Revista de
CIENCIAS AMBIENTALES
Tropical Journal of Environmental Sciences

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

Proposed guidelines to implement flexible-plastic circular economy business models in Colombia

Lineamientos propuestos para implementar modelos de negocio de economía circular de plástico flexible en Colombia

Nicolas Ramiro Orrego-Bustamante[1]; Amalia Alejandra Báez-Niño[2]; Darling Perea-Cabarcas[3]; Henry Adolfo Lambis-Miranda[4]

[**Recibido**: 27 de agosto 2024, **Aceptado**: 5 de noviembre 2024, **Corregido**: 18 de noviembre 2024, **Publicado**: 01 de enero 2025]

Abstract

[**Introduction**]: The lack of feasible circular economy models for recycling single-use plastics poses a significant challenge to sustainable waste management. Single-use plastics, particularly flexible types, contribute to environmental pollution and require effective recycling strategies. [**Objective**]: This study aimed to analyze global recycling models for single-use plastics under key parameters: type of pollutant, impacts on sustainability, value generation, stakeholders involved, and level of technology. [**Methodology**]: A global review of 21 circular economy models focused on single-use flexible plastics was conducted, evaluating their feasibility and effectiveness. Six models were identified as the most relevant based on the selected criteria. [**Results**]: The findings indicate that improving eco-efficiency requires the integration of physical and chemical recycling processes to achieve cost reductions. Additionally, maintaining a constant flow of recyclable materials is essential, emphasizing the critical role of material collection and classification cooperatives. In Colombia, the collection and classification of plastic materials emerged as a pivotal element for the long-term sustainability of recycling models. [**Conclusions**]: The study highlights the necessity of combining technological and logistical efforts to enhance recycling processes. Strengthening material recovery systems and cooperative efforts is crucial for advancing circular economy goals in the context of single-use plastics.

Keywords: business model; circular economy; flexible plastic; recycling; value chain.

Resumen

[**Introducción**]: La falta de modelos viables de economía circular para el reciclaje de plásticos de un solo uso representa un desafío importante para la gestión sostenible de residuos. Los plásticos de un solo uso, especialmente los tipos flexibles, contribuyen a la contaminación ambiental y requieren estrategias de reciclaje efectivas.

1 Gerente de I+D, Gerente de I+D. Esenttia MB, Medellin Colombia, Medellín, Colombia.
nicolas.orrego@esenttia.co; https://orcid.org/0009-0009-1833-819
2 Coordinadora de Marketing y Publicidad, Logros Factoring Colombia S.A., Bogotá, Colombia.
amaliaalejandra13@gmail.com; https://orcid.org/0009-0007-1085-9192
3 Docente-Investigador, Universidad Tecnológica de Bolívar, Cartagena, Colombia.
darling.perea@udea.edu.co; https://orcid.org/0000-0003-1556-2738
4 Docente-Investigador, *CIPTEC* Research Group, Fundación Universitaria Tecnológico Comfenalco, Cartagena, Colombia.
hlambis@tecnocomfenalco.edu.co; https://orcid.org/0000-0002-6261-4062

Revista de
CIENCIAS AMBIENTALES
Tropical Journal of Environmental Sciences

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

[**Objetivo**]: Este estudio tuvo como objetivo analizar modelos de reciclaje globales para plásticos de un solo uso bajo parámetros clave: tipo de contaminante, impactos en la sostenibilidad, generación de valor, actores involucrados y nivel de tecnología. [**Metodología**]: Se realizó una revisión global de 21 modelos de economía circular enfocados en plásticos flexibles de un solo uso, evaluando su viabilidad y efectividad. Se identificaron 6 modelos como los más relevantes, según los criterios seleccionados. [**Resultados**]: Los hallazgos indican que mejorar la ecoeficiencia requiere la integración de procesos de reciclaje físicos y químicos para lograr reducciones de costos. Además, es esencial mantener un flujo constante de materiales reciclables, destacando el papel crítico de las cooperativas de recolección y clasificación de materiales. En Colombia, la recolección y clasificación de materiales plásticos surgió como un elemento clave para la sostenibilidad, a largo plazo, de los modelos de reciclaje. [**Conclusiones**]: El estudio resalta la necesidad de combinar esfuerzos tecnológicos y logísticos para mejorar los procesos de reciclaje. Fortalecer, los sistemas de recuperación de materiales y las iniciativas cooperativas, es crucial para avanzar en los objetivos de la economía circular en el contexto de los plásticos de un solo uso.

Palabras clave: cadena de valor; economía circular; modelo de negocio; plástico flexible; reciclaje.

1. Introduction

The use of plastics by human beings has transformed their way of living. From products that have improved healthcare, food preservation and entertainment or are being used every day in packaging, electronics, and vehicles (Burgess *et al.*, 2021; Li *et al.*, 2022). While polymeric materials offer numerous technological advantages, their production and lifecycle contribute significantly to energy consumption and greenhouse gas emissions. In the USA, the polymer supply chain alone is responsible for the release of 104 megatonnes of carbon dioxide equivalent (CO2e) annually (Nicholson *et al.*, 2021). The demand for single-use packaging from various sources —especially from plastic— has increased, and its inadequate disposal has led to post-consumer waste environmental, social, and economic problems. According to the Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2017), global plastic packaging represents 26 % of total plastic consumption, however, 95 % of its value is lost.

According to Greenpeace (Greenpeace Colombia & Clínica Jurídica de Salud Pública y Medio Ambiente (MASP) de la Universidad de los Andes, 2019), 80 % of the world's population live in large cities; areas with high rates of hyper-consumption, caused by the culture of disposing with greater relevance in the disposal of packaging and flexible single-use plastic containers.

The low re-use of flexible plastic waste has prompted some institutions to alert the problem. It is estimated that the production of plastics will double by 2035 and almost quadruple by 2050 (Mrowiec, 2018), increasing pollution by solid waste and by emissions of greenhouse gases (GHG).

