C PLASTIC INDUSTRY, BARRIERS AND OPPORTUNITIES: COLOMBIA

C.1 THE PLASTIC INDUSTRY AT NATIONAL LEVEL

C.1.1 Description of the national plastics industry

The plastics sector in Colombia is an integral part of the country's manufacturing industry, characterized by a diversity of companies in terms of size and specialization.

Participation in the Gross Domestic Product (GDP): The Colombian manufacturing industry contributed, on average, 14.4% to national GDP between 2005 and 2023, reaching a peak of 16.7% in 2007 and a low of 12.9% in 2023. Among industrial sectors, the segment that includes the manufacturing of rubber and plastic products represented, on average, 36% of manufacturing GDP during the same period, with a maximum of 39% in 2023. Specifically, the manufacturing of rubber and plastic products contributed on average 2.9% of manufacturing GDP, with 3.5% and 3.2% in 2022 and 2023, respectively. However, its contribution to national GDP showed a decreasing trend, going from a maximum of 0.42% at the beginning of the period to a minimum of 0.31% in 2023 (see Figure C.1).

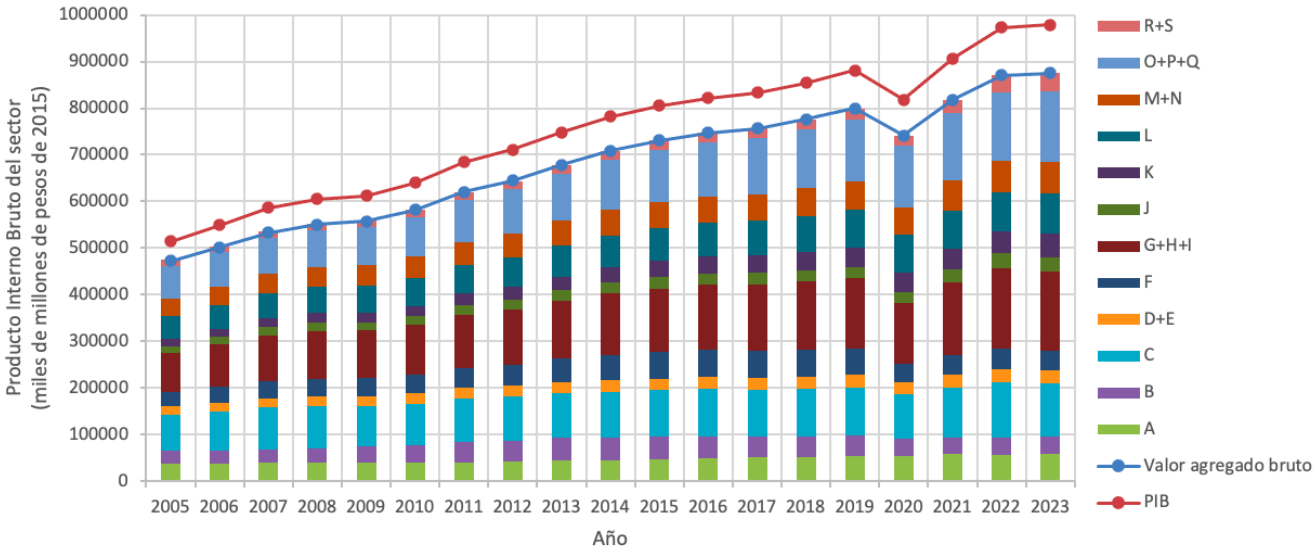

Figure C.1 Gross Domestic Product of the different sections of the International Standard Industrial Classification of all Economic Activities in Colombia for the period 2005 to 2023 at constant 2015 prices. A-Agriculture, livestock, hunting, forestry and fishing B-Mining and quarrying C-Manufacturing industries D+E-Electricity, gas, steam, and air conditioning supply; Water distribution; wastewater disposal and treatment, waste management, and environmental remediation activities F-Construction G+H+I-Wholesale and retail trade; motor vehicle and motorcycle repair; Transportation and warehousing; Accommodation and food services J-Information and communications. Main macroeconomic aggregates 2005–2023p, available athttps://www.dane.gov.co/index.php/estadisticas-por-tema/cuentas-nacionales/cuentas-nacionales-anuales, consulted on March 8, 2025.

Figure C.2 shows the share of C-section divisions in GDP of manufacturing industries. Division C04 (which includes coking, petroleum refining products manufacturing, and fuel blending activities; chemical and pharmaceutical manufacturing; and pharmaceutical botanical manufacturing;manufacturing of rubber and plastic products; manufacturing of other non-metallic mineral products) contributes on average 36% of manufacturing GDP in that period, with a maximum of 39% in 2023. Within the classes of that division, the manufacturing of rubber and plastic products (48 in Figure 3), contributed on average 2.9% of the GDP of section C, with 3.5% and 3.2% in 2022 and 2023. This represents an average contribution of 0.36% to national GDP, with a maximum of 0.42% at the beginning of the period and a minimum of 0.31% in 2023, with a clear tendency towards a decrease in participation in the Colombian economy.

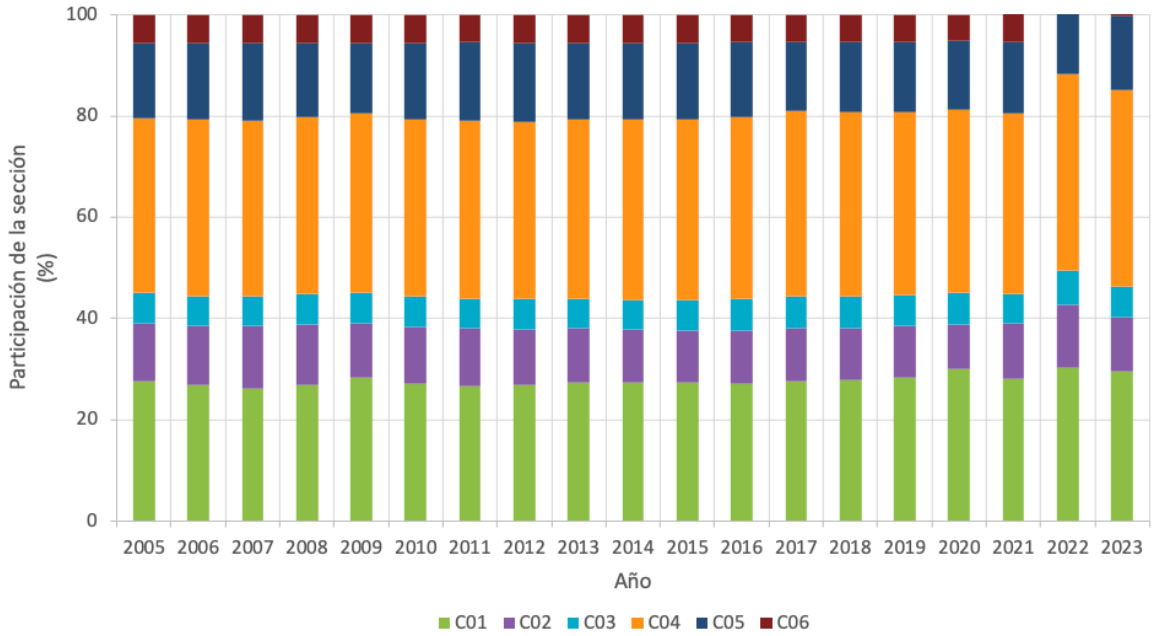

Figure C.2 Gross Domestic Product of the different divisions of section C, manufacturing industries, of the International Standard Industrial Classification of all Economic Activities in Colombia, for the period 2005 to 2023 at constant 2015 prices. C01- Manufacturing of food products; manufacturing of beverages; manufacturing of tobacco products C02- Manufacturing of textile products; manufacturing of clothing; tanning and retanning of leather; manufacturing of footwear; manufacture of travel goods, suitcases, handbags and similar articles, and manufacture of saddlery and harnesses; dressing and dyeing of leather C03- Wood processing and manufacture of wood and cork products, except furniture; manufacture of basketry and wickerwork; manufacture of paper, cardboard and paper and cardboard products; printing activities; production of copies from original recordings C04- Coking, manufacture of refined petroleum products and fuel blending activities; Manufacture of chemical substances and products; manufacture of pharmaceutical products, medicinal chemical substances, and botanical products for pharmaceutical use; manufacture of rubber and plastic products; manufacture of other non-metallic mineral products C05- Manufacture of basic metallurgical products; manufacture of fabricated metal products, except machinery and equipment; manufacture of electrical appliances and equipment; manufacture of computer, electronic, and optical products; manufacture of machinery and equipment n.e.c.; manufacture of motor vehicles, trailers, and semi-trailers; manufacture of other types of transport equipment; specialized installation, maintenance, and repair of machinery and equipment C06- Manufacture of furniture, mattresses, and bed bases; other manufacturing industries. Constructed from data reported in Main Macroeconomic Aggregates 2005–2023p, available athttps://www.dane.gov.co/index.php/estadisticas-por-tema/cuentas-nacionales/cuentas-nacionales-anuales, consulted on March 8, 2025.

