; Xavier et al., 2023).

The generation of WEEE has a diffuse character, with two main sources — non-domestic and household — whose flows are distinct. The first comprises WEEE from legal entities, including companies from all economic sectors and public institutions, while the second is generated in residences (Moura et al., 2017; Rodrigues et al., 2020).

The increase in the generation of WEEE is a global phenomenon, with a raising trend due to factors such as rapid technological development and planned obsolescence (Dias et al., 2022). Worldwide, generation grows at rates of around 3 to 5% per year, which is equivalent to almost three times the growth rates of municipal solid waste generation (Ilankoon et al., 2018).

Because they are composed of a complex mixture of hazardous, non-hazardous and high-value-added materials, WEEE finds, in recycling, environmental relevance and economic motivation for its valorization (Bizerra et al., 2023). However, due to the geographical dispersion of generation and the varied composition of WEEE, its management becomes costly from both an occupational and technical-economic point of view (Ongondo et al., 2011).

On a global scale, WEEE management presents deficiencies and major challenges, especially in developing countries, where take-back systems are under discussion or in the initial phase of implementation (Forti et al., 2020; Santos and Ogunseitan, 2022).

A management alternative that has strengthened in several countries focuses on making the productive sector responsible for the collection and recovery of WEEE discarded by consumers, using the accountability model known as Extended Producer Responsibility (EPR) (Forti et al., 2020). In operationalizing this accountability model, there are four main groups of actors involved (Lifset and Lindhqvist, 2008): i. producers: actors in the product's life cycle from the extraction of raw materials to the assembly and distribution or sale of the product, including distributors, importers and traders; ii. consumers: companies or citizens; iii. solid waste managers: those responsible for the collection, segregation, treatment, recycling/recovery and reuse of WEEE, and iv. authorities: the various government levels involved in the regulation, supervision and/or management of take-back systems, that is, systems that operationalize the EPR.

In Brazil, this model was adopted by the National Solid Waste Policy (*Política Nacional de Resíduos Sólidos* — PNRS), instituted by Federal Law No. 12,305/2010, a regulatory framework for solid waste management. The PNRS establishes that manufacturers, importers, distributors and traders of electrical and electronic equipment (EEE) are responsible for implementing take-back systems, upon return of these products after their use by consumers (Brasil, 2010).

To implement and operationalize the take-back systems, the PNRS defines three possible instruments: regulations, sectoral agreements (*acordos setoriais* — AS) and engagement agreements (*termos de compromisso* — TC), the last two being contractual instruments, executed by and between the public authorities and the business sector (Brasil, 2010). For WEEE, the instrument adopted at the federal level was the AS, with a call for AS proposals being opened in 2013 (Moura et al., 2017). During the process that began with the publication of the PNRS and included negotiations aimed at the execution of the agreement, two national producer responsibility organizations (PRO) were founded in 2011 and 2016 to manage the WEEE take-back systems (ABREE, 2023; Green Eletron, 2023; SINIR, 2023).

In October 2019, the "Sectoral Agreement for the Implementation of a Reverse Logistics System for Household Electrical and Electronic Products and their Components" was signed, the content of which was later replicated by Federal Decree No. 10,240, of February 12, 2020 (MMA et al., 2019; Brasil, 2020). It should be noted, however, that this regulation only covers household WEEE.

The Decree provides for the possibility of companies complying with the EPR individually or collectively, organizing the implementation of take-back systems in two phases. The first phase lasted until the end of 2020, being dedicated to structuring the systems. The second, from 2021 to 2025, consists of the implementation of WEEE collection points and operationalization of reverse logistics, with increasing annual targets that cover municipalities where the population was greater than 80,000 inhabitants in 2018, the reference year. In 2021, the collection target started with 1% (in relation to the weight of the household EEE placed on the Brazilian market in 2018), and the geographical target began with 24 Brazilian municipalities. In 2025, the targets should reach 17% (collection) and 400 municipalities, with the installation of one collection point for every 25,000 inhabitants, totaling more than 5,000 points (MMA et al., 2019; Brasil, 2020). According to Xavier et al. (2021), such goals are still mild, compared to those of other countries and considering the potential for expansion of WEEE take-back systems in Brazil.

