Deliverable 3.1

BRAZIL

Analysis of the perceived benefits of the Circular Economy in Brazil

Project: Assessment of the current status of the Circular Economy for developing a Roadmap for Brazil, Chile, Mexico and Uruguay

RFP/UNIDO/7000003530

May 2020

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Acronyms

ANP	National Agency of Petroleum, Natural Gas and Biofuels
ABDI	Agência Brasileira de Desenvolvimento Industrial
CNI	National Confederation of Industry
CE	Circular Economy
C2C	Cradle to Cradle
CDR	Fuels derived from waste
Embrapa	Empresa Brasileira de Pesquisa Agropecuária
EMF	Ellen MacArthur Foundation
EPE	Energy Research Office
GDP	Gross Domestic Production
GHG	Greenhouse Gases
IBGE	Brazilian Institute of Geography and Statistics
LCA	Life Cycle Assessment
NDC	Nationally Determined Contribution
PNRS	National Solid Waste Policy
PTI	Parque Tecnológico Itaipu
R&D+I	Research, Development and Innovation
SDG	Sustainable Development Goals
SME	Small and Medium Enterprises
SIRENE	Sistema Nacional de Registro de Emissões
SNIS	National Sanitation Information System
SINIR	National Solid Waste Management Information System
PMR	Partnership for Market Readiness
FINEP	Financiadora de Estudos e Projetos
NDC	Nationally Determined Contribution
MCTIC	Ministry of Science, Technology, Innovations and Communications
MDR	Ministry of Regional Development
MME	Ministry of Mines and Energy
PACTI	Science, Technology and Innovation Action Plan
PNDR	National Policy for Regional Development

PNA	National Adaptation Plan
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

1. Introduction

This report presents the results of Deliverable 3.1 of the CTCN technical assistance: Assessment of the current status of the Circular Economy for developing a Roadmap for Brazil, Chile, Mexico and Uruguay RFP/UNIDO/7000003530 with as objective describing the perceived benefits the circular economy could potentially generate for Brazil.

In order to serve as input for the development of a general circular economy roadmap to the implementation of circular economy in Brazil, this report assesses the benefits recognized in the circular economy by the different key players in Brazil based on the information gathered from actors that have participated in the survey and interviews from Output 2 (2.4 Evaluation Report), complemented by a desk research assessing relevant data about the national context, specially to understand the legal definition in Brazil for the differentiation between the concept of 'waste' and products that still have useful life and value.

This work also presents an assessment on the potential benefits that circular economy value chains may present to the implementation of the Nationally Determined Contributions (NDC) to climate change mitigation and adaptation as well as to the contribution to the Sustainable Development Goals (SDG) of 2030 Agenda in Brazil. A summary table shows the most relevant sectors that impacts in country's GDP, employment, GHG emission and related SDGs and NDCs for climate change mitigation and adaptation.

Thereafter, a systematization of the general economic, social and environmental benefits of the circular economy is done based on inputs from each group of actors namely, (1) government/public sector, (2) companies/private sector, (3) civil society organizations, (4) academia, (5) entrepreneurs and (6) non-profit organizations. This analysis takes into consideration the general aspects for implementation of a circular economy at the national level, obtaining a broader understanding of the many potential areas of impact to build circular economy value chains in the country.

Finally, a framework to assess CE value chains in the country is proposed, mapping economic activities established that might be most impacted by a circular economy, namely: (a) manufacturing; (b) agriculture and food; (c) natural resources (mining, forestry and fisheries); (d) construction, transport, logistics and retail; (e) IT and smart city; and (f) energy; and the potential products, sub-products and materials with potential value to integrate the circular economy material biological and technical cycles in Brazil.

2. Baseline for the assessment of the benefits of implementing a circular economy in Brazil

This section presents in general terms the information that will be the baseline for the assessment of the benefits of implementing a circular economy in Brazil.

2.1. The circular economy principles

The following circular economy principles are the basis of which the assessment of the benefits to CE value chains in Brazil were examined. It is hoped that the consideration of these principles will allow a clearer understanding for the analysis developed in this report.

Principle 1 – Design out of waste and pollution: This CE principle states that the design phase is essential to determine the environmental impacts of products and services. Therefore, to avoid design failures such as waste and pollution it is necessary to design products, services and business models that allow the recirculation of healthy materials (i.e. materials that have no potential hazard to the health of people or the life of any species) in infinite cycles in the economy, and designed to positively impact the environment. This principle involves innovating in materials and incorporating design strategies such as design for modularity and disassembly, and design principles such as those enacted by the Cradle to Cradle®[1] design and Biomimicry[2].

Principle 2 – Keep products and materials in use: This CE principle proposes stop wasting our resources by keeping products and materials circulating in the economy without ending up in landfills. For this, products and components must be designed so that they can be reused, repaired and remanufactured. For products such as food or packaging, we must create effective systems to recover materials and re-incorporate them into value chains. In addition, an important concept in this principle is the "power of the inner cycle", that means that it is more cost-effective to extend the life of a product than to recycle the materials that will be incorporated into the value chain after use.

Principle 3 – Regenerate natural systems: This CE principle, in addition to protecting the environment, proposes to actively improve it. Instead of trying to do less harm to the environment, circular economy value chains have the goal of enhancing ecosystems services by ensuring natural resources regeneration. By returning valuable nutrients to soil, water and air natural purification and biodiversity improvement and regeneration.

Unintended effects by the circular economy transition

The goal of circular economy is to reduce and change the manner of use of natural resources and support regenerative environmental effects. In practice, however, business innovations are not yet focused on increasing the circularity of materials and improving ecosystems services capacity of their surrounding environment and therefore

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[1] https://www.ideiacircular.com/o-que-e-cradle-to-cradle/ Cradle to Cradle ou C2C em inglês quer dizer 'do berço ao berço'. Essa expressão foi título de um livro-manifesto publicado em 2002 pelo arquiteto americano William McDonough e pelo engenheiro químico alemão Michael Braungart, que veio a se tornar uma das obras mais influentes do pensamento ecológico mundial. (No Brasil, o livro foi publicado em 2014 pela editora Gustavo Gilli, com o título Cradle to Cradle – Criar e reciclar ilimitadamente).

[2] https://biomimicry.org/what-is-biomimicry/ A biomimética é uma prática que aprende e imita as estratégias encontradas na natureza para solucionar os desafios do design humano - e encontrar esperança ao longo do caminho.

may not necessarily deliver the desired effect. In short, before deploying new technologies and socio-institutional innovations, it is important to check for systemic harmful unintended effects within potentially positive circular economy models, for example:

- Circular economy processes that are not supported by clean renewable energy sources may led to more GHG emission;
- Chemical recycling of plastics may intensify the extraction of non-renewable fossil resources;
- Product-service business models may facilitate the access to non-environmentally friendly products, like intensifying more rides in fossil-fuel cars through car-sharing systems.
- Recovering materials from a discarded product in many cases requires large amounts of energy accompanied with new or other streams of pollution.
- Mixing materials reduces their quality after recycling and secondary materials cannot be applied again for the same type of product but have only applications for lower quality requirements (also known as "downcycling").

2.2. Circular economy value chains

In Michael Porter's seminal work[3], a manufacturing (or service) value chain is understood as a system, made up of subsystems each with inputs, transformation processes and outputs that involve the acquisition and consumption of resources – money, labour, materials, equipment, buildings, land, administration and management. A value chain is made up of players collaborating in activities carried out to satisfy market demands for specific products or services. Rather like Michael Porter's value chain for transforming raw materials into finished goods, the Innovation Value Chain[4] aims to improve innovation focus on the process of transforming ideas into commercial outputs as an integrated flow. The first of the three phases in the innovation value chain is: to generate ideas (inside a unit, across units in a company, or outside the firm); to convert ideas (or more specifically, select ideas for funding and developing them into products or practices); and to diffuse those products and practices.

In a Circular Economy value chain, there is need for innovation, not only in the products, but all along many processes of the value chain. Beyond assessing where waste is most prevalent in their value chains and learning how to close the loops to get more from the resources and materials, circular economy is a value-creation driver across the value chain. The CE transition should not be thought of as a recycling or green program, instead, it requires top-down management and change across a company[5], not just being incremental, the circular economy elements of innovation profoundly challenges the way a value chain operates.

[3] Porter, Michael E., "Competitive Advantage". 1985. The Free Press. New York.
[4] Hansen, Morten & Birkinshaw, Julian. (2007). The Innovation Value Chain. Harvard business review. 85. 121-30, 142.
[5] https://www.mckinsey.com/business-functions/sustainability/our-insights/why-the-circular-economy-is-all-about-retaining-value

Strategies for materials and products management has to be acknowledged in every value chain, influencing product design and business models. Different circular economic practices can be applied[6]. Lifetime extension practices are the next option that obtains the most value of products for a longer period. Other practices for maintaining and upgrading products are ways to keep its value for longer with less use of new resources as well. Recycling of technical materials is the last alternative to recover materials' value as inputs back to the industry and avoid leaking to ecosystems, and cascading[7] practices recovers the value of bio-based materials, which changes its quality naturally over time. Energy recovery from production processes, and specially from renewable materials, makes a lot of sense to circular economy value chains, but incineration of non-renewable materials is not considered a circular economy activity because it means materials are "destroyed" or significantly modified to no longer be available to apply as suitable raw material component in products.