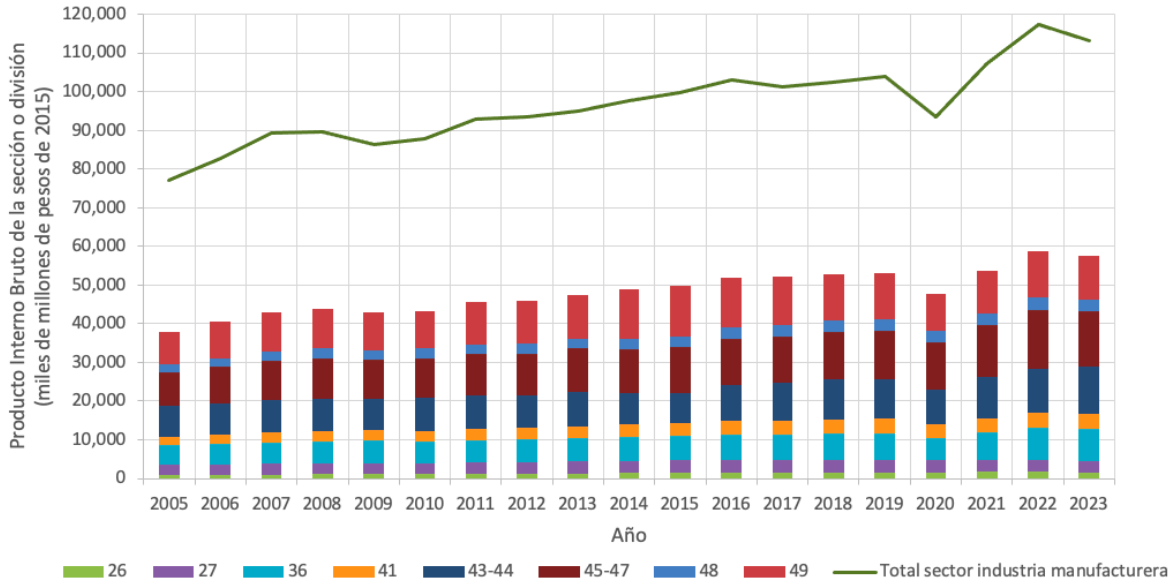

Figure C.3 Gross Domestic Product of some divisions of section C, manufacturing industries, of the International Standard Industrial Classification of all Economic Activities in Colombia, for the period 2005 to 2023 at constant 2015 prices. 26- Manufacture of vegetable and animal oils and fats 27- Manufacture of dairy products 36- Manufacture of beverages (including ice) and manufacture of tobacco products 41- Manufacture of paper, cardboard and paper and cardboard products 43-44- Coking, manufacture of petroleum refining products and fuel blending activities 45-47- Manufacture of basic chemicals, fertilizers and inorganic nitrogen compounds, plastics and synthetic rubber in primary forms; manufacture of other chemical products; manufacture of synthetic and artificial fibers; manufacture of pharmaceuticals, medicinal chemicals and botanical products for pharmaceutical use 48- Manufacture of rubber and plastic products 49- Manufacture of other non-metallic mineral products Constructed from data reported in Main macroeconomic aggregates 2005 – 2023p, available athttps://www.dane.gov.co/index.php/estadisticas-por-tema/cuentas-nacionales/cuentas-nacionales-anuales, consulted on March 8, 2025.

Number and Type of Companies in the Plastics Sector in Colombia (2007-2022)

Figure C.4 shows the evolution of the number of companies in classes 2013 (Manufacture of plastic products in primary forms), 2221 (Manufacture of basic plastic forms), and 2229 (Manufacture of plastic articles not previously classified) during the period 2007 to 2022. As expected, the largest number of companies, more than 95% in each year of the period, is dedicated to transforming polymers (primary forms) into other products (Superintendencia de Sociedades, 2023). Although the number of companies in these two classes exceeded 518 throughout the period, since 2015 a slight downward trend has been observed, with a 22% reduction in the number of companies (DANE, 2023).

This decline can be attributed to factors such as international competition, a lack of technological innovation, and regulatory pressures related to sustainability and the circular economy (MADS, 2018). Furthermore, microenterprises, which represent the majority of the sector, face significant challenges in terms of access to financing, technology, and broader markets (Superintendencia de Sociedades, 2023).

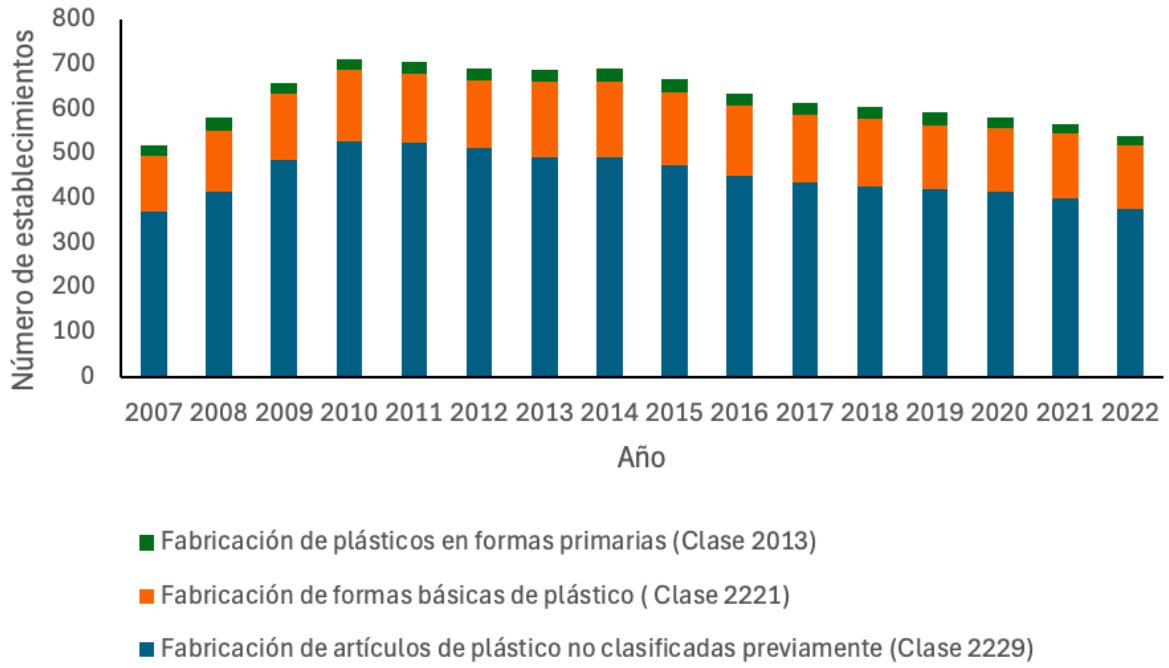

Figure C.4 Number of companies producing plastics in Colombia from 2007 to 2022.

Company Size Distribution in 2024

In Colombia, companies are classified according to their assets in micro, small, medium and large companies. The Figure C.5 presents the distribution of the group's companies 222 of the ISIC (Manufacture of plastic products) in 2024. According to data reported by Acoplastics (2024), he 67.9% of these companies are microenterprises, that is, they have assets between 0 and 500 times the current legal minimum wage (SMLV), which by 2024 is equivalent to approximately 300,000 USD. These microenterprises usually operate in low-scale segments, such as the manufacture of bags, containers and plastic products for everyday use (Superintendencia de Sociedades, 2023). On the other hand, large companies represent only the1.8%of the total, with assets greater than9 million USD (Acoplásticos, 2024). These companies are leaders in the production of primary plastic forms and in the manufacture of high-tech products, such as components for electronics or aeronautics (DANE, 2023).

Although exact percentages are not specified for the small and medium-sized enterprises, it is estimated that they represent around 20-25% and 5-7% of the sector, respectively (DANE, 2023). The small businesses, with assets between501 and 30,000 SMV (equivalent to a range of 300,000 to 18 million USD), tend to focus on the production of more specialized plastic items, such as parts for the automotive or construction industries. For their part, medium-sized companies, with assets between 30,001 to 100,000 SMV (equivalent to18 million to 60 million USD), participate in more structured markets, such as the manufacturing of packaging for the food industry or medical products (Superintendencia de Sociedades, 2023).

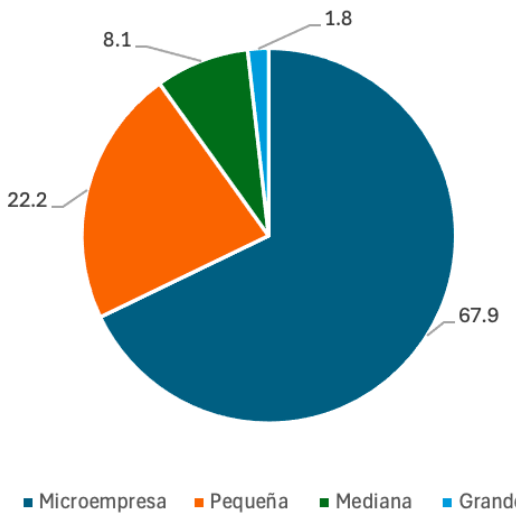

Figure C.5 Percentage distribution of plastics manufacturing companies in Colombia in 2024 according to company size. Constructed from data reported in Acoplásticos (2024).

Main Companies in the Plastics Sector in Colombia

According to the list of the Colombia's 1,000 largest companies in 2023, 20 companies belong to the classes related to the manufacture of plastics, which represents the 2% of the total. This percentage coincides with the contribution of the division C04 (Manufacture of plastic products) al Gross Domestic Product (GDP) national. Among the most notable companies are:

- **Esenttia S.A.:** It ranks 71st in the ranking, with operating revenues of 2,753,078,609 thousand COP (i.e. 668.4 million USD) and profits of 199,483,277 thousand COP (i.e. 48.4 million USD). Esenttia, part of the Ecopetrol Group, with a

majority stake in the Colombian state, specializes in the production of polyethylene (PE) and polypropylene (PP), using monomers produced at the Cartagena refinery (Reficar).

- **Mexichem Resinas Colombia S.A.S.:** It reported revenues of 1,862,829,027 thousand COP (i.e. 452.2 million USD) and profits of 2,318,089 thousand COP (i.e. 0.56 million USD). It specializes in the production and marketing of PVC resins. It primarily produces three types: suspension homopolymers, copolymers, and emulsion resins. Its plant is located in Cartagena (Mexichem, 2025).
- **Ajover Darnel S.A.S.:** It recorded revenues of 1,111,698,241 thousand COP (i.e., 269.9 million USD) and profits of 50,571,504 thousand COP (i.e., 12.3 million USD). The company offers 100% recyclable, compostable, or biodegradable packaging solutions. It offers more than 5,000 packaging references (Darnel, 2025).

The Table C.1 presents the companies on the list of the 1000 largest in Colombia in 2023, classified according to their operating income and belonging to the classes 2013 (Manufacture of plastics in primary forms), 2221 (Manufacture of basic plastic shapes) and 2229 (Manufacture of plastic articles n.e.c.) of the ISIC. These companies represent only the 2% of the list, reflecting the moderate participation of the plastics sector in the national economy.

Table C.1 Companies on the list of the 1000 largest companies in Colombia 2023 according to their operating income, which are part of classes 2013 - Manufacture of plastics in primary forms, 2221 - Manufacture of basic plastic forms and 2229 - Manufacture of plastic articles n.e.c. of the ISIC. Constructed from data published in the Superintendence of Industry and Commerce (2024).

