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When Circular Economy Meets Inclusive Development. Insights from Urban Recycling and Rural Water Access in Argentina

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Abstract: How is it possible to design and deploy circular economy (CE) strategies oriented to inclusive development? How can non-traditional units of production and consumption (i.e., actual productive actors such as waste picker cooperatives and peasant organizations) be integrated into these strategies? Using data collected as a result of two long-term participatory action research projects carried out with a waste picker cooperative in Buenos Aires and 65 peasant families in Chaco (both located in Argentina) the paper opens the door to a proactive critical debate in terms of how to integrate circular economy principles with the development of technological solutions (artifacts, processes and methods of organization). We show that CE holds great potential, both in terms of its contribution to the generation of new interpretive frameworks and also, in terms of nurturing local and inclusive development strategies when it is integrated with collaborative, bottom-up and innovative dynamics. Based on the idea of working with heterogeneous traditional production units (not only with profit-maximizing firms), it is possible to think of social development avenues for vulnerable populations, where the CE principles build up mechanisms capable of maximizing the transformative potential of the resources (including those understood as waste) presented in actual techno-economic matrices.

Keywords: sustainable development; social innovation; community action; resource management; waste picker cooperatives; peasant movements; circular economy; inclusive development

1. Introduction

Latin America is the world's most unequal region despite being a continent rich in natural and human resources [1]. According to specialized literature, this inequality is closely related to two dimensions which define the dominant linear economy based on the take-make-dispose model. Firstly, open access to key resources (land, water, minerals, etc.) is concentrated by powerful elites who impose restrictions on the rest of the population by enacting property rights and other related normative procedures [2]. Secondly, the negative impacts of the extractive and disposal activities are transversely distributed, disseminating their externalities among territories and populations [3]. In both processes, linear economy operates by managing stocks of materials, privatizing access to resources and the profits of production, while socializing the cost of final disposal. Circular economy (CE), instead, brings an opportunity to reshape our socio-economic development pathways towards social equity and environmental justice goals [4]. Based on the management of flows rather than stocks [5], it prompts sharing and collaboration instead of private appropriation, as well as the minimization of negative externalities, and the accountability of its mitigation among producers and consumers of energy and material flows [6].

In this regard, the promises which have arisen from CE narratives of change highlight their potential to build a development strategy decoupling the use of virgin resources from economic growth, contributing to prompt sustainable development dynamics and creating new job opportunities [7,8].

CE narratives propose a global scale shift in the approach towards the complex relationship between technological change, economic growth and sustainable development [9,10]. Specifically, they posit a reorientation of the dominant economic matrix, which is based on a linear conception of productive processes organized around the stages of extraction-production-disposal, pointing out the model's negative impact on environmental and human health [11].

CE puts forward the idea of leveraging the flows of matter and energy derived both from industrial manufacturing and final consumption, in order to reuse them as inputs in new productive processes [12,13]. Its goal is to develop a regenerative and restorative economy, based on the design of feedback loops from biological and technological perspectives [14].

The concept is characterized, more than defined, as an economy that is restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. It is conceived as a continuous positive development cycle that preserves and enhances natural capital, optimizes resource yields, and minimizes system risks by managing finite stocks and renewable flows. It works effectively at every scale. This economic model seeks to ultimately decouple global economic development from finite resource consumption.

This new way of conceptualizing production and consumption has not only sparked a theoretical-conceptual discussion [15–17], but has also given rise to a wealth of empirical case studies, mostly focused on China [18,19], the European Union [20–22] and the United States [23]. These studies are generally about experiences of design and redesign of factory processes [24,25], management of household and industrial waste [26,27] and, to a lesser degree, practices of market consumption and management of basic natural resources (such as water and soil) in food production systems [28–30].

Critical literature highlights particular biases and conceptual gaps which constrain the development of the CE proposal, even in the central countries in which it was developed [31,32]. In general, this literature stresses that CE narratives deploy an overrepresentation of innovations in the realm of industrial engineering and mass consumption patterns, neglecting the model's social and human dimensions [33]. Thus, some sensitive issues in developing countries are rarely analyzed, such as: impacts of CE on labor dynamics [34], the relation between CE principles and the issues of human development and social inequality [35], or the prevalence of cultural and institutional barriers to the implementation of CE business models [36].

In line with these critical perspectives, it is possible to state that CE narratives do not land in a vacuum. They dialogue with two complementary levels.

From a theoretical perspective, since the 1960s, Latin America has had a long tradition of intellectual organizations and social movements fostering the design and implementation of more equal and inclusive (and in some cases, sustainable) technologies [37,38]. Since the 2000s, the key issue of how to develop technological solutions for social and environmental problems has acquired new relevance in several developing countries worldwide and, of course, in Latin America. Particularly, the questions of how to produce knowledge, boost learning and foster innovation, empower local communities and enhance the democratization of technological decision-making have been revitalized as analytical and policy issues. Research centers, networks of researchers and international funders have been supporting research projects in Latin America focused on the analysis and concept generation of inclusive innovation [39], responsible innovation [40], social innovation [41], social technologies [42], grassroots innovation [43] and bottom of the pyramid [44].

From an empirical point of view, several social movements have been applying innovative, bottom-up solutions in order to improve the quality of life of low-income population, promoting alternative economic models: worker cooperatives [45], waste picker movements [46], family farming [47–49], among other examples of synergistic articulation carried out by community organizations, private companies and municipalities, with social inclusion and environmental sustainability goals.

Despite the diversity of conceptions and models, it is not clear how to avoid the failures of previous experiences. For example, most of these approaches seem to face tensions between local requirements and the need to scale up and between short-term funding and the chance to create deeper forms of social empowerment and social change [50]; the conceptualization and design of technological solutions are mainly based on the use of linear innovation models and old conceptions of technology transfer that tend to reduce poverty and social exclusion to a technical problem [51–53]; the stabilization of a misconception based on the narrow scope analysis of social and environmental problems ('one solution for one problem') which leads to top-down, pro-poor intervention strategies and research efforts in terms of appropriate technologies [54,55]; the missed engagement of traditional knowledge in the innovation process as a way to empower actors and as a way of finding adequate solutions [56,57] and the implementation of predefined technological solutions that do not achieve user engagement and do not get the expected results [58–60].