Within the national context, the case of the State of São Paulo stands out. In parallel with actions at the federal level, the State has implemented its own strategy based on the publication of regulations and the establishment of a TC with the private sector, which has contributed to the creation and expansion of take-back systems for different types of waste, including WEEE (Ribeiro and Kruglianskas, 2020). This strategy for gradually implementing the EPR in São Paulo can be divided into three phases, covering the period from 2011 to 2025 (SIMA, 2020). The first phase, from 2011 to 2014, had the main objective of

demonstrating the feasibility of implementing take-back systems, by means of the establishment of TCs to recognize existing reverse logistics initiatives and put pilot projects into practice. In total, 14 TC were signed by the environmental protection agency of the State of São Paulo (CETESB), the former State Secretariat for the Environment and the production sector, for various post-consumer products and packaging. In relation to WEEE, a TC was signed with mobile phone operators in 2012, covering only cell phones and their accessories, which was in force until 2016 (SMA et al., 2012). This first phase was marked by the participation of entities representing the productive sector in discussions and formulation of regulations, with the purpose of bringing these actors together in a single TC, and intense negotiations to reach consensus goals and commitments (Ribeiro and Kruglianskas, 2020).

Throughout the second phase, which extended from 2015 to 2021, the TCs were renewed to standardize the format of targets, terminologies and other aspects. By December 2021, six TCs had been renewed and another nine signed. Among these TCs, one was executed in 2017 for household WEEE, which resulted in the implementation of a take-back system involving manufacturers, importers and commerce. The TC relating to cell phones was not renewed and is no longer in force (CETESB, 2023; SMA et al., 2017). The main advance achieved at this phase was the establishment of a framework binding environmental licensing aiming at compliance with the EPR. With this change, it became a requirement to obtain operating licenses for manufacturers to present reverse logistics plans to the state environmental protection agency, containing a description of the take-back system and the goals to be achieved, as well as annual reports with the respective results (Ribeiro and Kruglianskas, 2020). In the third phase, scheduled to last from 2022 to 2025, the aim is to consolidate, in legislation, the advances in the implementation of the EPR in the State (SIMA, 2020).

In this context, the aim of this article is to evaluate how WEEE take-back systems responded to the evolution of regulation regarding EPR in the State of São Paulo, in order to discuss its potential to induce effective improvements in the systems.

Methodology

The methodology adopted consisted of a case study of WEEE EPR in the State of São Paulo, seeking correlations between the advancement of regulation and the behavior of take-back systems. The methodological steps included: i. bibliographic review; ii. documentary research, and iii. evaluation of the behavior of WEEE take-back systems in the State of São Paulo, from 2012 to 2021, between the first and second phases of the strategy adopted to implement the EPR in the State.

The documentary research involved consulting the following official documents relating to the establishment of the WEEE take-back systems in the State of São Paulo: i. the engagement agreements relating to WEEE signed in phase 1 and phase 2 of the EPR implementation in the State; ii. the reverse logistics plans received by the state environmental protection agency, including the reverse logistics plan that defines the TC goals for phase 2; iii. the relevant annual results reports, and iv. the websites of the National Information System on Solid Waste Management (*Sistema Nacional de Informações sobre a Gestão dos Resíduos Sólidos* — SINIR), CETESB and WEEE PROs.

The evaluation of the take-back systems was executed with two approaches: i. comparative analysis between the characteristics and results of the systems that were the subject of the two WEEE TCs signed in the State, and ii. analysis of the aggregate results of the WEEE take-back systems whose reverse logistics plans were presented to the state environmental protection agency in the first stage of EPR enforcement via environmental licensing, which lasted from 2018 to 2021.

The parameters considered in the comparative analysis were: i. number of companies participating in the take-back systems (manufacturers, importers, distributors and traders of electronics); ii. goals set out in the TC; iii. quantity, by weight, of WEEE collected by the systems; iv. number of collection points; and v. number of municipalities covered by the systems. In addition to these parameters, two qualitative aspects were chosen to characterize the progress between the two systems evaluated: i. variety of WEEE covered; and ii. management method.

The variables selected to evaluate the evolution of the WEEE take-back systems with reverse logistics plans in force between 2018 and 2021 were: i. number of participating companies (manufacturers and importers of EEE that are part of the system); ii. number of collection points that compose the system; iii. number of municipalities covered by the system; and iv. weight of WEEE collected by the system.

Evolution of regulation in the state of são paulo: the link to environmental licensing

Regarding the advancement of the EPR regulation in the State of São Paulo, an important innovation was regulated by CETESB Board Decision nº 076/2018/C. This rule linked, at the state level, the compliance with the EPR as a condition for the issuance or renewal of operating licenses, for enterprises that manufacture or are responsible for the import, distribution or commercialization of a series of products and packaging subject to EPR, including EEE. The new rule also determined that the demonstration of structuring, implementation and operation, as well as the presentation of the results of the take-back systems, would be required in successive stages, each with specific targets, with the first stage up to 31 December 2021 (CETESB, 2018).