2.3. Transition towards a circular economy

In a circular economy, the materials recycled from a discarded product ideally retain their original quality, more specifically, their original economic value and physical characteristics, so that they can be applied again in a similar product. As a result, no additional natural resources are needed to produce materials, and discarded products no longer become waste. Ideal circular economy value chains, that keep materials in the loop for all products, are not yet in place or deemed feasible. So, today's value chains innovations should be aware of their critical role in the transition towards a more circular economy.

In many ways, socio-institutional change may be at the forefront of CE innovation, relying on simply adapting or improving existing technology, for example in the case of organic urban waste composting, agri-ecological food production, short supply chains and local production networks systems. And even when the emergence of a new technology is central to CE innovation, a socio-institutional change has a complementary role to give the new technology a place in society, for example in the introduction of new bio-based materials, and through industry 4.0 systems like asset-sharing platforms, take-back systems and 3D printing factories. Fundamentally, the aim behind a transition towards a CE innovation is change from a linear to a more circular application and use of all resources.

In general, recycling in products does not need substantial socio-institutional changes in the form of revisions to rules, customs and beliefs, but when aiming at innovation towards higher levels of circularity in value chains a great effort in socio-institutional change is needed and this is facilitated by enabling technologies[8]. A transition strategy to implement circular value chains relies on socio-institutional changes together with incremental innovation in products, information and technological systems to enable the connection of service providers and users for purchasing the service of products.

[6] https://www.ellenmacarthurfoundation.org/explore/the-circular-economy-in-detail
[7] https://www.ceguide.org/Strategies-and-examples/Dispose/Cascading
[8] Potting, J., et. al. Circular economy: Measuring innovation in the product chain English translation of the report 'Circulaire economie: Innovatie meten in de keten' © PBL Netherlands Environmental Assessment Agency The Hague, 2017

3. Benefits of implementing a circular economy in Brazil

In this section the analysis of the potential benefits and recognized value of the circular economy in the Brazilian context, shared by the key interviewed actors is presented. This analysis takes into consideration the general aspects for the implementation of a circular economy at the national level, considering the stage of adoption, getting a broader understanding of the many potential areas of impact, to build circular economy value chains in the country. A systematization of the general economic, social and environmental benefits of the circular economy is done based on inputs from each group of actors namely, (1) government/public sector, (2) companies/private sector, (3) civil society organizations, (4) academia, (5) entrepreneurs and (6) non-profit organizations, which provided feedback in an extensive survey performed as input for Deliverable 2.4.

3.1. Potential economic benefits at the national level

CE as an enabler for a new business outlook

In Brazil, most investments are made to improve efficiency in the use of resources within the boundaries of the companies. Brazilian companies are facing the challenge of having to envision long-term benefits through the development of a strong market for second use cycle materials to substitute with the use of raw material. By adopting the circular economy approach, this will enable them to start looking for effectiveness and efficiency in the whole supply or value chain. The circular economy model is related to the whole chain and cycle of resources management; therefore, it can improve business perspective to increase competitiveness, market differentiation while reaching compliance, and lowering risks relating to regulatory and other operational costs.

Short-term economic benefits to be obtained through resource-efficiency

In general, the interviewees agreed that there is a short-term economic benefit of CE from the potential in efficiency in the use of resources, keeping the most value for longer as possible. By facing this challenge, it is expected that CE may drive the advance in technological modernization of the national industry. Thus, it also could help to reinforce and make tangible the benefits of implementing the Industry 4.0. compatible technological solutions. Besides that, CE business models may increase the access to a broader range of users and consumers while at the same time enables improved logistics control along the supply chain.

Impact of global trends

In the global scale, three main strategic areas of action where the circular economy is highlighted as the most important to deliver benefits in great scale and offering manifold opportunities in the production-consumption systems are: (1) **food**, specially by focusing on a regenerative approach to agriculture and the bio economy; (2) **plastics**, mostly for **packaging and fashion,** especially as a means to address oceans pollution; and (3) **cities**, as the places with the greatest concentration of materials and nutrients, with power to mobilize collaboration between multiple actors[9]. Brazil is part of global supply chains in

[9] https://www.ellenmacarthurfoundation.org/our-work/approach/systemic-initiatives

those areas, which includes many players in this value chain as well as a large consumer market.

CE Principles to R&D and innovation for leapfrogging stages

Research, development and innovation based on CE principles may help the country 'leapfrog' usual 'linear' technologies with CE compatible technological solutions to be deployed directly to activities more in line with sustainable development principles, not just for products and materials, but also for processes and development and management of infrastructures.

CE approach will facilitate the adoption of Industry 4.0 technological solutions

The CE approach is expected to facilitate the adoption of **Industry 4.0** innovative technologies in Brazil to bridge and interconnect the physical, biological and digital dimensions, which may rapidly improve efficiency for the supply chain, by gaining better control over resources, products and materials. By adopting CE, industry is offered an alternative and sustainable long-term vision, with new technological investments needs and different resources risk assessment considerations.

Opportunity to launch industrial symbiosis pilots as part of the CE transition

Pilot projects to explore CE systems may be a good way to accelerate innovation in CE in Brazil. Some experiments in **industrial symbiosis**[10] are already starting and this could change the way industrial parks are organized. Cycling waste materials and substances as resources from one industry to another may demonstrate economic and environment beneficial impacts.

Opportunity to boost Brazil's bioeconomy efforts

Brazil has great potential to boost bioeconomy, exploring new materials and biochemical resources from renewable sources. The circular economy (CE) biological cycle approach could inspire new innovations to create a beneficial synergy between agriculture production areas and ecosystems services regeneration of forests and coastal environments[11],[12]. This could drive innovation in many sectors like the food, textiles, packaging, hygiene, cosmetics or pharmaceutical sectors.

Opportunity for design innovations using biomaterials

Design innovations using biomaterials may create new products that are harmless to the environment and easy to recover. Innovative applications for bio-based materials may also enable the substitution of non-renewable resources to renewable ones from local suppliers, positively impacting short supply chains.

Opportunity for the implementation of response plans to climate change in Brazil

The Technology Needs Assessment - TNA project[13] currently in progress, seeks to map and analyze the technologies necessary for the implementation of response plans to climate change in Brazil, coordinated by the Ministry of Science, Technology, Innovations and

[10] https://www7.fiemg.com.br/produto/economia-circular
[11] https://www.circulardesignguide.com/post/circular-cards
[12] https://www.ellenmacarthurfoundation.org/explore/food-cities-the-circular-economy
[13] http://www.fazenda.gov.br/assuntos/atuacao-internacional/fundo-verde-do-clima/Programa-pais#:~:text=Programa%20Pa%C3%ADs%20do%20Brasil%20para%20o%20GCF&text=O%20documento%20busca%20apresentar%20as,e%20resultem%20em%20impacto%20transformacional.

Communications - MCTIC. The Circular Economy and Industry 4.0 may be field studies to be recognized as available sectors and technologies, as well as to develop Technological Action Plans for the implementation considered to be priorities.

Brazil's energy matrix to gain from 'regenerative' bio-cycling

The Brazilian government is proud of its clean energy matrix and sees many advantages to increase the offer of renewable energy sources for more sustainable production processes and mobility. The country already has much knowledge and built capacity on biofuels technologies and is advancing studies for the creation of a national carbon market within the Partnership for Market Readiness (PMR) initiative[14],[15]. Through a CE perspective, biological sources may come not just from agriculture biomass but other abundant sources of urban and industrial organic waste. Technologies for the production of renewable energy may gain from the 'regenerative' bio cycling approach to a more sustainable supply of biological resources for biofuels.

