



Reciclaje inclusivo hacia una economía circular

Analysis of packaging recycling and circularity in Latin America

Study prepared by Emprendia on behalf of Latitude R.

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General index

1 Introduction	5
2 Recycling technologies	7
2.1 Recycling of plastic packaging	7
2.2 Polymer-based multilayer packaging recycling	8
2.3 Paper and cardboard packaging recycling	8
2.4 Recycling of metal packaging	8
2.5 Recycling of glass containers	9
2.6 Recycling beverage cartons	9
3 Packaging use, recovery and recycling	11
4 Barriers and drivers of recycling	14
5 Barriers in the recycling chain	20
6 Innovations in plastic packaging recycling	23
7 Conclusions	25
8 Recommendations	28

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Glossary

BOPP: biaxially oriented polypropylene.

NAC: apparent national consumption. It is calculated as: production+ imports - exports.

EE: containers and packaging. EPS: expanded polystyrene.

HDPE: high density polyethylene. kt: thousands of tonnes.

LDPE: low density polyethylene. LLDPE: linear low density polyethylene.

ND: not available.

PE: polyethylene.

PET: polyethylene terephthalate. PP: polypropylene.

PS: polystyrene.

PVC: polyvinyl chloride.

EE recycling rate: ratio between the amount (in tonnes) of packaging recycled and the amount (in tonnes) of packaging used by the market.

Recovery rate of packaging: ratio between the amount (in tonnes) of packaging recovered from a material and the amount (in tonnes) used for packaging of that material.

Recovery rate compared to use in the USA: The ratio between the quantity (in tonnes) of a material recovered and the quantity (in tonnes) used for packaging and packaging of that material.

1. Introduction

Latitud R, formerly known as the Regional Initiative for Inclusive Recycling (IRR), is a collaborative platform created in 2011 between the Inter-American Development Bank Group (IDB), with its Water and Sanitation Division and its innovation laboratory, IDB Lab, Coca-Cola Latin America, Pepsico Latin America, Dow Chemical, the Latin American Recycling Network (Red-LACRE) and the Avina Foundation. Its purpose is to contribute to the development of inclusive recycling systems with economic, social and environmental sustainability across the continent, contributing to the formalisation and improvement of conditions for grassroots recyclers, and to the development of the Circular Economy in the region.

To this end, Latitud R aims to increase the capacities of ecosystem actors; strengthen the waste circular economy value chains in the region by introducing inclusion and innovation in both waste recovery and industrial processing; support the development and implementation of regulations and public policies that favour and promote inclusive recycling and the circular economy; and underpin the positioning of this issue on the public agenda through the generation and dissemination of knowledge, and through campaigns, actions and communication products.

To meet these objectives, it is key to strengthen the value chain of the recycling industry in the region, addressing its challenges in terms of innovation, scale, efficiency, transparency, among others. This requires understanding and addressing the existing constraints to recycling the containers and packaging of the products consumed by the market.

Objectives of the study

The **overall objective** of this study is to improve the information available on the set of packaging materials used, as well as their effective post-consumer recycling levels for each type of material, existing limitations and alternatives to increase the circularity¹ of these materials.

The **specific objectives** of the study are as follows:

1. **Identify and characterise the materials** used for packaging in three Latin American countries.

¹ We will use this term to refer to the extent to which the materials that are part of the study are susceptible or not to be used in "closed cycle" production systems, in which: energy and water use is reduced, emissions are reduced, the percentage of recycled raw material is maximised and the value of these materials is preserved, avoiding quality losses and the use of virgin raw material.

2. Analyse the **technologies available** for recycling.
3. Assess their **recycling and circularity potential**.
4. Determine their **effective levels of post-consumer recycling**.
5. Determine the main **barriers and drivers for recycling**.
6. Identify **the most relevant innovations** that offer a second life to plastics that do not have a closed-cycle market.
7. Provide a set of **recommendations to overcome the identified barriers**.

The study is aimed at decision-makers from public agencies, private companies, waste picker organisations, civil society organisations and other stakeholders interested in improving integrated waste management systems in the region.

The nature of this study aims to generate information valid for any country in Latin America, as it deals with packaging materials common to all countries. However, to facilitate data availability and to increase the depth of the analysis, the study focuses on three Latin American countries: **Brazil, Colombia and Mexico**.

Methodology

The study is developed around three main aspects associated with post-consumer packaging recycling:

- **The analysis of existing technologies for the recycling of the main materials used in packaging**, carried out through the study of scientific publications, books and websites specialising in the subject.
- **The investigation of the state of play regarding levels of packaging use, recovery and recycling**, which was carried out through the analysis of existing reports produced by NGOs, government agencies, companies, sectoral chambers, recyclers' organisations, as well as information provided directly by these actors through interviews and/or documents.
- **Research on the existing barriers and drivers for recycling and packaging circulation in the three countries addressed**, which was carried out by conducting interviews with actors in the recycling chain.

In addition, the study identifies innovations that offer a second life to plastics that are not recycled in a closed cycle and provides a series of recommendations to overcome the identified barriers to recycling and circularity. The latter arise from the interviews conducted, the literature studied and the author's own elaboration based on the analysis and interpretation of the results of the study.

2. Recycling technologies

This chapter presents the main materials used for packaging and an overview of the methods used for their recycling. A detailed description of the materials and an in-depth analysis of recycling technologies can be found in the full version of this study, available [here](#).

2.1 Recycling of plastic packaging

Plastic packaging is mainly made of six different polymer resins which are identified by the Resin Identification Code (RIC): **PET (1), HDPE (2), PVC (3), LDPE (4), PP (5) and PS (6)**. The number 7 is a general category meaning that the packaging is made of a type of plastic other than the six specified above, or is a mixture of plastics, or a combination of plastics in multiple layers [1, 2].