According to this regulation, individual systems (for each company) or collective systems can be implemented, although the preference is for systems that involve a group of companies represented by a PRO. Companies participating in the TC are considered compliant with the procedure, as long as they meet the provisions and goals. Companies subject to EPR and not participating in the TC must com-

ply with the same requirements, which must be enforced by the state environmental protection agency (CETESB, 2018).

According to the published standard, information about the take-back systems is provided to the environmental protection agency by presenting: i. reverse logistics plans, in which companies committed to meet annual targets for the period from 2018 to 2021; and ii. annual reports, containing data on the results of the system in the previous year, such as quantities of waste collected and recovered, geographic coverage, list of collection points, communication actions and achievement of goals (CETESB, 2023).

In October 2019, CETESB Board Decision nº 114/2019/P/C was published, replacing Decision nº 076/2018/C, which revised the targets and deadlines for EPR enforcement according to the size (built area) of each industrial facility. Similarly to the Decree at the national level, this regulation only covers EEE for domestic use, with voltage up to 240 Volts. It establishes, for WEEE, collection and geographic targets that are different from those set out in the previous Decision (Table 1), with two options: i. the same goals defined in the call notice of the sectoral agreement, analogous to those of the previous rule; or ii. the targets proposed by the productive sector in the reverse logistics plans, as long as they are of greater geographic scope. Furthermore, this regulation sets specific targets for large WEEE, differentiating them from small and medium-sized WEEE, as they require more complex collection methods, not necessarily via collection points (CETESB, 2019).

In October 2021, CETESB Board Decision nº 127/2021/P succeeded Decision nº 114/2019/P/C, maintaining the same logic as the previous ones and establishing targets (Table 2) for the period from 2022 to 2025, which included the presentation of new reverse logistics plans and annual reports through the online system SIGOR Reverse Logistics (CETESB, 2021).

Results of Weee Take-Back Systems in the State of São Paulo

The results of the WEEE take-back systems in São Paulo are presented for each of the approaches adopted.

Results of waste electrical and electronic equipment take-back systems subject to Engagement Agreements (TCs)

Two WEEE take-back systems were subject to TCs signed with the state environmental protection agency. The first TC was signed in 2012, during the first phase of EPR implementation in São Paulo, by a union representing mobile phone operators.

Table 1 – Targets defined in CETESB Board Decision nº 114/2019/P/C for waste electrical and electronic equipment.

Category	Collection Target	Geographic Target
Large WEEE	I) 2021: 6.8% in relation to the weight of EEE placed on the market in the same year; or II) 2019-2021: Collection growth rate at least equal to 100% in relation to the weight collected in the previous year, as long as this quantity is different from zero.	I) 2021: 40% of the municipalities of the State of São Paulo with more than 80,000 inhabitants; or II) 2019-2021: a) Rate of increase in the number of collection points at least equal to 100% in relation to the previous year, as long as this quantity is different from zero; b) 2021: 40% of the municipalities of the State of São Paulo with more than 80,000 inhabitants.
Small and Medium-Sized WEEE	I) 2021: 6.8% in relation to the weight of EEE placed on the market in the same year; or II) 2019-2021: Collection growth rate at least equal to 100% in relation to the weight collected in the previous year by the take-back system that is subject to TC.	I) 2021: 40% of the municipalities of the State of São Paulo with more than 80,000 inhabitants, with at least one collection point for every 25,000 inhabitants; or II) 2019-2021: a) Rate of increase in the quantity of collection points at least equal to 100% in relation to the previous year, taking as a reference the quantity of collection points operated by the take-back system that is subject to TC; b) Carrying out annual collection campaigns, which must cover an additional administrative region of the State of São Paulo per year; c) 2021: 80% of municipalities with more than 80,000 inhabitants.

Source: adapted from CETESB (2019).

Table 2 – Targets defined in CETESB Board Decision nº 127/2021/P for waste electrical and electronic equipment.

Year	Collection Target [1]	Geographic Target
2022	3%	80% of the municipalities of the State of São Paulo with more than 80,000 inhabitants, with at least one collection point for every 25,000 inhabitants
2023	6%	ND
2024	12%	85% of the municipalities of the State of São Paulo with more than 80,000 inhabitants, with at least one collection point for every 25,000 inhabitants
2025	17%	100% of the municipalities of the State of São Paulo with more than 80,000 inhabitants, with at least one collection point for every 25,000 inhabitants

Source: adapted from CETESB (2021).
Notes: [1]Quantity of WEEE collected in the year in relation to the quantity of EEE placed on the market in 2018; ND: not determined.