Thus, despite the promise of developing processes of inclusion and empowerment (provided by these theoretical and empirical approaches on technology and development) and of paving the way for a more sustainable and equal future provided by CE narratives, there are still several analytical (and political) issues related to: how is it possible to develop technological solutions to social and environmental problems fostering the strengths of these approaches and minimizing the unwanted effects? How can non-traditional units of production and consumption (such as worker cooperatives, grassroots social organizations and peasant organizations) be integrated? How could these new development strategies based on CE principles and bottom-up, collaborative and innovative practices be nurtured, not only through the proposal to reconvert existing processes, but also through the initial design of techno-productive systems?

Starting from these questions, the purpose of the present paper is to analyze two cases in which bottom-up, collaborative and innovative technological solutions, nurtured with CE strategies, generate inclusive development dynamics. Particularly, we focused on the integration of actors who are often overlooked in academic studies within this field: waste picker cooperatives and peasant movements.

In the first case, we present the development of a processing system for plastic materials recovered in their post-consumer phase by members of a waste picker ('cartoneros') cooperative from the Buenos Aires metropolitan area. The second case is a rural development program for isolated and scattered communities in the province of Chaco, Argentina, based on the design, implementation and management of water systems.

2. Theoretical and Methodological Framework

When the focus of analysis is moved from private firms to other types of organizations, it is possible to identify new ways of doing (innovation dynamics, learning processes, organization models for the production of goods) in new contexts: workers' cooperatives, recyclers, social movements (such as grassroots recyclers' organizations), NGOs, R&D institutions (both public and private) and governing bodies. Normally, organizations of this type are not considered in case studies where technology has positive effects over economic dynamics [61]. Due to this bias, the potential contributions of grassroots organizations in linking economic development with social and environmental justice and equity become underexploited. Grassroots organizations provide a wide range of innovative techno-productive and cognitive practices [62], which could easily be framed and fostered by CE narratives.

Considered within the context of an analytical-explanatory model, enhancing the heterogeneity of the organizations involved in the analysis is a key theoretical move towards a more complex system of socio-cognitive interactions showing dynamic goods' generation and circulation, learning, knowledge and capabilities [63]. However, it also requires a broader definition of technology.

In this sense, we use the definition of technology elaborated by Winner [64], which involves and integrates three different aspects: (i) "artifacts" (material technologies such as tools, instruments, machines, utensils, etc.), (ii) "processes" (skills, methods, procedures, routines, etc.) and (iii) "forms of organization" (companies, cooperatives, clubs and also non-institutional forms such as the neighborhood).

Technology understood this way allows us to think about how these three aspects connect with one another and, by extension, to implement consistent analysis. That is, to understand how artifacts are inscribed within processes and how they are both part of the forms of organization.

This broader definition of technology is complemented by a collaborative and participative research methodology. The data discussed in this article emerge from two long-term participatory action research (PAR) projects carried out with a waste picker cooperative in Buenos Aires (Cooperativa Reciclando Sueños Lta.) and 65 family farmers in Chaco (Paraje Pampa del Zorro), both located in Argentina. According to PAR methodology, a multi-stakeholder team (composed of researchers, non-governmental actors, governmental institutions and production units, among others) develops research and engagement activities in order to set common goals and methods and implement results "in a way that will raise critical consciousness and promote change in the lives of those involved—changes that are in the direction and control of the participating group or community" [65].

The PAR deployed in each case consisted of the creation of a multi-stakeholder team based on a long-term collaborative and transformative approach oriented to the generation of practical solutions [66] for social and environmental problems. In both cases, PAR strategies were grounded in three main conceptual (and associated) key elements: (i) co-design and co-production of problems and solutions; (ii) horizontal collaborative relations at the bottom oriented to transform the status quo (bottom-up dynamics) and (iii) development of innovative knowledge, artifacts, processes and organizational methods in order to deliver technological solutions.

The collaborative work with Reciclando Sueños started in 2004 and one of the main programs designed by the team (coordinated by one of this paper's authors) was the Inclusive Recycling Promotion. Framed within this program, we gathered empirical insights and lessons from a circular economy initiative carried out (and implemented between 2015 and 2018) by Reciclando Sueños and a transnational corporation located in Argentina. We selected this particular initiative because it shows how to create a win-win business partnership between a non-traditional actor (a waste picker cooperative) and a transnational corporation.

The second case began in 2014 with the project Right of Access to Goods: Water for Development (DAPED) coordinated by researchers from the Institute of Scientific and Technological Studies from Quilmes National University (IESCT-UNQ) and the National Institute of Agricultural Technology (INTA).

The DAPED project created multi-stakeholder teams involving local communities and public institutions for co-designed technological solutions. While it was carried out in four communities in the province of Chaco, Argentina, we will focus on the case of Pampa del Zorro (coordinated by two of this paper's authors), because it combines an actual stressed resource situation (the community is located in an arid zone, with a high concentration of rains in only three months and a very long period of dry weather which heavily harms food production) with a systemic, bottom-up, collaborative solution.

Finally, as a PAR inner activity, we collected relevant data during the fieldwork, through in-depth conversations with relevant actors, notes from teamwork sessions and several meetings held with other stakeholders. The gathered data were completed with official documents related to the cases (reports, memos and press releases).

3. Case Study Analysis

3.1. Industrial Waste: Generation of New Processes for Inclusive Sustainable Development

3.1.1. Definition of the Socio-Environmental Problem

Based on the gathered information, it is estimated that in 2014 the generation of municipal waste in Latin America and the Caribbean was 541,000 tons/day. Even though countries in the region show a quantitative and qualitative improvement in the collection of generated waste (covering 93% of the population), there are still more than 35,000 tons per day of uncollected waste, affecting more than 40 million people [67].

Although proper final disposal of solid waste has significantly improved over the past decades in Latin America and the Caribbean, the system presents two significant issues [68]:

1. Approximately 145,000 ton/day end up in dumpsites, are burned or are otherwise inadequately disposed of. This is equivalent to the waste generated by 170 million people.
2. The absence of well integrated and sound recycling public policies (from lack of waste sorting systems for dry and wet wastes to neglecting waste pickers as socio-productive actors) results in a low recycling rate (between 1–20%) which means that approximately 90% of municipal waste ends up in landfills.

Particularly, in Argentina, the generation of total waste is around 45,000 tons/day, with an official figure of collection coverage rate of 99.8% [69]. One half of the total waste is composed of food leftovers and other household by-products which are non-recyclables (ranging from 45% to 55% depending on each municipality). According to Inter-American Development Bank (IDB) data, in 2015, the average cost of collection was USD54.02 per ton and the cost of final disposal USD17.63 per ton, making them the most expensive services in Latin America.