The most common method of plastics recycling is mechanical recycling. Due to its high reliability and low cost, mechanical recycling is currently the ubiquitous industrial technique for recycling plastic waste [3, 4]. The general process of mechanical recycling of post-consumer plastics consists of sorting according to resin type and colour, washing, baling for transport, milling for reduction to flakes and finally pelletising (optional) to convert the flakes to pellets. The result of this process is raw material that can be transformed into new products. The main step for transformation into new products is the melting of the plastic, which limits this technique to thermoplastic polymers⁽¹⁾ [3].

Plastic containers made from resins 1 to 6 are recyclable by the mechanical recycling method. Packaging identified with the number 7 can be recycled by the mechanical method as long as they are thermoplastic polymers, however, due to the fact that their composition is not known in principle, the properties of the resulting material cannot be predicted.

The mechanical recycling of post-consumer plastic packaging presents several challenges that are related to its heterogeneity and contamination: contamination with non-plastic materials [6], contamination with different polymers [3, 4, 7], contamination with additives and paints [3, 4, 7], recycling of different plastic products [667], degradation during the recycling process [], and contamination of plastic products [].

¹ Thermoplastics are polymers that melt when heated and harden when cooled. These characteristics are reversible so that the material can be repeatedly melted and cooled. This allows thermoplastics to be mechanically recycled [5].

in the recycling process [4, 6] and chemical contamination [6]. **These difficulties may lead to a reduction in circularity**, caused by a decrease in the quantity and quality of recycled plastic, although to what extent has not yet been quantified [6].

2.2 Polymer-based multilayer packaging recycling

Polymer-based multilayer packaging is a structure of two or more layers that allows the packaging to achieve greater functionality, often at a lower cost than using a single layer to perform the same function. In turn, the multilayer structure allows the packaging to perform a combination of functions that are not possible with a single layer [8].

Mechanical recycling is not suitable for polymer-based multilayer packaging as most polymer blends result in materials with poor mechanical performance and unstable morphologies. Thus, in mechanical recycling processes of a single type of plastic, multilayer containers are considered an impurity that must be separated so as not to affect the quality of the recycled material [7].

Three polymer-based multilayer packaging recycling techniques were analysed: compatibilisation, dissolution - selective re-precipitation and delamination [7]. **None of the methods studied can be considered as a solution to multilayer packaging recycling**, as they have not reached a sufficient level of technological development and adoption. Therefore, at present, **the circularity potential of these containers is extremely limited**.

2.3 Paper and cardboard packaging recycling

Recycling of paper and board is done by spraying the material with large quantities of water to break it down into individual fibres (pulp). The pulp is pressed, dried and rolled into large thin sheets of recycled paper [9]. **Paper and board cannot be recycled indefinitely** as the recycling process shortens the fibres each time they are processed, so that after approximately five to ten cycles, the fibres are too short to make paper and become paper sludge. Therefore, virgin fibre must be introduced into the market on a regular basis to maintain the quantity and quality of paper. **This represents a constraint for the circularity potential of paper and board** [9].

2.4 Recycling of metal packaging

The main raw materials used in the manufacture of metal packaging are steel and aluminium. Through smelting, **these containers can be recycled infinitely without loss of properties**. Unlike paper and plastic, metals are recycled at the atomic level. This means that once re-melted, the recycled metal is indistinguishable from new metal [10]. For this reason, **metal packaging has a high circularity potential**.

2.5 Recycling of glass containers

Glass containers can be recycled infinitely without loss of strength or quality, giving them a high potential for circularity. Glass is recycled by heating it until it melts and then shaping it back into a container. For proper recycling, glass must be sorted according to its colour [11].

2.6 Recycling of beverage cartons

Beverage cartons are multi-laminated containers that **are made of 75 % paperboard, 20 % polyethylene and 5 % aluminium.** These three materials are layered together using heat and pressure to form a six-layer armour that protects the contents from light, oxygen, air, dirt and moisture [12].

Three methods have been identified for recycling beverage cartons. **The most common method of recycling is similar to paper and board. There, the extracted polyethylene and aluminium are processed into a composite material known as polyaluminium,** which is used to make corrugated sheets for roofing and plates for furniture manufacturing, among other products [12, 13].

The second available technique is delamination, where the different materials are separated without loss or transformation and can be reused as raw materials [14]. This technology is sufficiently developed for beverage carton recycling and is commercially available, however, the level of adoption on a global scale is very limited.

The third recycling method is the thermal pressing of the complete container in combination with other recyclable plastics to produce a chipboard-like board that replaces wood in various applications, such as school furniture [15].

So far, beverage cartons are not recycled in a closed cycle because the carton needs to have a specific strength that can only be achieved by using virgin fibre and because polyaluminium separation processes are not sufficiently widespread in the world. In Latin America, there is not enough material volume to justify the investment in a processing plant. For this reason, combined processing is used, which is less expensive [16].

Table 2.1 gives an overview of the main packaging materials used, their most common applications and the methods used for their recycling.

Table 2.1: Materials used for packaging, examples of applications, recycling methods and their maturity level.