Company name	Region	CIIU class	Operating income		Revenue	
			miles of COP	MUSD	miles of COP	MUSD
ESENTIA S.A.	Atlantic Coast	C2013	2,753,078,609	668.4	199,483,277	48.4
MEXICHEM RESINAS COLOMBIA SAS	Atlantic Coast	C2013	1,862,829,027	452.2	2,318,089	0.6
ADD DARNEL SAS	Bogotá - Cundinamarca	C2229	1,111,698,241	269.9	50,571,504	12.3
TAGHLEEF LATIN AMERICA S.A.	Atlantic Coast	C2221	889,252,272	215.9	-20,905,879	-5.1
DOW CHEMICALS OF COLOMBIA S.A.	Bogotá - Cundinamarca	C2013	873,427,333	212.0	-31,755,658	-7.7

Company name	Region	CIIU class	Operating income		Revenue	
			miles of COP	MUSD	miles of COP	MUSD
MEXICHEM COLOMBIA SAS	Bogotá - Cundinamarca	C2229	859,953,005	208.8	57,150,020	13.9
ESENTTIA MASTERBATCH LTDA	Atlantic Coast	C2013	805,784,476	195.6	203,096,749	49.3
CARVAJAL PACKAGING S.A.	Pacific Coast	C2229	672,090,436	163.2	191,023,907	46.4
AMERICAS STYRENICS DE COLOMBIA LTDA	Bogotá - Cundinamarca	C2013	601,435,324	146.0	19,670,376	4.8
FLEXOSPRING S A S	Bogotá - Cundinamarca	C2229	444,704,708	108.0	20,220,117	4.9
PVC GERFOR S.A.S	Bogotá - Cundinamarca	C2229	426,331,958	103.5	43,569,587	10.6
MULTIIDMENSIONALES S.A.S	Bogotá - Cundinamarca	C2229	424,426,187	103.0	44,501,117	10.8
ALICO SAS BIC	Antioquia	C2229	416,662,584	101.2	31,992,016	7.8
SMI COLOMBIA SAS	Bogotá - Cundinamarca	C2229	396,817,711	96.3	51,381,143	12.5
PLASTILENE SAS	Bogotá - Cundinamarca	C2229	349,563,245	84.9	15,229,575	3.7
TOCANCIPA PACKAGING S.A.S	Bogotá - Cundinamarca	C2229	343,277,831	83.3	63,137,304	15.3
AMCOR HOLDINGS AUSTRALIA PTY LTD SUCURSAL COLOMBIA	Pacific Coast	C2229	335,996,714	81.6	43,482,429	10.6
LITOPLAS S.A.	Atlantic Coast	C2221	307,669,784	74.7	6,515,190	1.6
OBEN COLOMBIA SAS	Atlantic Coast	C2221	298,812,627	72.5	-28,306,561	-6.9
MINIPAK S.A.S.	Bogotá - Cundinamarca	C2221	293,723,829	71.3	31,046,504	7.5

C.1.2 Geographical and economic distribution

Figure C.6 presents the distribution of companies in ISIC group 222 across Colombia's departments. Plastics manufacturing companies are present in eight of the 32 departments and the Capital District. 52.1% of the companies are located in the country's capital and Cundinamarca, while 24% and 11.8% are located in Antioquia and Valle del Cauca,

respectively. This behavior is typical of the other classes in the Manufacturing Industries section and coincides with the demographic distribution of Colombia, where the largest percentage of the population is located in the Andean region, with the largest cities being Bogotá, Medellín, and Cali. Figure C.7 presents the distribution of companies in group 222 by metropolitan area, information that confirms what was described in Figure 6; that is, more than 70% of the companies are located in Bogotá and Medellín. Regarding the information in Table 2, 52% of large companies are in Bogotá and 30% on the Atlantic Coast.

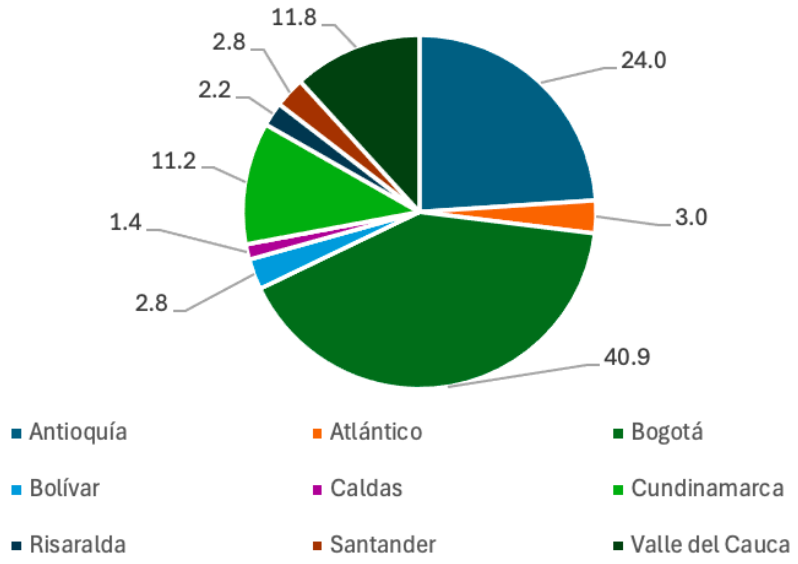

Figure C.6 Percentage distribution of companies in class 222 of the International Standard Industrial Classification of All Economic Activities in the departments of Colombia in 2022. Constructed from the data reported in the Annexes, disaggregation of product and raw material variables of the Annual Manufacturing Survey, available athttps://www.dane.gov.co/index.php/estadisticas-por-tema/industria/encuesta-anual-manufacturera-enam/eam-historicos, consulted on March 8, 2025.

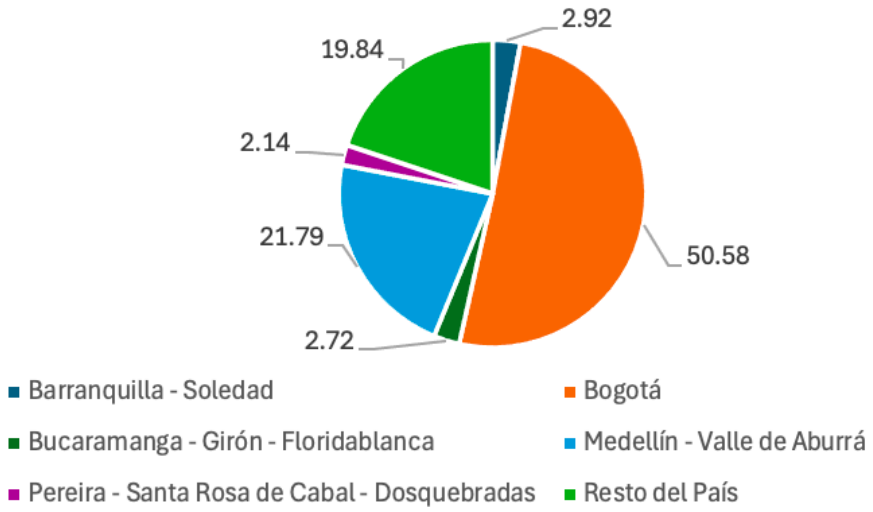

Figure C.7 Distribution of companies in class 222 of the International Standard Industrial Classification of all Economic Activities in the metropolitan areas of Colombia in 2022. Constructed from the data reported in the Annexes, disaggregation of product and raw material variables of the Annual Manufacturing Survey, available athttps://www.dane.gov.co/index.php/estadisticas-por-tema/industria/encuesta-anual-manufacturera-enam/eam-historicos, consulted on March 8, 2025.

Considering that information regarding the 2013 class is unavailable, and that they are reported grouped in group 201, the analysis of the geographic distribution of these companies will be based on the information in Table C.1. The largest percentage of companies that manufacture plastics in primary forms, i.e., polymers, are located on the Atlantic Coast (Mamonal industrial area - Cartagena). This region is home to the production plants of Essentia, Essentia Masterbatches, Mexichem Resinas, and Americas Styrenics of Colombia, producers of polyethylene, polypropylene, masterbatches of these polymers, PVC, and polystyrene. This distribution is explained by the ease of access to ship transportation for the import of raw materials required for polymer production or for the export of final products. For example, Ecopetrol's Cartagena refinery (Reficar) produces monomers and has the facility to receive vinyl chloride and styrene on ships from the Caribbean islands or Mexico, or from Southeast Asia via the Panama Canal. Furthermore, the plastic resins produced by Esenttia are not only distributed throughout Colombia but also shipped to more than 20 countries, making its location in this geographical area strategic (Esenttia, 2025).

C.1.3 Main plastic products in the national market

To determine the polymers most relevant to the domestic market, the production and consumption data reported in the disaggregated Annexes of the product and raw material variables of the Annual Manufacturing Survey for the period 2012 to 2022 for class 2013 of the ISIC were consulted. For the first class, which corresponds to plastic products in primary forms, Tables C.2 and C.3 present the annual production and consumption of products that average over 10,000 tons per year during the aforementioned period.

The most produced polymer is polypropylene (PP), and this production exceeds consumption by approximately 200,000 t (~50%), followed by PVC, whose production also exceeds consumption by a similar amount (~53%). Polystyrene (PS) behaves similarly, with production exceeding consumption, but in this case by approximately 36,000 t (~40%). In the case of polyethylene (PE), which is the most consumed, the behavior is different, since consumption exceeds production by approximately 326,000 t. A particular case is that of polyethylene terephthalate (PET), whose annual consumption is 78,335 t, while production does not exceed 3,000 t (see Figure C.8).

Table C.2 Average annual production for the period 2012 to 2022 of plastics in primary forms (Section C, Division 20, Group 201, Class 2013) in Colombia. Constructed from the data reported in the Annexes, disaggregation of product and raw material variables of the Annual Manufacturing Survey, available athttps://www.dane.gov.co/index.php/estadisticas-por-tema/industria/encuesta-anual-manufacturera-enam/eam-historicos, consulted on March 8, 2025.

Product	Production (tons)
Polypropylene	407,841
PVC	372,654
Polyolefin resins of polypropylene	130,927
Polystyrene	87,237
Polyethylene	50,208
Acrylic resins	37,147
Copolymers	28,225
polyols (polyalcohols)	20,896
Phenolic resins	19,509
Alkyd resins	19,386
Unsaturated polyester resins	18,601
Vinyl plastic compounds	18,476
Aminoplast resin (urea-formaldehyde)	18,107
Polyester resins	15,537

Table C.3 Average annual consumption for the period 2012 to 2022 of plastics in primary forms (Section C, Division 20, Group 201, Class 2013) in Colombia. Constructed from the data reported in the Annexes, disaggregation of product and raw material variables of the Annual Manufacturing Survey, available at: https://www.dane.gov.co/index.php/estadisticas-por-tema/industria/encuesta-anual-manufacturera-enam/eam-historicos, consulted on March 8, 2025.