In terms of recycling capacity, 21 out of the 24 provinces have mechanized separation plants with an installed capacity to treat 17.7% of the waste generated, although most of them work below their capacity [70].

Currently, Argentina has 200,000 waste pickers. They conduct recovery of dry recyclable materials by collecting them from curbsides and/or dumpsites. Moreover, a small proportion of them (between 15% and 20%) are organized in terms of formal or semi-formal units of production and process materials, adding economic value [71]. There is a lack of official statistics about the volume of recyclables recovered by waste pickers. However, specific jurisdictions—such as the City of Buenos Aires—have estimated that in 2017, waste picker cooperatives recovered up to 20% of the 2,000,000 tons of waste generated that year [72], while other scholars have stated that waste pickers contribute with over 20% of the inputs used by industries that recycle [73]. Unfortunately, these contributions are poorly recognized in both social and economic terms, as the waste management systems are oriented to its final disposition (not to its valorization) and therefore organized around private firms which provide logistics and landfilling services to municipal governments [74]. In other terms, though Argentina has a huge workforce dedicated to recovering materials from waste, it is not formally recognized by waste management public policies.

3.1.2. Changing the Scenario, from Household Waste to Industrial Scrap: An Opportunity to Develop Collaborative and Bottom-Up Inclusive Dynamics

Management of industrial waste is a key business activity in Argentina, both in terms of operating costs and—more recently—of its impact on aspects related to corporate image and social accountability. However, the dominant rationale for the organization of this activity in the industrial world stems from a linear take-make-dispose model. According to this scheme, waste is managed exclusively in the last stage (disposal), with a focus on the logistics of moving waste to the place of treatment and/or final disposal.

Not all waste is managed in the same way. Certain inputs used in the manufacturing process can generate "hazardous waste" (as defined by National Law No. 24051/91); such is the case of those involving chemicals (e.g., hydrocarbons) and/or biological components (e.g., hospital waste), which could potentially affect the environment and health, including that of human beings. Thus, there is a distinction between two industrial waste flows: those deemed hazardous and those which are similar to household waste, for example a cardboard box used for packaging; objects made of defective plastic, cellulose and/or metal; paper used in administrative tasks and containers for drink and food consumed at staff canteens, among many others.

The management of household-like waste basically comprises waste treatment and transportation to the place of final disposal, or to the place in which it is marketed as a part of the recycling industry. In the case of waste deemed hazardous, the procedure is more complex, as it may involve its burning (for instance, when it comes to pathological waste) or various treatments aimed at neutralizing its active ingredients before its final disposal.

Since their emergence, linked to the 2001 social and economic crisis, waste pickers have been making a living out of retrieving and sorting recyclables from household waste, but not from industrial sources, which are basically managed by a couple of large private firms. However, in 2013, the environmental authority of the Province of Buenos Aires (OPDS) started a process to reshape the regulatory framework of waste management for those companies considered as large generators of waste (which produce more than 1 ton/month). This process opened a window of opportunity for the formalized waste picker cooperatives to be certified by the OPDS as sustainable destinations, and therefore possibly able to provide professional services to the large generators, managing their recyclable waste streams [75]. However, how can waste picker cooperatives be included in the industrial scrap flows as a way to improve labor conditions and enhance waste pickers' monetary income? Furthermore, is it possible to develop new technologies, managed by waste pickers, oriented to improve the recycling rate? Or, in other terms, is there room to deploy a first step towards an inclusive CE?

We will now present the results of a case study based on the analysis of the waste management process of a cleaning product factory from the greater Buenos Aires area (hereinafter referred to as "company X"). In general, its waste management system can be considered an example of the circular economy of waste (CEW). However, the analysis we put forward makes a distinction between two stages. In the first stage, management is carried out exclusively by a private company. The second stage involves a cooperative of urban waste pickers.

3.1.3. First Phase: A Restricted Version of Circular Economy

The production process of company X involves two main stages: the formulation stage, in which chemical components are synthesized into the different products and the packaging stage, in which the products are prepared to be marketed as mass consumption goods. The second stage creates a large volume of recyclable solid waste, namely, goods discarded after adjustments in assembly lines and/or failures in packaging machines: cardboard boxes and spools, polyester film, high-density polyethylene and polyethylene terephthalate containers, and also textile products (tow) and even metal (iron-based) containers, are some of the most frequently-generated materials.

These products were captured directly at the assembly lines, through three circuits which shall be labeled 1, 2, and 3.

The first circuit (1) comprised clearly-marked sorting areas with three containers that were colored based on the type of waste to be disposed of:

- Black: uncontaminated paper and cardboard, specifically, clean papers, cardboard, boxes, sheets and related products.
- Green: household-like uncontaminated waste, specifically, paper towels, plastic straps, nylon, film, paper spools, seals, food, plastic cups and labels.

- Blue: materials contaminated with hydrocarbons, fats and/or oils, specifically, used contaminated elements, such as oil filters, paint cans and contaminated materials (gloves, rags, tow, papers, absorbent cushions).

The second circuit (2) was not specifically marked and was comprised of bins with large transparent plastic bags, into which operators discarded exclusively containers and/or labels which left the production process with defects. In general, said containers had been in contact with chemicals, and were thus considered hazardous.

Finally, the third circuit (3) comprised metal racks reserved for cardboard boxes, including defective packaging boxes, and those in which the inputs used in the process had been carried.

All recyclable materials recovered in the three circuits were managed by a private company (hereinafter, "company Z"), which served company X. In theory, company Z worked on this waste based on two main classifications, one which separated hazardous and non-hazardous materials, and a second one which distinguished between recyclable and non-recyclable materials. Thus, in operational terms, some waste from circuits 1 and 2 were managed together. More specifically, the containers from circuit 2 contaminated with chemical products and the waste left in the blue bin of circuit 1 were treated as hazardous waste. The materials discarded in the green and black bins of circuit 1, together with all cardboard goods recovered in circuit 3, were managed as household-like waste, which were in turn separated into materials which could be recycled (cellulose-based, textile, plastics) and materials for final disposal, as in the case of food waste. In the last case, company Z could classify this waste in order to specifically segregate recyclables which could then be marketed by the company independently.

However, this is a description of how the operation should have worked in theory. The analysis of the actual practice, based on an observation in the assembly lines, revealed some important differences (see Figure 1).