Maturity levels of recycling technologies			Maturity level
The technology is standard in the recycling of post-consumer material.			
The technology is sufficiently developed for the recycling of post-consumer material but the level of adoption worldwide is very limited.			
Technology is not sufficiently developed for the recycling of post-consumer material.			
Material	Packaging applications	Recycling method	Maturity level
PET (Polyethylene terephthalate)	Bottles of soda, oil, water, juices	Mechanic	
HDPE (Polyethylene high density)	Bottles for non-food products (cosmetics, shampoo, detergents, household cleaners) Bottles for food products (water, juices, milk)	Mechanic	
PVC (Polyvinyl chloride)	Rigid: blister packs for chewing gum, medicines and other products. Egg and food trays in general. Flasks. Flexible: Stretch film	Mechanic	
LDPE (Polyethylene low density)	All-purpose bags: cleaning, frozen food, fresh produce, household waste. Stretch film. Squeeze bottles (mustard, ketchup).	Mechanic	
PP (Polypropylene)	Containers for yoghurt, cream, take-away food. Medicine bottles. Bottle caps and closures. BOPP: Snacks, soups, dry pasta, rice, label.	Mechanic	
PS (Polystyrene)	Food containers, plates, cutlery, yoghurt cups. Meat trays, egg containers, protective foam for electronics and other delicate items (EPS).	Mechanic	
Other	Reusable 5, 10, 20 litre water bottles. Shampoo bottles.	Mechanic	
Polymer-based multilayer packaging	Snacks, biscuits, ice cream, frozen food, stand-up pouch.	Selective dissolution and re-precipitation	
		Delamination	
		Compatibility	
Glass	Flasks, bottles	Foundry	
Metal (steel and aluminium)	Food, beverage, aerosol cans	Foundry	
Paper and cardboard	Tea and coffee bags, flour bags, folding cartons, rigid boxes, corrugated boxes.	Pulping	
Beverage cartons	Milk, yoghurt, juices	Pulping and processing combined polyaluminium	
		Delamination	

3. Packaging use, recovery and recycling

This chapter presents the quantities of packaging used of the different materials and their corresponding recovery and recycling rates in Brazil, Colombia and Mexico. In addition, in order to put the local figures into context, European packaging use and recycling rates are presented. Further details on each of these points can be found in the full version of this study, available [here](#).

It is important to mention that the figures presented are based on the sources of information¹ collected for this study and are estimates. In some cases, own estimates are presented based on the data obtained. Polymer-based multilayer packaging is not analysed separately as it falls under the group of plastic packaging.

Table 3.1 presents the quantities used of each material in packaging and their percentage share. The latter represents the fraction of the packaging market occupied by each of the materials, ranked by weight.

	Colombia		Mexico		Brazil		Europe	
	Use in EE (kt)	Percentage share	Use in EE (kt)	Percentage share	Use in EE (kt)	Percentage share	Use in EE (kt)	Percentage share
Paper and cardboard	900	44,3 %	3.295	31,8 %	4.861	55,5 %	31.200	48,3 %
Glass	266	13,1 %	3.420	33,0 %	1.000	11,4 %	14.000	21,7 %
Plastic	691	34,0 %	2.640	25,5 %	1.931	22,0 %	14.500	22,5 %
Steel	102 ^a	5,0 % ^a	530	5,1 %	425	4,9 %	3.394	5,3 %
Aluminium	61 ^a	3,0 % ^a	295	2,8 %	303	3,5 %	564	0,9 %
Beverage cartons	13,6	0,7 %	190	1,8 %	240	2,7 %	915	1,4 %

a) Own estimate based on the share of this material in Mexico and Brazil, due to lack of data for Colombia.

Table 3.1: Use of packaging materials in Mexico, Brazil, Colombia and Europe.

¹ Sources of information: Colombia [17-22]; Mexico [16, 23-26]; Brazil [27-32]; Europe [33-39].

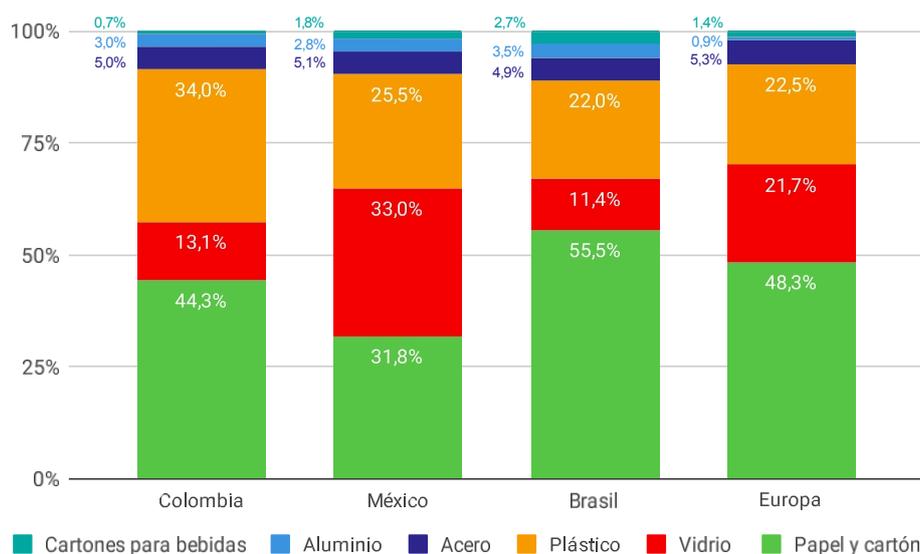


Figure 3.1: Percentage share of materials used in packaging Colombia, Mexico, Brazil and Europe.

As can be seen in Figure 3.1, the share of packaging materials is similar in the countries under study and in Europe. In all cases, paper and board, plastic and glass are the most widely used packaging materials, accounting for around 90 % of the market (calculated by weight). Metal packaging and beverage cartons have a share of around 10 %.

Table 3.2 presents the recovery and recycling rates in Mexico, Brazil and Colombia and the average recycling rate in Europe for each material. It is important to note that the figures shown represent different rates², as indicated by the superscript in each case. Paper and board has a recovery rate for packaging use of over 100 per cent because more material is recovered than is used in packaging.