Product	Consumption (tons)
Polyethylene	150,769
Polypropylene	78,335
PVC	50,494
PET	36,101
Polystyrene	35,073
polyols (polyalcohols)	33,447
Polyolefin resins of polypropylene	32,521
Acrylic resins	28,060
Polystyrene resins	26,773
Polymers n.c.p.	21,730
Polyester resins	19,630
Vinyl resins	19,234
Copolymers	18,316
Polyurethane	12,398
Aminoplast resin (urea-formaldehyde)	8,296
Alkyd resins	7,233

Figure C.8 reveals significant differences between plastic production and consumption in Colombia, suggesting specific patterns in market supply and demand. Polyethylene and polypropylene show high consumption, indicating their high demand in containers, packaging, and industrial products, while their production is considerably lower, reflecting a dependence on imports. In contrast, PVC production exceeds its consumption, which may be due to its use in sectors such as construction, where demand is stable but less dynamic compared to single-use plastics.

On the other hand, specialized resins such as polyurethane and aminoplast resins have low consumption, possibly due to their use in specific niches with lower market turnover. These differences demonstrate that the structure of the Colombian plastics industry responds not only to domestic demand but also to factors such as the availability of raw materials, installed production capacity, and competitiveness against imports, suggesting

the need to strengthen local production strategies to reduce the sector's vulnerability to external fluctuations.

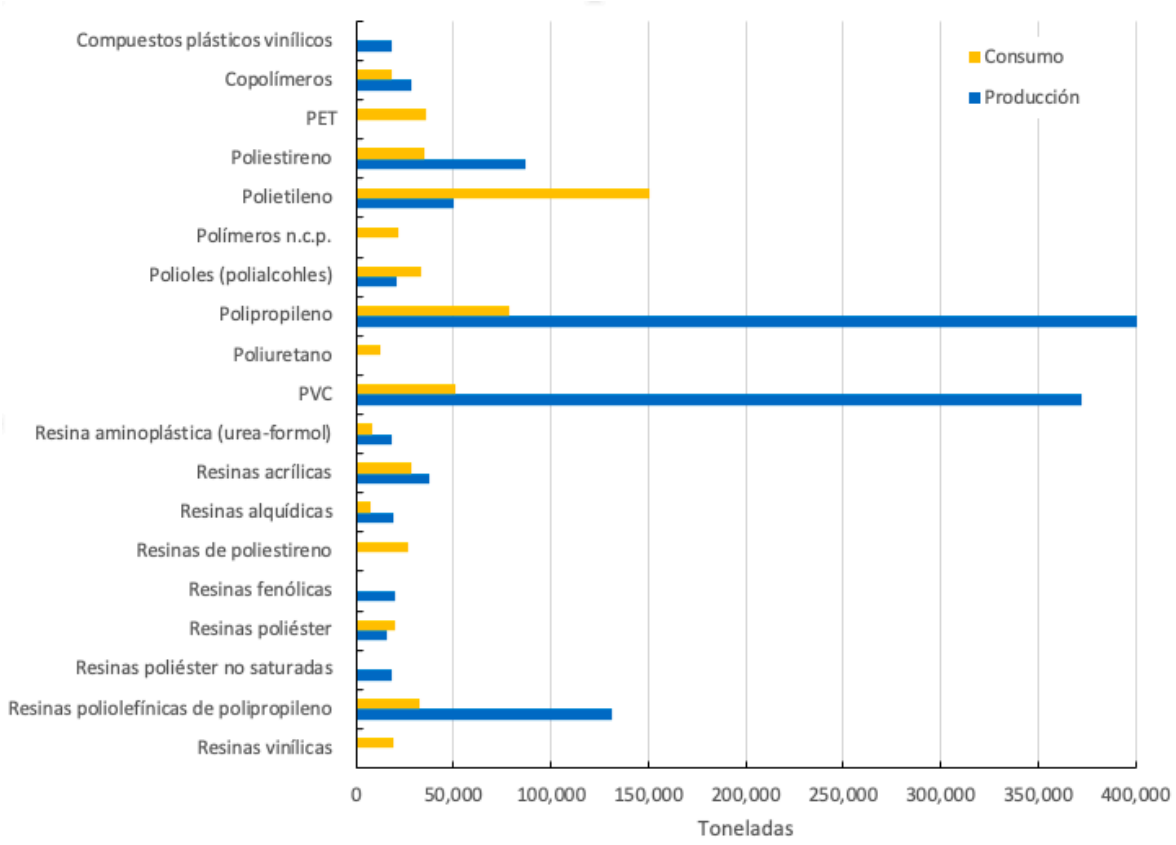

Figure C.8 Average annual production and consumption for the period 2012 to 2022 of plastics in primary forms based on information reported in Table 3 and 4.

In the 2019 Prospective and Benchmarking study conducted by Colombia Productiva, an estimate of the global evolution of plastic production was presented by 2030. This study shows that Colombia will not experience significant changes in production or the market in the coming years. In comparison, China and India will remain the countries with the highest growth, and Germany will increase its production and specialization in high-value-added products (See Figure C.9) (Colombia Productiva, 2019).

So far in the first quarter of 2025, according to Daniel Mitchell, CEO of Acoplásticos, there has been an increase in plastic exports. Despite the crisis in the Colombian plastics industry, the plastics sector saw an 18% increase in exports (in tons and value) compared to 2024. Regarding plastic materials, these are particularly polypropylene and PVC. However, regarding plastic products, exports include pipes, packaging films, caps,

preforms, tableware and kitchen utensils, fabrics, vinyl, among others. This demonstrates the diversification of the export market (Portafolio, 2025).

C.1.4 Main applications of plastic at the local level

To determine the most relevant end uses in the domestic market, we consulted the production and consumption data reported in the Product and Raw Material Variables Breakdown Annexes of the Annual Manufacturing Survey (EAM) for the period 2012 to 2022 for ISIC classes 2221 and 2229. Tables C.4 and C.5 show the average production and consumption of basic forms of plastic and previously unclassified plastics (Section C, Division 22, Group 222, Classes 2221 and 2229) for the period 2012 to 2022. According to the data, the most consumed basic forms of plastic in Colombia are containers, bags, sacks, and films. The most produced and consumed basic form of plastic in Colombia is plastic containers of 1L and larger. For this product, the units consumed are more than those produced by more than 62%. Nearly 50% of the sector is comprised of packaging used for rice, detergents, shampoo, soap, dairy products, dry grains, snacks, and other foods. More durable plastics include those used in construction, pipes, tiles, tanks, containers, profiles, and ceilings, among others (Portafolio, 2025).

Table C.4 Average annual production for the period 2012 to 2022 of basic plastic shapes and plastic products not previously classified (Section C, Division 22, Group 222, Classes 2221 and 2229) in Colombia. C Constructed from the data reported in the Annexes, disaggregation of product and raw material variables of the Annual Manufacturing Survey, available athttps://www.dane.gov.co/index.php/estadisticas-por-tema/industria/encuesta-anual-manufacturera-enam/eam-historicos, consulted on March 8, 2025.

Product	Units	Production
Plastic container of 1000 cm3 and more	units	723,825,023
Synthetic material packaging bags	units	225,406,962
Polyvinyl pipes	kg	122,070,087
Unprinted plastic bags	kg	76,591,371
Printed plastic bags	kg	65,060,898
Decorative and artistic figures made of plastic material	units	61,977,873
Polyethylene film	kg	61,548,799
Articles n.e.c. of plastic material for household use	units	56,327,880
Plastic caps and plugs	kg	37,163,496
Printed plastic tubular film	kg	36,461,435
Plastic plumbing fittings	units	27,535,224
Promotional items made of plastic material	units	26,110,537
Polypropylene film	kg	25,656,771
Unprinted plastic tubular film	kg	24,561,234

Product	Units	Production
Polyvinyl fittings for pipes and other plastic materials	kg	21,484,494
Laminated film of plastic materials	kg	20,547,577
Plastic articles and accessories for agriculture	units	20,327,667

Table C.5 Average annual consumption for the period 2012 to 2022 of basic forms of plastic and plastic products not previously classified (Section C, Division 22, Group 222, Classes 2221 and 2229) in Colombia. Constructed from the data reported in the Annexes, disaggregation of product and raw material variables of the Annual Manufacturing Survey, available athttps://www.dane.gov.co/index.php/estadisticas-por-tema/industria/encuesta-anual-manufacturera-enam/eam-historicos, consulted on March 8, 2025.

Product	Units	Consumption
Plastic container of 1000 cm3 and more	units	1,214,193,547
Plastic containers of less than 1000 cm3	units	767,382,318
Plastic caps and plugs	kg	613,781,095
Printed plastic bags	kg	329,871,155
Synthetic material packaging bags	units	241,998,069
Unprinted plastic bags	kg	155,629,472
Printed plastic tubular film	kg	79,761,955
Laminated film of plastic materials	kg	72,321,285
Plastic packaging for drugs and cosmetics	units	68,876,225
Polyethylene film	kg	68,770,090
Plastic casings for sausages	kg	52,167,884
Polypropylene film	kg	42,884,733
Self-adhesive tape	kg	38,734,095
Packaging material n.e.c. of rigid foamed plastic	kg	37,734,898
Plastic hose couplings and nozzles	units	33,567,151
Plastic hoses	m	28,708,786
Plastic material screen	m	27,647,867
Parts and accessories for plastic caps and plugs	thousands	25,084,821

C.1.5 Which segments of the plastics production chain have the greatest potential for adopting circular economy models?

According to the National Circular Economy Strategy (ENEC) (MADS - MinComercio, 2019), Colombia prioritizes six lines of action as the axes of the CE implementation strategy. Within these lines, the one of flows of packaging materials, is directly related to the purpose of this project. The use of packaging materials is concentrated in sectors such as food, beverages, pharmaceuticals, and cosmetics.

The main materials used to make containers and packaging worldwide and in Colombia are plastic, paper, and cardboard. Another line related to the project is the construction

material stream, composed of clay, cement, wood, plastics, glass, gypsum, and other materials (which corresponds to 22 Mt/year). This is a priority stream in terms of sector growth and the area requirements for final disposal, although the contribution of plastics to this type of waste is not significant.

Regarding the first line of action (packaging materials), which would be the priority within the framework of the project, according to EC's strategy, to take advantage of this flow of materials it is necessary to implement:

(i) Eco-design, toward packaging that is more efficient in its use of materials while maintaining its functionality, and using materials with a lower impact throughout its entire life cycle.
(ii) Industrial symbiosis between business clients who constantly exchange materials that maintain their value in the chain.
(iii) Regulatory harmonization, which incorporates responsibilities and economic instruments that encourage the use and closure of cycles, such as the limitation or prohibition of final disposal.
(iv) Economic instruments, such as deposit-refund systems or usage fees, that change the rationale for disposal.
(v) The articulation of the public sanitation service system with the extended responsibility of the producer, including the providers of the utilization activity
(vi) The potential for its energy use.

