E-waste and Circular Economy: An approach to the Latin American case

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Abstract

This research analyzes the opportunities, barriers, and challenges presented by the implementation of the principles proposed by the circular economy in the waste electrical and electronic equipment sector in Latin American countries. Likewise, it studies the current reality of how this type of waste is managed in the region, and, in addition, proposals for alternatives are presented to promote sustainable practices, generate environmental awareness in producers, promote repair and reuse, and develop and implement a circular supply chain. Likewise, the document highlights the potential benefits that would result from implementing the circular economy for the correct management of waste, including the reduction of environmental impact and the generation of economic opportunities. The objective of this article is to approach the consumption of electronic waste and the role of the circular economy in its management in the case of Latin America. To achieve this objective, a descriptive methodology was applied through the data obtained from the Global E-waste Monitor for the period 2011-2019. The results obtained show an increase in electronic waste in recent years. In conclusion, this sector must be well-regulated to improve the management of environmental resources.

Keywords

E-waste, Circular Economy, Latin America

1. Introduction

1.1. E-waste

Electronic waste refers to electronic devices that have been discarded, such as computers, cell phones, and televisions, among others. They are also suitable for commercial or domestic use. In most cases, these devices are composed of materials that are dangerous for people, such as lead, cadmium, and mercury, which could have harmful effects on human health and generate significant environmental risks if they are not properly controlled [1, 2, 3].

The excessive number of waste of this type has experienced sustained growth over time, and even its increase is truly shocking over different years according to analyses carried out, in 2019, 53.6 million metric tons of waste were recorded in electronics worldwide[1]. Highlighting the

ICAIW 2023: Workshops at the 6th International Conference on Applied Informatics 2023, October 26–28, 2023, Guayaquil, Ecuador

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[1]Global E-Waste Statistics Partnership https://globalewaste.org/

United States as one of the countries with the highest production of electronic waste, recording 9.4 million tons generated in 2020[2].

Certain characteristics explain the behavior of electronic waste [1, 4, 5, 6]:

- The waste streams produced by Waste Electrical and Electronic Equipment (WEEE) have experienced impressive growth in recent decades worldwide due to the exponential growth of the technology industry and the shortening of the life cycle of products. This fact is that there are often new product launches (models and improved versions) that make existing ones obsolete.
- E-waste represents an important factor that could cause transcendental risks and an impact on the environment, due to the presence of toxic substances in its components. These devices are generally produced with large amounts of lead, mercury, cadmium, and other substances that are harmful to human health. The inadequate management and recycling of this waste has caused irreparable consequences, such as soil and air pollution and serious damage to the ecosystem, and, above all, it has generated an impact on human health.
- To partially minimize the impact imposed by the mismanagement of these artifacts, recycling programs that involve the extraction of certain important materials and that can be reused by producers have been applied through public policies. Likewise, it is noteworthy that the correct application of recycling processes is in part a guarantee of the safe elimination or disposal of components dangerous to the environment.
- Around the world, this type of waste is treated empirically, that is, techniques that are harmful to the environment are used, such as open burning of waste or dismantling of devices without any type of safety or security processes that generate impacts either on human life or the environment. Informal recycling can cause risks of impact, especially on the people involved, and subsequent damage to the ecosystem in which they are located.
- Another aspect to highlight is that the illegal importation of WEEE has become a constant concern for the environmental areas in charge of the different nations because this activity does not have regulations that allow this activity to be kept controlled or it is not allowed. They have established the necessary parameters to guarantee minimizing the impact produced. This type of practice is driven by economic interests since the investment made by importing this waste to other countries to carry out the process is less than implementing an adequate recycling system for the treatment of waste.
- The process of eliminating this waste must be adequate because it can not only generate health and environmental impacts, but can also cause inappropriate loss of personal data, and in some cases, there could even be data theft. Therefore, it is necessary that within the correct disposal process of these devices, the appropriate way to eliminate personal information and prevent the security of data use is provided.
- At a global level, there has been a need to implement or establish Extended Producer Responsibility (EPR) programs, to provide options that motivate producers to carry out appropriate procedures for the implementation of WEEE management that can be of benefit to the entire community. These types of programs promote strategies that benefit manufacturers by reusing materials that may still have a second opportunity for use.

