



CIRCULAR ECONOMY & URBAN MINING

Waste Electrical and Electronic Equipment

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Summary

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Introduction

The circular economy and urban mining have been gaining ground in public policies and lines of research as concepts that seek to add value to waste materials. In this context, they contribute to job creation, mitigation of environmental impacts, increased industry competitiveness and support for the transition from a linear to a circular economy, which results in new sustainable business models. The depletion of the natural resources has motivated actions, such as the replacement of materials and the search for alternative sources. The recovery of secondary raw material has emerged as a potential solution, especially regarding critical raw materials, fundamental for the maintenance and improvement of quality of life, besides having economic importance. For this reason, continuous and secure access to these materials is a strategic objective.

This document is designed to provide the reader with general information on the circular economy in the context of urban mining of waste of electric and electronic equipment (E-waste) and the actions performed by Center for Mineral Technology (CETEM/MCTIC) on this challenging 21st century theme.

Good reading!

Center for Mineral Technology (CETEM/MCTIC)

The Center for Mineral Technology conducts research in order to innovate and develop technology for the mining and metallurgical sector, which uses them for the benefit of society, contributing to the economic growth and development of the country. Its research is focused mainly on chemical, mineralogical and technological characterization, mineral processing, extractive metallurgical processes regarding rocks, minerals and industrial minerals, as well as the development and application of environmental technologies. It is noteworthy that the institution plays a significant role in the development of mineral technology in the country and the dissemination of knowledge, being the only Brazilian public research center dedicated exclusively to mineral technology.

Mission

Develop innovative and sustainable technologies and mobilize skills to overcome national mineral challenges^[1].

Vision

To be the center of excellence in mineral technology research, development and innovation, recognized for its strategic contribution to the country.^[1]

Values

Ethics and transparency

Conduct management committed to ethical and transparent actions, valuing employees and respecting diversity and / or working methods.

Organizational growth

Develop management that stimulates creativity, innovation and knowledge sharing to increase institutional capacity.

Technological excellence

Perform Research, Development and Innovation (RD&I) actions in all areas of its activities, using methods and procedures based on quality, consistent with interdisciplinarity and with a global view of the themes.

Valorization of knowledge

Invest in the continuous training of its professionals by encouraging and valuing the competencies.

Social responsibility

Acting in line with sustainability paradigms, considering the social, economic, cultural, technological and environmental influences and consequences.

Brief History

1978

CETEM began its activities, reporting to the Ministry of Mines and Energy (MME), under the operational agreement signed between the Mineral Resources Company (CPRM) and the National Department of Mineral Production (DNPM);

1988

CETEM changed its ministerial affiliation and was inserted in the Ministry of Science, Technology and Innovation (MCTI) management system by Law 7.677 / 88 and is now managed as one of the research units of the National Council for Scientific and Technological Development (CNPq);

2000

CETEM became a member institution of the MCTI, under the coordination of the Research Units Coordination Secretariat (SCUP);

2013

CETEM had its bylaws amended by Ordinance MCTI No. 292 of March 28, 2013, which included the Regional Center in its structure.

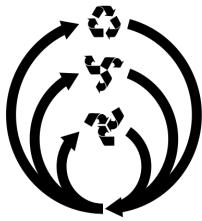
R3MINARE



The research group of the Center for Mineral Technology (CETEM / MCTIC) emerged from the initiative of studies applied to the Urban Mining of Waste Electrical and Electronic Equipment from mid-2017.

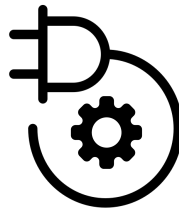
R3MINARE aims to contribute, within the premises of the Circular Economy, with research in the scientific-technological field and development of projects aimed at Urban Mining of electronic waste, with the purpose of identifying the potential of recovery and reinsertion of secondary raw material. critical materials in the production chain.

Research conducted by R3MINARE addresses multiple areas of knowledge, and relate to the following thematic axes:



Circular economy

An industrial system that is restorative or regenerative by intention and design and aims to 'project' waste through optimal cycles of products, components and materials, maintaining them at their highest utility and value, distinguishing between technical and biological cycle. ^[2].