	Colombia	Mexico	Brazil	Europe
Paper and cardboard	77,4 % ^b	103,2 % ^a	81,4 % ^c	72,3 % ^c
Steel	ND	96,6 % ^b	47,0 % ^c	82,5 % ^c
Aluminium	ND	96,6 % ^b	97,3 % ^c	74,5 % ^c
Plastic	13,1 % ^a	26,2 % ^a	20,3 % ^c	42,0 % ^c
Beverage cartons	10,0 % ^c	25,0 % ^c	31 % ^c	47,0 % ^c
Glass	42,5 % ^b	9,9 % ^a	47,0 % ^c	76,0 % ^c

a) Recovery rate for use in packaging.

b) Packaging recovery rate.

c) Recycling rate.

Table 3.2: Recovery and recycling rates of used packaging materials in Mexico, Brazil and Colombia and average recycling rate per material in Europe. ND: not available.

² The definition of the different recovery and recycling rates can be found in the [Glossary](#).

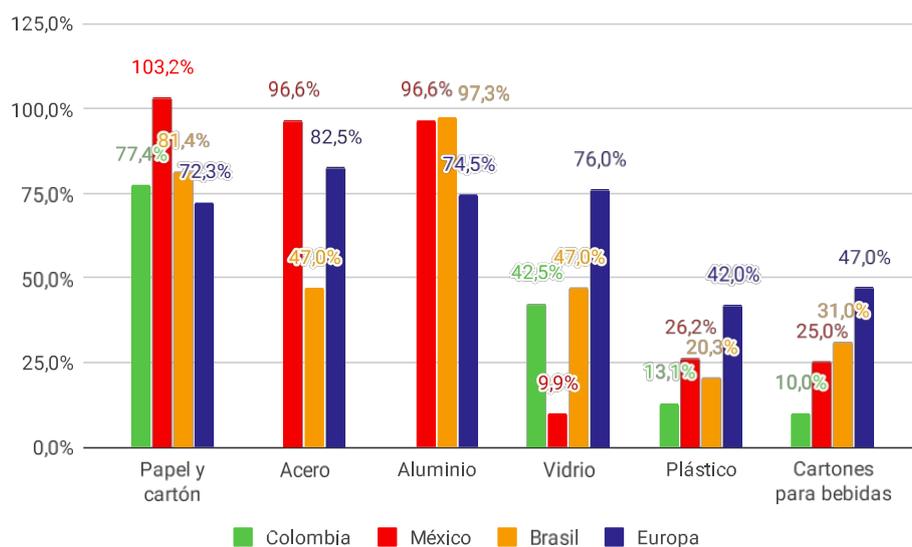


Figure 3.2: Recovery and recycling rates of used packaging materials in Mexico, Brazil and Colombia and average recycling rate per material in Europe.

As can be seen in Figure 3.2, the highest recovery and recycling rates in the countries under study are for metal³, paper and board and glass packaging (except in Mexico), with figures ranging from approximately 40% to 100%. These rates are similar and in some cases higher than the European average. Only in the case of glass are they markedly lower.

On the other hand, in the countries under study, beverage cartons have recycling rates ranging from 10% to 31%. While the rates for plastic packaging are in the range of approximately 13% to 26%. In both cases, the figures are significantly lower than the European average recycling rate, which is 49% for beverage cartons and 42% for plastic containers. Furthermore, in Europe the lowest recycling rate for plastic packaging is 18.3 % (Liechtenstein) and the highest is 74 % (Lithuania) [38]. Therefore, the recovery and recycling rates of plastic packaging in Colombia, Brazil and Mexico are closer to the European minimum than to the average rate.

Among plastics, PET bottles stand out with recovery and recycling rates of over 50 % in Brazil and Mexico and 30 % in Colombia, while in Europe the average rate is 58.2 % [40].

³ Does not include Colombia as there is no data on the recovery and recycling of metal packaging.

4. Barriers to and drivers of recycling

This chapter presents the identified barriers and drivers for recycling and packaging circularity of the materials studied. A detailed description of the barriers and drivers can be found in the full version of this study, available [here](#).

Plastic packaging (including multi-layers and excluding PET) and beverage cartons have the most barriers and the fewest drivers for recycling and circulation. They have the lowest recovery and recycling rates, which are in the range of 0% to 37%. The packaging with the fewest barriers and the most drivers for recycling and circularity are metal, paper and board, PET bottles and glass packaging, which have recovery and recycling rates in the range of 40% to 100% (except glass Mexico)¹.

Plastic packaging

Plastic packaging faces a number of complex technical difficulties in recycling associated with heterogeneity and contamination, which were described in section 2.1. Further complicating the situation are the lack of uniformity of packaging [41], the use of dyes [41, 42], the tying of the profitability of the recycling process to the price of oil [3], the lack of development of closed-loop recycling processes for all resins, and the consequent regulatory limitation on the use of post-consumer recycled plastic in food packaging.

In particular, some resins suffer from greater difficulties, e.g. PE and PP retain chemical compounds when recycled [6], are difficult to differentiate from each other [30] and their low weight discourages their collection [43]. The latter is also true for EPS due to its extremely low density [44].

Plastic is the second or third most used packaging material with a share of between 22% and 34% depending on the country. This, coupled with the barriers mentioned above and their recycling rates, means that **plastic packaging faces the greatest challenges of all the packaging analysed.**

¹ This analysis does not consider the recycling rate of metal packaging in Colombia due to lack of data.