[2]EPA https://www.epa.gov/recycle/electronics-donation-and-recycling

- An extremely important factor is establishing an awareness program for consumers, so that they understand the benefits and impact that would be generated by giving adequate treatment to their WEEE, in addition to showing them what the consequences would be of making these devices obsolete in a short period, rather than giving it a more extended opportunity. Likewise, knowledge regarding these treatments must be clear and defined so that consumers can access official disposal points for electronic devices.
- Correct use and reuse of WEEE can significantly reduce the impact that these wastes generate. Devices that are still functional should be donated or sold for their corresponding use and allowed to extend their life cycle.
- It is important that producers, from the beginning, can design products with elements that can be recycled and that can be considered for reuse in others. Likewise, these should have an ecological design, which presents a modular construction and the use of sustainable elements, which facilitate recycling and minimize the possible environmental impact.

In this context, although the environmental risks are extreme, and the reality is known by the producers and policymakers of the nations, there are very few countries that have implemented timely actions to try to minimize the impact that this activity generates. In this sense, a large part of this waste is exported to developing countries, generating even more pollution due to the unsafe and unofficial treatment that is given, instead of proposing a recycling management system that allows for minimizing human and environmental risks [7, 8].

The main changes that could be implemented to contribute to this cause include establishing clear and concise legislation that addresses proper waste management and promoting incentives for producers to recycle and reuse appliances that are still in working condition. On the other hand, it is of interest that producers can contribute to meetings with decision-makers to specify timely and manageable actions, and that they also favor the responsible and conscious use of this waste [9].

WEEE is a constant problem worldwide, however, in certain areas, such as Latin America, the situation is somewhat more complex because there are no established policies that can stop the excessive growth of this type of waste. Furthermore, no global policies or objectives have been proposed that can be replicated for all countries regarding the disposal, recovery, and use of these devices. Some studies reveal that the disposal of this type of waste is one of those that register the greatest growth, in the specific case of Latin America the figure rose to 4.9 million in 2009 [10, 11] representing an increase of 21% compared to 2015 [12].

In this context, and faced with this reality, the authorities on duty have not taken timely actions to stop the excessive consumption of this type of device, or at least, established policies that help recycle or reuse elements that can still be used. Furthermore, it is important that, within the policies and regulations, a specific treatment of this waste is established that does not cause harm to those involved in the process [13, 14, 15, 16, 17].

Likewise, efforts should be made jointly by all Latin American countries so that a common policy can be managed that allows the reduction of electronic waste, through the establishment of centers specialized in the recycling of this type of products [18, 19, 20, 21, 22] and that, in addition, the care and prevention of possible risks for the parties involved, in this case society and the environment, can be guaranteed.

1.2. Circular economy and E-waste

In recent years, the Circular Economy (CE) has taken interest, which constitutes a form of economic system that seeks the elimination of waste through the use of resources, thus reducing pollution to keep materials in continuous use and promote the regeneration of natural systems [23, 24, 25, 26, 27].

In this context, the phenomenon under study has taken on importance worldwide, particularly from the environmental and public health approach due to the rapid obsolescence and high turnover of electronic devices [28, 29, 30], which provokes the interest of the current authorities in orienting their governments towards the management of electrical and electronic waste (e-waste). In this regard, the CE proposes alternatives to the challenge represented by the disposal of electrical and electronic devices by promoting alternative production processes and sustainable consumption by the population. Likewise, the novelty it presents is the approach of strategies for the efficient management of resources and therefore, the reduction of electronic and electronic waste and waste through the basic principles that it professes.

In general, CE and e-waste complement each other in such a way that the joint management of these two areas provides diverse results, so that the most sustainable management of resources is achieved, minimizing the negative impact on the environment and society in general. For example [28, 31, 32]:

- The implementation of eco-friendly designs in the manufacturing of electrical and electronic devices extends the life cycle of the products in the market because they would be made to last and therefore consumers would generate less e-waste. The design within circularity implies the application of principles that contemplate easy repair, updating, and disassembly, due to the very fact that modular components are incorporated.
- Circularity is responsible for promoting three basic aspects such as repair, renewal, and reuse of products to extend their useful life. This means promoting the creation and generation of repair-oriented services, as well as programs that allow the reconditioning or remanufacturing of electrical and electronic devices. In this sense, it is noted that in certain countries it is customary to throw away devices that do not work well, while in others citizens go to a repair service center to continue using them.
- Regarding the management of electrical and electronic waste, the circular economy guarantees proper management from collection to final disposal. Therefore, it is considered of public interest to promote effective management systems for this type of waste to reduce the extraction of natural resources that strongly impact the environment.
- The CE philosophy promotes the recovery and readaptation of waste through the correct recycling of the valuable materials that make up electronic devices. Such recycling allows the extraction of precious metals, such as gold, silver, and copper, among others. Therefore, these materials become inputs to make way for the manufacture of new devices, minimizing the environmental footprint.
- Within the CE, closed circuits are formulated, in which materials and products continue to circulate within society and are not eliminated after being used once. In this sense, the closed circle helps minimize waste and reduces environmental impact.
- It requires the collaboration and interest of stakeholders such as manufacturers, consumers, policymakers, and public and private entities in general. Joint work allows for

the implementation of better measures aimed at eco-design, the management and implementation of infrastructure for collection and recycling, as well as innovative proposals to reduce the production of e-waste.
- Finally, it is noteworthy that the design of effective policies and regulations plays a key role in raising awareness among the population and promoting good production practices. Such is the case of governments that implement Extended Producer Responsibility (EPR) programs to create shared responsibility for products and consumers regarding the materials used and the life cycle of the devices.

In general terms, the integration of the principles of the circular economy in the practical management of waste from electrical and electronic devices allows us to minimize the environmental impact of waste and prolong the conservation of natural material resources to create a socially and economically sustainable system.

Some studies have been relevant to the circular economy and e-waste management. For example, studies of [33, 34, 35] analyzed circularity and waste management in China, concluding that a functional system for managing waste and recycled or reconditioned materials, as well as expanded producer responsibility and reverse logistics, would help minimize the effects caused in the environment.

Along the same lines, other studies carried out by [36, 37] evaluated the feasibility and feasibility of circular economy-based business models for e-waste management in India. The authors concluded that CE through repair, renovation, and resale is more likely to generate high economic results and at the same time reduce e-waste.

In Latin America, in recent years, there has been a growing interest in the adoption of CE to address and solve environmental and social challenges. The Inter-American Development Bank (IDB) has channeled resources to actively promote the circular economy throughout the region [38, 39].

However, the Latin American region faces major challenges that are related to electronic waste management. As a result of the accelerated growth and evolution of technology, e-waste has become one of the main environmental and health problems [40, 41]. Some of the countries in the region, if not the vast majority, lack adequate infrastructure and policies for the management of waste of all types, in general, and electrical and electronic devices, in particular, which leads to problems of environmental and health pollution [42, 43].

In the region, this problem has been addressed through various initiatives and policy programs. In this case, the United Nations Environment Program (UNEP) has worked with countries in Latin America and the Caribbean to design strategies for effective e-waste management and promote CE principles in society. In addition, various investigations have been carried out that address the opportunities, challenges, threats, and strengths for the governance and management of electronic waste in the region [44, 45].

2. Methodology

In this research, descriptive research was applied, with an approach based on the theoretical review carried out through consultation in books, magazines, and scientific articles that allowed the establishment of a theoretical basis for the analyzed phenomenon. Likewise, the theoretical

and descriptive approaches were combined in the research, to achieve a broader understanding of the real effect of the inadequate WEEE process.

Regarding the descriptive approach, we proceeded to evaluate how the management of this type of waste is currently being developed, what is the role of the interested parties, and what type of policies are being applied. On the other hand, from a more theoretical approach, we delved into how these practices affect political, economic, social, and technological areas. Carrying out an in-depth analysis of the main implications that this could generate in the development of public policies and strategies that minimize the effects of poor management of WEEE.

The data used for the analysis comes from the Global E-waste Monitor for the period 2011 – 2019 for thirteen countries in the Latin American region. Methodologically, the main objective corresponds to collecting data, preparing an analysis and evaluation of practices and what is currently happening in the world, regarding electronic waste management and the circular economy in Latin America. To achieve these objectives, a quantitative and qualitative approach is applied with the ultimate goal of providing a clearer idea of the reality that this situation presents worldwide about what policies are applied, what challenges must be faced, and propose possible alternatives that can result in public policies in favor of the development of a sustainable and sustainable process for this conflict area.