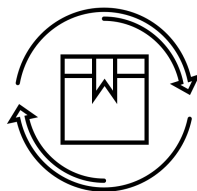
Smart e-waste management

Management that takes into account the particularities of e-waste, such as characteristics that may pose environmental and human health risks, but, on the other hand, composed of materials with high market value. E-waste are defined as those derived from products that require electric current or magnetic field for their operation. ^[3].



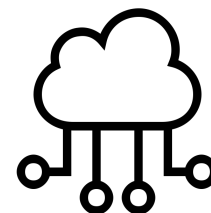
E-waste urban mining

Urban Mining comprises actions and technologies aimed at the recovery of materials and energy from urban catabolism products, being an opportunity to compete with the more expensive traditional mining, due to the few mineral reserves in many countries^[4].



E-waste reverse logistics solutions

An instrument of economic and social development characterized by a set of actions, procedures and means to enable the collection and return of solid waste to the business sector, for reuse, in its cycle or other production cycles, or other environmentally appropriate final destination. ^[5].



Industry 4.0

Industry 4.0 is considered a new industrial stage, in which the integration of vertical and horizontal manufacturing processes and product connectivity can help companies achieve higher industrial performance ^[6]. There is an exceptional technological boost in industrial practice through applications, Information Systems etc. ^[7].

Waste Electrical and Electronic Equipment

The adequate management of Waste Electrical and Electronic Equipment (e-waste) is justified not only by the risks associated with e-waste as a result of its composition, but also by its growing potential for value recovery, a topic of significant interest to the industrial segment.

E-waste composition



Heavy Metals



e.g.: Cathode Ray Tubes (CRT)



Persistent Organic Pollutants (POPs)



e.g.: Capacitors, Plastics



Valuable Metals



e.g.: Printed Circuit Boards (PCBs)

From the understanding of the average composition of e-waste, it is possible to list the potential risks associated with this type of waste, if inadequately managed, namely: contamination by heavy metals and Persistent Organic Pollutants (POPs)^[8], both with life-toxic characteristics and high persistence and biomagnification in the environment^[9].

The e-waste composition also points to the possibility of recovering certain valuable elements from industry. It is estimated that in each tonne of e-waste it can be recovered between 80g and 250g of gold, significantly higher than those found in gold mines^[10,11]. The total present value in e-waste in 2016 was estimated at around \$ 60 billion, although only a fraction of this amount is actually extracted from e-waste management practices^[12]. Thus, it is justified that the economy promotes the return of e-waste to the production chain, a premise of Circular Economy.

It is also worth mentioning in this section the e-waste classification currently adopted by the Brazilian Association of Electrical and Electronic Industry (ABINEE), and the one suggested by XAVIER et al. (2017)^[13], focusing on the recycling industry of this waste typology.

Classifications for e-waste in Brazil

| ABINEE | | XAVIER et al. (2017) | |
|-------------------|--|----------------------|-----------------------------------|
| White Line | 1 <i>Large Household Appliances</i> | 1 | Large Household Appliances |
| Brown Line | 2 <i>Audio and Video Equipment</i> | 2 | Large Household Appliances |
| Blue Line | 3 <i>Tools and Small Household Appliances</i> | 3 | Monitors |
| Green Line | 4 <i>IT & Telecom Equipment</i> | 4 | IT/Telecom Equipment |
| | | 5 | Cables |
| | | 6 | Batteries |
| | | 7 | Lighting Equipment |

Circular Economy and Urban Mining in the E-waste Chain

Circular economy

Circular Economy is designed as an integrated, restorative and regenerative model primarily focused on industrial systems, but can also be applied to other areas of knowledge. This concept encompasses the idea of reducing or eliminating waste through optimized cycles of products, components, materials and services, keeping them at their highest utility and value as “nutrients” for the technical and biological cycles ^[2]. A successful circular economy contributes to all three dimensions of sustainable development. ^[15].

Urban mining

Urban Mining encompasses a set of operations, such as collection, analysis, processing, recycling, etc., aimed at recovering Secondary Raw Materials (SRM) from Municipal Waste (MW), in stocks of materials incorporated in cities or in landfills ^[16]. This concept includes all logistics systems for returning discarded products back to the production chain, or Reverse Logistics, to extract their value as resources for other sequential phases.