Furthermore, on November 21, 2023, the National Government, industry, universities and research centers, non-governmental organizations, and professional recycling associations joined forces in the Pact for the Reduction and Substitution of Plastics and Single-Use Items, promoted by the Ministry of Environment and Sustainable Development. This Pact aims to combine efforts to promote environmental sustainability for single-use plastic products in the country through the implementation of strategies such as ecodesign, eco-labeling, strengthening of value chains, social inclusion, training, awareness-raising, responsible consumption, and civic culture. Among the commitments contemplated in this pact are (i) the strengthening of the value chain through collaboration between actors in the plastics production and value chain, (ii) the development of strategies to implement the Extended Producer Responsibility (EPR) for containers and packaging, particularly for single-use plastics, which has been in force since 2018, and (iii) the training and

strengthening of professional recyclers in the plastics value chain. According to Acoplásticos:

“The pact establishes concrete commitments focused on strategies and investments vital to sustainable development. For example, it promotes the exploration of innovative financing mechanisms, such as investment funds for the circular economy, tax incentives to promote the implementation of sustainable practices in plastics management, and financing programs for entrepreneurship. It also seeks to incentivize projects that seek innovative solutions to reduce the generation of plastic waste, its leakage into the environment, and promote its recycling, as well as the promotion and encouragement of research, development, and innovation (R&D&I) into sustainable alternatives for plastics.” (Acoplásticos, 2023).

Thus, considering the plastics sector value chain shown in Figure 9, the value chain segments that have the greatest potential to implement circular economy strategies are:

(i) The production of plastics in primary and basic forms. This takes into account that Colombia has implemented extended producer responsibility for containers and packaging for food and beverages, including their caps, since 2009 (Resolution 1407 of 2018, amended by Resolution 1342 of 2020 of the Ministry of Environment and Sustainable Development).
(ii) The consumption of final products, which is the link where the flow of materials that can be incorporated into the EC is generated.
(iii) The recovery of usable materials.
(iv) The transformation of usable materials.

Figure C.9 Simplified representation of the plastics sector value chain. (Own elaboration)

C.2 KEY FACTORS AND ACTORS IN THE TRANSITION TOWARDS THE CIRCULAR ECONOMY

C.2.1 Opportunities to promote the circular economy in the plastics sector

The ENEC (Ministry of Environment and Sustainable Development; Ministry of Commerce, Industry and Tourism, 2019) prioritizes six lines of action as the axes of the EC implementation strategy in Colombia, and one of these lines, that of packaging and container material flows, is directly related to the objective of this project.

On the other hand, the National Plan for the Sustainable Management of Single-Use Plastics (Ministry of Environment and Sustainable Development, 2021) sets the following goals:

> **By 2025 at least 25% (by weight) of the following single-use plastic products will be effectively recycled**: (i) Containers used to pack or package meals and food prepared on-site, for takeout or consumption, including products made of expanded polystyrene (Styrofoam). (ii) Plates, trays, knives, forks, spoons, and glasses.
>
> **For 2030:**
>
> - **100% of single-use plastics placed on the market will be reusable, recyclable, or compostable.**All single-use plastic products placed on the market, which are technically permitted and determined by the government, have a c**minimum average content of 30% recycled material.**
> - **At least 50% (in tons) of the following single-use plastic products are effectively recycled**Containers used to pack or package meals and food prepared on-site, for takeout or consumption, including products made of expanded polystyrene (Styrofoam). Plates, trays, knives, forks, spoons, and cups.

According to data reported by the EAM (Economic and Environmental Management), for the period 2012 to 2022, an average of 1.28 Mt of plastics in primary forms were produced in Colombia, and around 1.4 Mt in 2021 and 2022. During the same period, an average of 0.76 Mt of these same plastics were consumed. Regarding basic forms of plastic, it is

more difficult to make an estimate since production and consumption data are presented in different units (units, thousands, kg, m, etc.). However, organizations such as the WWF estimate that 0.7 Mt of plastic containers and packaging are generated annually, of which only 30% is used in the production of new plastics (WWF, 2024). For its part, Greenpeace estimates a consumption of 1.25 Mt of plastics based on a per capita consumption of 24 kg per year. Of this consumption, 76% ends up in landfills, and 54% is single-use plastics. The Ministry of Environment and Sustainable Development reports that Colombia recycles 163,000 tons of plastic materials per year, and that Bogotá and Medellín process 13,000 tons of plastic waste per month. This has been achieved thanks to the work of professional recyclers and the network of nearly 260 processing industries. In 2019, the Single Information System for Household Services identified that 15.1% of the recycled materials, or 212,434 tons, correspond to plastics.

Finally, the Plastics Sector Business Plan – Vision 2032 It establishes that "an excellent articulation between academia, the public sector and the private sector is necessary to pave the way for innovation in the development of additives and biomasses for the production of plastics with recycled or biodegradable resins, or recycled products (chairs, containers, packaging, bricks, etc.) or high added value for export in order to reach new markets such as Canada, Panama, El Salvador, France and Germany to boost production and employability of the Plastics sector in the long term" (Colombia productiva, 2019).

The same Colombia Productiva report presents a diagram of the impact and uncertainty for industrial development in Colombia. It shows an industry in transition, where uncertainty stems from the intersection of regulation, innovation, and the productive structure. To mitigate risks and capitalize on opportunities, policies are required that balance economic incentives with environmental restrictions, encouraging the adoption of new technologies and strengthening the formalization of the sector. Thus, taking into account the country's policies, plans, and strategies for CE and single-use plastics, there is a significant opportunity to promote CE in the plastics sector.

In summary, key economic and infrastructure opportunities are identified that can drive the advancement of the circular economy in the Colombian plastics sector:

- **Growing regulatory and government support:** There is consensus on the fundamental role of policies such as the ENEC (National Environmental Protection Agency), Law 2232 of 2022, and Decree 1076 of 2015, which provide a solid legal framework for promoting the circular economy through tax incentives and access to financing.
- **Opportunities in recycling infrastructure:** The expansion of waste management infrastructure is recognized as a priority, generating opportunities for investment in technology and process optimization (Resolution 1342 of 2020; Rodrigo-Ilarri et al., 2021).
- **Generation of green jobs:** The potential of the circular economy to open new business opportunities and promote job creation in areas such as recycling, eco-design, and waste management is highlighted (Law 2232 of 2022; CONPES 3874, 2016).

Diverging views emerge regarding the scope of public and private investment, the emphasis on technological innovation and cultural change, and the differentiated focus on large companies and SMEs:

- **Scope of public and private investment:** Some authors (Ministry of Environment, 2021; Ellen MacArthur Foundation) emphasize that public investment is crucial for the transition. Others (Ortiz et al., 2022; Jiménez et al., 2019) highlight the importance of attracting private capital through tax incentives.
- **Emphasis on technological innovation and cultural change:** While authors such as Vera-Acevedo and Raufllet (2022) underline the need to invest in advanced technologies, others (Rodrigo-Ilarri et al., 2021) prioritize strengthening the culture of recycling and community cooperation.
- **Differentiated focus on large companies and SMEs:** Some documents (Acoplásticos, 2023; Cifuentes et al., 2021) focus on how large companies can lead the change, while others (Ministry of Environment, 2021) highlight the need to support informal recyclers and small businesses.

The Colombian plastics sector has a promising economic and financial outlook for moving toward a circular economy. Growing access to financing and economic incentives, both nationally and internationally, facilitates investment in sustainable technologies and

practices. The development of new sustainable business models, such as eco-design and reverse logistics, opens up opportunities for innovation and value creation. Attracting foreign investment, especially in recycling infrastructure, drives the modernization of the sector and the adoption of advanced technologies.

Furthermore, the expansion of markets for recycled and biodegradable products fosters demand for sustainable materials and strengthens the circular economy. These opportunities, combined with strategic management and effective collaboration among key stakeholders, position the Colombian plastics sector to lead the transition toward a prosperous and sustainable circular economy.

Additionally, other key aspects for the advancement of the circular economy in the Colombian plastics sector:

- **Development of clean technologies and more efficient processes:** There is widespread consensus on the crucial importance of developing new clean technologies, such as chemical recycling, automated quality control, and advanced materials separation, to improve the sector's efficiency and reduce its environmental impact (WRAP; Ellen MacArthur Foundation; Department for the Environment, 2021).
- **Digital platforms for waste traceability:** Documents such as CONPES 3874 (2016) and ENEC (2019) highlight the need to implement digital systems to track the flow of recyclable materials and optimize waste management (Rodrigo-Ilarri et al., 2021; Recycling for Peace Program).
- **Expansion of the market for biodegradable products:** Law 2232 of 2022 and Decree 1076 of 2015 promote the development and commercialization of compostable and preferably biobased packaging, which creates an opportunity for companies to invest in technologies that replace traditional single-use plastics (Chicas Sierra & Arias Ver, 2022; Ministry of Environment, 2022).

However, there are differing views regarding the speed of technological adoption, the efficiency of economic incentives, and the focus on emerging technologies versus traditional solutions:

- **Speed of technological adoption:** Ortiz et al. (2022) argue that innovation in ecodesign and modular production is advancing rapidly thanks to public-private

collaboration. In contrast, Rodrigo-Ilarri et al. (2021) argue that the lack of infrastructure in rural areas significantly limits the adoption of circular technologies.

- **Efficiency of economic incentives:** According to González (2021), government incentives are essential for the circular transition. However, Vera-Acevedo & Raufllet (2022) warn that these incentives are not always well structured or accessible to SMEs.
- **Focus on emerging technologies or traditional solutions:**Cifuentes et al. (2021) prioritize investment in emerging technologies such as chemical recycling and artificial intelligence. On the other hand, Hernández et al. (2017) suggest that traditional solutions, such as optimizing existing processes, still have significant potential for improvement.

On the other hand, according to Daniel Mitchell, CEO of Acoplásticos, the Colombian plastics sector has invested approximately $150 million over the last four years exclusively to increase installed plastics recycling capacity. In summary, this adds up to an additional 90,000 tons of capacity, for a total of between 400,000 and 500,000 tons (Portafolio, 2025).

In conclusion, the Colombian plastics sector has significant potential to advance toward a circular economy through the adoption of innovative technologies. The momentum in research, innovation, and development (R&D), along with the strengthening of strategic alliances, creates an enabling environment for the adoption of advanced technologies such as chemical recycling and Industry 4.0. Furthermore, access to financing and support programs, backed by key regulations, facilitates investment in circular technologies. Digitalization and waste traceability improve waste management efficiency, enabling the large-scale implementation of circular solutions. To seize these opportunities, it is critical that the Colombian plastics sector continue to invest in innovation, strengthen alliances, and leverage available support programs.