The agreement covered cell phones and established structuring goals, referring to the implementation of collection points to receive devices discarded by the consumers in the operators' own stores and authorized resales (SMA et al., 2012). It should be noted that producers and importers of cell phones were not signatories to the TC. This system was in operation until 2016, when negotiations began to sign a new TC.

In the second phase of EPR implementation in the State, the "Engagement Agreement for the Reverse Logistics of Household Electrical and Electronic Products" was signed in October 2017 by three highly representative entities: i. a national association representing manufacturers and importers of EEE, especially small and medium-sized ones; ii. a federation representing trade; and iii. a producer responsibility organization, which represented 15 participating companies at the time of execution of the Agreement (SMA et al., 2017). In this TC, two stages were defined: i. the pilot project, which consisted of the implementation of 16 collection points in three municipalities in the State of São Paulo in the first six months of the document's validity; and ii. evaluation of the results of the pilot project and preparation of a report specifying obstacles, opportunities for improvement and proposal for gradual expansion of the take-back system, in order to establish a permanent system in the State, based on a network of collection points for small and medium-sized WEEE (SMA et al., 2017). After signing the sectoral agreement, this system began a process of expansion to other Brazilian States, as it covers a large part of EEE manufacturers and importers and is managed by one of the two national PROs.

The comparative analysis, focusing on the characteristics and results of these two WEEE take-back systems subject to TCs in the State of São Paulo, is presented in Table 3.

Results of waste electrical and electronic equipment take-back systems with reverse logistics plans until 2021

From 2018 to 2021, period when the first regulation that enforced EPR compliance via the state environmental licensing was valid, two collective reverse logistics plans were presented to the state environmental protection agency by the two WEEE PROs, one of which comprised an Engagement Agreement. Four individual plans were also presented, one of which was canceled due to the company's transference to a collective plan.

The evolution of the aggregate results of these take-back systems per year in the period is shown in Figures 1, 2 and 3, based on the following parameters: i. number of participating companies; ii. quantity of WEEE collected; iii. number of collection points, and iv. number of municipalities covered by collection points or collection campaigns.

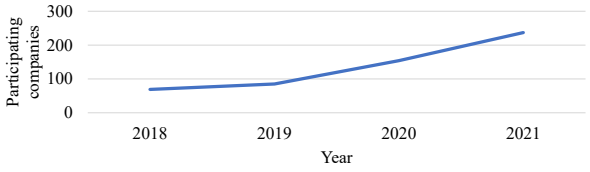

Figure 1 – Evolution of participating companies per year, from 2018 to 2021.
Source: prepared by the authors based on CETESB (2022).

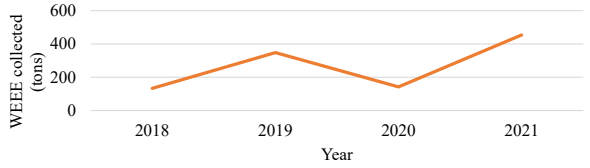

Figure 2 – Evolution of the amount of waste electrical and electronic equipment collected per year, from 2018 to 2021.
Source: prepared by the authors based on CETESB (2022).

Table 3 – Targets and results of the two waste electrical and electronic equipment Engagement Agreements signed in the State of São Paulo, per year, from 2012 to 2021.

Year	Participating Companies	Targets	Collected WEEE[1] (tons)	Collection Points	Cities Covered
2012	5	Make collection points available in all company stores and authorized resellers by the end of the first year of the TC	51.7	1,487	NDA
2013	5		44.7	1,344	NDA
2014	5		23.5	NDA	NDA
2015	5		7.25	NDA	NDA
2016	**End of validity of the Cell Phone TC**				
2017	15	At least 16 collection points in 3 cities	2.5	16	3
2018	25	Collection of 90 tons of WEEE, in 7 cities, with 35 collection points	102.4	36	8
2019	33	Collection of 180 tons of WEEE, in 19 cities, with 70 collection points	331.8	169	69
2020	107	Collection of 450 tons of WEEE, in 39 cities, with 175 collection points	88.8	378	95
2021	188	Collection of 1% of the amount of EEE placed on the market, in 76 cities, with 235 collection points	275.1	527	111

Source: prepared by the authors based on SMA et al. (2012, 2017) and CETESB (2023).
Notes: [1]Quantities from 2012 to 2015 refer to cell phones and their accessories; NDA: no data available.