Circular Economy in the Urban Mining context

The concept of the circular economy emerges at a time when several countries signal the commitment of natural resources, the search for the redesign of productive systems to meet sustainable business models. The circular economy, with the proposal of a restorative and regenerative model, can be performed by different instruments such as reverse logistics, the sharing economy and urban mining. These tools constitute a potential solution for waste management, while enabling the recovery of value and reinsertion of secondary raw material in production processes.

The circular economy has been incorporated by different countries ^[17]. In China, for example, it is considered as a policy for sustainability. British standard BS 8001 states that the concept is not new but, in fact, rescues proposals from the 1960s ^[18]. Since then, concepts such as industrial metabolism, industrial symbiosis, industrial ecology, and others have discussed the relationship between resource availability and production and consumption demand.

Together, the circular economy and closed-loop management concepts reinforce the concept of urban mining ^[19]. Some alternatives exist for waste collection and processing and are practiced in different countries. However, materials flow from large generators to countries with well-developed refineries and recycling industries ^[20]. The main reasons seem to be the lack of efficient reverse logistics to collect and recycle on an industrial scale, i.e. to process significant amounts of e-waste. In this context, a desirable solution may be the establishment of an integrated solution to collect and manage the secondary raw material based on the identification of chain agents acting in the country, the characterization of the materials contained in the post-consumer product and the structuring models compatible with current regulations.

Circular Economy

integrated, restorative and regenerative system model for material recovery

Reverse Logistics

mechanisms to enable the collection and return of waste for its reintegration into production cycles

Remanufacturing

repairing of parts and post-consumer products for their use in future production processes

Urban Mining

set of operations for the recovery of secondary raw materials from waste

Recycling

processes that change the physical / physicochemical / biological properties of wastes for use as inputs

Reverse Manufacturing

transformation of materials into parts and pieces without obtaining new products

The value found in e-waste

The recovery of materials from waste electrical and electronic equipment represents a strategic segment for the most diverse sectors of humanity, motivating various researches focused on the properties of materials.

Since the last decade, developed countries have been using the classification of critical raw materials as the set of materials considered indispensable to the maintenance of important economic sectors of a country and which may present risk of external supply, such as scarcity, natural resource and geopolitical issues. The degree of criticality may change over time due to such factors.

For this reason, continuous and secure access to these materials is a strategic objective for countries. To support this action, a list of critical raw materials, last updated in 2017, with their respective producing countries was proposed in the European Union (EU) [21].

| Raw material | Main Producers |
|---------------------------|--|
| Antimony | China (87%) Vietnam (11%) |
| Cobalt | Dem. Rep Congo (64%) China (5%) Canada (5%) |
| Indium | China (57%) South Korea (15%) ... Japan (10%) |
| Niobium | Brazil (90%) Canada (10%) |
| Phosphorus | China (57%) Vietnam (19%) Kazakhstan (13%) USA (11%) |
| Heavy rare earth elements | China (95%) |
| Light rare earth elements | China (95%) |

Key Critical Raw Materials^[21].

The supply of critical raw materials is compromised by their low substitutability and low availability of raw materials from the EU waste recycling rate, related to EU demand [21].

Rare earth elements (REE) are defined as the 15 lanthanide elements plus scandium and yttrium. These elements have similar electronic configuration, but distinct chemical and physical properties. Thus, ERTs are applied to many technological products because of their magnetic, luminescence and strength characteristics that make them unique. The uses of REE include the manufacture of magnets, batteries, lamps, glass, alloys, lasers and screens [22]. REE occur in low concentrations in ores such as xenotime and monazite and are extracted together with other metals such as iron, platinum and tin. Complementation with recycling can provide heavy rare earths [23]. However, the main obstacle to mining and recycling of REE is the difficulty of separating them. The complexity of the waste and the low content of these elements are also problems to be solved through recycling [22].

The challenges of e-waste urban mining

The e-waste is a source of plastics, metals, glass and critical raw materials. This is the fastest growing generation category in the world ^[24,25]. However, some e-waste may have significant hazardous potential ^[8,9] and therefore care should be taken in the process of characterizing and handling electronic waste. In 2016, worldwide e-waste generation reached nearly 44.7 million metric tons ^[12], with the USA, China and South America being the major generators ^[26]. In Brazil, the estimated annual generation is about 1.5 million tons in 2016 ^[12]. In developing countries, informal collection and processing of e-waste has spread without proper monitoring of urban mining.