To apply the statistical methods, six categories of electronic waste were used [46] which were defined as follows:

- Large Household Appliances (Category 1): large household appliances such as refrigerators, freezers, washing machines, dishwashers, stoves, ovens, air conditioners, and other similar devices.
- Small Household Appliances (Category 2): small household appliances, including vacuum cleaners, toasters, coffee makers, microwaves, irons, electric fans, electric toothbrushes, and other similar devices.
- IT and Telecommunication Equipment (Category 3): wide range of information technology (IT) and telecommunication equipment, including computers, laptops, printers, monitors, keyboards, mice, mobile phones, landline phones, routers, modems, and other related devices.
- Consumer Electronics and Photovoltaic Panels (Category 4): includes various consumer electronics, such as TVs, audio/video equipment, cameras, game consoles, DVD players, music players, and photovoltaic (solar) panels.
- Lighting Equipment (Category 5): lighting equipment, including fluorescent lamps, LED lamps, and other types of light fixtures.
- Electrical and Electronic Tools (Category 6): electrical and electronic tools used for professional or DIY purposes, such as drills, saws, sewing machines, lawnmowers, electric screwdrivers, and similar devices.

The categories presented about WEEE allow strategic decisions to be established about proposing efficient alternatives about the collection, recycling, and correct disposal of this waste. Likewise, through these, management strategies could be generated that guarantee the correct processing and subsequent use of these wastes when giving them a second opportunity for use, thus reducing the impact they generate on the environment.

3. Results

The production of electronic waste generated per capita placed on the market for the years 2015-2019 (see Table 1) experienced a growth of around 8 kg. In the first year of analysis about the second year of study, in this sense, it should be highlighted according to the data shown, that the growth that occurred in 2019 reached 13.8%. These results show that there is an upward trend, that is, that this waste will increase over the years if there is no policy that can be applied to reduce this waste production, and there may also be a truly dangerous impact on the environment.

Concerning the amount of EEE (Electrical and Electronic Equipment) that has been placed on the market per capita, it reflects a slight decrease between the two reference years of analysis, presenting the following results: from 11.5 kt in 2015 to 11.2 kt in 2019, reflecting a reduction of 2.6% in the period analyzed. This reality reflects that, despite there being a small reduction, the results are not as expected. Although it could be partly the process of raising awareness among the consumer population about environmental sustainability, it is necessary to apply rigorous policies that help minimize these figures.

In general, the data shown in the table below reflects the general reality; in terms of EEE waste and commercialized EEE, there is still a gap, since figures reveal that waste production continues to be higher in numbers of EEE reused each year, which directly shows the non-existence of the establishment of public policies or at least efficient alternatives that are productive for the reduction or at least the diminution of the impacts produced on human health and environmental sustainability.

Table 1
E-waste generated and EEE Put on Market (kg per capita) in Latin America. 2015 – 2019

Year	E-waste generated (kg per capita)	EEE Put on Market (kt per capita)
2015	8	11.5
2016	8.3	10.6
2017	8.6	10.6
2018	8.8	10.1
2019	9.1	11.2

Figure 1 shows the results related to the percentage distribution of six categories of electronic waste that were generated in 2019. It is necessary to mention that the results presented by each of the countries will be different, due to specific causes, such as population, and geographic area, among others. Likewise, it is important to comment that the production of this type of waste depends greatly on factors such as consumption patterns, good or bad waste management practices, and the technological advances that countries present

The data analyzed shows that for the year 2019, the category called small teams is the one that registers the highest value (33%) among the others in the classification, followed by 21% generated by large teams. Regarding the category of temperature exchange equipment, which includes heat pumps and boilers within its classification, they reached 21% of the total