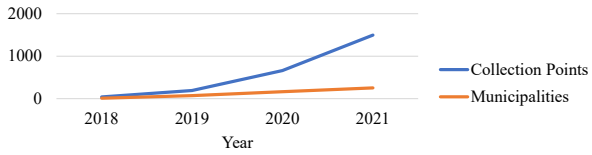

Figure 3 – Evolution of the number of waste electrical and electronic equipment collection points and respective municipalities per year, from 2018 to 2021.
Source: prepared by the authors based on CETESB (2022).

Analysis and Discussion of Waste Electrical and Electronic Equipment Take-Back Systems Results in the State of São Paulo

The results of the comparative study between the take-back systems subject to engagement agreements (TCs) are discussed per variable, as follows.

Targets

It is observed that, in the TC for cell phones (2012 to 2016), there was only one qualitative goal: the installation of collection points in all company-owned stores and authorized resellers of the five participating companies (mobile phone operators); while, in the TC for household electronics (2017 to 2021), there are increasing quantitative targets, referring to the amount of WEEE collected (weight), the number of collection points and the quantity of municipalities covered by the take-back system. It is worth noting that the 2018 and 2019 targets are not included in the TC itself, but in the reverse logistics plan that was presented by the system subject to this TC in compliance with CETESB Board Decision nº 076/2018/C, which highlights the importance of this regulation for advancing the goals. Furthermore, it is observed that the targets for 2021 met the provisions of the Federal Decree nº 10,240/2020, which regulates WEEE EPR.

Participating companies

During the validity of the TC for cell phones, the number of participating companies remained constant (5), and represented all mobile phone operators with activity in the country; however, it has grown (188) since the execution of the TC for household electronics, doubling from 2017 to 2019 and multiplying 12.5 times in the period. Therefore, the publication of the aforementioned regulation represented a significant factor in this increase.

It is worth noting that the number of companies participating in 2021 refers only to manufacturers and importers. If merchants participating in the system are also considered, who provide space in their stores or shopping centers for the implementation of WEEE collection points, this number increases considerably.

Qualitative changes were also noted in the period, with an increase in the variety of participating actors. From 2017, the new system began to be integrated by EEE manufacturers, importers and traders, in a model closer to the shared responsibility for the product life cycle recommended by the PNRS, as opposed to the small portion of participating traders previously (five mobile phone operators).

Quantity of waste electrical and electronic equipment collected

Without quantitative targets to boost the progress of collection, it is observed that the amount of cell phones and their accessories collected decreased between 2012 and 2015. It is inferred that the higher collection in the first year of the TC's validity was due to its wide dissemination at the time of its signature and large amounts of WEEE stored, which induced consumers to dispose of their devices through the system.

On the other hand, the opposite phenomenon occurred throughout the validity of the TC for household WEEE. The first six months of implementation dedicated to the pilot project, the absence of a quantitative collection target and limited advertising were determining factors for the low collection in the first year (2017). However, with increased dissemination and greater capillarity of the system, the impact in terms of WEEE collected was significant: it increased to almost 332 tons (132 times) in 2019, the year that recorded the highest amount collected. In 2018 and 2019, results exceeded targets by a wide margin; however, in 2020, the target was not achieved, due to restrictions on the movement of people and the operation of establishments where collection points are located caused by the COVID-19 pandemic.

Collection points and cities covered

During the term of the first TC (2012 to 2015), there was no increase in the number of collection points, probably equivalent to the number of company-owned stores and authorized resellers of mobile phone operators located in the State of São Paulo. Unlike this scenario, in the second TC, there was a significant increase, since the receiving network reached in 2021 more than 32 times the initial one, far exceeding the annual target. Furthermore, even with less collection points, the annual average of WEEE collected by the take-back system of the second TC was 5 times greater than that of the first TC.

The number of municipalities covered by the collection points was not recorded in the first TC, nor was it part of its targets, while in the second it grew 37 times from 2017 to 2021, exceeding the annual targets for 2020 and 2021. There was also an expansion in relation to the regions of the State covered by the take-back system: in 2017, the collection points were concentrated in some municipalities in the metropolitan region of São Paulo, while, in 2021, they were spread across municipalities belonging to 15 of the State's 16 administrative regions. Only the region of Registro, located in the south of the State, did not have collection points in 2021, despite a municipality in that region being covered by itinerant collection campaigns.