World



44,7
millions of
tons



China



7,2
millions of
tons



USA



6,3
millions of
tons



India



1,9
millions of
tons



Brazil



1,5
millions of
tons

Generation of e-waste in the world^[12].

Inadequate waste disposal is a problem due to lack of planning, strong urban growth and inefficient resource management. For a long time, waste landfilling was considered an efficient solution for end-of-life products and materials. Today, however, waste is understood as a source of materials to be returned to the supply chain in a circular economy. In the linear economy, raw materials are obtained from natural resources (ores, oil, etc.), but in a process of transition to a circular economy, secondary raw materials can be recovered from residual sources.

Developing countries face a dual challenge regarding waste management. The first is to establish and comply with environmental regulations on this subject, and the second is related to infrastructure and management procedures for waste processing. Some developing countries have primitive waste management processes that result in negative health and environmental impacts ^[27,28].

Brazil has been a protagonist in the discussion of environmental causes. However, the regulation of waste management was consolidated late. The Brazilian Policy on Solid Waste (BPSW) was sanctioned in 2010 by Law No. 12,305 ^[5], a federal regulation that addresses the issue of waste management by specifying the approach to e-waste, representing an important milestone in the regulation of sustainable practices and in the implementation of Reverse Logistics Systems (SLR). Some Brazilian states, such as Rio de Janeiro, São Paulo, Paraná and Pernambuco, have laws prior to BPSW, highlighting the mobilization within the states as a proposal for the configuration of efficient channels and adjusted to local realities and new business models. However, there is still significant potential for the improvement of regulatory instruments to match the interest of different segments.

Projects and Research Lines

1

URBAN MINING FEASIBILITY STUDY FROM FLUORESCENT LAMPS

| | |
|------------------|--|
| Summary | Part of the post-consumer lamp management research project at CETEM. Its proposal is to identify viable and sustainable techniques in a cooperative model. |
| Financing | Brazilian Council for Scientific and Technological Development (CNPq) |
| Period | 2019-2021 |
| Team | Ellen Giese (Coordinator); Marisa Nascimento, Lúcia Helena Xavier, José Antônio Sena, and researchers at CETEM. |

2

MANUALS FOR E-WASTE CORRECT DESTINATION (1st & 2nd edition)

| | |
|------------------|--|
| Summary | <p>1st Edition: Citizen guidance on how to properly dispose of e-waste in the city of Rio de Janeiro. Current overview of e-waste management and e-waste classification. Location of collection point, guidance and relevant contacts. Destination Term Model for e-waste.</p> <p>2nd Edition: Guidance to citizens on how to properly dispose of e-waste in the state of Rio de Janeiro. E-waste management scenario in the state of RJ, and e-waste classification. Survey of Recycling Industries operating in the e-waste segment. Destination Term Model for e-waste.</p> |
| Financing | CETEM |
| Period | 2018 e 2019 |
| Team | Lúcia Helena Xavier (Coordinator); Hermann Nascimento, Marianna Ottoni, collaborators at UFRJ and INEA. |
| Link | http://www.cetem.gov.br/livros |

3

DATA SURVEY ON E-WASTE RECYCLING IN BRAZILIAN MINISTRY OF SCIENCE, TECHNOLOGY, INNOVATION AND COMMUNICATION (MCTIC) RESEARCH INSTITUTIONS

| | |
|------------------|---|
| Summary | Questionnaire application and data analysis on the perception of researchers regarding e-waste management in public institutions in Brazil. Research aiming to guide actions, training and decision making. |
| Financing | CETEM |
| Period | 2019 |
| Team | Lúcia Helena Xavier (Coordinator); Renata Barreto, Letícia Motta, Marianna Ottoni |