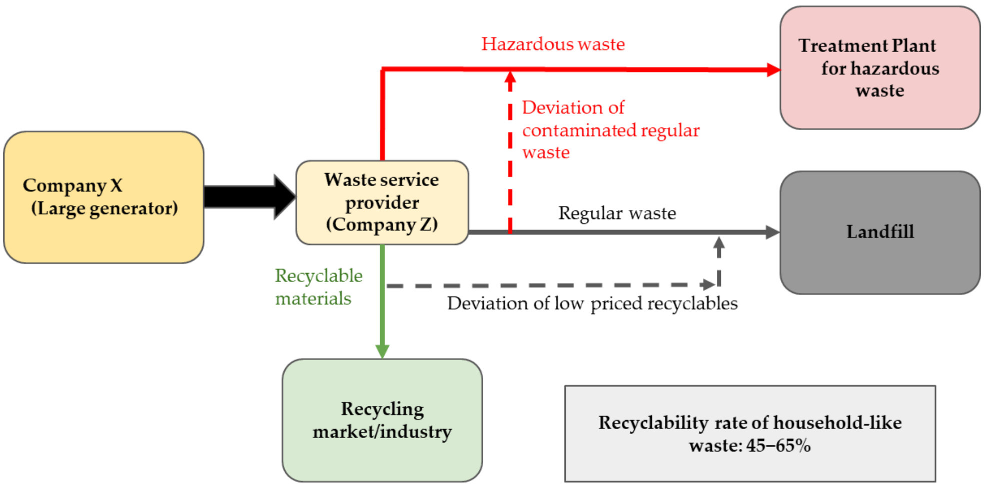

Figure 1. Restricted version of circular economy in corporate waste management. Source: own elaboration.

As regards circuit 1, it was possible to see that the existence of a sorting infrastructure (the series of colored bins) did not necessarily ensure that the system was accomplished. The analysis of the contents in the bins often revealed contaminated waste (which should have been discarded in the blue bin) in the green and black bins. In practice, this increased the volume of hazardous materials managed by company Z, which in turn increased the cost of the service it provided to company X: in other words, waste which should have been deemed non-hazardous was managed as hazardous, due to failures in the sorting practices.

Moreover, it was possible to verify that the contents of the green and black bins (i.e., materials which were in theory considered recyclable) were not subsequently sorted by company Z in order to separate materials to be sold back into the productive circuit. As a result, said waste was compacted together with organic waste for final disposal in landfills.

This does not mean that company Z failed to manage the materials generated by the process which could be used in the recycling industry. Rather, it did not recover household-like materials from circuit 1 (which theoretically included most of the materials which could subsequently be recycled), focusing instead on the cardboard from circuit 3 and, occasionally, plastics from circuit 2 (which in theory included contaminated, and thus unrecyclable, materials). In fact, company Z had two full-time employees whose job involved emptying the racks and taking the cardboard to be pressed into bundles, which were then sold to large recycling companies. Something similar happened with some plastic materials from circuit 2: these operators would walk along assembly lines, identifying bags with uncontaminated materials, generally deformed or damaged containers, which did not reach the filling stage.

Thus, company Z focused its sorting activity on those materials which were not only profitable (cardboard and blown plastic), inasmuch as they could be sold in bulk into the market, but also required little investment in more specific classification and organization activities, as in the case of the many types of waste considered household-like. Thus, company Z's operation did not focus on the materials' recyclability (that is, the potential to reuse them in a productive circuit), but on the profitability of the activities. In this sense, the company did not perform off-site classification activities: all management stages took place on site and depended on the materials' final destination. Thus, household-like waste was compacted together with organic waste (food), to be ultimately buried in landfills. Materials deemed hazardous were sent to private treatment plants. Lastly, only the cardboard and some plastic from circuit 2 were sold to the recycling industry.

In sum, only a small share of the potentially-recyclable waste (between 45% and 65%) was ultimately reused in productive circuits based on recycled inputs, as proposed by the CEW model. Company Z operated under standard profit-maximizing rationale. That is why it contributes exclusively to the recycling of those materials which can be sorted without any cost, as they are classified by the assembly line operators, and then retrieved by its own employees. In contrast, sorting household-like waste would have required not only a minimal level of infrastructure to classify and stock materials, but also an investment in labor dedicated to separating the different materials. Instead, the dominant rationale is one of "waste de-stocking", using the phrasing with which company Z describes the service it provides to company X and others. In this respect, the operation described above revolves around a concept of production related to the management of solid waste based on the linear take-make-dispose model, which focuses all activities on the last stage, that of final disposal.

3.1.4. Second Phase: Circular Economy in Terms of Inclusive Development

Under the program, a series of actions were implemented to reorganize the waste management system of the plant, through the reinforcement of two key guidelines: to deepen CEW dynamics while incorporating social inclusion goals.

The following were the program's highlights:

1. Inclusive recycling training workshops for plant staff (both operators and administrative employees).
2. Co-design and implementation of clean circuits throughout the plant (production lines and offices): based on the results of the assessment and the employees' feedback during training, the work-team developed a proposal to reorganize the management system through the creation of clean circuits aimed at recovering the largest possible share of recyclable materials, to be managed by the cooperative.
3. Technical-professional assistance for the incorporation of the Reciclando Sueños cooperative as a service provider.
4. Recyclable material management migration from the private provider (which was the sole provider) to the cooperative (the new provider).

The new system was implemented in February, 2016 (see Figure 2) and entailed a comprehensive reformulation of the internal waste management in relation to the previous phase.

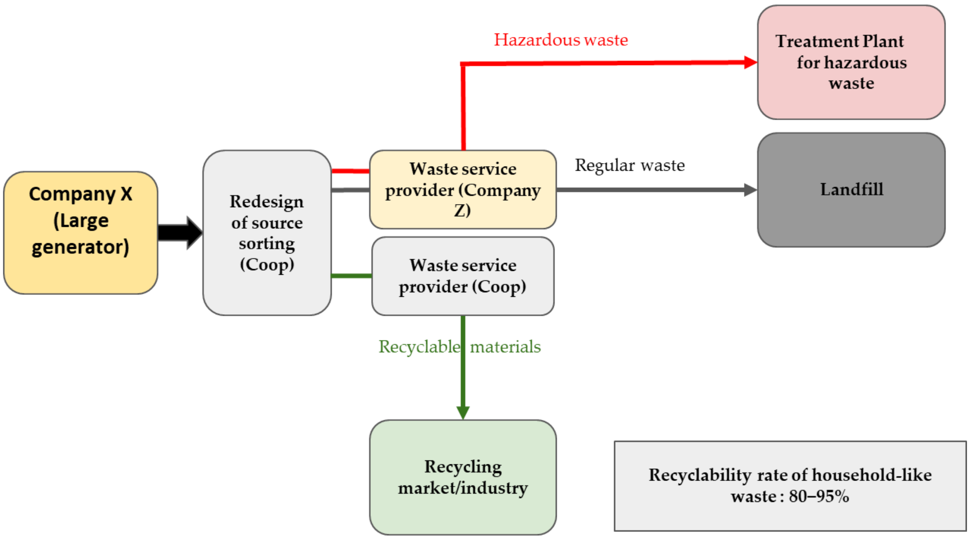

Figure 2. Enhanced version of circular economy in corporate waste management. Source: own elaboration.