[14] http://repositorio.ipea.gov.br/bitstream/11058/9583/1/PMR%20Brazil%20project_perspectives%20on%20the%20brazilian%20emission%20reductions%20market.pdf
[15] https://www.thepmr.org/country/brazil-0

Table 1: Potential economic benefits* of the circular economy to Brazil

Source: own ellaboration

- Keeping the value of products for longer time may support resilience in national macro and micro economic levels;
- CE efficiency in the use of resources by keeping most value for longer periods has also impacts to increase economic gains;
- CE approach in EU's strategic plan "Green New Deal" challenges the companies that integrates global supply chains, thus also in Brazil;
- Brazil has a diverse and fertile context to experimentation and can deliver CE business cases that can also impact abroad;
- CE can drive advancements in technological modernization and help to reinforce the Ind. 4.0 potential benefits for national industry;
- By the idea of "GHG cycling" CE brings a new perspective regarding climate change mitigation for the industrial and agriculture sectors;
- CE approach can help develop business strategies for GHG's reduction related to production and consumption.
- Take advantage in this global newborn market of bioeconomy and country's developments in this field, and boost the adoption of biomaterials by the industry;
- Favor product and business model innovation in specific sectors: textile, paper and cellulose, packaging, cleaning, agriculture and biochemical industry;
- Demonstrating the energy - food - soil nexus through nutrients circulation is an expected promise to deliver value to agriculture.
- CE approach can prepare and guide the changes in civil construction supply chains for more sustainable patterns;
- CE approach can pull improvements in transportation and logistics efficiency through new technologies in CE business models;
- CE offers a new business perspective to companies to gain competitiveness, gain market differentiation, reach compliance and lower risks in resources, regulation and costs;
- CE helps develop efficiency in the whole supply chain and improve the long-term vision of benefits;
- Projects on CE put different departments inside companies to work together;
- CE has the potential to communicate sustainability issues related to products in a positive way and easier to understand;
- CE may enhance the "sustainability profile" thus consolidate this profile for all productive sectors, so Brazilian products gain a differential and competitive advantage;
- Packaging, textiles and household appliances are possibly main areas that CE product service can deliver business opportunities;
- CE may be the basis for the agreements in waste management for electro-electronic products.
- CE product-service systems may push the development of 4.0 embedded technology in products;
- CE for food, energy and nutrient cycling, explores the potential of cross-sector integration of agriculture systems;
- To bring up CE innovation, multi-sectorial collaboration between organizations and companies should increase;
- CE is positioned as a drive to guide the efforts regarding Industry 4.0 technologies and processes and regarding resources management and recovery;
- CE push advances in Industry 4.0 to the growing need of data and information management;
- CE can enable the creation of a market for 2nd cycle materials for replacing virgin materials;
- CE may drive the commitment to changes in industry especially regarding global concerns like for plastics, food and textiles production;
- To evaluate CE products and processes, the country can take advantage from advances in Life Cycle Assessment national databases and software available;

* These statements were extracted from the survey, showing benefits that can be indirectly associated with economic issues.

3.2. Potential environmental benefits at the national level

A positive trend to reduce extraction of natural resources and limit pollution

Currently, most of the initiatives in the country are looking for improvements in waste reduction and reverse logistics. A lot of potential benefits for electronics, paper and cellulose, textile and cement value chains are observed to be gained from the development of CE models. Also, packaging and steel are mentioned as sectors that are making some important steps. Changes in the way the industry designs products are underway and CE approach is starting to be adopted in the textile industry and soon may get to civil construction sector. The design approach of the CE has significant impact on value chains by keeping the product market value for longer time while reducing extraction and pollution of ecosystems as well as improving resilience at macro and micro economic levels.

Positive effects of the CE on the reduction of GHG emission and support SDGs

Having the circular economy implementation in alignment with the national Bioeconomy Action Plan and the climate change governmental initiatives, may be also key to reach the SDGs to contribute to water security and conservation and sustainable use of land and underwater biodiversity, particularly concerning protected areas. The implementation of CE value chain in Urban territories can also contribute with key issues of SDGs for social equity and responsible use of materials and products, which may impact to the development of sustainable patterns in cities, as well as impacting for climate change adaptation of more than 85% of the Brazilian population, as is mentioned in the NDC. In addition, Energy supply systems sustained from bio-based resources main greatly impact in climate change mitigation and natural ecosystems conservation and CE approach can be a driver for a change in production and consumption patterns contributing to reduce GHG emission and positively impacting on many SDGs related to more sustainable innovations as well in more responsible consumption and production, and protecting land and water resources.

CE can help bring about many environmental benefits through adoption of biomaterials

The CE in Brazil has the potential to also boost the adoption of biomaterials and bring benefits in many environmental dimensions like remediation of contaminated soil and water management. Also, within the biological cycle, are the initiatives around small-scale and urban food production, agri-ecology systems that support ecosystems and value creation through preserving biodiversity with social development.

CE as means to understand the importance of ecosystem services

CE approach helps understanding the importance of ecosystems services – water, air, soil and biodiversity – to increase the country's economic resiliency, to find alternatives to deliver social improvements while protecting endangered natural environments. The 'regenerative' approach of the biological cycle to create circular economy value chains may be key to trigger change in the short-term and make it sustainable in the long term.

CE approach is suitable for urban planning and better management of resources

The wellbeing in urban areas is related to the development of more sustainable production and consumption patterns including urban waste management systems. The CE approach where products and materials are not wasted, besides supplying recovered materials for industry, may help Brazilian cities to build a more interlinked beneficial relationships of urban resources management with urban systems like energy and water supply, sewage treatment and food production.

Table 2 - Perception of Environmental benefits* of the circular economy to Brazil

Source: own ellaboration

- CE can create an engagement of communities by influencing in the perception of the relation between materials and environmental issues;
- Applying CE approach to redesign products also impacts the reduction in raw material extraction and in ecosystems pollution;
- Designing products with healthier and safer materials for people and nature, industry can avoid toxic substances, protect workers, the environment, and public health in general;
- Expanding the country's energy matrix towards renewable energy is essential to make every circular economy system more environmental responsible;
- CE approach may improve the environmental benefits of biofuels on the mitigation of climate change;
- CE can push great advances to the energy matrix as a competitive differential for agriculture;
- The viability of sustainable CE value chains will support the increase of energy supply from renewable resources with clean processes;
- Implementation of CE regenerative approach to more sustainable agriculture and food production and supply chain;
- Deployment of the CE systems like integrating food, energy and nutrient cycling is seen as a field that has a huge potential in Brazil;
- CE models can recover the greatest concentration of materials and nutrients located in cities;
- Industry and startups can take advantage from CE international calls for funding innovations;
- CE is a new approach that engages more industries in materials management, which has beneficial impacts to environment;
- CE systems using green chemistry creates innovative materials and production processes that generates "negative emissions" using GHGs as a resource.

* These statements were extracted from the survey, showing benefits that can be indirectly associated with environmental issues.

3.3. Potential social benefits at the national level

National Solid Waste Policy as economic and social development tool

In the case of Brazil, for a decade it has had a National Solid Waste Policy implemented through Law 12.305 / 2010. This regulation establishes that waste management must be used as **an economic and social development tool** for the country, the law recognizes the potential that management of **waste as a resource** has to generate employment and go hand-in-hand with social fairness needs.

CE applied in urban development

By understanding the CE in urban development, Brazilian cities can leapfrog the current 'linear' technologies and infrastructures and get directly to more sustainable solutions and services and thus, obtain more social benefits, for all. If buildings and facilities are to be built based on circular economy design principles this will lead to significant efficiency improvements to construction, renovation and upgrade. So, expanding the access to good quality housing, schools and public spaces, with great recoverability of the building materials after their use cycle is a positive direction stimulated by CE.

CE solutions applied to sanitation needs

Sanitation through sewage treatment plants turned into nutrient recycling facilities is one important way to deliver social impacts through CE approach, bringing manifold benefits, such as creation of new jobs, overall improvements to health, food, water and air quality.

CE systems to increase job creation through labour intensive services

The Brazilian social context may be interesting for setting up commercial CE systems for product reuse, refurbishment and redistribution. New business models that support the circular economy, such as product-service, product sharing models, dematerialization, etc. are also important to Brazil, as this could also increase the rate of job creation through labour intensive services related to the CE [16,17].

CE as means to increase access to quality products and services

Product-service systems and shared business models on CE may also improve access to better quality products (including home) for a broader range of people in cities, increasing the access to basic products and services for low income families. Embedded technology for tracking products may also improve efficiency and costs in public transportation and logistics efficiency in cities.

Gender equality considered a 'must be' for the CE transition

For some key actors interviewed, gender equality is a 'must be' for any development approach and CE is one of them. Although CE approach is not directly linked with the gender equality agenda, it is part of a movement for change, so it may favor the debate on issues also related to this topic. As an example, the ERA-MIN 2 international consortium that invested in Brazil approximately 750 thousand Euros to support CE innovation in mining sector, has specific criteria for gender equality in the process.

CE may contribute to engage more women and address gender equality

The EC is directly linked to recycling activities, in which women are around 70% of the workers and thus, impacts to women empowerment in poor communities. The EC will also contribute to gender equality by the involvement of female entrepreneurship, observed with the actors who responded to the research in this work.

CE could help strengthen women's leadership position

The urban waste management policy in Brazil has intended consequences like formalization, job creation, value of waste, innovation and energy that may indirectly affect gender equality. The country has roughly 1200 associations and cooperatives working with waste management in 827 municipalities, more than 27,000 workers in recycling cooperatives, and around 70% of them are woman. So, CE could strengthen women's leadership with a gender approach to women who, although part of the Brazilian workforce, mostly are not represented in positions of power.

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[16] https://www.wrap.org.uk/sites/files/wrap/Employment%20and%20the%20circular%20economy%20summary.pdf
[17] https://www.iisd.org/sites/default/files/publications/employment-effects-circular-economy.pdf

CE deemed as a "fresh perspective" with different values and female leadership

Many women are leading the CE globally, like Ellen MacArthur. In COP25 many of the global leaders in CE were women. In Brazil, many circular economy leaders are women, like in the Ellen Macarthur Foundation LatAm office, Ideia Circular, and Exchange 4 Change. The strong presence of women in CE all over the world may bring a "fresh perspective" for the CE exactly because woman have mostly been outsiders to the linear economic systems.