The recycling of laminated flexible structures commonly used in food packaging is costly nowadays, resulting in considerable amounts of this flexible material going to landfills (Curtzwiler *et al.*, 2019). Mechanical recycling could be an option for recovering flexible plastics by processing innovations (Bashirgonbadi *et al.*, 2022), and chemical recycling is a good option for recycling laminated flexible films (Huang *et al.*, 2023). The apparent consumption of plastics in Colombia for 2018 was 1 280 000 tons, of which 493 000 tons correspond to flexible plastics

Revista de
CIENCIAS AMBIENTALES
Tropical Journal of Environmental Sciences

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

(extrusion process, **Figu**re 1) (Acoplásticos, 2020). According to calculations based on the Sectorial Report of the Utilization Activity - 2018 of the Superintendencia de Servicios Públicos Domiciliarios, only 16 600 tons of flexible plastic waste are recovered in the country, this is 3.36 % of the total consumption (Superintendencia de Servicios Públicos Domiciliarios, 2019).

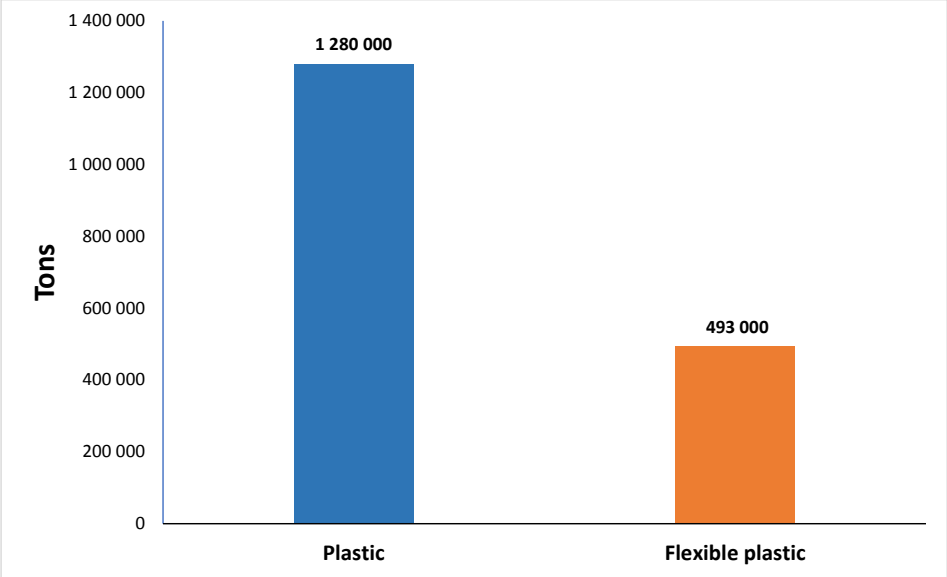

Figure 1. Plastic consumption in Colombia in 2018.
Figura 1. Consumo de plásticos en Colombia en 2018.

One primary obstacle hindering the valorization of recycled plastics is the persistently low rate of household plastic waste collection. This insufficient collection significantly reduces the availability of recyclable materials, thereby limiting the scale and economic viability of recycling operations (Burgess *et al.*, 2021). The low collection of flexible plastics originated for multiple reasons, starting with an unsuitable design that does not allow recyclability and the generation of circular flows (Ellen MacArthur Foundation, 2017). Deficiencies in waste collection reverse logistics are due to: 1. Low prices and incentives for recyclers and consumers; 2. Lack of information on the location of collection centers; 3. Limited transportation infrastructure and few alliances with other companies; 4. Inefficiencies in the collection and recovery systems (Superintendencia de Servicios Públicos Domiciliarios, 2019); 5. Failures in communication to the consumers about recycling, consumption, and circularity issues that allow a correct separation at the source and maximum use of the waste (Cerantola, 2016); 6. The low regulations for waste disposal and the technical restrictions in flexible plastics recycling.

Due to the challenge of the use of flexible post-consumer packaging, in Colombia, the government issued the National Plan for the Sustainable Management of Single-use Plastics, looking to develop communications and citizen culture programs with the objective of increasing

Revista de
CIENCIAS AMBIENTALES
Tropical Journal of Environmental Sciences

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

education in solid waste management and establishing the extended producer responsibility to the disposal of post-consumer products, through circular economy strategies to promote the recycling of plastics (Ministerio de Ambiente y Desarrollo Sostenible, 2021).

To generate and increase the value of flexible plastic materials, their wastes should be reintroduced into their own life cycle, being used as raw material in the creation of new containers and packaging materials, allowing "Cradle to Cradle" processes, developed by McDonough and Braungart, since they use the outputs (end of life of a product) as inputs and/or raw material for a new production process, avoiding the waste generation through a regenerative design (Ellen MacArthur Foundation, 2021).

Increasing recyclability requires the establishment of a robust flexible plastic value chain that actively engages key stakeholders, including governments, the plastics industry, universities, research institutions, brand owners, and consumers (Távora de Mello Soares *et al.*, 2022). Enhancing plastic collection rates also necessitates significant investments in waste management infrastructure.

This study aims to encourage further exploration of solutions to one of the most pressing environmental challenges: the accumulation of plastic bags in ecosystems, particularly in marine environments, where they have severe adverse effects on biodiversity.

2. Methodology

The business model research, about flexible plastic in circular economy was made through the different databases in Colombia and worldwide (Asia, Europe, Africa, Oceania, and the Americas). A comprehensive literature review was conducted utilizing the databases of ScienceDirect® and Scopus®, as well as relevant web pages, to identify pertinent research published between the years 2016 and 2023. The models found were evaluated and qualified according to the criteria shown in **Table 1**, based on the methodology approved by the Universidad Pontificia Bolivariana (UPB).

Table 1. Qualification criteria for business models.
Cuadro 1. Criterios de calificación para los modelos de negocio.

Qualification	1	3	5
Waste components	Business cases include waste different to plastics.	Business cases include rigid and flexible plastic waste.	Business cases are exclusive for flexible plastic.
Impact in sustainability	Impacts only one dimension of sustainability.	Impacts two dimensions of sustainability.	Impacts three dimensions of sustainability.
Generation of value	Reduces the value of flexible plastic recycling.	It gives equal value to flexible plastic recycling.	Increases the value of flexible plastic recycling.
Stake holders involved	Two or less groups of interest.	Three or four groups of interest	Five or more groups of interest
Technology Use	Low technological level.	Medium technological level.	High technological level.