The new waste management model had the following characteristics:

(a) More effective internal classification system for each one of the circuits.

As regards circuit 1, the categories and the physical infrastructure for the sorting areas were modified, including colors assigned to bins, as well as new signage and informative posters. As a result, the percentage of recovered recyclable materials now hovers around 80%–95%, compared to a previous percentage of 45%–65%.

As regards circuit 2, actions were focused on making it visible and establishing a distinction between contaminated and uncontaminated materials. This made it possible to minimize the volume deemed hazardous and, thus, increase the volume of household-like waste.

Finally, in circuit 3, new signage was implemented to make it more visible and it was integrated into the flow of recyclables to be managed by the cooperative.

(b) Reallocation of waste flows based on the provider. Through these modifications, the management system incorporated the idea of inclusive recycling. This entailed making a distinction among waste flows based on the following structure.

Private provider: the private provider no longer has a monopoly on the service. It remains only in charge of the special and hazardous waste flows and, within the household-like waste flow, of those which cannot be currently recycled (basically organic waste produced by the cafeteria).

Cooperative: the cooperative becomes a service provider in charge of all recyclable materials.

(c) Development of a traceability system for household-like recyclable materials. Unlike the previous (private) management model, which lacks a mechanism to verify where the waste went after leaving the plant, the model put forward by the cooperative includes a monitoring system, by type and volume of material, for the waste that is sold to the recycling industry. At the same time, this latter had OPDS's backing, since the cooperative was accredited as a sustainable destination, and therefore could issue an official receipt stating all this information. In turn, those receipts became key documents for the environmental managers of Company X, as they were useful to establish a reliable monitoring of its recyclability rates, and also endorse their performance according to the ISO 14000 standards.

3.2. The Circular Economy of Water in the Context of a Collaborative Inclusive Development Strategy

3.2.1. Definition of the Socio-Environmental Problem

Access to water for consumption, sanitation and production has become a priority around the world, but especially in Latin America and Argentina, due to the processes related to climate change, the territorial conflicts it entails, the contamination of fresh water sources and, of course, the cross-cutting nature of water management in regard to the quality of human life, agricultural and industrial production, and ecosystem regeneration [76].

In Argentina, the supply of water and sanitation services is included within the sustainable development goals (SDG6), which the national government and the different provincial jurisdictions want to achieve through specific public policies (National Water and Sanitation Program, Belgrano Plan, among others). However, 22% of households currently lack access to the safe water network, and 41% lack access to the sanitation system [77].

According to government figures, approximately 8 million inhabitants lack access to drinking water at home. About 448,000 of the households without access to drinking water are structurally poor and 82% of rural households lack drinking water [78].

Moreover, based on the type of access to water (water mains, wells, community outlets, cultivation systems), we can see a correlation with the level of unmet basic needs. In this sense, for instance, 51% of the households which resort to a community outlet are structurally poor. The provinces of Santiago del Estero, Formosa, Chaco, Salta, Tierra del Fuego, Jujuy and Misiones show the highest shares of the population without access to this basic service [79].

Statistics on access to sanitation show an even more dramatic scenario. Currently, 40% of the population lack access to adequate sanitation, and approximately 687,000 households have no sanitation at all and show unmet basic needs (structural poverty) [80].

Complementarily, if we divide Argentina's population by type of area, we find that 18% of urban households have no access to the drinking water network at home and the share increases to 35% in rural conglomerates and to 85% in the case of isolated rural areas [77]. This shows that access to and quality of water depends on the urban or rural scenarios.

Thus, developing inclusive sustainable development strategies for isolated and scattered rural households is an urgent priority for the Argentine public policy agenda [78], but also for the Latin American region as a whole [81].

3.2.2. A Collaborative and Bottom-Up Inclusive Sustainable Development Strategy

Right of Access to Goods: Water for Development (DAPED), a project coordinated by the IESCT-UNQ and INTA, started in 2014. The DAPED project had the support of Network of Technologies for Social Inclusion (RedTISA), the National Ministry of Social Development and the National Council of Social Policies and financing from the Science and Technology Ministry.

When defining the first level of shared issues, the research-intervention team from the public institutions began to study the various water systems for scattered, relatively isolated rural areas (lacking communication and adequate rural roads).

When analyzing available solutions, it was observed that:

- Many of the initiatives identified (dug wells, drilled wells, community outlets, small reverse osmosis plants) were not used due to lack of maintenance or breakdown.
- The available technological solutions were exclusively aimed at solving the issue of access to water for human consumption and most failed to include processes related to the use and reuse of water for household or productive consumption. Moreover, the solutions' design did not consider the final disposal or greywater and blackwater.
- The solutions entailed new related problems: transportation towards the water source, which led to a degradation of the source and of the resource during the process; high transportation costs associated with the use of tanker trucks; in the cases in which reverse osmosis processes were employed to purify the water, the solutions failed to consider what was done with the hazardous waste (arsenic), which was ultimately buried close to the water source, among other issues.
- The communities failed to see those technologies as their own, they did not know the person responsible for the water source and they did not have the tools for a comprehensive and sustainable management of the resource, seeing as they had never received any assistance in order to secure a water supply.

These cognitive issues are inherent to the linear model underlying the take-use-dispose economy. The ways of thinking about the problem focused on aspects related to technological endowment for the provision of water and considered no operational strategies or mechanisms (in organizational and technical terms) after the artefactual solutions were implemented. At the same time, the technologies were not defined based on the quantity and quality of water needed by the families, ways in which water was transported, local production capabilities, reuse loops and allocation of the resource to multiple complementary uses.