Table 3 - Perception of social benefits* of the circular economy to Brazil

Source: own ellaboration

- The CE biological cycle 'regenerative' approach may indirectly improve health and food nutrition while supporting the environment.
- CE systems for cycling biological nutrients can improve sewage treatment with potential impacts on public health, food, water and air quality.
- Understanding the different roles of resource management stakeholders – including informal activities – and coordinating the cooperation between them, can help improve work conditions and wages in cities.
- In general, the CE influences new business models towards sustainability and social inclusion.
- By putting market value to residues, the CE can deliver social benefits and improve job conditions.
- CE in cities can lead the pathway for circular economy implementation in Brazil, to mobilize great collaboration between many actors from commerce, government, academy and civil society for change;
- CE commercial systems for product reuse, refurbishment and sharing can gain fast adoption in Brazilian socio-cultural context;
- Food and cities have a powerful relation, and there are a number of CE global projects starting in for this purpose;
- CE can positively impact in key issues like sanitation, water value perception, water systems innovation, sewage treatment to nutrient recycling, etc.;
- The EC is directly linked to recycling activities, in which women are around 70% of the workers and thus, impacts to women empowerment in poor communities.
- The EC will also contribute to gender equality by the involvement of female entrepreneurship, observed with the actors who responded to the research in this work.

* These statements were extracted from the survey, showing benefits that can be indirectly associated with social issues.

4. Potential contribution of a Circular Economy to the implementation of NDC and SDG in Brazil

Examples where the CE demonstrates its potential to deliver beneficial social impacts are important in the Brazilian context. Here are the main considerations perceived about the positive relations between the implementation of a Circular Economy to Brazil's Nationally Determined Contribution (NDC) and the Sustainable Development Goals (SDGs) towards achieving 2030 agenda.

4.1. Economic activities in Brazil and its impacts to GHG emissions

Brazil committed to reduce greenhouse gas emissions by 37% below 2005 levels in 2025 and reduce greenhouse gas emissions by 43% below 2005 levels in 2030[18]. According to GHG emission data provided by the SIRENE – National Emissions Registration System[19], in the 5ed Estimative (2018) CO2 Equivalent GWP 1995 (Gg) for the year 2016 Brazil accounted for 1,305.6 million ton of CO_2eq[20]. The energy sector and agriculture and livestock account for almost two-thirds of all emissions. Land-Use change and Forestry activities account for almost a quarter of total emission. Industrial processes and waste treatment together are estimated to contribute only to 12% of total emissions.

In Brazil, climatic risks main threats to development are extreme weather events, temperature increase, excess and scarcity of rainfall, and sea level rise. Therefore, the main vulnerable sectors to climate change are agricultural production and water supply scarcity for consumption, irrigation, and electricity generation. Also, the loss of biodiversity and increase in incidence of tropical diseases are important concerns, especially in this global context concerning pandemics. Table 1. Summary the economic activities that most contribute to Brazil's total annual (2016 estimative) GHG emissions of CO2e GWP 1995 (Gg).

Table 4 - GHG emission data provided by the SIRENE – National Emissions Registration System

Source: Digital book - Anual estimative of GHG emission in Brazil (5a. Ed 2020), SIRENE[21]

Sector	energy	agriculture and livestock	change in land use and forestry	industrial processes	waste treatment
Share in total emissions (1,305.6 million ton)	32% (422,498.40)	34% (439,212.80)	22% (290,867.40)	7% (90,106.78)	5% (62,884.40)
Most predominant GHGs emissions	CO_2 (94.6%)	CH_4 (62.5%) N_2O (37.4%)	CO_2 (92,5%)	CO_2 (86.7%)	CH_4 (95.7%)

[18] http://www.itamaraty.gov.br/pt-BR/politica-externa/desenvolvimento-sustentavel-e-meio-ambiente/712-mudanca-no-clima

[19] http://sirene.mctic.gov.br/portal/opencms/paineis/2018/08/24/Emissoes_em_dioxido_de_carbono_equivalente_por_setor.html

[20] https://sirene.mctic.gov.br/portal/export/sites/sirene/backend/galeria/arquivos/2020/06/Livro_Digital_5Ed_Estimativas_Anuais.pdf

[21] https://sirene.mctic.gov.br/portal/export/sites/sirene/backend/galeria/arquivos/2020/06/Livro_Digital_5Ed_Estimativas_Anuais.pdf

Sector	energy	agriculture and livestock	change in land use and forestry	industrial processes	waste treatment
Main source of emissions	burning fuels (mainly by transportation)	enteric fermentation*	change in biomes**	metallurgy and Cement production	solid waste disposal (mainly by anaerobic digestion*** of organic matter in landfills)
	*Enteric fermentation is a natural part of the digestive process in ruminant animals such as cattle, sheep, goats, and buffalo. Microbes in the digestive tract, or rumen, decompose and ferment food, producing methane as a by-product. **A biome is a community of plants and animals that have common characteristics for the environment they exist in. ***Anaerobic digestion, or also biogasification or biomethanation, is a set of processes in which microorganisms degrade biodegradable organic matter in the absence of oxygen gas.				

4.3. Benefits of circular economy in Brazil to the National Determined Contribution (NDC)

Many climate change challenges are related to the linear nature of countries' economy that currently are still, in many ways, reliant on resource extraction, deforestation, the use of fossil fuels for sustaining the economy, and the waste of resources as a consequence of improper design, use and management.

A CE study in 2019 [22] argued that global efforts to tackle GHG mitigation have focused on a transition to renewable energy complemented by energy efficiency, but estimates that 45% of emissions are associated with the production of goods and materials, and thus applying circular economy strategies in five key areas (cement, aluminum, steel, plastics, and food) could eliminate almost half of this remaining emissions from the production of goods in industry.

The CE approach goes beyond the focus on the 'production side' of GHG emissions, and also assesses the impact of socioeconomic practices that create the 'demand side' for GHG emitting technologies in the first place, with great mitigation potential [23]. Specifically, in the food system, using regenerative agriculture practices and designing out waste along the whole value chain can sequester carbon in the soil and avoid emissions related to uneaten food and unused by-products. Recently, some compelling studies have been released on the positive impacts of circular economy to GHG's reduction related to production and consumption activities[24,25,26]. **It is estimated that 67% of global GHG emissions are related to material management and the excessive use of primary**

[22] https://www.ellenmacarthurfoundation.org/assets/downloads/Completing_The_Picture_How_The_Circular_Economy-_Tackles_Climate_Change_V3_26_September.pdf
[23] https://www.circle-economy.com/news/5-opportunities-for-the-circular-economy-to-strengthen-the-paris-agreement
[24] http://www.circle-economy.com/wp-content/uploads/2016/06/ircle-economy-ecofys-2016-implementing-circular-economy-globally-makes-paris-targets-achievable.pdf.pdf https://publish.circle-economy.com/climatechange
[25] https://www2.deloitte.com/content/dam/Deloitte/fi/Documents/risk/Deloitte%20-%20Circular%20economy%20and%20Global%20Warming.pdf
[26] https://www.ellenmacarthurfoundation.org/assets/downloads/Completing_The_Picture_How_The_Circular_Economy-_Tackles_Climate_Change_V3_26_September.pdf

resources, and that the circular economy could deliver emissions reductions to cut by half the existing gap to reach the Paris Agreement commitments[27].

This interface between CE and GHG mitigation efforts is a relatively new field of study, more search will have to be stimulated in Brazil to understand and quantify the specific potential contribution of CE approaches adopted in the various economic sectors of the country and its contribution to GHG reduction or avoidance. In the case of Brazil, the implementation of a CE has the potential to contribute with GHG reductions in the food production related activities plus in changes in production and consumption patterns. Additional reduction in GHG regarding renewable energy production could yet be contribute to the energy sector.

4.4. Contribution of circular economy in Brazil to the Sustainable Development Goals (SDG)

The UN 2030 Agenda is improving the adherence of circular economy implementation as an important element towards an economic development that supports the socio-environmental conditions by tackling the issues related to sustainable production and consumption. The circular economy potential benefits to economic, environment and social development presented in this work relate or respond to several of the Sustainable Development Goals outlined in the 2030 Agenda.

The circular economy has a transversal role to sustainable development and may be a mean to reach many of the SDGs. From this assessment in Brazil it was possible to recognize some general contributions of the circular economy to the SDGs 2, 3, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15 and 17.

In bellow, highlights of the beneficial impact of the Circular Economy model to some of the Sustainable Development Goals of the UN 2030 Agenda are described:

- The CE model imposes a change in patterns in the use of materials and the commercialization of products towards a more responsible consumption and production (SDG 12) and pushing forward industry innovation and infrastructure (SDG 9).
- In addition, the circular economy's "regenerative" approach to production-consumption systems in the management of biological resources, water, food and renewable sources for energy shows great potential to deliver benefits that may contribute for Climate Change (SDG 13) and also for expanding affordable clean energy supply (SDG 7)[28].
- The circular economy applied to agriculture offers new options for improvement of food production in heathier and more ecologic systems (SDG2), which may improve food quality in support of good health and wellbeing (SDG 3) for people.
- The CE may also increase communities' access to sewage treatment by turning it into nutrient recycling systems with positive impacts in the environment, with potential impacts on clean water and sanitation (SDG 6).