Revista de
CIENCIAS AMBIENTALES
Tropical Journal of Environmental Sciences

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

To define the guidelines that would be potentially applicable to flexible plastic circular economy business models in Colombia the selected models were studied under the following five sustainability aspects:

- Level of eco-efficiency: Economic productivity / environmental cost.
- Ecological sustainability: Environmental footprints.
- Resource productivity: Recovered material per unit of flexible plastic waste.
- Social Impact: Employment generation.
- Technology Innovation: New technologies scope level.

Their impact on the sustainability aspects was classified at a qualitative rate: low, medium, high.

3. Results

3.1 Identification of business models in circular economy of flexible plastics

The bibliographic review made in Colombia and worldwide business models of the circular economy of flexible plastic, results in 21 models: (1) in Africa, (1) in Oceania, (1) in Asia, (8) in Europe, (10) in the Americas (**Table 2**).

Table 2. Selected business models.
Cuadro 2. Modelos de negocio seleccionados.

ID	Business model	Continent	Description
1	Circular economy with informal recycling sector (IRS)	Africa	Business Model developed in Nairobi, Kenya, classified according to the National Circular Economy Strategy of Colombia (ENEC). (Ministerio de Ambiente y Desarrollo Sostenible, 2019), as Valorization of Waste and deals with the formalization of the work of recyclers to obtain better income (Gall *et al.*, 2020).
2	Flexible plastic recovery project Replast Australia	Oceania	The Oceania business model was developed in Australia and is classified according to the ENEC's system as Recovery of waste and Extension of Life and deals with the generation of items of value from flexible waste with incorporation of the value chain (Replast, 2021).
3	Unilever Indonesia	Asia	Business model developed in Indonesia and promoted by Unilever to recover flexible sachet-type packaging. (Unilever, 2022)
4	Management of plastic bags in Sweden	Europe	Management of plastic bags in Sweden, which deals with a system for collecting and using plastic bags in supermarkets (Singh & Cooper, 2017)
5	Plastic credit + Blockchain system	Europe	Credit system with blockchain based on the quality of plastic in the United Kingdom (Liu *et al.*, 2021).

Revista de
CIENCIAS AMBIENTALES
Tropical Journal of Environmental Sciences

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

ID	Business model	Continent	Description
6	Smart ticket system	Europe	Smart purchasing tickets system implemented in Spain, which through a barcode scanner in the ticket shows its correct disposal (TheCircularLab, 2018).
7	Multibiobarrier	Europe	Development in Spain of new biopolymers with oxygen and water vapor barrier that replaces multilayer plastics (Nurel, 2018)
8	Plastic Zero Copenhagen project	Europe	Plastic Zero project in Copenhagen Denmark aimed at reducing the amount of plastic in the waste stream (Cooper, 2018)
9	Nestle recycled pellets	Europe	The manufacture of recycled pellets made by Nestlé in Spain to reintroduce them into the polyethylene products stream (Grupo de acción de Economía Circular & Forética, 2020).
10	Mass Value crafts	Europe	Mass Vase, crafts made with the plastic that cannot be recycled, used it to turn them into stone (Díaz del Río, 2020).
11	Foams from plastic film	Europe	The use in Spain of plastic films for the manufacture of foams and textile fiber (Rivas Salmón, 2019).
12	Botellas de Amor "Love Bottles" in Colombia	South America	*Botellas de Amor* in Colombia classified within the ENEC's system as Waste Extension Life, deals with the collection and use of flexible post-consumer packaging for the manufacturing of plastic wood (Fundación Botellas de Amor, 2021; Robayo, 2019).
13	EcoPazifico and community Urubamba National Park	South America	EcoPazifico and the community Parque Nacional Uramba in Colombia, through tourism collect flexible waste for the manufacture of some low-value products (EcoPazifico, 2019).
14	Cataki Mobile App	South America	Mobile application called Cataki in Cali, Colombia, for the collection of waste through recyclers (Cardona, 2019).
15	Unilever Argentina	South America	In Argentina, Unilever developed a model looking for circularity in detergent packaging (Kowszyk & Maher, 2018).
16	Bag Central Station program city of Phoenix	North America	Collection of flexible plastic through the "Bag Central Station Program of the City of Phoenix, Arizona, United States" (American Chemistry Council, 2021).
17	Flexible packaging sustainability – Scholle IPN	North America	The sustainability program for flexible packaging developed by the Scholle IPN company by the bag-in-box application (Scholle IPN, 2021).
18	WRAP Program, Plastic film Collection	North America	The collection of plastic films in the United States, by the WRAP program with the participation of 18,000 retailers and collection sites. (American Chemistry Council, 2021)
19	Flexible Plastic waste recycling in Pennsylvania	North America	The Pilot Program for the Collection and Recycling of flexible plastic waste in Pennsylvania, United States, for the manufacture of articles of high value. Classified under ENEC's system as Recovery of the waste and Extension of Life (Sandford *et al*., 2020).
20	Novoloop – Chemical Recycling	North America	Chemical recycling process developed by Novoloop in USA, takes advantage of municipal plastic waste to produce high-value plastics, with the ENEC's focus on Waste Recovery (Linnenkoper, 2021)
21	Enerkem - Chemical recycling	North America	Chemical Recycling process developed in Canada by Enerkem takes advantage of municipal plastic waste for producing fuels, chemicals, or plastics. According to the ENEC, its approach is Waste Recovery (Enerkem, 2023).

Revista de
CIENCIAS AMBIENTALES
Tropical Journal of Environmental Sciences
Desde Since 1980

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

3.1.1 Evaluation of business models of the circular economy of flexible plastics

Each business model described above was evaluated according to the criteria mentioned in the methodology. Six of them obtained the highest score among all the 21 business models, because of their exclusivity in the management of flexible waste, their impact on the three dimensions of sustainability, the increase in the value of plastic waste, the involvement of five or more interest groups and its high use of technology. The six selected models with the highest score are shown in Table 3, they scored over 90 % of the maximum grade.

3.1.1.1 Selection of flexible plastics business models

The six business models selected and described in **Table 3** will be the benchmarks to be applied in Colombia. Their drivers and obstacles were identified to show the strengths and weaknesses for being implemented in Colombia and finally, their assessment based on five sustainability criteria shows the path for their use in the country.