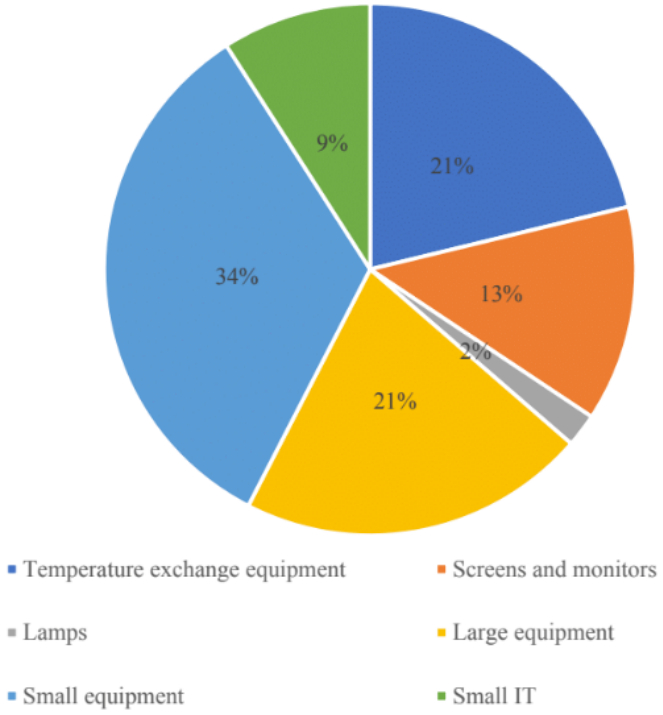

Figure 1: E-waste generated disaggregated to category (%) 2019.

classification, while those known as screens and monitors registered 13%. Finally, small IT and lamps represented a relatively lower value with the other categories of 13% and 2% respectively.

Temperature exchange equipment, which includes items such as heat pumps and boilers, accounted for 21% of the e-waste generated. Screens and monitors accounted for 13% of e-waste generated in the analyzed year. Finally, small IT accounted for 9% of e-waste generated in 2019 and Lamps accounted for the smallest percentage of e-waste generated at only 2%.

In Figure 2, the data reveals that both small and large devices, which include those used for temperature exchange, are two of the categories that produce the largest amount of electronic waste generated for the year 2019, generating between the two a total of 75% of the total. On the other hand, when it comes to screens and monitors and small technologies, they have generated a significant amount of waste; when it comes to lamps, the percentage is relatively lower. In this context, this information is relevant, because it could serve as a basis for recognizing the sectors that should receive greater treatment and be considered a priority to be included in programs to reduce environmental and health impacts caused by e-waste.

Within the results presented, it is shown that Costa Rica is the country that registers one of the highest collection rates of this type of waste among the others analyzed, followed by Chile with 8%, Ecuador, Bolivia, and Argentina showed a 4% collection rate, while Uruguay has a 3%. The lowest WEEE collection and treatment rates of the countries analyzed were those of Honduras and El Salvador, both with 1%, and Venezuela and Panama, showed a rate below 1%.

It is important to mention that the average collection rate of this type of waste for the region,