PET bottles

However, the high demand for the material, its low heterogeneity and consequent ease of sorting, together with the possibility of closed-loop recycling [41, 45] and its relatively high price [44, 46, 47] promote its recycling.

Polymer-based multilayer packaging

The main barrier to the recycling of polymer-based multilayer packaging is the lack of technologies that have reached a sufficient level of technological development and adoption for recycling.

Paper and cardboard packaging

Paper and cardboard face barriers to recycling due to contamination with organic residues [48] and their low price [44, 46-51]. In addition, they are limited in the number of recycling cycles due to the loss of quality in the process [9]. In Brazil, regulations do not restrict the use of recycled paper and board in food packaging [52], unlike in Colombia where it is partially limited [53]. In Mexico, existing regulations do not refer to the use of any type of post-consumer recycled material in packaging intended to come into contact with food, however, they do state that packaging materials must be safe [54]. The paper and board industry's long history of recycling and the ease of handling the material act as drivers.

Metal packaging

In the case of aluminium packaging, no barriers to recycling have been identified, and for steel packaging, contamination with organic debris is the only barrier found [55]. Both materials share several drivers: closed-loop recycling [10, 56], energy cost savings [57, 58], use in other industries [55, 56] and high density. Aluminium also has a high price [44, 46, 47] and is easy to compact [55]. Steel, on the other hand, is easily sealed by magnetic strips [55]. In addition, metal packaging can be recycled indefinitely without loss of properties and the resulting material is indistinguishable from the virgin raw material. This gives metal packaging a high potential for circularity. Finally, regulations in Colombia and Brazil do not restrict the use of recycled metal in food packaging [59, 60].

Glass containers

Glass containers have the lowest price in the market for recyclable materials [44, 46, 47]. This, together with their reuse for the adulteration of alcoholic beverages (Colombia and Mexico) [61, 62], are the main constraints to their recycling. Glass containers can be recycled without loss of quality and in a closed cycle [10, 11], are easily identifiable during collection [49, 61], have a high density, are generated in large quantities and do not face regulatory constraints [63, 64].

Beverage cartons

Beverage cartons are rejected by recyclers due to their low price [15, 27, 44, 46, 47] and contamination with organic residues [49]. For its part, the paper industry fears that the incorporation of these containers in its processes will jeopardise the quality of the paper obtained, as well as causing a decline if a dedicated recycling line is not implemented to obtain pure polyaluminium [16]. Despite this, the fact that the paper industry is responsible for the recycling of beverage cartons can be seen as a driver for their recycling, as the high utilisation rates of recycled material could generate a sustained demand for these post-consumer containers and ensure the recovery of the paperboard. However, as it cannot be closed-loop recycled [16], the demand for post-consumer beverage cartons is partly limited by the demand for polyaluminium for the manufacture of a narrow range of products.

The recovery and recycling rates of beverage cartons are similar to those of plastic containers, however, they differ from plastic containers in that they only account for between 0.7% and 2.7% of the containers placed on the market in the countries under study.

Tables 4.1, 4.2 and 4.3 show a summary of the identified barriers and drivers together with the corresponding recovery or recycling rates for each material.

		General analysis	Brazil	Colombia	Mexico
Containers of PAPER & BOARD	CIRCULARITY	<ul style="list-style-type: none"> - Loss of quality in successive recycling cycles + Retains sufficient quality to be recycled some cycles 	<ul style="list-style-type: none"> + Legislation allows the use of recycled material in food packaging 	<ul style="list-style-type: none"> - The regulation prohibits the use of recycled food contact material that is not suitable for food contact. are not dry solids + The regulation allows the use of recycled material in food packaging that necessarily peeled for consumption 	_____
	RECYCLING	<ul style="list-style-type: none"> - Low international prices - Pollution + Ease of handling + Long history of the paper and paper industry cardboard in recycling + High quantities of material generated 	_____	<ul style="list-style-type: none"> + Stable market - Seasonal closure of industries 	_____
	RECOVERY AND RECYCLING RATES		81,4%***	77,4%**	103,2%*
Containers of ALUMINIUM	CIRCULARITY	<ul style="list-style-type: none"> + Recycling without loss of quality 	<ul style="list-style-type: none"> + Legislation allows the use of recycled material in food packaging 	<ul style="list-style-type: none"> + Regulations do not restrict the use of recycled material for food contact. 	_____
	RECYCLING	<ul style="list-style-type: none"> + Ease of compaction + High density + Closed-loop recycling + Energy cost savings 	<ul style="list-style-type: none"> + High price + Use in other industries 	<ul style="list-style-type: none"> + High price 	<ul style="list-style-type: none"> + High price + Use in other industries
	RECOVERY AND RECYCLING RATES		97,3%***	ND	96,6%**
Containers of STEEL	CIRCULARITY	<ul style="list-style-type: none"> + Recycling without loss of quality 	<ul style="list-style-type: none"> + Legislation allows the use of recycled material in food packaging 	<ul style="list-style-type: none"> + Regulations do not restrict the use of recycled material for food contact. 	_____
	RECYCLING	<ul style="list-style-type: none"> - Pollution + High density + Separation by magnetic strips + Closed-loop recycling + Energy cost savings 	_____	_____	<ul style="list-style-type: none"> + Use in other industries
	RECOVERY AND RECYCLING RATES		47%***	ND	96,6%**

* Recovery rate of the material with respect to its use in packaging.
 ** Container and packaging recovery rate.
 *** Recycling rate of containers and packaging.

- Barrier
 + Impeller

Table 4.1: Barriers and drivers for the recycling of paper and board, aluminium and steel packaging.