4

GEOREFERENCE OF COMPANIES IN THE CIRCULAR WEEE ECONOMY

| | |
|------------------|--|
| Summary | The lack of consistent data for the e-waste management represents a significant challenge for the public policy and decision making. Thus, we propose data collection and georeferencing of e-waste management units in Brazil for a preliminary analysis of the current scenario. |
| Financing | Brazilian Council for Scientific and Technological Development (CNPq) |
| Period | 2019-2020 |
| Team | Lúcia Helena Xavier (Coordinator); Raissa Araújo |

5

MASS BALANCE AND GRAVIMETRIC ANALYSIS OF TECHNOLOGICAL WASTE

| | |
|------------------|---|
| Summary | One of the premises of the circular economy is the valorization of secondary materials. Thus, through the mass balance of the different materials in the e-waste composition, we propose the feasibility analysis of recovery processes for different product categories and brands, as well as contribute to Design for Disassembling. |
| Financing | CETEM |
| Period | 2019-2020 |
| Team | Lúcia Helena Xavier (Coordinator); Carlos Gomes |

6

DATA MINING FOR URBAN MINING: POTENTIAL ANALYSIS

| | |
|------------------|--|
| Summary | Data mining techniques can also be valuable for waste management. In the e-waste segment, there is already a significant volume of negotiations on digital platforms, as well as the potential of treatments given to support the decision making. |
| Financing | CETEM |
| Period | 2019-2021 |
| Team | Lúcia Helena Xavier (Coordinator); Marianna Ottoni |

Brazilian Cases



Tramppo
ESTÁO SUSTENTÁVEL DE LÂMPADAS

TRAMPPPO

Brazilian company that operates in the fluorescent lamp management segment, performing the collection, storage, decontamination and processing of post-consumer material in different states of the country. It operates in partnership with the only managing entity of the segment, RECICLUS, despite having previous experience from acting as a company incubated at the University of São Paulo between 2003 and 2009.

The company processes about 200,000 lamps per month and has already reached the mark of 20 million collected and decontaminated lamps, a significant contribution in the circular economy segment.

In partnership with CETEM, TRAMPPPO has been active in the rare earth recovery project from fluorescent lamps, a partnership that aims to contribute to urban mining from post-consumer lamps.

Tramppo's processes include simple grinding, chemical treatment grinding and thermal treatment grinding.



<http://www.tramppo.com.br/tecnologia/>



VERTAS
Gerenciamento e Transformação
de Resíduos Tecnológicos

VERTAS

The Brazilian company operates in the market since 2009 with a device considered innovative in the Americas, performs dry processing, i.e. does not consume water or generates effluents for crushing and separation of materials obtained from e-waste. By providing samples of this process, CETEM is analyzing the diversity and quality of the recovered secondary raw material.

Operating in the reverse logistics, reverse manufacturing, decharacterization and recycling of post-consumer electronics products, the company has contributed to urban mining and the circular economy.



Vídeo institucional: <https://youtu.be/wRqkOYR-IWQ>



GM&CLog

Brazilian company that operates in the management of batteries and other electronic equipment since 2002, when it began, in an innovative way, the information management in the reverse logistics channels in the country.

Despite being a reference in the collection, storage and processing of batteries, the company serves a variety of post-consumer products including wire and cable, cell phones and others. It also acts as a hub that centralizes the receipt and destination or receipt and processing of materials. The company has diversified its activities in order to expand its operations in urban mining with the recovery of secondary materials.

Thus, CETEM has sought to establish a partnership to analyze and contribute bench techniques to improve processes in partnership with recognized research institutions.



<https://www.gmclog.com.br/site/index.php/servicos/separacao-de-materiais>



INDÚSTRIA FOX

The Fox industry is one of the few Brazilian companies that operates in the reverse logistics, reverse manufacturing, reconditioning and recycling of electronic equipment segment. It has diversified its activities investing in rebuild for reuse, as well as process automation with data collection on material recovery. Another area of expertise has been capacity building to raise awareness, thereby increasing the collection of post-consumer materials.

The company began its activities in 2009 as the first reverse refrigerator manufacturing plant in Brazil, with the dual challenge of secondary raw material recovery and climate protection. The recovery of potentially contaminating refrigerant gases was the focus of the action.

It is intended the establishment of future partnership with the purpose of knowing and expanding the proposal of information management in partnership.



<http://www.industriafox.com/>

Technical Team

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