[27] https://www.circle-economy.com/news/policy-brief-on-circular-economy-and-climate
[28] https://sustainabledevelopment.un.org/post2015/transformingourworld

- The CE management systems for materials have positive impacts on job formalization, employment and business models innovation that may create more decent work and economic growth (SDG 8).

Circular Economy's holistic approach for business embraces women leadership, also contributing to gender equality (SDG 5).

By applying the CE approach in product design, by using healthy and safe materials to people and the environment, producers can improve workers and consumer's health, while protecting the ecosystems, by avoiding risks related to toxicity to life on land (SDG 15) and below water (SDG 14).

Efforts to disseminate the circular economy principles through education and design have also the potential to change the general mindset. By communicating the CE principles and improve the way resource sustainability is perceived, influencing new cultural behavior (dealing with waste as a valuable resource), thus accelerating change towards more sustainable cities and communities (SDG11).

Measuring and communicating CE benefits is critical to engage consumers, to influence the government, guide the industry and pull value chain collaboration and partnerships towards the SDGs (SDG17).

Table 5 - Summary of sectors and GDP, employment, GHG emissions and related SDGs in Brazil

Source: own ellaboration

	% in GDP	% in employment	% in GHG emission	Main related SDGS	Main related Benefits
Service sector	63%	70,3%	-	SDG 8, 11, 12	adaptation policies for housing, basic infrastructure for health, sanitation and transportation
Industrial sector	18,4%	20,4%	7,0%	SDG 5, 6, 8, 9, 11, 12	material management and efficient use of primary resources
Agriculture and livestock	4%	9,3%	31,3%	SDG 2, 3, 13, 14, 15	low carbon and resilient agriculture
Energy sector	-	-	32,8%	SDG 7, 9, 11, 12, 13	biofuels, increase renewable and clean energy participation in the energy matrix
change in land use and forestry	-	-	24,3%	SDG 13, 14, 15	forest monitoring, restoration and reforestation, and management of protected areas
Waste management	-	-	4,6%	SDG 3, 6, 9, 11, 12	material management and efficient use of primary resources

5. Waste management potential for a circular economy in Brazil

Through a literature review a general indication is presented of how the materials at the end of use – waste and the products or by-products – that still have useful life and value are managed in the country. Also, a general understanding about the current legal definition for the concept of 'waste' and the regulatory framework for management of wasted products, goods or material streams that can actually be used for new economic activities is presented. The main goal is to know whether the present waste management regulatory regime is suitable or compatible to facilitate the Circular Economy in Brazil and what circular economy value chains could be implemented in cities, industry and agriculture.

5.1. The National Solid Waste Policy (PNRS)

In Brazil the National Solid Waste Policy (PNRS, Law n°. 12.305) released in 2010 has been mandatory since 2014. It regulates the prevention and reduction in the generation of waste through a set of instruments to increase the recycling and reuse of solid waste (which has an economic value and can be recycled or reused) and the environmentally responsible and appropriate disposal of rejected waste[29].

The PNRS recognizes the market value potential of wasted materials for future use. The law embeds a systems perspective prioritizing the avoidance of the generation of waste, considering the whole product life cycle for supply chain management integration. It also expresses that waste management must be used as a social and economic tool for development in the country. Therefore, the law understands that a solid residue is a good with economic and social value and recognizes its intrinsic potential to create jobs and generate income to promote citizenship. As a principle, the new policy calls for a systemic approach in the search for solutions in the planning and decision-making process of waste management. It states that the design and planning of solid waste management must bring solutions envisioning sustainability, meaning that political, economic, environmental, cultural and social dimensions should be considered at all stages of the solid waste flow.[30]

The Brazilian legislation defines 'solid waste' as *any material, substance or good (solid, liquid or gas) under management, use or ownership that is discarded as a result of human activities and requires a proper destination*. By law, solid waste will be considered rejected only if there is no other means to recover it and put it to a new use by available cost-effective technologies. To this aim, the PNRS established reverse logistics as a legal instrument, characterized by "a set of actions, procedures and means designed to enable the collection and return of solid waste to the business sector, for reuse, in their cycle or in other production cycles, or other environmentally appropriate final destination".

As an instrument of the law, the "Shared Responsibility" principle for product life cycle and reverse logistics includes industry, public administration and consumers to create

[29] https://www.mma.gov.br/cidades-sustentaveis/residuos-solidos/politica-nacional-de-residuos-solidos (assessed in Jan 11th 2020)
[30] Fernandes, AG (2016). CLOSING THE LOOP: THE BENEFITS OF THE CIRCULAR ECONOMY FOR DEVELOPING COUNTRIES AND EMERGING ECONOMIES, Tearfund.

systems of recovering waste products and materials as a social and economic development tool. Therefore, manufacturers, importers, distributors and traders are obliged to establish reverse logistics programs of recyclable and reusable materials, primarily in partnership with recycling cooperatives. To this aim, companies are collaborating to have "sectorial agreements" and municipalities are adopting new regulations and tax schemes to comply with the new law, regarding urban and industrial waste management.[31]

5.2. Shared responsibility and Sectoral Agreements for reverse logistics implementation

The PNRS aims that every recyclable material – Internally or externally to industry – should not be disposed or discarded, but diverted, collected, separated, reprocessed and used as raw materials again in the manufacture of new products. Recycling processes can be in many levels of the supply chain: to the recovery of raw materials and by-products from one industrial process as inputs to another, the recovery of end products or packaging from a waste, and also the process of recovery of basic elements, chemicals or energy from wasted resources. The implementation of reverse logistics allows channels for the return of products to industry or other production cycles as a circular system [32].

The PNRS brought to the Brazilian industry the concept of shared responsibility for the reverse logistics of wasted materials, so companies must offer means for the return of end-of use products and packaging. The principle of shared responsibility establishes that consumers are also responsible for the return of products and packaging to traders and distributors which, in turn must send this back to the manufacturers that takes the responsibility for the materials recovered. To adapt to Brazil's great differences in national regional conditions, the PNRS establishes guidelines for shared responsibility, reverse logistics and other instruments, which may be specified by state and municipal legislation.

Also, the particularities of each production chain require the adaptation for each waste management system, and so this voluntary sectoral agreement has to be established for the creation and expansion of reverse logistics mechanisms throughout the country. The relationship between retail, industry, importer and the role of each actor involved is one of the most important in the sectoral agreements. The industry participants are the manufacturer and importer, the filler or producer of goods, etc. and in commerce the wholesalers, retail chains, small businesses, etc. All these private relationships need to be understood and adapted to establish the reverse flow of packaging and discarded products after end use.

The sectoral agreements negotiation between industry, commerce, service providers, distributors and consumers, aims to avoid fragmentation of waste management practices. This model is complex and challenging, since there are several conflicting interests among the sectors affected. To the efficient recovery of materials, each actor - government, the consumer, the retail and the manufacturing or importing industry - has its own responsibilities.

[31] Fernandes, AG (2016). CLOSING THE LOOP: THE BENEFITS OF THE CIRCULAR ECONOMY FOR DEVELOPING COUNTRIES AND EMERGING ECONOMIES, Tearfund.
[32] CNI – Confederação Nacional da Indústria.Visão da Indústria Brasileira sobre a Gestão de Resíduos Sólidos- Brasília, 2014 https://bucket-gw-cni-static-cms-si.s3.amazonaws.com/media/filer_public/b5/a9/b5a9b960-6caa-48f3-967c-23a228ece3ea/visao_da_industria_brasileira_sobre_a_gestao_dos_residuos_solidos.pdf

5.3. Industrial Waste Management

Regarding solid industrial waste (RSI), Law no. 12,305/2010 (PNRS) foresees obligations for the productive sector to reduce, reuse and recycle, recognizing the economic value of wasted materials and encouraging the integration of industries with the cooperatives of collectors of recycled materials. According to the PNRS, the residues generated in the industry, whose characteristics are similar to the urban solid residues, can be collected by the same kind of waste management services. The management of the RSI has an important relation with the adequate expansion of the economic and social infrastructure of the country.

Different types of waste originate from the industrial activities such as metallurgical, chemical, petrochemical, pulp and paper, food, mining, etc. According to the Conama regulation 313/2002[33], which establishes the National Inventory of Industrial Solid Waste, industrial solid waste is everything that results from industrial activities and that is in the solid, semi-solid, gaseous (when contained) and liquid states, unsuitable for discharge into the public sewage system or into water bodies, or there are no technical or economically viable solutions in view of the best available technology. This includes sludge from water treatment systems and/or generated in pollution control equipment and installations.

Besides the waste from materials like:

- plastics,
- paper,
- wood,
- fibers,
- rubber,
- metal,
- slag,
- glass,
- ceramics,

The industrial waste may also come from other sources like:

- waste from pollution control or decontamination operations,
- adulterated materials,
- materials and substances resulting from activities of remediation of contaminated soil,
- waste from the purification of raw materials and products,
- ashes,
- sludge,
- oils,

[33] http://www2.mma.gov.br/port/conama/legiabre.cfm?codlegi=335

- alkaline,
- acid resins.