Based on those contributions, the team began researching the water supply regime, water use modes and mechanisms and the resource's daily requirements. The following is a highly-summarized account of the findings:

- The families traveled to a community well with 20 L tanks. Thus, each household invested up to four hours every day to secure the resource, needed for human and animal consumption.
- Each family farm comprised, on average, 50 hectares of native forest [82], which were basically used as a source of: natural resources for producing small-scale charcoal and wooden posts, fuel for cooking, heating and goat's food.
- Available water sources (community wells and frequently-used drilled wells) had high concentration of salinity and arsenic, which represents a high risk to human health. Moreover, most of the few sources of safe water dried up during droughts.
- Most families raised goats and chicken for self-consumption and their production volumes were constrained by the scarcity of water.
- Finally, the families were only able to grow vegetables during the rainy season, which spans only three months (November–January).

Thus, the team identified in Pampa del Zorro an opportunity to design and implement a system for the production, supply and (re)use of water, human, biomass and food resources, based on the main axiomatic action level of CE: an economy which is "restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times" [83].

The process of co-design of a CE strategy for inclusive development began with the following definitions:

1. Creating learning processes regarding the available technological options to supply water for consumption, sanitation and animal and agricultural production;
2. Carrying out practical training activities in order to learn about the technologies and assess them in operation; and
3. Making collective plans about the use, reuse and complementarity of water and production systems.

The types of household needs and uses required putting forward a new matrix of problem-solution dynamics, one which focused, in principle, on various water-related issues (see Figure 3).

Under this scheme, the team and the community began devising an inclusive sustainable development strategy for households, with the goal of creating solutions for the 65 households in the area. In 2015, training activities were carried out in relation to cased wells, drilled wells, plate cisterns and masonry cisterns. With the information available, each family decided how they wanted to address the water issue at home. The construction system for the needed infrastructure chosen and agreed upon by the families entailed a community-based model: families were divided in groups of eight, which were to cooperate with each other to build the water systems for each household.

As this forest area is home to some species of prickly pear, a trial was carried out with two varieties: Italian and santiagueña. The trial attempted to experiment with the possibility of generating controlled plantations of prickly pear as a complement to water for raising goats. The harvest of the stalks during droughts could ensure 40% of the goats' water needs.

Through these actions, each family was able to decide on a work plan. In this sense, the chosen water technologies were different in each case: some chose dug wells, some, drilled wells and others opted for rainwater collection systems. When the first wells were dug and drilled, some issues were revealed: high salinity levels and low flow rate. This made it possible to consider mixed or complementary water systems: dug and drilled wells were to be used for the future sanitation facilities and for production, with rainwater collection systems for consumption. The first systems were built in 2016. By 2018, 100% of the families in the area were covered by the project.

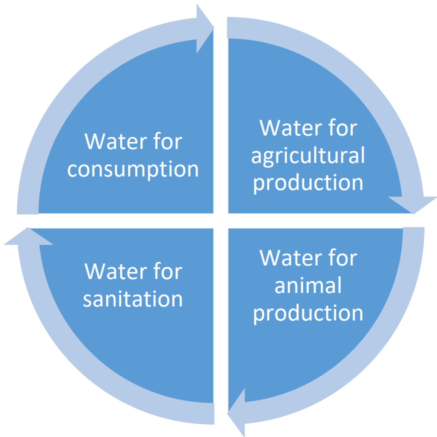

Figure 3. Water needs. Source: own elaboration.

The co-design of a sanitation system was undertaken in parallel (human waste disposal, greywater reuse, blackwater treatment and processing into a natural fertilizer), funded by the National Ministry of Science and Technology during 2017. This research and development (R&D) project enabled the co-design and test, in the field, of three different toilet models: (i) a traditional toilet with greywater ending in a cesspool, (ii) a dry-toilet and (iii) an integrated sanitation system where toilets with latrines, showers and washbasins have a secondary mechanism to recover greywater for orchard production. Needless to say, the third option showed higher approval. In the same way as the water supply solutions, toilet co-design involved families both when it came to the definition of the parameters to be used and in the construction of the facilities themselves. After the end of the seed fund, in 2018 the municipality of Las Breñas started a rural toilet program under the scheme proposed by the third option, which is currently ongoing.

As seen in Figure 4, the development strategy revolved around a system with four types of water:

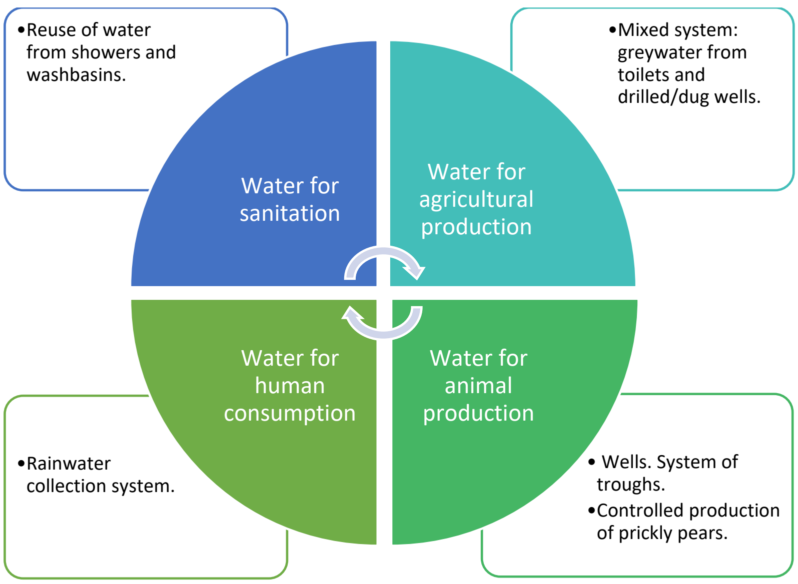

Figure 4. Circular economy for inclusive development. Source: own elaboration.

1. Water for human consumption from rainwater collected in home cisterns, which represented an increase in the available supply of 32,000 L per year/family. With an average cost of USD1600 per water harvest system deployed with a life-cycle of 15 years, each new liter of water costs 0.003 U.S. cents (or the equivalent of 0.036 cents in Argentine pesos from 2016).
2. A second use for that water for human consumption, that is, the greywater produced by personal hygiene activities, washing clothes and utensils, is reused to flush the toilet. Thus, families have access to a level of sanitation (namely, toilets) which was virtually non-existent in Argentina's arid and semi-arid regions.
3. A third use of that water entails the employment of a bio-digester which uses treated water, in combination with that from a well, to water orchards throughout the year. This enables cultivation and farming beyond the rainy season.
4. Water for production, that is, well water which, combined with the prickly pear plantations, is used by animals. This removes the competition between humans and farm animals over the resource.