Table 3. Evaluation of selected business models.
Cuadro 3. Evaluación de los modelos de negocio seleccionados.

Business model	Materials	Impact on sustainability	Generation of value	Stakeholders involved	Technology Use	Value
1	3	5	5	3	5	21
2	5	5	3	3	3	19
3	5	5	3	5	3	21
4	3	3	3	3	5	17
5	1	5	3	3	5	17
6	3	3	5	3	5	19
7	5	3	5	1	1	15
8	5	5	3	5	1	19
9	3	5	3	3	3	17
10	5	3	3	1	1	13
11	5	5	5	3	5	23
12	3	5	3	3	3	17
13	5	5	5	3	5	23
14	5	5	3	3	3	19
15	3	5	3	3	3	17
16	5	3	3	3	5	19
17	5	3	3	3	3	17
18	3	3	5	3	5	19
19	5	3	5	3	5	21
20	5	3	5	1	5	19
21	3	5	5	3	5	21

Revista de
CIENCIAS AMBIENTALES
Tropical Journal of Environmental Sciences

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

The six business models selected (highlighted in **Table 3**) are described below and will be the benchmarks to be applied in Colombia. Their drivers and obstacles were identified to show the strengths and weaknesses for being implemented in Colombia and finally, their assessment based on five sustainability criteria shows the path for their use in the country.

3.1.2 Circular economy of plastics with informal recyclers in Kenya

In low and middle-income countries, recycling activities are predominantly informal. The informal recycling sector (IRS) is characterized by social marginalization economic exploitation and the absence of formal employment, regulations, and taxes (Gall *et al.*, 2020).

Business model

Green Africa (MGA) a company in Nairobi, Kenya, has implemented a business model together with the IRS, seeing them as facilitators of a circular economy (CE).

The basic idea is to abandon the traditional IRS value chain based on multiple intermediaries and replace it with a direct fair trade relationship between the individual recycler and the formal company. For this, proprietary commercial points were established where recyclers sell plastic waste to MGA. The commercial price is set at a rate of 19 Kenyan shillings (KSh) or 0.14 USD per kilogram of plastic, therefore it is not subject to market price volatility. That price is openly communicated and set in a way that is highly competitive with respect to that offered by other local buyers.

The company's mobile application has a profile for each recycler where their productivity and reliability are recorded and analyzed. Recyclers who regularly trade with MGA are eligible for a loyalty program that awards a premium price in exchange for meeting monthly supply targets. In this way, and with the integration of other informal collectors such as scrap yard owners, the company maintains a relatively constant supply of waste, additionally, thanks to the interaction at commercial points, there is a certain degree of control over types and qualities of received materials, besides building trust, acceptance, and inclusion of the IRS (Gall *et al.*, 2020).

Table 4. Informal recycling sector (IRS) model assessment.
Cuadro 4. Evaluación del modelo del sector informal de reciclaje.

Optimal drivers	Main obstacles
The establishment of proprietary commercial sites as points of interaction for the reception of waste. The direct interaction of waste pickers with MGA staff, because it generates transparency and trust. The establishment of a stable commercial price. Financial incentives to meet monthly supply targets. Ensure a constant volume of recycled material.	Establishment of a network of reliable suppliers, since it is common that they also try to take advantage of buyers. Supply and demand fluctuations for material to be recycled.

Revista de
CIENCIAS AMBIENTALES
Tropical Journal of Environmental Sciences

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

3.1.3 Botellas de Amor, in Colombia

The recovery and recycling of flexible packaging in Colombia has not been enough to cope with the growing volume of the material and the concern about its environmental impacts. Faced with this problem, the Botellas de Amor non-profit Foundation aims to take advantage of flexible plastic waste by closing the cycle with the manufacture of plastic wood (RPL), which would be used to build houses and other types of furniture.

Business model

The process begins with the training of consumers in educational centers and collection points. The participants fill plastic bottles of Polyethylene Terephtalate (PET) with flexible post-consumer waste as tightly as possible, carrying them to the collection points and then to the processing plants in Medellín and Bogotá, where the plastic bottles "are broken to remove the content of flexible plastics. PET bottles are marketed with container manufacturing companies and the flexible packaging materials are mechanically bonded to later apply modifiers that reinforce their properties" (Rivas Salmón, 2019). The model also receives plastic surpluses from industry.

"The recycling model is designed so that the flexible post-consumer material is delivered in plastic bottles (PET) and not in loose bags, since the aim is to generate the least of gas emissions. For this reason, the collection points are designed or prepared to receive bottles" (Fundación Botellas de amor, 2021). The project does not force the bottles and the flexible material to be washed and dry, however, it emphasizes draining them well to eliminate the remains and improve their quality.

Table 5. *Botellas de Amor* model Assessment.
Cuadro 5. Evaluación del modelo *Botellas de Amor*.

Optimal Drivers	Main Obstacles
- Training people in educational centers and collection points. - Community participation. - Motivation to benefit educational institutions and vulnerable population through delivery of housing and furniture. - The compliance of the participating companies to meet the collection and sustainability goals.	- There is no other way to deliver the flexible material, apart from PET (Polyethylene Terephthalate) bottles. - To improve the process, the material must be clean or washed and dried. - The model is not established in all the cities of Colombia.

Among the sustainability aspects we found: 1. The level of eco-efficiency is medium, since RPL handles one of the most difficult wastes to recover flexible plastics, however, the RPL is not useful for high end constructions due to lack of standards and regulations 2. Ecological sustainability is low, because there is no control of emissions since the transport used for carrying the residues to the collection points and some of them may need washing, thus generating an increase in the water footprint. 3. Resource productivity on average since the flexible material

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

for recycling depends solely on the management of separation and introduction of waste in PET bottles for the consumers. 4. Its social impact is medium, because some jobs are created in the plastic wood production and in the manufacturing of housing and recreation items destined for low-income communities. 5. Technological innovation is low, because they use traditional systems in the transformation of waste, however, they work in the design of buildings

3.1.4 Flexible plastic waste collection and recycling pilot program in Pennsylvania, United States

This pilot project was developed by the Materials Recovery for the Future (MRFF) organization, the Total Recycle company and the Pennsylvania Recycling Markets Center and the community of Birdsboro, Pennsylvania, a city near Philadelphia.