		General analysis	Brazil	Colombia	Mexico
GLASS Containers	CIRCULARITY	+ Recycling without loss of quality	+ Legislation allows the use of recycled material in food packaging	+ Legislation allows the use of recycled material in food packaging	_____
	RECYCLING	+ Ease of identification + High density + Closed-loop recycling	- Low price + High quantities of material generated	- Low price - Reuse of packaging for adulteration of alcoholic beverages + High quantities of material generated + High demand for the material	- Low price - Reuse of packaging for the adulteration of alcoholic beverages + High quantities of material generated
	RECOVERY AND RECYCLING RATES		47%***	42,5%**	9,9%*
BEVERAGE Cartons	CIRCULARITY	- Insufficient technological development for closed-loop recycling	_____	_____	_____
	RECYCLING	- Risk of the recycling process - Additional investment required to recovery of polyaluminium - Pollution - Open-cycle recycling + Recycling in the paper industry	- Low price	- Low price	- Low price
	RECOVERY AND RECYCLING RATES		31%***	11%***	25%***
Packaging MULTILAYER polymer-based	CIRCULARITY	_____	_____	_____	_____
	RECYCLING	- Insufficient technological development for recycling	_____	_____	_____
	RECOVERY AND RECYCLING RATES		1,1%***	ND	ND

* Recovery rate of the material with respect to its use in packaging.

** Container and packaging recovery rate.

*** Recycling rate of containers and packaging.

- Barrier
+ Impeller

Table 4.2: Barriers and drivers for the recycling of glass, beverage cartons and polymer-based multilayer packaging.

		General analysis	Brazil	Colombia	Mexico
PLASTIC Containers	CIRCULARITY	- Technical difficulties of mechanical recycling	- Regulations generally prohibit the use of recycled post-consumer plastic in packaging intended to come into contact with food + The regulation states that special technological processes may be considered for obtaining of resins from recyclable materials that can be used in contact with foodstuffs	- Regulations generally prohibit the use of recycled post-consumer plastic in packaging intended to come into contact with food + Regulation allows the use of recycled post-consumer plastic in multilayer packaging that have a functional barrier + The regulation allows the use in packaging of validated food-grade post-consumer recycled plastic foods	
	RECYCLING	- Contamination with non-plastic materials - Contamination with different polymers - Contamination with additives and paints - Recycling of different plastic products - Degradation during its lifetime and in the recycling process - Chemical contamination - Co-recycling of food packaging and non-food packaging - Use of dyes - Oil price volatility			
	RECOVERY AND RECYCLING RATES		20,3%***	13,1%*	26,2%*
Containers of PET	CIRCULARITY	+ Food grade recycling technology	+ Food grade recycling technology	+ Food grade recycling technology	+ Food grade recycling technology
	RECYCLING	- Technical difficulties of mechanical recycling + Closed-loop recycling + Low heterogeneity + Medium - high price + Average density	+ High quantities of material generated	+ High quantities of material generated	+ High quantities of material generated
	RECOVERY AND RECYCLING RATES		54,9%***	30%***	56,2%*
Packaging of other resins (PE, PP, PVC, PS)	CIRCULARITY		- Lack of food grade recycling technology	- Lack of food grade recycling technology	- Lack of food grade recycling technology
	RECYCLING	- Technical difficulties of mechanical recycling - High heterogeneity - Open-cycle food packaging recycling - PE and PP: Retention of chemical compounds - PE and PP (flexible packaging): Low weight - EP and PP: Difficulty of differentiation - EPS: Very low density		PVC, PS, EPS: - Low demand - Low price	
	RECOVERY AND RECYCLING RATES		Flexibles <12,3% PS: 8,6% ***	ND	Flexibles < 8.2% Rigid PP: 12.1% Rigid HDPE: 36.9%* .

* Recovery rate of the material with respect to its use in packaging.
 ** Container and packaging recovery rate.
 *** Recycling rate of containers and packaging.

- Barrier
 + Impeller

Table 4.3: Barriers and drivers for plastic packaging recycling.

5. Barriers in the recycling chain

This chapter presents a series of obstacles identified in the recycling chains of Brazil, Colombia and Mexico. It is important to clarify that since it is not one of the objectives of this work to carry out an analysis of the recycling chains, the information presented here is not intended to be exhaustive, but rather represents a sample of the main factors that the interviewees and the literature analysed identify as difficulties in the operation of the recycling circuits of the countries under study. The obstacles are presented jointly for the three countries and the relevant clarification is made in those cases where the information does not correspond to the group of countries. For more details on the barriers in the recycling chains, please consult the full version of this study, available [here](#).

To simplify understanding, the barriers are presented in order of the stages of the recycling chains.

Design and production of goods

- Lack of regulations governing the design of recyclable packaging [65].
- Production of complex and difficult to recycle or non-recyclable packaging to simultaneously meet the requirements of the packaged products, marketing needs and cost constraints [65-67].
- Cost competition of recycled materials with virgin raw materials or imported recovered materials, e.g. in the cases of plastics and glass [45, 61, 66].

Consumption and waste generation

- Lack of a culture of waste separation by citizens [20, 27, 65, 68, 69].
- Lack of incentives and sanctions to promote source separation [43, 68].
- Contamination of materials with organic or other residues that reduce their quality and make them difficult to recycle [48, 67, 69].