The Brazilian environmental legislation for industrial waste treatment requires the elaboration of a waste management plan including identification and classification of the types of industrial waste existing in the company, discrimination of hazardous or non-hazardous waste, listing of recyclable waste and listing of what is the environmentally correct destination for industrial waste. Industrial waste may produce leftovers, often of mixed composition, so an inventory of the types of waste generated with a diagnosis of industrial waste considered hazardous is needed. When not treated properly, such waste causes risks to nature and public health through contamination of the air, soils, rivers and springs, and the emergence of diseases.

In Brazil, several opportunities already identified in the industrial sector can be explored in new business models, design, recovery of materials, and formalization of the existing informal economy. Among them, a) the electrical and electronics sector, b) the civil construction sector, c) the textile sector, and d) the plastic sector [34], [35].

Unfortunately, in the official assessment of industrial waste found in this research [36], neither have nationally consolidated information nor quantitative information of waste generated by industrial typology in the country due to the absence of a national inventory of industrial waste and many state inventories missing, and outdated data or lack of standardization in the presentation of data.

5.4. Data from the solid waste management in Brazil

The National Sanitation Information System (SNIS) is the most robust information system in the country for the sanitation sector. It gathers information on water and sewage services (SNIS-AE), urban solid waste management (SNIS-RS) and rainwater drainage and management (SNIS-AP). The main role of SINIR is to aggregate all the information under Federal, State, and Municipal competence, keeping periodical assessment of the situation of solid waste in the country and making the National Solid Waste Inventory available to public.[37] It covers the institutional, technical-operational, administrative, economic-financial and quality aspects of the services provided. The National Solid Waste Management Information System (SINIR) is an important instrument for evaluation and reformulation of actions for implementing the National Solid Waste Policy (PNRS). It has the necessary infrastructure to assess, consolidate and disseminate qualitative and quantitative data and information on solid waste management.

[34] ELLEN MACARTHUR FOUNDATION. Uma economia circular no Brasil: uma abordagem exploratoria inicial. 2017.

[35] Circular economy: opportunities and challenges for the Brazilian industry / National Confederation of Industry. – Brasilia : CNI, 2018

[36] Instituto de Pesquisa Econômica Aplicada – ipea Diagnóstico dos Resíduos Sólidos Industriais Diagnóstico dos Resíduos Sólidos Industriais 2012. http://www.ipea.gov.br/portal/images/stories/PDFs/relatoriopesquisa/120927_relatorio_residuos_solidos_industriais.pdf

[37] Brasil: *Ministério do Meio Ambiente* https://sinir.gov.br/index.php/component/content/article/2-uncategorised/117-sistema-nacional-de-informacoes-sobre-a-gestao-dos-residuos-solidos-sinir *publicado em Março de 2018, última atualização em Agosto de 2019.*

In the edition of the SINIS – RS report published in 2019, 'Assessment of the Management of Urban Solid Waste for Brazil in 2018' [38], data were collected from 3,468 municipalities (62.3 % of the country's total) with 85.6 % of the Brazilian urban population (151.1 million inhabitants). The assessment was designed for a national, macro-regional and population segment analysis. It aimed at a better understanding of the specificities and peculiarities of the panorama of solid urban waste management in the country. SNIS accounted an amount of 72.2 million tons received in 4,035 processing units in operation across Brazil in 2018, which includes only types of household and public urban waste, including debris, pruning and others. The data that are part of the assessment are of the responsibility of the municipal governments and therefore, the results of this analysis do not consider waste coming from industrial generators.

Some relevant data referred to urban solid waste is presented below:

- Organic solid urban waste generated by cities is basically food and gardening not included paper, textiles, industrial waste, agriculture waste and sewage.
- Solid urban waste generated by cities is considered recyclable is classified in paper, plastic, metals and glass.
- Solid urban waste generated by cities is considered rejected sent to landfill or incineration, when does not fit for recycling nor composting.
- Today, collection services for solid waste covers 98.8% of the urban population and 92.1% of the total population in Brazil.
- Potentially recoverable "dry recyclable materials" are paper, plastic, metal and glass - except organic matter.
- In small Brazilian municipalities (up to 30 thousand inhabitants), there is almost four times greater efficiency in recovering recyclable waste, but only 1/4 of the amount of "dry recyclable materials" of the total collected mass is recovered.

Table 6 - Summary table on urban solid waste data in Brazil.

Source: Own elaboration, based on SINIS-RS Report Assessment in 2018 [39]

Total urban waste collected in the country in 2018	62.78 million tons/yr.	172.0 thousand tons/day	7.37 kg/yr. per capita	0.96 kg/day per capita
Governmental spending on solid waste management in 2018	R$ 22 billion/year (R$130.47/inhabitant)	47.0 % of municipalities charge for waste collection services.	taxes cover only 54.3 % of the waste management costs	333,000 workers employed
Recycling and Composting	1.05 million tons (1.7 %) of recyclable waste recovered in 2018 sent to 1,030 sorting facilities for recycling	124,000 tons of waste sent to 70 composting facilities (around 0,4% of total organic waste collected in 2018)	Around 50 % of total urban waste is organic.	

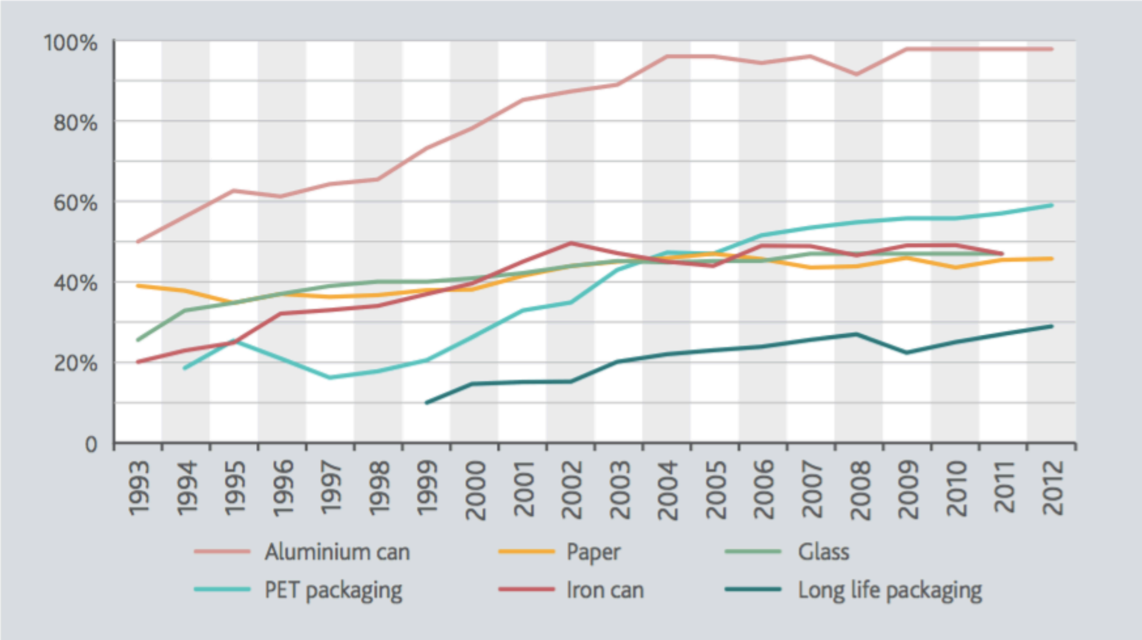
[38] Brasil. Ministério do Desenvolvimento Regional. Secretaria Nacional de Saneamento – SNS. Sistema Nacional de Informações sobre Saneamento: Diagnóstico do Manejo de Resíduos Sólidos Urbanos – 2018. Brasília: SNS/MDR, 2019.
[39] https://www.mma.gov.br/images/agenda_ambiental/residuos/programalixaozero_saibamais.pdf

Selective collection services for waste recovery	Offered to 37.8% of the country's urban population (household and public waste)	30% is the fraction potentially recoverable from the total amount of waste collected (62.71 million/yr).	Only 5.6 % was recovered (from the fraction potentially recoverable)	About 1.7 million tons (14.4 kg/yr per capita) of waste was recovered.
Waste recycling organizations	1/3 of the total material is recovered by formally established partnerships with government.	1,232 associations or cooperatives spreads over 827 municipalities across the country	More than 27,000 associated workers are enrolled	
Collected waste disposed in landfills and dumps in 2018.	46.68 million tons disposed in landfills facilities	75.6% of the approximate total waste collected is landfilled	15.05 million tons were disposed in inadequate landfills and dumps	

Table 7 - Composition of urban waste by type of material.
Source: Own elaboration, based on SINIS-RS Report Assessment in 2018

Type of material	*Composition*	*Amount recovered to recycling (ton.) in 18.5 % the municipalities*
Paper and cardboard	*42.0 %*	*241,085.7*
Plastics	*22.6 %*	*129,493.2*
Metals	*13.1 %*	*75,304.9*
Glass	*12.2 %*	*69,820.2*
Others	*10.1 %*	*58,022.4*
TOTAL	*100.0 %*	*573,726.4*

Figure 1 - Urban solid waste recovered through collection for recycling in Brazil.