B.2.2 Barriers faced by companies in the transition to the circular economy

In 2023, the National Association of Manufacturers (ANDI) conducted the study "Recyclability Potential of Packaging in Colombia," identifying the weaknesses and barriers

of each group of flexible and rigid plastics (ANDI, 2024). The most relevant results are presented below:

> “For the use of flexible plastics to be profitable, collection and storage must be optimized so that the collected weight occupies a significant load on the road and, subsequently, in the warehouse. Furthermore, due to the weight-volume relationship, these materials present a barrier to transport because managers prioritize the collection of other heavier materials. However, these barriers are not unique to Colombia. Likewise, the stakeholders consulted mentioned that the lack of regulatory incentives affects the use of flexible plastics and that the implementation of regulations plays a crucial role in creating markets and stimulating innovation, given that the challenge for these materials is to improve their recyclability and efficiency without compromising their high standards of functionality and durability” (ANDI, 2024).

> “For rigid plastics, the most significant barriers center on quality and price, compared to virgin materials. Additionally, some identified factors that are important because they can be a limiting factor when utilizing and marketing different rigid materials include component design, the use of color tones, material incompatibility, lack of identification, and production conditions” (ANDI, 2024).

However, innovation is vital to the success and survival of SMEs. These companies often face difficulties due to a lack of resources and experience in developing and implementing innovative management systems (National Planning Department - DNP, 2016). Many SMEs fail to fully leverage the benefits of innovation, which limits their growth and competitiveness. The 2018-2022 Development Plan report highlights the limited technological availability and lack of digital inclusion among Colombian SMEs. Only 1% use advanced robotics technologies, and 9% turn to the Internet of Things. Despite efforts implemented in policies to promote innovation in Colombia (DNP, 2019), SMEs lack a solid understanding of how their operations impact the Sustainable Development Goals (SDGs). Often, their actions focus on charity rather than adopting a strategic vision that recognizes the medium and long-term risks and opportunities that these effects can generate (Arango, 2018, p. 101)

According to Khalid et al. (2023), it is questionable whether SMEs can balance environmental and economic objectives. It is argued that, due to resource constraints,

SMEs often face difficulties in developing sustainability capabilities, which can generate additional costs and hinder their competitiveness. Furthermore, SMEs often struggle to capitalize on green business opportunities due to a lack of necessary skills. However, empirical studies suggest that SMEs can develop the organizational capabilities to achieve both economic and environmental objectives. A better understanding of these challenges, opportunities, and strategies that SMEs can employ to maintain their competitiveness and achieve sustainability objectives is crucial, and further research is needed. It is also necessary to study how innovation promotion instruments or strategies can contribute to SMEs achieving sustainability objectives and how they can be articulated with the SDGs.

On the other hand, in a study on progress in the implementation of circular economy business models in Colombia, González et al. (2025) found three major barriers: Insufficient infrastructure for the collection and recycling of materials in many regions of the country, predominance of linear business models and resistance on the part of companies to move towards circularity, and lack of knowledge of consumers and companies about the circular economy.

In another direction, in a thesis of the Environmental Engineering program at the Central University developed within the framework of the present TechTraPlastiCE project, Dayana Luque Avendaño (2025) carried out an analysis of factors that influence the transition of the Colombian plastics sector towards the circular economy, considering the economic, technological, political-legal, environmental and sociocultural dimensions. The study advances a systematic literature review of 58 documents including scientific articles, documents from governmental and union entities, regulations and policies, identifies gaps and drivers for the circular economy in the sector, and proposes strategies to Correct (weaknesses), Confront (threats), Maintain (strengths) and Exploit (opportunities), summarized with the acronym CAME. Table C.6 summarizes the main findings of the thesis.

Table C.6 Gaps, drivers, and strategic proposals by dimension (economic, technological, political-legal, environmental, and sociocultural). Source: Luque Avendaño (2025), pp. 56-58.

Dimension	Key gaps	Key drivers	CAME Strategies
Economic financial	High dependence on imported raw materials. Difficulties in accessing financing (especially SMEs). Inadequate tax incentives.	Export growth of 15.6% (2024). Increase in investments (US$150 M). Alliances such as GoPlastic and A2censo.	Correct incentives and improve access to credit. Addressing volatility and diversifying recycled products. Maintain investment in machinery. Exploit international markets and demand for sustainable products.
Technological	Low R&D capacity. Poor recycling infrastructure. Technological gap between SMEs and large companies. Weak adoption of ecodesign.	Investments in advanced recycling. Use of 4.0 technologies. Alliances with universities and innovation centers.	Correct by promoting R&D and technology centers. Facing with technical training. Maintain current investments. Exploit alliances and new technologies in automation and traceability.
Political legal	Fragmented regulations and weak implementation. Slow procedures. Exclusion of informal recyclers. Lack of inter-institutional harmonization.	Recent laws (2232/2022, 2277/2022). Pact for Plastics. International participation (COP26, SDGs).	Correct regulatory weaknesses. Addressing lack of harmonization with effective coordination. Maintain public-private pacts and alliances. Exploiting the legal framework as a lever for innovation and eco-design.
Environmental	Low recycling rate. High waste generation. Insufficient infrastructure. Critical environmental impact of unrecovered waste.	Law 2232 and EC goals. Alliances like Vision 30/30. Growing public interest. Potential international financing.	Correcting data and knowledge gaps. Tackling informality and fragmentation. Maintain investments in recycling plants. Exploit regulations and alliances to access international resources and increase waste recovery.

Dimension	Key gaps	Key drivers	CAME Strategies
Sociocultural	Low level of environmental culture. Weak citizen participation. Stigmatization of informal recycling. Poor business training.	Educational campaigns (Give Life to Plastic). Pact for Plastics. Institutional and academic alliances.	Correct with continuing education programs. Addressing cultural barriers with community leaders. Maintain successful campaigns. Leverage collaborative networks to spread circular values in schools, businesses, and communities.

Barriers and opportunities from the perspective of sector actors

To gain a broad and accurate perspective of the companies in the sector, a survey was conducted with relevant questions about barriers and potential opportunities. The form used is presented in Annex I, which was shared via email and social media with members of the Bogotá Chamber of Commerce (CCB) Printing and Packaging Cluster and Acoplásticos associates. Additionally, interviews were conducted with key industry and academic stakeholders using a semi-structured interview guide presented in Annex II. The interviews were audio-recorded, but not video-recorded, and despite the semi-structured interview guide, interviewers had the option of including questions or continuing the thread proposed by the interviewee based on their initial responses.

Regarding the survey forms, responses were obtained from companies of different sizes, with a greater representation of large companies (see Figure 10). The main economic activities and products of these companies include: plastics manufacturing; manufacturing of primary plastics; manufacturing of flexible packaging; manufacturing of inks and pigments; manufacturing of colors and additives; manufacturing of food packaging; management of plastic from waste electrical and electronic equipment; production of raw materials and compostable products; marketing of plastic raw materials for injection, extrusion, and blow molding.

When it comes to these companies' plastic products and applications, there's a wide variety: raw materials such as polypropylene, polyethylene, and recycled polypropylene; flexible packaging; varnishes and adhesives; inks for flexographic and rotogravure printing; organic and inorganic pigments, pearlescent pigments, and aluminum used in masterbatch manufacturing; liquid colors and additives for the plastics industry in general; plastic containers and lids for the cosmetics, pharmaceutical, personal care, and industrial sectors; food packaging for industrial clients (dairy, margarine, and confectionery) and restaurant chains.

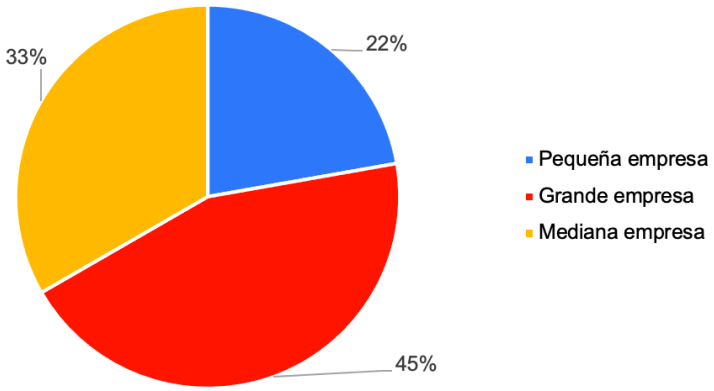

Figure C.10 Size of companies that responded to the survey form.

The surveyed companies are located on the Atlantic Coast, Bogotá-Cundinamarca, Cali and Medellín, with a higher percentage of companies in the Bogotá-Cundinamarca region (see Figure C.11), which was expected, since it is the region where the largest number of companies in the sector are located.

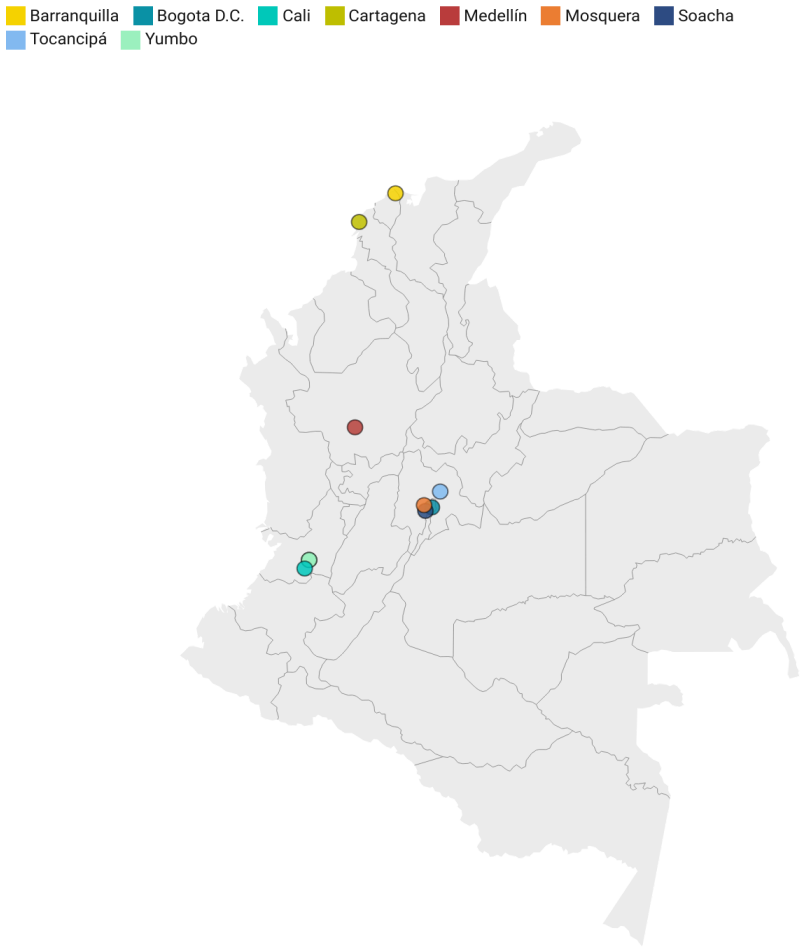

Figure C.11 Location of the companies that responded to the survey.