Collection, sorting and storage

- In Brazil and Mexico, high levels of informality in the activity [16, 25, 43, 65, 66, 68].
- In Brazil and Mexico, waste pickers tend to collect the materials that allow them to generate the most income. This is because they are not paid for the service they perform, but derive their remuneration solely from the sale of the materials [67, 68]. Colombia is the first country in the world where waste pickers are remunerated for the collection of recyclables through the public service fee paid by waste users [44].
- The low level of training and technification in the activity of recycling associations has a negative impact on the quality of recovered materials [43, 65, 70].
- In general, waste picker associations in Colombia do not have the capacities to add value to materials beyond collection and sorting [49].
- In Mexico, there is a lack of investment in infrastructure for the separation and collection of recyclables by the state. Waste pickers separate them on the streets as they collect waste with trucks [43, 45, 67].
- In Mexico, there is a lack of support and recognition for waste pickers by the state [43, 67, 69].
- Limited municipal separate collection [20, 71, 72].

Marketing

- With some exceptions, due to issues of scale, economics and informality, waste pickers' associations find it difficult to sell recovered materials directly to the processing industries. [44, 49, 68-70].
- In general, waste picker associations report that they are paid low prices for recovered materials, and that there are many price variations in the market for recyclables [44, 49, 69, 70].
- The participation in the recycling chain of *brokers* (middlemen) raises the price that industries pay for materials and reduces the price that reaches collection centres and reclaimers. The reduction in the prices that collectors receive discourages their activity and at the same time results in certain materials not being worth enough to be recovered [45, 65, 66, 68, 69].

Transformation

The barriers to recycling at this stage vary according to the material and have been presented in chapter 4.

6. Innovations for the recycling of plastic packaging

In view of the existing barriers to closed-loop recycling of plastic packaging, this chapter presents a number of technological innovations that offer a second life for plastic packaging through open-loop recycling. While a wide variety of products are currently made from recycled plastic, the purpose of this chapter is to show some alternatives that can generate a demand for post-consumer recycled plastic comparable to the volumes introduced to the market.

For more details on technological innovations, please refer to the full version of this study, available [here](#).

Plastic gravel

The Argentinian company Arqlite produces gravel for construction, gardening and landscaping, from the remains of plastic containers of all types (flexible, rigid, multilayer, metallised). In the construction industry, plastic gravel is used as a replacement for mineral gravel in precast concrete, lightweight concrete, non-structural applications and drainage systems. Plastic gravel is three times lighter than mineral gravel, provides better thermal and acoustic insulation, and reduces the carbon footprint of concrete mixes [73].

At present, Arqlite only produces gravel from post-industrial plastic scrap that is sent to its plant by packaging companies at costs similar to landfill disposal. The main challenges facing the company are, firstly, to gain acceptance of the product in the construction sector, and secondly, to get more plastic for recycling. For the latter, they plan to continue the development of the technology in order to be able to use post-consumer plastic packaging in the near future [74].

Streets with plastic

Two technologies have been identified worldwide that use post-consumer plastic waste in road and street construction. The first was developed and patented in India in 2006. The process, which is simple and does not require new machinery, involves replacing 10% of the bitumen used in asphalt with post-consumer plastic. The asphalt obtained has a longer service life than traditional asphalt [75], although a major disadvantage could be the generation of microplastics as a result of the wear and tear of the material during its service life [76]. Some of the packaging used in the mix with asphalt are bags, snack wrappers,

biscuits and chocolates, among others, presumably made of PE, PP and multilayers. This technology has been used in several cities in India [77] and in Indonesia [78], the UK [79] and Mexico [80].

The second plastic street construction technology originates from the Netherlands and represents a new concept in street construction in which prefabricated and modular hollow blocks are produced from post-consumer recycled plastic. This technique can speed up street construction times, simplify repairs and extend the life of streets, as well as providing new functionalities such as drainage capacity in case of rain, the installation of pipes, cables and sensors, or the charging of electric cars. As of late 2018, the technology was in the pilot stage, with two thirty-metre sections of bicycle paths built in two Dutch cities [81].

Wood plastic

A third alternative for the recycling of post-consumer plastic packaging is the manufacture of wood-plastic, a wood-like material made of a combination of wood and plastic or entirely made of plastic.

In Colombia, the Asociación de Recicladores de Bogotá has developed an initiative for the production of plastic wood, using technology developed by the Botellas de Amor Foundation. The project has its own plant in Bogotá that produces this material from containers collected by waste pickers belonging to the association. The plastic wood produced is used to build and improve the recyclers' homes. In addition, posts, fences, benches, tables, chairs and other products are made [82].

There are also wood-plastic ventures in Brazil, Mexico and other countries in the region and the world [83-88].

All of the technologies presented above offer a second life for post-consumer plastics that are not recycled in a closed cycle, and could generate significant demand for them by overcoming some of the barriers that currently exist for their reintroduction into production cycles. However, none of these alternatives could by itself and in isolation solve the difficulties of post-consumer plastic packaging recycling in Brazil, Colombia and Mexico. For this, the barriers in the recycling chains and the inherent limitations of plastic packaging recycling must be addressed in a systemic manner.

7. Conclusions

This paper studied the technologies available for recycling the set of used packaging materials, the state of play in terms of levels of use, recovery and recycling of packaging and the existing barriers and drivers for recycling each material in Brazil, Colombia and Mexico. In addition, innovations were identified that offer a second life to plastics that are not closed-loop recycled.