Source: IBGE (2015) Sustainable Development Indicators, Brazil

Table 8 - Urban Waste received by waste facilities in municipalities in Brazil.

Source: Own elaboration, based on SINIS-RS Report Assessment in 2018

Usual "Linear" Waste Management	***Total mass (ton.)***	***%***
Landfill	*40,092,144.1*	72.6 %
Dumping ground	6,171,946.3	11.2 %
Controlled landfill	5,816,254.4	10.5 %
Inert landfills RCC (Civil Construction Waste)	2,850,384.6	5.2 %
Specific trenches RSS (Health Services Waste)	*209,839.6*	0.38 %
Microwave or autoclave treatment	*79,65.,6*	0.14 %
Incineration treatment	*13,794.8*	0.02 %
TOTAL	**55,234,016.40**	***100 %***
Potentially Recoverable Waste Managed	***Total mass (ton.)***	***%***
Recycling RCC (Civil Construction Waste)	*1,169,535.7*	46.9 %
Recyclable household waste recovered (estimative)	*1,100,000.0*	44.1 %
Composting facilities	*127,498.1*	5.1 %
Tree branch and pruning facilities	*97,703.8*	3.9 %
TOTAL	**2,494,737.60**	**100 %**

The figures in the tables can give some important analysis on material management in cities in Brazil, to better understand and draw insights about potential benefits to apply the CE approach in the current context.

Urban waste management in Brazil shows that the amount of materials in usual "linear" systems – like landfilling, incineration (and dumping ground) – is around 55.2 Million tons/year in cities. So, there is a lot of room for CE technological innovations and related facilities advancement to "leapfrog" and deliver improvements to avoid and diverge wasted materials to be recovered.

From the total amount of the potentially recoverable organic waste, only around 9% is collected and sent to composting and branches and pruning facilities - which shows that there is a huge potential yet to be explored in CE biological cycle systems, like renewable energy applications (biogas), soil nutrition (fertilizers) and other CE applications in biochemicals and bio based materials.

Most of urban waste that is being recovered with potential to be incorporated in a circular economy are recyclable materials from civil construction and household waste (91%). And the majority of materials recovered are paper, plastics, metals and glass (probably, mainly from packaging), and this can indicate that even when the technology is available, a circular economy could help push improvements in current systems for enabling conditions like logistics, regulations and tax mechanisms.

5.5. Energy generation from organic waste

Here some national initiatives are presented that can give an understanding of the benefits of implementing circular economy value chains for more sustainable energy generation in Brazil. By supporting biological materials cycles, a circular economy approach for technology and systems innovation could boost the renewable energy generation from organic residues management from cities, industry and agriculture.

Animal Waste Treatment

Strategies for Animal Waste Treatment (TDA) to organic manure by farm bio-digesters are part of the Brazilian Adaptation and Low-Carbon Emission Agricultural Plan[40] (ABC Plan), integrating actions between agriculture and energy sectors (storage, purchase and distribution). TDA processes generates energy locally and produces fertilizers as byproducts increasing resources autonomy in rural areas, impacting in reduction of GHG emissions and less dependence in the use of inorganic fertilizers [41]. By promoting interlinkages among different sectors of the economy, this results in awareness-raising and engagement of stakeholders and better understanding of the interdependence of factors that are essential to enhance actions towards a more sustainable agriculture.

Biogas

[40] http://observatorioabc.com.br/ Observatory of the actions of the ABC Low Carbon Agriculture Program.
[41] Brazilian contribution to the dialogue on the relationship between land and climate change adaptation related matters In light of the Decision 1/CP.25 https://www4.unfccc.int/sites/SubmissionsStaging/Documents/202003311910---Brazil.%20Submission.%20.pdf

The Brazilian National Biofuels Policy – RenovaBio aims at the expansion of the biofuels market in the country. Biomethane is produced from sewage treatment plants and landfills, from the decomposition of organic waste, for vehicular use to replace natural gas. In Brazil, there are great expectations to create a market for biogas, based on the progress that has occurred in recent years[42]. The Brazilian Energy Research Office (EPE) included biogas as a real alternative among sources of fossil origin for the Brazilian energy matrix. Organic residues from many different sources are transformed into fertilizers and bio-methane for electricity generation in substitution of natural gas. Aiming to increase the national renewable energy matrix, the Biogas Brazil Project[43] for technical support for biogas production to improve value and technological innovation for the conversion of organic waste from rural and agro-industrial sources into energy. Besides that, the biogas production processes also result in organic material with high potential for agricultural and agri-industrial use as fertilizers.

Table 9 - Production units and energy use of biogas in the country.
Source: Own elaboration, based on MapBiogas open web tool, 2020

	Number of facilities	Biogas production (m³/year)
TOTAL units installed in the country	548	2.303.247.268 m³/year
Substrate Source from Sanitary facilities (Sewage, Landfill, Sewage Sludge and Waste co-digestion)	59	1.849.891.588 m³/year
Substrates Source from Industry (Sugar, Food and/or Beverage, and Dairy)	69	287.204.754 m³/year
Substrates Source from Agriculture Livestock (Pig farming, Dairy or Cutting Cattle, Poultry or Pig Slaughterhouse and Posture or Cutting Poultry)	416	165.546.026 m³/year

Currently in Brazil, there are 548 biogas production plants with bio-digestion technology for waste treatment. The country's potential of biogas production is up to 2,303,247,268 m³/year, for application in electric, thermal, mechanical and bio-methane energy generation (almost 40% of this potential from plants currently under construction). Although the vast majority of the plants in the country (413 units) are small (< 2,500 nm³/day), more than half of the production (1,428,389,132 m³/year) are from large plants (> 12,501 nm³/day). In 2019, 113 plants were installed with a biogas production capacity of 340,114,548 m³/year. The biogas production process allows the treatment of waste and organic effluents, and bio-fertilizers production as a byproduct, with application in agriculture, forestry and reforestation. The predominant sources of organic substrates come from industry (sugar-energy; food and/or beverage and dairy products) and agriculture (pig farming, dairy or beef cattle farming, poultry or pig slaughterhouse and laying or

[42] http://www.mme.gov.br/c/document_library/get_file?uuid=868dc2f2-d486-14dc-2b3b-3aa0d0007f4d&groupId=36224
[43] https://www.gefbiogas.org.br/sobreoprojeto.html

cutting poultry) and sanitary treatment plants (sewage, landfill, sewage sludge and co-digestion of waste) [44].

Table 10 - Data from BiogasMap open web tool for visualization of production units and energy use of biogas in the country.

Source: Own elaboration, based on on MapBiogas open web tool, 2020

	Number of facilities	Biogas production (m^3/year)
Installed facilities in 2019	113	340.114.548 m^3/year
Facilities in operation	493	1.329.672.161 m^3/year
Facilities in construction	47	933.470.307 m^3/year
Large Facilities (production capacity > 12.501 nm^3/day)	37	1.428.389.132 m^3/year
Small Facilities (production capacity < 2.500 nm^3/day)	413	124.265.903 m^3/year

[44] BiogasMap web tool open for visualization of production units and energy use of biogas in the country. https://mapbiogas.cibiogas.org/

6. Assessment of potential secondary raw materials to supply circular economy value chains in Brazil

In this section, a framework to assess CE value chains in the country is proposed, mapping each economic activity established: (a) Manufacturing (Technical Cycles); (b) Agriculture and Food; (c) Natural Resources (Mining, Forestry and Fisheries); (d) Construction, Transport, Logistics and Retail; (e) IT and Smart City; and (f) Energy that might be most impacted by a circular economy and the potential products, sub-products and materials with potential value integrate the circular economy material biological and technical cycles in Brazil.

6.1. The biological Cycle and Technological Cycle

Keeping the continuous flow of materials is a vital theme for a circular economy. Every time a product is thrown away, the energy, materials and water used in its manufacture are also thrown away and pollution is generated. If these products or their components can be kept in the value chain instead, this means far fewer pollutants are emitted, less water is used, and less energy is required in the system. [45]

In contrast to a linear economy, in which we make a product, use it and dispose it, the circular economy is an economic model that distinguishes the materials between two separated streams according to the Cradle to Cradle[46] design framework: the technical cycles and the biological cycles, keeping them at their highest value, to optimize their flow and maintain or increase both technical and natural resource stocks[47]. In this circular production systems, the 'biological cycle' keep the value of renewable bio-based resources as nutrients to natural ecosystems and the 'technical cycle' keeps non-renewable synthetic materials as valuable inputs to industry for as long as possible.

Some examples of materials suitable for the "Technical Cycle" identified as potential inputs to supply circular economy value chains in Brazil are:

- metal,
- aluminum;
- plastics,
- glass,
- ceramics,
- rubber,
- synthetic fibers
- Electronic parts (rare earths and precious metals).

[45] Fernandes, AG (2016). CLOSING THE LOOP: THE BENEFITS OF THE CIRCULAR ECONOMY FOR DEVELOPING COUNTRIES AND EMERGING ECONOMIES, Tearfund.
[46] Cradle to Cradle: Criar e reciclar ilimitadamente, de Michael Braungart e William McDonough, edição brasileira. Gustavo Gili, 2014.
[47] ELLEN MACARTHUR FOUNDATION. Towards the circular economy: economic and business rationale for an accelerated transition, 2013.