This system made it possible to increase the production of food for self-consumption, improved families' health and hygiene conditions and freed the families from the burden of spending four hours every day fetching the resource. The time saved was the main improvement in terms of cost-effectiveness metrics. In this sense, families used their time to build-up new houses (20% of the households did so), make better use of the time assigned to economic activities (the mortality rate of goats, one of the main productive activities, fell on average 45%) and children spent such saved time on recreational purposes.

4. Discussion

After the empirical cases presented in the previous sections, we are now in a position to recover their main lessons learned. These lessons can be organized in terms of the 3 key conceptual elements of the PAR strategy:

1. From a problem and solution co-design and co-production perspective

The integration of the cooperative Reciclando Sueños as a service provider for Company X started with the reconfiguration of the problem and not with the typical ex-ante solution. The first task of the multi-stakeholder team was to co-design the problem mix (i.e., the interrelated problems deployed in a situated scenario). Company X needed an action framed within the corporate social responsibility (CSR) activities. The cooperative Reciclando Sueños had the requirement to add new incomes but not in terms of being a beneficiary of a CSR activity. Company Z wanted to preserve the service contract with Company X in the presence of a potential competitor (the cooperative).

The problem's co-design was not an easy task. The presence of the research team facilitated the translation of the different problems in terms of a new business model for waste treatment, but also, the material promise (to increase the recyclability rate) performed a key role in the bargaining process, making the cooperative proposal more significant to Company X.

As a result, the whole system was changed, integrating all actors in a more efficient productive matrix (as we presented in Figure 2).

In the DAPED project's case, in Pampa del Zorro, a similar dynamic took place about the co-design of problems and solutions. Although researchers from IESCT-UNQ and public officers from INTA had had an initial problem-agenda, during fieldwork the agenda was transformed from the problem of "access to water" (and we here refer to one kind of water) to the problem of "access, harvesting, use and reuse of water" (where water has different material forms: rainwater, greywater, water as fuel for bio-digester, among others).

Taking into account the multiple ways in which the different social groups within a community understand local problems, there could not be one single solution ("one solution for all"). The elaboration of a set of possible solutions (considering the advantages and disadvantages of each one) was a key step for the integration of different stakeholders in the horizontal decision-making process.

In dynamic terms, the integration of new concepts (such as CE) in local development strategies sparks processes of re-adaptation of practices, language and institutions. The actors on the ground (management groups, neighbors, teachers, firefighters and the major, government officials) interpret and reinterpret new techno-cognitive practices (for instance, construction techniques, water collection and storage technologies and food production techniques) based on new ways of doing which intertwine social change, community development and technological solutions.

2. From the standpoint of horizontal collaborative relations at the bottom, oriented to transform status quo (bottom-up dynamics)

In the first case, the main collaborative bottom-up dynamics were established between researchers and the cooperative Reciclando Sueños. This collaborative work was oriented towards changing the common sense about legal partners (private companies working through contracts) and about good circular economy narratives. According to common sense, CE can be understood simply as a business opportunity for private sector companies looking to maximize their profit rate.

As regards waste management in particular, this entails, paradoxically, a strengthening of the global take, make, dispose model: as the focus is on profit, the effort needed to turn waste into inputs favors materials which require less labor and less investment in R&D, and which fetch a higher price when sold. This means that an extensive range of plastics is ignored, and thus an opportunity is lost to mitigate the high environmental impact caused by the saturation of landfills.

In the second case, the DAPED project was performed by a highly heterogeneous multi-stakeholder team. However, the integration of stakeholders was not initiated all at once. As in the case of Reciclando Sueños, the work in Pampa del Zorro started with a core team. In the former case, the core team was composed of researchers and waste pickers, in the latter, the team put together researchers from the IESCT-UNQ, public officers from INTA, teachers from the local public school and an initial group of peasants. These core teams defined the project's first set of actions in the field: to create a collective decision-making mechanism about who—and when—would tackle problems and how to involve and engage the whole key actors.

So, in terms of bottom-up dynamics, the main lesson is the reconfiguration of the social and legal relations between legitimated and traditional actors (private companies, the local government) and subordinated and non-traditional actors (waste picker cooperatives or peasant families) changing the meaning allocated to daily activities, to international narratives (as CE), to validated metrics (profit rate, recyclability rate, liters of harvested water) and also, of course, to the waste picker cooperatives and peasant themselves.

From the point of view of inclusion dynamics, the incorporation of a waste picker cooperative as the key economic agent or the deployment of an integrated system, using four types of water, carried out by peasants entails not only better incomes (in money and species) for its members, but also the recognition of their work as priority socio-environmental actors.

3. Development of innovative knowledge, artifacts, processes and organizational methods in order to deliver technological solutions

The main innovative dynamics, in the first case, were the introduction of waste pickers' knowledge in terms of reconfiguring: the daily waste management by workers from Company X (due to training efforts) and the improvements in the sorting system (changing the treatment of household-like waste flow).

The changes implemented in the processes upgraded the recyclability rate, which is increasingly relevant in the corporate sector's accountability systems, thus proving that the cooperative could provide a better service when it comes to this kind of industrial waste.

With regard to organizational technologies, the multi-stakeholder team itself working in the field was the first significant innovation in Pampa del Zorro. Applying a horizontal decision-making mechanism among heterogeneous actors was the first step that eventually led to a legal peasant association linked with the public school, the local government (the municipality) and the INTA.

In the matter of processes, the collective constructive work (of each technological solution) in groups of eight families had significant results in terms of learning dynamics. At the beginning of the project, families produced and deployed one water system every five days, and four months later families built up two household solutions every three days. In this respect, the integration of final users in the production of solutions had a significant impact in participatory dynamics but also, in efficiency metrics.

As regards artifacts, the innovation was made in the integration of particular technologies in terms of water and sanitation systems, from the upgrading of roofs to enhance rainwater harvesting in home cisterns to the integration of greywater as bio-digester fuel and the introduction of prickly pear plantations.

In a complementary analytical level, we are now in a position to recover the main questions addressed by this paper.

Question 1: How is it possible to develop technological solutions to social and environmental problems, fostering the strengths of these approaches and minimizing the unwanted effects?

Empirical analysis shows that co-design activities are broader than the production of new equipment or final goods. In practice, the generation of local development entails the design of a comprehensive system, including artifacts, naturally, but also processes and organizational technologies.