The pilot program object involved the community, with the support of Total Recycle staff through workshops, analyzing the collection of flexible plastics gaps, monitoring the collection and introducing new practices for separating the material, improving the quality of the post-consumer material and increasing its value (Sandford *et al*., 2020).

The results of the pilot project were:

1. Capture of 90 % of the flexible plastic in the classification system of the recycling plant.
2. Decrease the amount of paper that comes in the flexible waste stream to less than 15 %.
3. Reduction in the number of employees in quality control of film waste at the recycling plant by 25 %.
4. In the first year of operation, it was possible to demonstrate that by making a good selection of flexible plastic at the source, recycling companies accept the material from the containers that are on the curbsides, improving their possibility of sale (Sandford *et al*., 2020).

Table 6. MRFF model assessment.
Cuadro 6. Evaluación del modelo MRFF.

Optimal drivers	Main obstacles
- The transmission of the message that recycling captures value. - The use of technology in the recycling of flexible plastic and the search for valuable applications - The participation of the communities in the project, giving their feedback about the progress and contributing to its development. - The promotion and support of the companies associated with the project. - The interest of the recycling company in participating in the project in increasing efficiency and reducing costs. - Interest of brands in increasing the recycling rate of their packaging.	- Not all the communities involved in the pilot project had containers to collect flexible plastic waste, a high investment had to be made due to their high cost. - Additionally, the containers for handling flexible plastic waste should have a lid or be closed to prevent the flexible packaging from being carried away by the wind or from getting moisture from the rain, which makes recycling difficult. - Flexible black plastic appears within the collected streams that cannot be separated by infrared separation systems.

Revista de
CIENCIAS AMBIENTALES
Tropical Journal of Environmental Sciences

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

Within the guidelines of this business model, we found: 1. Its level of eco-efficiency is high because it increases economic productivity, uses resources better and reduces waste, 2. Its ecological sustainability is high because by the separation of waste in the source it increases the collection of flexible plastic, 3. Its social impact is medium because, although it involved the community, it decreased jobs in the recycling company, 4. Its impact on the productivity of resources is high because it generated the recovery of 2000 tons of plastic and 5. Its impact at the level of technological innovation is medium because it requires the implementation of an infrared equipment to increase the separation (Sandford *et al*., 2020).

3.1.5 Recovery of flexible plastic project Replast, Australia

Replast processes recycles plastic and produces sustainable, high quality and cost-competitive articles, using state-of-the-art equipment and robots. Its portfolio includes traffic dividers, terraces, trails, furniture for sports practices, parks, gardens, among others. They indicate that their products contain 98 % recycled material, (Replast, 2021).

Replast sources flexible plastic waste through the RedCycle program with partner companies for manufacturing aproducts that are to be used outdoors. The RedCycle program places clean and dry flexible plastic and bag collection containers in a supermarket chain with 830 locations in Australia (RedCycle, 2017).

The benefits of the project are the reduction of waste in sanitary landfills, the creation of local jobs and the manufacture of sustainable products.

Table 7. *Replast model Assessment.*
Cuadro 7. Evaluación del modelo *Replast.*

Optimal drivers	Main obstacles
- The generation of a culture towards recycling through training programs and the purchase of items made with recycling. - The work with organizations like RedCycle and retail companies to collect flexible plastic. - The guarantee in the commercialization of articles made with flexible recycled plastic, which allows processors to make investments in state-of-the-art equipment. - The transmission of the message of the value of waste. This message is powerful because it prompts communities to properly separate flexible plastic at the source. - The support from the government, schools and local communities through the purchase and use of recycled products.	- High cost to build a state-of-the-art recycling plant. - The development of technology to provide value for recycling. - The insufficient number of collection centers.

Revista de
CIENCIAS AMBIENTALES
Tropical Journal of Environmental Sciences

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

Within the guidelines of this business model, we found: 1. Its level of eco-efficiency is high because the final products contain 98 % recycled plastic, 2. Ecological sustainability is high due to its low carbon footprint, 3. Productivity of resources is high due to the use of state-of-the-art technology, 4. The social impact is high due to community involvement and job creation, and 5. Technological innovation is high due to the use of robots in the production process.

3.1.6 Novoloop© Chemical recycling, a plant to recover flexible material and convert it into high-value plastic material

Novoloop©, a Silicon Valley start-up company, produces high-performance products from the thermo-accelerated oxidative breakdown of post-consumer polyethylene waste. Through a chemical process, of accelerated thermo-oxidative decomposition of Polyethylene, they are solving one of the greatest environmental challenges as stated by its CEO Miranda Wang. The idea for Novoloop© arose because the founders of the company visited the waste management plants in America, and they realized that polyethylene and especially film were difficult to recycle once they were contaminated (Linnenkoper, 2021).

The patented process allows Novoloop© to use plastic bags, pallet wrappers, agricultural films, food packaging products and more to turn them into a higher value product such as running shoes. The chemical recycling process breaks the polyethylene chains into basic elements, this occurs at low temperature (less than 200 °C) and using a mechanism that recirculates an acidic solvent in the appropriate equipment for the chemical reaction, in this process greatest reduction of CO_2e is achieved, around 68 %. They produce materials, such as thermoplastic polyurethane, with up to 50 times the value of waste (Linnenkoper, 2021).

Chemical recycling offered by Novoloop© offers an alternative to mechanical recycling to solve the technical and economic disadvantages of mechanical recycling due to the difficulty of handling contaminants such as fats, inks, colorants, and fillers that are easily removed in chemical recycling. The Novoloop© process requires less energy than other chemical recycling processes (Karidis, 2020).

Table 8. Novoloop© model Assessment.
Cuadro 8. Evaluación del modelo Novoloop©.

Optimal drivers	Main obstacles
- Financial support from the city of San José California for US $ 120 000 for the constitution of the pilot plant. - The support of the recycling company "GreenWaste Recovery Recycling Company" with the supply of post-consumer waste and the location of the pilot plant. - Search for appropriate technologies to recycle flexible plastic into higher value products. - Interest in reducing the polluting effect of plastic and offering alternatives to the recycling of flexible plastic. - Interest in brands in buying the products of the plant.	- Technology scaling. - Financing for the project.