In addition, some examples of materials suitable for the "Biological Cycle" identified as potential inputs to supply circular economy value chains in Brazil are:

- Organic substrates from industrial activities: sugar; food and/or beverage and dairy products, bio-fibers, paper, biopolymers;
- Organic substrates from agriculture activities: crops and forestry biomass, cattle manure, slaughterhouses, agricultural effluents;
- Organic substrates from sanitary treatment plants in cities: sewage, landfill, sewage sludge and organic solid waste.

6.2. Assessing the value of materials for circular economy value chains in Brazil

Based on the Circular Economy approach, classifying resources suited to the Technical Cycle and Biological Cycle, an example of table is proposed that relates waste, products and sub-products with potential to supply some of the economic activities that might be impacted by a circular economy implementation in Brazil. Based on this, an indexed spreadsheet could be developed to enable the selection of applications for each productions sector.

This table may be also useful to get insights of opportunities of CE projects for economic activities within the strategic action areas proposed in the Output 2, recognized by the high potential to support the implementation of circular economy value chains in Brazil. Assessing these relations is also possible to get insights to find contextual trends (opportunities and threats) and internal capabilities (strengths and weaknesses) for the SWOT analysis in the next deliverable of this technical assistance, and further analysis to the implementation of circular economy value chains in Brazil.

Table 11 - Materials with potential value to supply CE value chains in Brazil

Source: Own elaboration

Economic Activities	Biological Cycle	Technical Cycle	
	cascading, composting, composting, biodigestion, biochemicals/ biofuels/ biofertilizers/ biobased-materials	Product-service systems (share/maintain/extent use/reuse/resale/redistribution/ refurbishment/re-manufacture); Recycling	General examples in Brazil where this could be applied

Manufacturing	Paper; Wood; Biobased materials; Organic fibers;	Plastics; Aluminum; Metals; Glass; Rubber Synthetic fibers;	Packaging from aluminum (coffee capsules) recycling . https://www.nespresso.com/br/pt/sustentabilidade/reciclagem/nossas-parcerias https://www.nespresso.com/br/pt/sustentabilidade/reciclagem/ideia-pioneira Textile Fibers and clothes up cycling and recycling (organic and synthetic) to yarn production. https://www.retalhar.com.br https://jffibras.com.br/blog/fios-reciclados/ Electronic reverse logistics and recycling for Plastics and Metals http://www.sinctronics.com.br/index.html https://www.greeneletron.org.br
Agriculture and Food	Industrial residues from sugar, Food, Beverage, and Dairy industries; Livestock residues from cattle farming); Biomass from crops: sugarcane, coffee, corn, soybean); Organic-rich effluents and sludge (to energy or fertilization);		Food waste to biomethane (PTI/ABDI Living Lab) https://www.abdi.com.br/postagem/biogas-e-alternativa-para-geracao-de-energia-e-tratamento-de-lixo
Construction, Transport, Logistics and Retail	Wood from construction paper from packaging	Non-metallic minerals:(gypsum, concrete, ceramic, glass, building stone) Metals: (steel, aluminum) Ceramics;	Gypsum waste to fertilizers for agriculture http://www.sulgesso.com/site/produtos/#

IT and Smart City	Organic waste (Food, cooking oil, fibers) Paper (office paper, packaging) Wood (branches and pruning) Organic-rich industry effluents and sludge (to energy or fertilization) Sanitary facilities: sewage, landfill, sludge	Product-service systems for electronic devices, household appliances, furniture, automobiles; Recycling: plastics, aluminum, steel, glass, electronic parts (precious metals and rare earths), ;	Organic-rich effluents from Sanitary facilities: sewage, landfill, sludge (to energy or fertilization) http://www.fec.unicamp.br/~bdta/esgoto/tourFranca.html https://revistaoe.com.br/sabesp-projeto-de-economia-circular/ Product-service systems for household appliances https://www.brastemp.com.br/purificadores-de-agua/para-sua-casa,
Energy	Organic substrates from industrial activities: sugar; food and/or beverage and dairy products, bio-fibers, paper, bio-polymers; Organic substrates from agriculture activities: crops and forestry biomass, cattle manure, slaughterhouses, agricultural effluents; Organic substrates from sanitary treatment plants: sewage, landfill, sewage sludge and organic solid waste.		Biogas production from sugar-cane waste https://www.canalbioenergia.com.br/setor-sucroenergetico-e-a-producao-de-biogas/ https://www.raizen.com.br/nossos-negocios/energia#biogas

7. Final remarks

This report has presented facts and insights that supports the adoption of the Circular Economic model in Brazil. The assessment showed that there are important potential benefits in adopting the circular economy value chains, delivering many economic, environmental, and social gains to the country at the general level. The implementation of the circular economy shows potential to contribute reaching the Paris agreement National Determined Contributions (NDC) as well as for many of the UN 2030 Agenda Sustainable Development Goals (SDG). This assessment aims to enable a SWOT analysis from potential strengths, weaknesses, opportunities and barriers that may influence the success of circular economy transition and systems implementation in Brazil, to be applied in the next deliverable 3.2-3.3.

Brazilian NDCs for climate change mitigation and adaptation shows some points that could specially benefits from the circular economy approach to the biological cycle to support advances in biofuels, low carbon and resilient agriculture, forest monitoring, restoration and reforestation, and management of protected areas. Also, in the country's fast urbanization process, climate adaptation in key areas like housing, basic infrastructure for health, sanitation and transportation, can benefit from circular economy systems approach to foster changes in consumption unsustainable patterns and the urban infrastructures like for water, sewage, energy and buildings. In addition, the circular economy approach related to the biological cycle – specially by improving the "regenerative potential" of ecological systems for water, food, energy, and biodiversity improvement – has the potential to deliver positive impacts beyond just reducing GHGs. The CE brings a perspective through "GHGs cycling" – e.g. using recovered carbon as a resource or building block for products or other solutions. For renewable energy supply, the implementation of a circular economy may pull the demand for renewable energy and positively impact GHG emissions reductions, as this is an essential source to power every circular economy system and make it sustainable. The support for the creation of CE value chains may be integrated in current incentives to increase renewable and clean energy participation in the energy matrix in the country. Thus, CE can also be a driver for investments in increasing renewable energy production, and also help renewable energy designers and manufacturers to adopt CE design principles to stimulate R&D and the deployment the next generation of technologies.

In Brazil, the Waste Management National Policy (PNRS) recognizes the market value potential of wasted materials for future use and the economic value of wasted materials and products for social development, creating an obligation for collaboration within sectors and potentially across sectors. This means that Brazil could build upon this existing regulatory framework to propose specific CE policy documents, including the National Circular Economy roadmap, to incentivize and facilitate the transition toward a Circular Economy in Brazil. Recyclable solid urban waste generated in cities and industries are a significant opportunity to CE business models, with many potential market opportunities. Potentially, by deploying CE innovations expenditure in waste management by the government with tax money could be reduced and new businesses could be triggered. Even when recycling technologies are available, the CE approach could help push forward by improving enabling conditions like logistics, regulations and tax mechanisms. Moreover, with the aim of having positive social impacts the reverse logistics systems for materials recover is already regulated including recycling cooperatives into the arrangements between municipality and the Industry. Overall, there is a lot of room for investments and gains from CE technological and systems innovations, and a window of opportunity to "leapfrog" the current linear approach going directly to implementation of circular economy value chains, avoiding loss of valuable materials and products delivering social, environmental and economic improvements.

Above all, it is important to prepare a transition strategy to implement circular value chains by promoting socio-institutional changes together with incremental innovation in products, information and technological systems, enabling the connection of service providers and users for purchasing the service of products. Embedded technology for tracking products may improve efficiency for the industry and reduce costs in transportation and logistics in urban areas. Aspects from the Brazilian social-cultural context may be a very fruitful environment to explore commercial CE systems for product-services like reuse, share, resale, maintenance, refurbishment and redistribution. In general, new CE business models are also important to Brazil as is expected that this also increases the rate of jobs creation through labour intensive activities. Product-service systems and shared business models on CE improves the access to better quality products (including home) for a broader range of people and, in Brazilian cities, this could increase the access to basic products and services for low income families.

To conclude, Brazil is well positioned to become a relevant nation and global player to come with solutions to the industry, agriculture and cities, with particular potential to explore renewable sources and boost the bioeconomy. Organic solid urban waste generated by cities, industry and agriculture could be a great resource of organic materials, as input for several bio-economic activities and processes. From applying a biological cycle CE approach for technology and systems innovation, CE value chains could also boost the renewable energy generation from organic solid waste and effluents. Furthermore, circular economy value chains across agriculture, forests and coastal areas can be established to supply a high-tech industry and vice-versa. Promoting interlinkages among different sectors of the economy, also results in awareness-raising and engagement of stakeholders and better understanding of the interdependence of factors that are essential to enhance actions towards a more sustainable industry and agriculture. All these factors could drive innovation in many sectors and strengthens Brazil's competitiveness and sustainability globally.

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