Co-designing does not begin with finding solutions; in fact, it is initially addressed by defining the problem-agenda. How and who defines the problems to be solved is a key aspect in the resolution of actual inclusive and sustainable issues. Avoiding ex-ante solutions allows for the integration of a new concept in practice: in both cases, the notion of CE is integrated in the problem-solution dynamics, performing new ways of understanding materiality, technological options and desirable outcomes. Moreover, the definition of problems in multi-stakeholder dynamics puts the meaning of allocation of actions, knowledge and imaginaries into practice. In this sense, the daily activities (involving knowledge and capabilities) of waste picker cooperatives and peasant organizations gain momentum in terms of a new development paradigm: circular economy.

As a learning field, the initial generation of a multi-stakeholder team requires explicit and planned out actions implemented by a core team. In the cases that have been analyzed, the core team constituted of researchers, but the clue here is not the people involved, but the epistemic position in terms of avoiding universal and unique problems and fostering community participation towards the identification and resolution of their own critical situations.

Question 2: How can non-traditional units of production and consumption (such as worker cooperatives, grassroots social organizations and peasant organizations) be integrated?

In the first case, the Reciclando Sueños worker cooperative managed to increase recyclability levels and improve efficiency in material recovery processes, through a proposal not based solely on profit maximization, but also on the idea that new productive processes to treat recyclable (but not recycled) materials are the source of employment and income for actors who had always been excluded from conceptual and policy frameworks.

In the second case (that of the peasants from Pampa del Zorro), the non-mercantile production system—aimed at generating and supplying the resources necessary for the reproduction of human life in decent conditions and based on criteria of efficiency and the preservation of nature—is a clear example of how CE can go beyond a simple business-centric view.

In both cases, the key element of success was the generation of a horizontal decision-making process where people could choose among a variety of technological options, make use of these technologies by themselves and, throughout the construction, use and repairing process, learn how to make incremental innovations to solve new problems.

Question 3: How could these new development strategies based on CE principles and bottom-up, collaborative and innovative practices be nurtured, not only through the proposal to reconvert existing processes, but also through the initial design of techno-productive systems?

In the first case, the simplest solution was to include the cooperative as a beneficiary of a CER strategy by taking a marginal place in the production process of Company X. However, as a result of the negotiations that were carried out, the entire waste management process of Company X was modified, integrating the cooperative as a formal supplier. In this sense, the solution implied a systemic change for all the actors involved.

In the case of Pampa del Zorro, the easiest option would have been to make the cisterns with hired labor. However, that would have eliminated the dynamics of community integration, social learning and innovation (of product and process) that produce the collaborative dynamics of problem-solution co-design. The main learning here is that CE principles were put into action through the implementation of systemic solutions based on the definition of heterogeneous problems.

The integration of CE principles in terms of inclusive development dynamics requires the design of a system, not of isolated technologies.

We summarized the discussion in Table 1. We think it can be useful in the re-application of similar initiatives oriented to integrate CE principles in terms of inclusive development (see Table 1).

Table 1. Summarized learnings from discussion. Source: own elaboration.

-	Co-Design Strategies	Bottom-Up Processes	Innovative Dynamics
Question 1	Foster: co-design of the problem agenda. Avoid: ex-ante solutions.	Foster: bottom-up processes need planned actions. A key step is to develop proactive teamwork. Avoid: naïve conceptions of self-organization. Bottom-up processes are dynamic: different actions are required during each process.	Foster: enhance participation in the research and development activities. Avoid: traditional metrics as profit. Instead, use a combination of economic, social and environmental metrics.
Question 2	Foster: enhance the conceptual scope, gaining flexibility. Co-design involves deployment actions. Avoid: non-reflexivity actions. Researcher is part of the multi-stakeholder team.	Foster: create horizontal decision-making mechanisms. Avoid: oversimplification in terms of generic problems. Each social group has different perceptions of the actual problem.	Foster: integration of non-traditional production units in terms of production cycles (of commodity and non-commodity goods). Avoid: palliative (or pro-poor) solutions.
Question 3	Foster: system co-design (integrating artifacts, processes and methods of organization). This is an opportunity to include CE principles. Avoid: co-design only artifacts.	Foster: generation of new material facts, from infrastructure to alternative metrics, associated with narratives of change (as CE). Avoid: universal definitions not related to actual productive practices.	Foster: deployment of integrated system, taking into account that CE is regenerative and restorative by design. Avoid: solutions based on isolated artifacts.

5. Conclusions

Throughout this paper, we have analyzed how circular economy principles can be reinforced when they are integrated in bottom-up, collaborative and innovative dynamics. Both technological systems connected actors, actions and artifacts that proved much more heterogeneous and diverse than what the mainstream definition of circular economy would have entailed.

CE as a concept derived from the experience in developed countries is still very strong, and very few analyses challenge it through emerging processes from the Global South: CE, in terms of innovation, would appear to be restricted to the area of industrial productive processes oriented towards maximizing a profit rate. According to that system, the place for cooperatives and grassroots movements within the model is still marginal, but these cases show alternatives which expand on and reinforce the implementation of CE strategies for inclusive sustainable development.

An expansion of the CE concept which diversifies the favored actors (companies, cooperatives, social organizations, universities, local governments) and provides new rationales to organize actions (mercantile, non-mercantile, job creation) and their insertion in inclusive development strategies integrating the two-fold dimension of social inclusion and environmental sustainability will make it possible to shed light on the work being done outside traditional spaces, with actors on the ground, tangibly striving to find technological and social alternatives for the construction of possible life paths.

We have tried to show that CE holds great potential in terms of its contribution to the generation of new interpretive frameworks associated with local and inclusive development strategies. Based on the idea of thinking beyond the traditional production unit (the factory, in any of its legal varieties), it is possible to think of social development avenues for vulnerable populations, where the circular rationale builds mechanisms capable of maximizing (inasmuch as they do not follow a linear rationality) the transformative potential of the resources (including those understood as waste) presented in actual techno-economic matrices.

Finally, we want to stress that there is still a lot of research work (in the near future) to be done to create an inclusive CE. Particularly, issues related to economic informality, technological change and employment, global trade implications for actual CE activities at the bottom of the pyramid, among others, are significant to understand how CE will soon change social and economic relations on a global scale. In this paper, we have tried to move one step forward in the direction towards a better comprehension of the capabilities and opportunities generated by an inclusive circular economy.

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