Regarding the interviews, the actors belong to different organizations, which are listed below:

- Acoplásticos: Daniel Mitchell Restrepo - Executive President; Jenny Paola Ruje Roncancio - Technical Director; Paola Ocampo Seferian - Executive Vice President.
- Plastics and Rubber Training and Research Institute (ICIPC): Laura Fernanda Flórez Sastre - General Director.
- University of Antioquia (Circular Alliance): Pablo Andrés Maya Duque - Professor and Research Director of the Circular Alliance.
- National University of Colombia - Bogotá Campus: Óscar Javier Suárez Medina - Chemical Engineer and professor.

The responses from the various stakeholders and companies were structured into four relevant categories. The main findings related to these categories are presented below:

- **Compliance with legislation**
    - Business support strategies

In its business support strategies, Acoplásticos acts as a mediator between industry and government regarding regulations issued by the latter. This mediation seeks to balance sustainability and economic growth, promoting synergies between companies and the government to comply with circular economy regulations. Its role also includes facilitating the communication of opportunities, such as calls for MSMEs, providing technical support for implementing sustainable practices, and facilitating the adoption of sustainable standards through programs such as Operation Clean Sweep and recyclability labels. Additionally, it participates in national working groups (e.g., the National Plastics Roundtable) and supports companies in submitting projects to access funding from calls for proposals.

A key factor in supporting companies is the implementation of best practices, such as carbon footprint measurement and recycled content certification, to align them with regulations such as Extended Producer Responsibility (EPR) and the Single-Use Plastics Law. According to Paola Ocampo, Acoplásticos supports companies by disseminating regulations, offering clear technical information on how to comply with the Single-Use Plastics Law and Extended Producer Responsibility (EPR). It conducts training sessions, webinars, and produces educational materials such as infographics to clarify obligations and reduce confusion. It organizes sessions with member companies and their clients to explain regulations, such as the plastics tax and recycled raw material usage targets, helping to align the industry with regulations.

For its part, the ICIPC supports companies through injection molding training, ONAC-accredited certification of recycled plastic content, and the generation of technical

information to help them comply with Extended Producer Responsibility (EPR) and the Single-Use Plastics Law. According to Laura Florez, the Institute offers companies certifications that allow them to participate in tax exemptions and offer products made with recycled plastic on the market.

The National University, through technical roundtables and projects with municipalities and recycling associations, supports companies in waste management, promoting technical solutions and training to comply with regulations. Professor Óscar Suárez has participated firsthand in projects with municipalities to evaluate waste management proposals, providing technical analysis and recommendations for process improvements.

The Circular Alliance project supports companies in waste management under the Extended Producer Responsibility (EPR) framework. It also conducts workshops and interviews to identify sector needs.

However, according to the companies surveyed, various strategies have been adopted to comply with environmental legislation, particularly in the plastics sector and the circular economy. Esenttia, for example, has developed source separation programs and a certified recycled resin plant, while Intecplast participates in groups such as Acoplásticos and has implemented circular economy diagnostics. Others, such as Empaques Transparentes and Carvajal Empaques, have focused their efforts on social awareness campaigns, portfolio changes, and participation in sector projects. Meanwhile, Avient, a company with an international presence, stands out for offering its clients innovative solutions to help them comply with regulations.

World Compost and Grupo Plásticos de Colombia also demonstrate significant actions, such as participating in awareness-raising events and registering on REP transformation platforms. However, some companies, such as OCADE, request greater visibility and institutional support. Technical support for clients, the incorporation of eco-design criteria, and investment in clean technologies are also common strategies for companies like Sun Chemical, reinforcing their commitment to regulatory compliance from a systemic perspective.

- Adaptation actions for regulatory compliance

For its part, Acoplásticos promotes the incorporation of post-consumer recycled materials and the use of methodologies such as life cycle assessment (LCA) to comply with regulations like Law 2232. It encourages eco-design and certifications (recycled content seals) to align companies with the regulations. It works with the Ministry of the Environment to include clear concepts of circularity in regulations, such as those required for the use of recycled plastic in bags, although its action is limited to providing information and presenting technological and scientific arguments. It advocates a proactive approach to regulatory development, using technical arguments and data to avoid prohibitive regulations and promote viable solutions. It has been actively involved in regulatory

development since 2016, providing technical arguments to avoid excessive prohibitions and promote viable regulations.

Laura Flórez highlighted the work of ICIPC, which participates in technical roundtables with the Ministry of the Environment to provide technical input and improve regulations. Its collaboration with Acoplásticos and the Ministry itself is being established to clarify regulations, such as biodegradation standards and certifications. For its part, the National University participates in technical roundtables (Senar, RedSEC, Conaza) to adjust regulations and guarantee their technical viability. Its technical approach ensures that regulations are practical, correcting errors in initial proposals and promoting extended producer responsibility (EPR).

Companies are implementing concrete measures to align with regulations. For example, Sun Chemical is developing internal plans such as "Zero Waste," energy consumption controls, and efficient technologies. Empaques Transparentes already manufactures packaging with 100% PCR, while Esenttia operates a recycling plant and is developing chemical recycling pilots. Intecplast has adapted its process with three-layer dies that allow the use of PCR, and Carvajal Empaques has migrated its materials and substrates to align with sustainable requirements.

OECD applies a specialized strategy by separating plastics with hazardous contaminants and sending them to certified compost bins, while World Compost is developing a comprehensive plan to reduce misinformation. In all cases, there is a trend toward adjusting production processes, implementing traceability, and focusing on specific compliance, such as that of the REP or Law 2232. However, adaptation remains uneven, and many actions are driven more by business leadership than by robust policies.

- Barriers

Some of the barriers identified by Acoplásticos, according to Paola Ruje, include the difficulty for MSMEs to adopt modern technologies and the complexity of reverse logistics in remote regions, which makes it difficult to comply with regulations. The structure of the sector (mostly MSMEs) and the lack of financial incentives also limit compliance. Daniel Mitchell, on the other hand, commented that barriers include the complexity of designing sustainable products without compromising functionality or costs, the difficulty of incorporating recycled materials due to their variable properties, and a cleaning system geared toward landfill disposal (85% of waste in Colombia ends up in landfills). He also highlights logistical challenges in collecting recyclable materials.

Paola Ocampo stated that the main barriers are regulatory uncertainty due to regulatory delays, a lack of clarity in standards, and the absence of tools for industrial reconversion. She also highlighted greenwashing, a lack of oversight by authorities, and the cultural resistance of business leaders to sharing information. The delay in regulations (e.g., until June 2024 for a standard expected in December 2023) has generated chaos, and the lack

of response from companies (only 20 of 3,000 surveyed) hampered reconversion plans. According to her, the main barriers are the lack of regulatory disclosure, the absence of oversight bodies, the shortage of recycled materials for SMEs, and the poor technical drafting of the Single-Use Plastics Law. She also mentioned the lack of clarity in biodegradation standards and the cultural resistance of some companies.

For his part, Oscar Suárez stated that the main barriers are the lack of reliable data on waste composition, the absence of infrastructure for differentiated collection, and the lack of citizen education. He also highlights the ineffectiveness of regulations without adequate collection systems. The lack of precise characterization of plastics and the mixing of waste in compacting trucks hinder regulatory compliance. Meanwhile, Maya mentioned that the barriers are associated with the lack of regulations for reuse and refill models, the reluctance of companies to participate in studies for fear of legal consequences, and the difficulty of transferring technological tools due to bureaucratic restrictions and lack of trust. Uncertainty about the legality of certain models and the lack of clarity in the transfer of tools from universities to the private sector are significant obstacles.

The most common barriers cited by companies include a lack of regulatory clarity, weak implementation, and limited government support. Companies such as Intecplast and World Compost believe that existing regulations lack sufficient guidelines, while Sun Chemical and Esenttia criticize the lack of instruments promoting the use of non-PET recycled resins. Lack of knowledge about the value chain and high implementation costs, as is the case with ecodesign, are also common challenges.

Another recurring obstacle is the disconnect between the actors in the chain: recyclers, brands, converters, and consumers, which hinders coordinated action. Additionally, smaller companies such as OCADE and Grupo Plásticos de Colombia cite a lack of financial and technological resources as a major obstacle. This situation creates a gap in adaptability, especially for medium-sized or specialized companies, which require greater government support to comply with legal requirements.

- Benefits

Regulatory compliance drives innovation, opens new lines of business, and improves competitiveness by aligning with sustainability standards and differentiating itself in the market. For example, regulations such as Law 2232 allow companies to develop sustainable products, such as 100% recycled bags, that meet environmental standards and maintain functionality. Colombia leads Latin America in chemical recycling and plastics regulation, positioning the sector as a benchmark. According to Daniel Mitchell, "Colombia is currently the only country in Latin America that is already practicing chemical recycling." Investments in mechanical recycling (more than $150 million over three to four years) and regulations have accelerated the transition to circularity, generating economic and environmental benefits.

The REP has generated valuable information and driven industry change, promoting recycling and the formalization of the value chain. ICIPC certifications allow companies to access tax exemptions and maintain their market presence. Legislation promotes circularity and recycling, especially in PET, although the benefits are more accessible to large companies. Additionally, the REP has made it possible to hold producers and importers accountable, reducing public health risks and fostering more structured management systems. Regulations have driven changes in sectors such as light bulbs, with energy and environmental benefits. The transition to technologies such as LEDs shows how regulations can drive innovations that facilitate recycling and reduce costs, a move that could also occur in the plastics sector.

Complying with current legislation has become not only an obligation but also a competitive advantage for many companies. Esenttia and Sun Chemical highlight benefits such as avoiding sanctions, maintaining their operating licenses, and improving their brand positioning. They also mention indirect economic advantages, such as access to more demanding markets, third-party recognition, and building customer trust. Intecplast reports environmental and fiscal benefits, such as tax exemptions.