Revista de
CIENCIAS AMBIENTALES
Tropical Journal of Environmental Sciences

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

Within the guidelines of this business model, we found: 1. Its level of eco-efficiency is high due to the increase of up to 45 times the value of recycling, it allows offsetting the costs of processing; 2. Ecological sustainability is high because this model allows reducing the carbon footprint by 45 % versus polyurethane that is made with virgin resin and address the problem of products that are difficult to recycle mechanically; 3. The productivity of resources is low because the initial conversion rate is low due to the size of the plant pilot; 4. The social impact is high due to the generation of current and potential jobs; 5. Technological innovation is high because it develops novel technology that transforms plastic waste through chemical reactions.

3.1.7 Enerkem©, generation of biofuels and chemical products

Enerkem© works on a revolutionary idea about the manufacture of biofuels and chemical products from non-renewable waste, its objectives are the generation of solutions to waste, the diversification of energy and the construction of a circular economy. It works with communities to reduce waste going to landfills and incinerators. Enerkem's competitive advantage is Research and Development, which allows it to be at the forefront of the circular economy, generating more than 100 patents since 2000 when the company was established. Enerkem's technology uses waste such as textiles, non-recyclable packaging plastics, wood waste, or dirty food containers (Enerkem, 2023).

Enerkem's technology would allow the production of plastic resins such as Polyethylene from difficult-to-recycle plastic waste, household waste and construction materials, which would reduce one of the largest environmental problems in the world, generating a circular economy of plastics, increasing participation of recycled material in new containers and packaging (Grupo Axioma Group S.A.S, 2020). This technology will allow the construction of a plant in Spain that will convert 4 000 000 tons of waste into 220 000 annual tons of methanol and reduce 200 000 tons of CO_2 (Repsol, 2021).

Table 9. Enerkem© model Assessment.
Cuadro 9. Evaluación del modelo Enerkem©.

Optimal drivers	Main obstacles
- Cooperation and support of government entities and brands - Generation and technological development - Research and Development - Interest in reducing the polluting effect of plastic. - Offer alternatives to flexible plastic recycling. - Reduce the amount of municipal plastic waste. - Value generation for plastics that are difficult to recycle	- Technology scaling - Financing for the project

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

Within the guidelines of this business model, we found: 1. Its level of eco-efficiency is high because it gives value to municipal waste that goes to landfills and has no value; 2. Ecological sustainability is high because this model allows reducing the carbon footprint, for example in a project that will be carried out in Spain will reduce 200 000 tons / year of CO_2 eq. The productivity of resources is medium because it has a productivity of around 50 % of waste material such as methanol 4. The social impact is high due to the generation of current and potential jobs and 5. Technological innovation is high because they have developed around 100 patents.

Although there is not an established business model in Colombia to solve the problem of flexible plastic waste, it is necessary to implement actions such as those detailed below. However, it is important to clarify that one by itself does not fully solve the difficulties and uncertainties related to its collection and recovery, but a combination of these actions will allow its management in the long term.

4. Discussion

Based on this research, we propose the following 7 guiding principles to address the challenge of increasing the utilization rate of flexible plastic waste in Colombia:

a) *Develop business models for high-value products*: establish business models that produce high value-added products from recycled materials. By generating additional value, processors can justify investments in advanced equipment, thereby enhancing the recycling chain's capacity to effectively manage and sort plastic waste.

b) *Build infrastructure for collection and management*: create business models focused on developing infrastructure for the collection and management of flexible plastic waste, incorporating reverse logistics to increase the availability of recyclable materials. A sustainable approach to collection and supply is critical as these form the foundation of the recycling chain.

c) *Adopt chemical recycling technologies*: implement business models that utilize chemical recycling to process flexible plastic waste streams that are difficult to recycle through mechanical methods. Chemical recycling enables the production of high-value chemicals or circular virgin plastics, suitable for a wide range of applications.

d) *Formalize the recycling chain*: promote business models that formalize the recycling chain, reducing intermediaries. Direct engagement with waste pickers fosters transparency and trust while increasing collection rates by providing better wages, ultimately improving their quality of life.

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

e) *Invest in innovative recycling technologies*: encourage business models that leverage innovative technologies to enhance the recycling process. These include devices for separating multilayer films, systems for sorting inked films or coextruded materials, and equipment for isolating aluminum from potato chip bags, among other advancements.

f) *Foster alliances among stakeholders*: establish partnerships with brands, governments, communities, and other stakeholders in the value chain to lower costs and improve recycling efficiency. Broader participation enhances recycling rates, maximizes value, and effectively communicates the importance of waste separation to communities, encouraging proper disposal practices.

g) *Utilize mobile applications*: deploy mobile apps to connect individuals with recyclers and waste pickers. These apps can educate users on source separation, increase collection rates through loyalty programs, identify disposal sites, optimize waste collection routes, highlight demand trends for specific types of plastic waste, and ultimately help waste pickers improve their incomes.

5. Conclusions

The implementation of circular economy business models for flexible plastics in Colombia must prioritize methods oriented toward achieving long-term sustainable outcomes. The primary objective would be to address the challenges posed by flexible materials through cyclical processes that not only eliminate waste but also generate economic savings and enhance the value of residual materials.

In our research, we developed an innovative methodology classifying 21 worldwide different circular business models for flexible plastics based on the sustainability pillars: social, environmental, and economic, selecting the six more relevant through sustainability criteria such as Useful Materials, Impact on Sustainability, Value Generation, Stakeholders involved and Use of Technologies. One of the novelties of this methodology is the inclusion of interest groups due to their fundamental role in guaranteeing the sustainability of business models.

Our findings reveal no existing business model in Colombia—or globally—that fully addresses the complexities of flexible plastic recovery, particularly the challenges surrounding collection and reuse. Consequently, a synergistic approach, integrating elements from the aforementioned models, is essential to overcome the persistent issues of low recycling rates and limited value generation from post-consumer flexible plastic waste in Colombia.