Complementary aspects

The variety of WEEE was expanded, as the first take-back system only covered mobile phones and their accessories, while the second included household EEE, except large ones.

Regarding the management method, each mobile phone operator participating in the first TC implemented and maintained its collection points and was responsible for managing the waste collected and reporting, separately, the data to the state environmental agency. Although the entity representing the operators acted as a coordinator for these companies and liaised with environmental agencies, it did not effectively manage the system. On the other hand, the system covered by the second TC is managed by a non-profit entity, founded by manufacturers and importers especially for this purpose, which is also part of the AS. Furthermore, the second TC included the participation of an entity representing commerce, strengthening shared responsibility and, possibly, contributing to the expansion of the network of collection points.

Take-back systems with reverse logistics plans in force between 2018 and 2021

The analyzed parameters (participating companies, mass of WEEE collected, number of collection points and number of municipalities covered) showed increasing values in the period, except for the mass of waste collected, which fell in 2020 due to restrictions arising from the new coronavirus pandemic. However, it is observed that not all take-back systems met the annual targets set out in their reverse logistics plans, especially in the years 2020 and 2021, which may also have been influenced by the effects of the pandemic.

These results confirm what was expected. On the one hand, the requirement to present reverse logistics plans by companies that are in the process of obtaining or renewing environmental licenses, at the state level, tends to drive an increase in the number of companies adhering to the take-back systems, with a large concentration in the two collective systems managed by PROs. On the other hand, the plans establish, over time, gradual expansion of the systems in terms of geographic coverage and waste collection. Therefore, a positive effect of the regulation is observed on WEEE take-back systems, especially after 2018, with the publication of the first regulation that links compliance with the EPR to state environmental licensing.

Conclusions

From the parameters analyzed, it can be seen that the implementation of EPR in the State of São Paulo has advanced progressively, based on the publication of regulations and the execution and renewal of engagement agreements, in a synergistic way. As for regulation, it is observed that, between the first and second phases of the EPR implementation in the State, there was a continuous process of improvement. The most recent advance consisted of the publication of rules that use environmental licensing as an instrument for requiring compliance with the EPR, a pioneering strategy whose main promoter is the environmental agency. The increasing aggregate results of the WEEE take-back systems that presented reverse logistics plans to the state environmental agency demonstrate the positive effects of this regulatory advance.

Regarding the engagement agreements for WEEE that were executed in the two phases of the state strategy, all adopted criteria presented progress: more categories of WEEE covered, improvement in the management method, greater participation of stakeholders, change from qualitative to quantitative targets, increased geographic coverage and higher amounts of WEEE collected.

Additionally, there was a more pronounced growth in the goals and quantity of companies participating in the TC after the publication of CETESB Board Decision nº 076/2018/C, which indicates the importance of adopting not only agreements with the regulated sector, but also command and control instruments to increase compliance with the EPR, such as requiring it through environmental licensing. This evidence corroborates the results of previous research (Pereira et al., 2022), highlighting the importance of enforcement mechanisms for the evolution of environmental regulation and its practical effects.

However, given that not all take-back systems were able to meet the targets and considering the increasing annual targets set out in the regulations until 2025, it can be inferred that fully meeting the targets will require continuous improvement in the management and governance of the systems, as well as investments in consumer awareness strategies about returning WEEE to the systems.

Other challenges to be overcome to achieve the ideal WEEE management scenario in the State of São Paulo, with a focus on the circular economy and within the principles of sustainability, include: i. implementation of take-back systems for large WEEE, capable of meeting the goals defined in the new state regulation; ii. requirement for compliance with EPR on entities in the electronics chain not subject to licensing by the state environmental agency, such as importers, manufacturers located in other states, distributors and retailers; iii. participation of municipalities in controlling and monitoring compliance with the EPR, and even in the collection of WEEE in synergy with take-back systems, acting mainly with retail; iv. formalization of the WEEE recycling chain and expansion of the capacity for reuse and recycling of collected WEEE; v. evolution of the regulation of WEEE EPR for those of institutional source, considering that the regulations currently in force focus on the flow of household WEEE, and vi. definition of the strategies to be adopted in order to establish the third phase of implementation of the EPR in the state.

Authors' contributions

PEREIRA, R.S.C.: data curation, investigation, methodology, project administration, visualization, writing – original draft. RIBEIRO, F.M.: conceptualization, methodology, writing – review & editing. GÜNTHER, W.M.R: supervision, validation, writing – review & editing.

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