Recycling technologies

- The materials used for packaging worldwide are plastic, paper and board, aluminium, steel, glass and two types of composite packaging: polymer-based multilayer packaging and beverage cartons.
- The most commonly used plastic resins are PET, HDPE, PVC, LDPE, PP and PS.
- The predominant technology for the recycling of plastic packaging is mechanical recycling due to its high reliability and low cost. All resins used for packaging can be recycled by this method.
- The mechanical recycling of post-consumer plastic packaging presents a number of difficulties associated with its heterogeneity and contamination. These can lead to a reduction in the quantity and quality of plastic recycled and therefore a reduction in circularity, although the extent of this has not yet been quantified.
- In the case of polymer-based multilayer packaging, no methods were identified that could be considered as a solution for recycling, as these have not reached a sufficient level of technological development and adoption. For this reason, the circularity potential of these containers is currently extremely limited.
- Paper and board packaging is recycled by a standard method in the paper industry in which the material is broken down into individual fibres through the use of water. The loss of quality of paper and board in successive recycling cycles partly limits the potential for circularity.
- Metal packaging is recycled at the atomic level through smelting, making the recycled metal indistinguishable from new metal. This gives metal packaging a high potential for circularity.
- Glass packaging is also recycled by melting the material and can be infinitely recycled without loss of strength or quality, or the generation of harmful by-products. This gives them a high circularity potential.

- Beverage cartons are processed in the paper industry to use the paperboard for the production of recycled paper. Polyaluminium is processed as a composite material used to make products such as corrugated sheets for roofing and plates for furniture manufacturing. Currently, beverage cartons are not closed-loop recycled.

Packaging use, recovery and recycling

- The most commonly used packaging in Brazil, Colombia and Mexico is paper and cardboard, glass and plastic. These have a market share of around 90 % (calculated by weight). The remaining 10 % is accounted for by metal packaging and beverage cartons. Furthermore, it was found that in Europe the distribution of the packaging market is similar.
- Metal¹, paper and board and glass² packaging have recovery and recycling rates ranging from approximately 40 % to 100 %. These figures are close to and in some cases above the European average. Only in the case of glass are they significantly lower.
- Beverage cartons have recycling rates ranging from 10 % to 31 %. For plastic packaging the rates are in the range of approximately 13% to 26%. In both cases, the figures are considerably lower than the average European recycling rate.
- The best recovery and recycling rates among plastics are for PET bottles, with over 50 % in Brazil and Mexico and 30 % in Colombia, while in Europe the average rate is 58.2 %.

Barriers to and drivers of recycling

- The packaging with the fewest barriers and the most drivers for recycling and circularity are metal, paper and cardboard, PET and glass bottles.
- Beverage cartons and plastic packaging (including multilayer and excluding PET) face the most barriers and have the fewest drivers for recycling and circularity.
- Considering the recycling rate, the level of market share and the barriers to recycling, it is concluded that plastic packaging faces the greatest challenges of all the packaging analysed.

¹ Does not include Colombia as there is no data on the recovery and recycling of metal packaging.

² Except in Mexico. There the recovery rate for packaging use is 9.9%.

Barriers in the recycling chain

- The main constraints at the production stage are the manufacture of packaging that is not compatible with recycling and the price competition of recycled resins with virgin resins.
- At the waste generation stage, the most important obstacle is the lack of waste separation by consumers.
- The waste collection stage is where the greatest number of barriers were found. The most significant barriers are the high levels of informality in the sector, the lack of recognition and remuneration of the recyclable waste collection service by the state³ and the low level of technification of waste pickers' associations.
- At the marketing stage, the fundamental constraint is the inability of waste pickers' associations to sell the recovered materials directly to the processing industries.

Innovations for plastic packaging recycling

- Three technological innovations were identified that offer a second life to post-consumer plastic packaging that is not closed-loop recycled: plastic gravel, plastic wood and asphalt made partly from plastic.
- These technologies could in the short term generate significant demand for post-consumer packaging and become an alternative to landfill disposal.

Access to information

- Significant barriers to accessing information on the status of recycling were identified during the development of this study.
- Difficulty in accessing information is in itself a barrier to progress on the challenges posed by the circular economy. Without information on the gaps between the reality of the sector and the circular economy ideal, it becomes very difficult - if not impossible - to develop strategies to address them.

³ In Brazil and Mexico.

8. Recommendations

This chapter presents a series of recommendations to overcome the barriers to recycling that were presented in Chapters 4 and 5. The recommendations aim to increase both the quantity and quality of recycled materials, as both aspects are fundamental to the circular economy. General proposals and specific proposals are made for plastic packaging as it faces the greatest challenges for recycling and circularity.

It is of fundamental importance to understand that in order to overcome the barriers to recycling and circularity of packaging it is necessary to adopt a systemic perspective that considers the relationships and interactions between all the variables and actors that make up the recycling chain, in general and for each material. For this reason, it is recommended to carry out actions related to all the solutions proposed here.

A detailed description of each of the recommendations can be found in the full version of this study, available [here](#).

General recommendations

- Designing for recycling.
- Promote separation at source of recyclable materials.
- Establish a selective collection scheme.
- Strengthen the technical capacities of municipalities.
- Facilitate the direct sale of materials from waste pickers' associations to processing industries.
- Formalise the work of waste pickers and incorporate them as providers of a public service for the recovery of recyclable waste.
- Strengthen the organisational capacity of waste pickers' associations.
- Strengthen the technical and operational capacities of waste pickers' associations.
- Develop the recycling chain for beverage cartons.

Recommendations for plastic and multilayer packaging

- Designing for recycling. There are design guidelines for the plastics industry to follow in order to design and produce recycling-compatible packaging [42]. For polymer-based multilayer packaging, there is a trend towards replacing these containers with mono-material structures [7].
- Reduce the heterogeneity of plastic packaging to limit quality losses in the recycling process [6].
- Facilitate the identification of the resin in the container to minimise errors in manual sorting by resin type.
- Separate plastic containers intended for food contact from other containers to avoid chemical contamination [6].
- Develop and validate food grade recycling processes for resins other than PET, mainly PE and PP.
- Promote the development of new recycling technologies.
- Promote in the short term the development of technological innovations that offer a second life to plastic packaging through open-cycle recycling.

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