As an outcome of this research, we propose guidelines for six business models focused on generating value from waste through mechanical recycling, developing infrastructure for flexible plastic waste collection, expanding the adoption of chemical recycling technologies, formalizing the recycling chain in Colombia, advancing technologies for the separation and classification of flexible plastic waste, fostering alliances among stakeholders in the value chain to promote the

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

value of recycling, and creating mobile applications to engage consumers in the recycling process. These guidelines provide a comprehensive roadmap to address the challenge of increasing the utilization rate of flexible plastic waste in Colombia.

To establish effective circular economy business models for flexible plastics in Colombia, new methods and long-term development processes must be adopted. This includes identifying high-value applications through research and the development of innovative technologies for sorting, cleaning, and removing toxic substances. Furthermore, new reverse logistics systems must be created, emphasizing direct consumer participation and the formalization of informal recyclers. Establishing robust value chains with the involvement of all stakeholders is essential for achieving sustainable outcomes.

6. Ethics and conflict of interest

The authors declare that they have complied with all relevant ethical and legal requirements, both during the study and in the production of the manuscript; that there are no conflicts of interest of any kind; that all financial sources are fully and clearly mentioned in the acknowledgments section; and that they fully agree with the final edited version of the article.

7. Acknowledgements

Gratitude is extended to the anonymous reviewers and the editorial team of the journal for their contributions to the final edited version of the article.

8. References

Acoplásticos. (2020). Plásticos en Colombia 2019-2020. https://vip.acoplasticos.com.co/_lib/file/doc/informe_sectorial_aprovechamiento_2020.pdf

American Chemical Council. (2021). Recycling commercial film value chain case study. https://www.americanchemistry.com/content/download/6921/file/Plastics-and-Sustainability-A-Valuation-of-Environmental-Benefits-Costs-and-Opportunities-for-Continuous-Improvement.pdf

Bashirgonbadi, A., Saputra Lase, I., Delva, L., Van Geem, K. M., De Meester, S., & Ragaert, K. (2022). Quality evaluation and economic assessment of an improved mechanical recycling process for post-consumer flexible plastics. *Waste Management*, (*153*), 41-51. https://doi.org/10.1016/j.wasman.2022.08.018

Burgess, M., Holmes, H., Sharmina, M., & Shaver, M. P. (2021). The future of UK plastics recycling: One Bin to Rule Them All. Resources, Conservation and Recycling, (*164*), 105191. https://doi.org/10.1016/j.resconrec.2020.105191

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

Cardona, M. (2019). Cataki: una APP para el progreso social llega Cali para conectar a los ciudadanos con los recicladores de oficio. https://www.cali.gov.co/serviciospublicos/publicaciones/150944/cataki-una-app-para-el-progreso-social-llega-cali-para-conectar-a-los-ciudadanos-con-los-recicladores-de-oficio/

Cerantola, N. (2016). El envase como elemento de marketing. https://www.ecoembesthecircularcampus.com/web/app/uploads/2021/01/el-envase-como-elemento-de-marketing.pdf

Cooper, J. (2018). Copenhagen – Will its waste be wonderful? https://www.letsrecycle.com/news/copenhagen-waste-wonderful/

Cooper, T., & Singh, J. (2017). Towards a Sustainable Business Model for Plastic Shopping Bag Management in Sweden. *Procedia CIRP*, (61), 679-684. https://doi.org/10.1016/j.procir.2016.11.268

Curtzwiler, G. W., Schweitzer, M., Li, Y., Jiang, S., & Vorst, K. L. (2019). Mixed post-consumer recycled polyolefins as a property tuning material for virgin polypropylene. *Journal of Cleaner Production*, (239), 117978. https://doi.org/10.1016/j.jclepro.2019.117978

Díaz del Río, M. (2020). La magia de la economía circular en 10 objetos de diseño hechos con basura. https://elpais.com/icon-design/decoracion/2020-12-02/la-magia-de-la-economia-circular-en-10-objetos-de-diseno-hechos-con-basura.html

EcoPazifico. (2019). Operación Estación OQ Shoes By Claudia Bahamon. https://ecopazifico.org/operation-station-2-oq-by-claudia-b/

Ellen MacArthur Foundation. (2017). The New Plastics Economy: Catalysing action. https://ellenmacarthurfoundation.org/topics/plastics/examples

Ellen MacArthur Foundation. (2021). Schools of thought that inspired the circular economy. https://ellenmacarthurfoundation.org/schools-of-thought-that-inspired-the-circular-economy

Enerkem. (2023). Supplier partner profiles. https://enerkem.com/Feedstock/Supplier-Partner-Profiles/

Fundación botellas de amor. (2021). Respuestas a preguntas frecuentes. https://botellasdeamor.org/co/la-fundacion/

Gall, M., Wiener, M., Chagas de Oliveira, C., Lang, R. W., & Hansen, E. G. (2020). Building a circular plastics economy with informal waste pickers: Recycle quality, business model, and societal impacts. *Resources, Conservation and Recycling*, 156, 104685. https://doi.org/10.1016/j.resconrec.2020.104685_

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

Graff, S., Johnson, A., King, C., & Sandford, K. (2020). Materials recovery for the future. Flexible Packaging recycling in material recovery facilities pilot. https://www.materialsrecoveryforthefuture.com/wp-content/uploads/MRFF-Pilot-Report-2020-Final.pdf

Greenpeace Colombia, & Clínica Jurídica de Salud Pública y Medio Ambiente (MASP) de la Universidad de los Andes. (2019). Situación actual de los plásticos en Colombia y su impacto en el medio ambiente. http://greenpeace.co/pdf/2019/gp_informe_plasticos_colombia_02.pdf

Grupo Axioma Group S. A. S. (2020). Nova Chemicals y Enerkem trabajan para producir etileno a partir de desechos. https://www.plastico.com/es/noticias/nova-chemicals-y-enerkem-trabajan-para-producir-etileno-partir-de-desechos

Grupo de acción de Economía Circular & Forética. (2020). La ambición empresarial para avanzar hacia la nueva economía de plásticos. https://foretica.org/wp-content/uploads/2020/07/La_ambicion_empresarial_para_avanazar_hacia_la_nueva_economia_de_plasticos.pdf

Huang, P., Pitcher, J., Mushing, A., Lourenço, F., & Shaver, M. P. (2023). Chemical recycling of multi-materials from glycol-modified poly (ethylene terephthalate). *Resources, Conservation and Recycling*, (*190*), 106854. https://doi.org/10.1016/j.resconrec.2022.106854