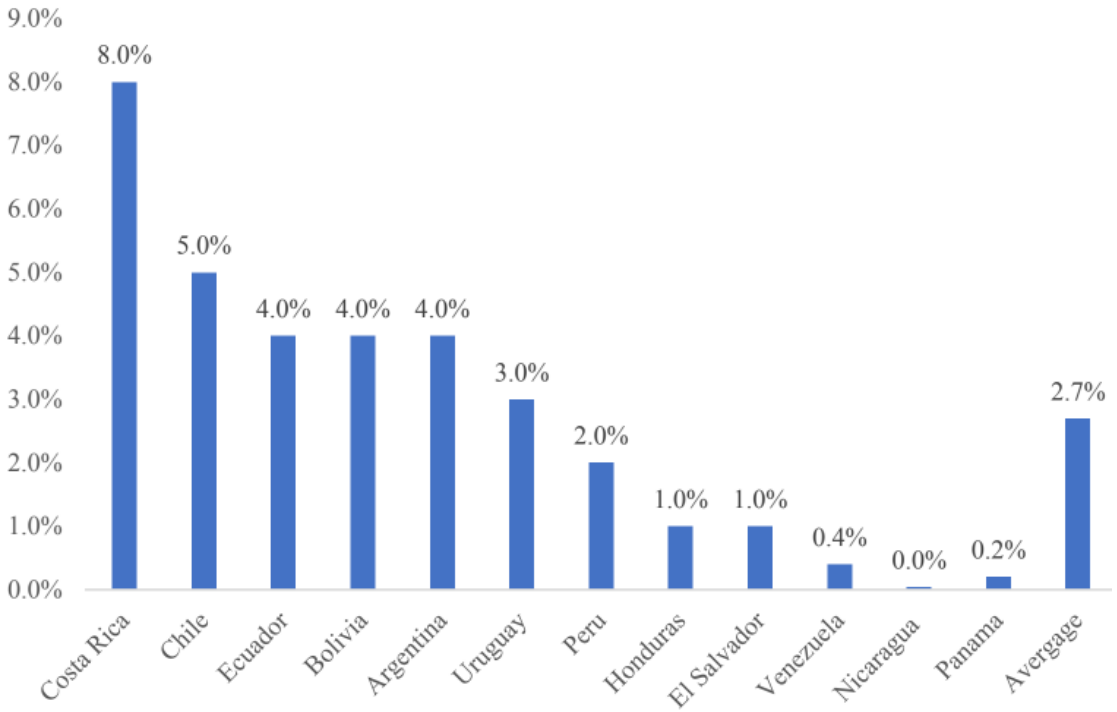

Figure 2: E-waste collection rate (%) 2019.

registering 2.7%, is an extremely low rate, which in turn highlights the great work that remains to be done by different countries regarding the care and management of waste electrical and electronic equipment.

The collection rates of WEEE produced in Latin America can vary significantly between the different countries analyzed. The data show the real challenge that awaits the rulers in power and policymakers concerning the implementation of public policies that apply to different contexts and that are useful for each country.

Likewise, the data shows which countries are those that present the greatest problems in the collection of this type of waste and that may not yet be implementing any type of solution in this regard.

The data obtained show a reality that has been occurring in the previous analyses, of the six categories analyzed, the one that has generated the most WEEE corresponds to temperature exchange equipment, screens and monitors, lamps, large equipment, small equipment, and Small IT for 2019.

Regarding large and small equipment, they continue to be the categories that generate the most waste with the others in the classification, with one exception, countries such as Chile and Panama, in which screens and monitors were the most representative categories, and, in Panama and Guatemala in which lamps were the smallest category (see Table 2).

The proportion of generation of this type of waste varies significantly between the different

countries analyzed, thus, for example, Bolivia registered a higher proportion of waste known as large equipment and lamps, while Costa Rica and Uruguay registered a relatively higher production of screens and monitors than other countries studied.

Table 2
Share of the categories of e-waste generated (%) (2019)

EU-6 categories	Argentina	Bolivia	Chile	Costa Rica	Ecuador	El Salvador	Guatemala	Honduras	Nicaragua	Panama	Peru	Uruguay	Venezuela
Temperature exchange equipment	22	15	26	17	16	24	17	28	26	24	17	24	23
Screens and monitors	14	6	15	14	11	15	14	15	13	13	16	14	12
Lamps	3	8	2	3	4	6	7	3	3	2	4	6	2
Large equipment	28	22	16	17	15	13	12	12	9	20	22	18	22
Small equipment	26	39	34	41	49	31	37	34	38	33	33	30	32
Small IT	8	11	7	9	10	10	14	8	11	8	10	8	8

Also, it is highlighted that the production of this waste per capita in Latin America is relatively low concerning other regions, however, the rate continues to grow. According to the analyses studied, a total of 9 million tons is expected to be reached by 2030, which represents a real challenge for the governments in power, which must pay greater attention to the implementation of efficient strategies to try to minimize the impact that this situation can have.

4. Conclusions

The irreversible damage presented by the production of WEEE represents a constant concern for Latin America and the world because it has become a pressing situation that does not give truce, since each year higher percentages of waste that have not been processed are recorded and recycled or that are simply dumped in landfills or exported to developing countries.

This problem is difficult to treat through a type of linear economy and it is more about facing the challenges that this waste brings through the implementation of Circular Economy business models, which allow establishing appropriate strategies and maintaining the clear objectives that must always be followed related to the Sustainable Development Goals, which are aimed at clean production and the generation of policies that allow generating appropriate management processes for the treatment of this type of waste and, which, in turn, allow the quality of life of people to improve and minimize the environmental impact.

The challenge at the regional level is still in an incipient state, and there is a long way to go; the different countries must act jointly and consciously towards the same purpose, so that joint strategies can be generated that facilitate and improve recycling processes, in addition to generating shared public policies that minimize the illegal export of this waste, which causes a real danger to human health and, above all, an impact on the environment.

5. Acknowledgements

Thanks to the Technical University of Ambato, Department of Research and Development (DIDE) for the endorsement granted for the development of the project "Potencialidades de la economía circular en países de América Latina (POTENCIAL)", external project with DIDE endorsement. The project in question is led by the Research Group Innovation, Structural Change and Development (ICEDE), University of Santiago de Compostela.

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