Karidis, A. (2020). BioCellection's Chemical Recycling Process Backed by Green Waste Recovery and City of San José. https://www.waste360.com/recycling/biocellections-chemical-recycling-process-backed-greenwaste-recovery-and-city-san-jose

Kowszyk, Y., & Maher, R. (2018). Estudios de caso sobre modelos de Economía Circular e integración de los objetivos de desarrollo sostenible en estrategias empresariales en la UE y ALC. https://eulacfoundation.org/es/system/files/economia_circular_ods.pdf

Li, B., Ma, Y., & Li, H. (2022). A new journey of plastics: Towards a circular and low carbon future. *Giant*, (11), 100115. https://doi.org/10.1016/j.giant.2022.100115_

Linnenkoper, K. (2021). Novoloop ceo Miranda Wang: 'We want to help double the size of the circular economy. https://recyclinginternational.com/business/interview/novoloop-ceo-miranda-wang-we-want-to-help-double-the-size-of-the-circular-economy/32810/

Liu, C., Medda, F., & Zhang, X. (2021). Plastic credit: A consortium blockchain-based plastic recyclability system. *Waste Management*, (*121*), 42-51. https://doi.org/10.1016/j.wasman.2020.11.045

Ministerio de Ambiente y Desarrollo Sostenible. (2021). Plan Nacional para la Gestión Sostenible de los Plásticos de un solo uso. https://www.minambiente.gov.co/wp-content/uploads/2022/02/plan-nacional-para-la-gestion-sostenible-de-plasticos-un-solo-uso-minambiente.pdf

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

Ministerio de Ambiente y Desarrollo Sostenible, y Ministerio de Comercio Industria y Turismo. (2019). Estrategia nacional de economía circular: Cierre de ciclos de materiales, innovación tecnológica, colaboración y nuevos modelos de negocio. https://www.andi.com.co/Uploads/Estrategia%20Nacional%20de%20EconA%CC%83%C2%B3mia%20Circular-2019%20Final.pdf_637176135049017259.pdf

Mrowiec, B. (2018). Plastics in the circular economy (CE). *Environmental Protection and Natural Resources*, *29*(4), 16-19. https://doi.org/doi:10.2478/oszn-2018-0017

Nicholson, S. R., Rorrer, N. A., Carpenter, A. C., & Beckham, G. T. (2021). Manufacturing energy and greenhouse gas emissions associated with plastics consumption. *Joule*, *5*(3), 673-686. https://doi.org/10.1016/j.joule.2020.12.027

Nurel, (2018). Nurel participa en el proyecto multibiobarrier. Desarrollo de film flexible biodegradable con propiedades barrera para envase alimentario. https://nurel.com/es/noticias/proyecto-multibiobarrier-film

RedCycle. (2017). Soft Plastic Recycling. https://wastemanagementreview.com.au/redcycle-suspends-soft-plastics-collection-industry-reacts/

Replast. (2021). Recycling At Replas. Ecobuy factsheets. https://wastemanagementreview.com.au/roadmap-to-restart-soft-plastic-recycling-released/

Repsol. (2021). Repsol se une a Enerkem y Agbar para construir una planta de valorización de residuos en Tarragona. https://www.repsol.com/content/dam/repsol-corporate/es/sala-de-prensa/documentos-notas-de-prensa/2021/np27042021-ecoplanta.pdf

Rivas Salmón, A. (2019). Potenciando la economía circular en torno al envase flexible. https://Www.Interempresas.Net/Reciclaje/Articulos/252374-Potenciando-La-Economia-Circular-En-Torno-al-Envase-Flexible.Html_

Robayo, L. (2019). Fundación Botellas de Amor: un modelo de reciclaje que cautiva. https://www.Mundopmmi.Com/Empaque/Sustentabilidad/Article/14037922/Fundacin-Botellas-de-Amor-Un-Modelo-de-Reciclaje-Que-Cautiva

Scholle IPN. (2021). ESG Report. Flexible Packaging and Sustainability. https://www.Scholleipn.com/

Sandford, K., King, C., Johnson, A., & Graff, S. (2020). Materials recovery for the future. Flexible Packaging recycling in material recovery facilities pilot. https://www.americanchemistry.com/better-policy-regulation/plastics/resources/flexible-packaging-recycling-in-material-recovery-facilities-pilot

Superintendencia de Servicios Públicos Domiciliarios. (2019). Informe Sectorial de la Actividad de Aprovechamiento 2018. https://www.superservicios.gov.co/sites/default/files/inline-files/informe_sectorial_aprovechamiento_2018_0.pdf

Revista de Ciencias Ambientales (Trop J Environ Sci)
e-ISSN: 2215-3896
(Enero-Junio, 2025) . Vol 59(1): 1-20
DOI: https://doi.org/10.15359/rca.59-1.11
Open Access: www.revistas.una.ac.cr/ambientales
e-mail: revista.ambientales@una.ac.cr
Orrego-Bustamante N.R; Báez-Niño A.A.;
Darling Perea-Cabarcas; Lambis-Miranda H.A.

Superintendencia de Servicios Públicos Domiciliarios coplásticos. (2020). *Plásticos en Colombia 2019-2020*. https://vip.acoplasticos.com.co/_lib/file/doc/informe_sectorial_aprovechamiento_2020.pdf

Távora de Mello Soares, C., Ek, M., Östmark, E., Gällstedt, M., & Karlsson, S. (2022). Recycling of multi-material multilayer plastic packaging: Current trends and future scenarios. *Resources, Conservation and Recycling*, (176), 105905. https://doi.org/10.1016/j.resconrec.2021.105905

TheCircularLab. (2018). Carrefour, Dondelotiro y TheCircularLab testan en Logroño un sistema que ayuda a reciclar mejor a través de tickets de compra inteligentes. https://www.thecircularlab.com/carrefour-dondelotiro-thecircularlab-testan-sistema-reciclar-mejor/

Unilever. (2022). Our solution for recycling plastic sachets takes another step forward. https://www.no-burn.org/wp-content/uploads/2022/03/Chemical-Recycling-of-Sachet-Waste_A-Failed-Experiment-2022.pdf