Even for smaller companies or those with a diverse focus, such as OCADE, compliance is an opportunity for visibility and access to new markets. Companies generally recognize that adopting regulations not only allows them to compete on a more level playing field, but also strengthens their sustainability principles, as is the case at World Compost. In short, regulatory compliance represents a strategic tool for positioning themselves in an increasingly demanding regulatory environment.

- Measures implemented to comply with single-use plastic guidelines or Extended Producer Responsibility (EPR) compliance

Acoplásticos promotes measures such as the use of post-consumer recycled materials, the promotion of eco-design, and the strengthening of reverse logistics. For the REP, it emphasizes the need to improve the availability of recyclable materials and formalize professional recyclers. For example, it implements initiatives such as Operation Clean Sweep to prevent plastic pellet leaks, recyclability and recycled content seals, and projects to incorporate recycled plastic in applications such as asphalt mixes. For example, projects such as Emplázate (recycling in market squares) and partnerships with recyclers in regions such as San Andrés and La Guajira support the achievement of REP goals. Furthermore, Acoplásticos implements intensive training (such as talks every three days after a law goes into effect) and produces educational materials.

The National University has worked on post-consumer regulations for pesticide containers, promoting their controlled incineration due to contamination. It also supports the training of recyclers for source segregation.

Among the concrete measures established by companies are the use of recycled plastics (PCR), product redesign, and investment in cleaner processes. Empaques Transparentes leads the way with the manufacture of 100% PCR-certified packaging. Esenttia promotes REP and has a 100% certified recycled resin plant. Intecplast reuses scrap and adopts eco-design practices. Sun Chemical has developed product portfolios that comply with sustainability principles and has established strict monitoring of resource consumption.

For their part, companies like OCADE are adapting their processes through specialized WEEE management, ensuring the safe disposal of contaminants and responsible recycling. Grupo Plásticos de Colombia works with collected waste, although it states that it still needs more information to strengthen its implementation. Companies thus show varying degrees of progress in complying with the guidelines, with a common focus on reducing, reusing, and recycling, although structural challenges persist.

- **Innovation (barriers and opportunities)**
    - Barriers to innovation

According to Ruje, the main barriers are the lack of R&D areas in MSMEs, the use of obsolete equipment, a short-term mindset focused on immediate productivity, and a scarcity of financial incentives. MSMEs lack the resources to invest in R&D, and obsolete equipment limits their ability to implement innovative processes. The disconnect between academia and industry, along with the complexity of incorporating recycled materials, are additional obstacles. Paola Ocampo commented that the absence of government incentives, the complexity of sanitary regulations for products in contact with food, and limited laboratory capacity in Colombia hinder innovation. Furthermore, the lack of digitalization in the plastics industry and the absence of continuous improvement departments in companies are key barriers. She also highlights the lack of control over plastic marking and the low quality of recycled materials. According to Paola Flórez, manual waste sorting and the lack of standardization in marking hinder innovation in recycling.

Oscar Suarez mentioned that the lack of waste classification, cultural resistance to segregation due to the lack of a solid proposal from government agencies, and the absence of infrastructure for differentiated collection are key barriers. He also highlighted the lack of trust between industry and academia, and the reliance on short-term solutions. Maya asserts that the lack of regulations for models such as refilling, companies' reluctance to participate in studies, and bureaucratic restrictions on technology transfer are key barriers.

The main barriers identified by companies to innovating in sustainable practices include high costs, limited infrastructure, and weak coordination between stakeholders. Companies such as Sun Chemical emphasize that ecodesign still represents a higher cost compared to conventional solutions. Intecplast cites the lack of clear guidelines in

legislation, which impedes the more agile development of sustainable products. Furthermore, many companies, such as Esenttia and World Compost, point to the lack of financial incentives as a major obstacle to investment in innovation.

Additionally, there are barriers associated with business culture and a lack of technical information. Avient states that the market is unwilling to pay more for sustainable products, which discourages their development. Carvajal Empaques and OCADE also highlight limitations such as the lack of specialized recycling infrastructure and the limited resources available for innovation, especially in small and medium-sized companies. In general, it is observed that the barriers are not only technical, but also regulatory, financial, and cultural.

- Opportunities for innovation

Innovation offers opportunities for new business lines, such as recycled or compostable products, and the development of sustainable applications. Regulation drives the creation of value-added products. Examples such as Enka (PET recycling) and Natura (refill system) show how innovation can transform the sector. Market differentiation through sustainable products is a significant opportunity. Maya presents the development of minimum viable products (such as water filters with flexible plastics), digital tools for decision-making, and controlled pilots to test reuse and returnability models as opportunities.

Despite the barriers, companies recognize multiple opportunities to innovate in sustainability. For example, Esenttia has identified the development of new circular businesses as a concrete possibility, while Sun Chemical and Carvajal Empaques are migrating their portfolios toward more sustainable solutions, such as redesigned packaging or the use of PCR. These opportunities are especially linked to growing market demand and the desire to remain competitive.

Furthermore, companies like World Compost highlighted that the market is increasingly demanding in terms of environmental solutions, creating an opportunity to position themselves as pioneers. Intecplast is taking advantage of these opportunities through practices like eco-design, while Avient is orienting its product offering to facilitate the recycling, reduction, and reuse of plastics. Opportunities appear to be concentrated in the integration of recycled materials, product redesign, and the adoption of clean technologies.

- Ongoing or implemented projects

Acoplásticos has supported projects such as the replacement of glass fibers with natural fibers with the Jorge Tadeo Lozano University and studies on the recycling ecosystem with the Piloto University. It also participates in projects with Colombia Productiva to incorporate recycled materials. Currently, a project with Colombia Productiva supports 40 companies, including some in the plastics sector, in ecodesign and the use of post-consumer recycled resin. It promotes projects such as the use of recycled plastic in asphalt mixtures (with

Invías), solutions for the cement sector, and the strengthening of recyclers in regions such as Ciénaga, Nuquí, and San Andrés. It also promotes recyclability seals and campaigns such as Emplázate (Emplazate). Furthermore, Acoplásticos participates in projects such as a composting pilot project with companies and the German cooperation agency (GIZ), and promotes the Observatory of Technologies and Information for the Circular Economy (Plas-TIC) to generate quality information.

Oscar Suárez stated that the National University has worked on waste characterization projects with recyclers and process optimization in sectors such as floriculture. Escamilla participated in a returnable waste pilot with the company Ciclo and the Mayor's Office of Medellín, using German cooperation funds. It has also developed digital tools, booklets, and virtual courses on the circular economy.

Several companies reported concrete progress in innovation projects. Esenttia is developing a plastic resin identifier and a pilot program for chemical recycling using pyrolysis. Empaques Transparentes has been recognized as the first company endorsed by ANLA (National Association of Laboratories) for 100% PCR packaging and is participating in the EnCadena project. Sun Chemical has implemented a portfolio of sustainable products and adopted energy efficiency measures such as partial solar energy operation and CO_2 emission control.

For its part, Intecplast has invested in technologies such as three-layer die-cutting heads and eco-design developments, while OCADE is working on the reconditioning of electronic equipment and the separation of contaminated plastics. Carvajal Empaques is implementing initiatives with social impact for professional recyclers. Even World Compost is designing a clear and understandable legal plan for its compostable solutions. In all cases, a practical and technical focus of innovation, linked to legal compliance and sustainability, is emphasized.

- Business support strategies

Some strategies are supported by the coordination of different actors in the plastics value chain. Acoplásticos acts as a facilitator, connecting companies with resources, promoting training in energy efficiency and processes, and facilitating certifications for recycled products. It also offers technical assistance and encourages the adoption of simple tools, such as data measurement, to improve processes. ICIPC organizes open innovation challenges, calls for entrepreneurs, and events to connect supply and demand for recycled materials. It facilitates the connection between recyclers and processing companies and promotes the formalization of the recycling market. The National University offers training to recyclers and technical advice to companies to optimize processes and reduce waste.

According to companies, internal and external support strategies are varied and, in many cases, insufficient. Companies such as Sun Chemical and Esenttia report having developed partnerships with universities or other stakeholders in the supply chain to

promote innovation projects. Others, such as Empaques Transparentes, opt for educational and social outreach campaigns and collaborative projects with centers like the ICIPC. However, many companies still require more structured support from the State, in the form of financial incentives, technical training, and clear regulations.

Avient, for example, highlights the importance of communication between brands and processors to understand common challenges, while Grupo Plásticos de Colombia calls for more up-to-date information and financial support. It is recognized that the role of the State, academia, and business associations is fundamental, but still insufficiently coordinated. Therefore, strengthening support networks is critical to accelerating circular innovation in the sector.

- **Transition to the circular economy**
    - Opportunities to adopt EC practices

Opportunities include new lines of business and certifications that generate consumer confidence. Regulations promote sustainable alternatives. Examples mentioned above, such as Cristal and Natura, highlight the potential of circularity. The development of sustainable products with recycled materials, market differentiation through certifications, and the creation of new markets are also opportunities. Flórez stated that the transition to circularity is driven by the use of PCR, eco-design, and improved waste management. REP groups and ICIPC research facilitate the incorporation of recycled materials into new products. Packaging, which consumes 50% of plastics, is key to closing the loop, with opportunities in monomaterials and chemical recycling.

Companies identify significant opportunities to accelerate the adoption of circular economy practices, especially related to process improvement, product redesign, and access to new markets. Carvajal Empaques cites the shift toward sustainable models and innovation in raw materials as key opportunities. Esenttia and Sun Chemical agree that complying with these principles is not only an environmental necessity but also a competitive advantage in the market.

World Compost sees an opportunity in positioning itself as a unique option in the face of the growing demand for compostable solutions, while Intecplast has identified benefits in recirculating materials and adopting more sustainable technologies. OECD sees the potential to strengthen its production chain if its best practices are disseminated and recognized. These opportunities are anchored in both regulatory pressures and market dynamics, and suggest that the transition to a circular economy is viable if resources and stakeholders are properly coordinated.

    - Weaknesses or barriers

The weaknesses are similar to those mentioned in the barriers to innovation. Additionally, there are limitations in reverse logistics (especially in remote regions) and a lack of public awareness about waste disposal. The negative perception of plastic and a lack of resources for innovation are significant obstacles. Acoplásticos identified the barriers to innovation as a landfill-oriented cleaning system, logistical challenges in collecting recyclable materials, and the difficulty for MSMEs to innovate due to limited resources. Flexible packaging and products in contact with food present additional challenges due to food safety requirements. According to Mitchell, "the raw materials for recycling are generated in absolutely every home in Colombia, so logistics are much more complex."

Additionally, there is a lack of citizen awareness about waste separation, a shortage of recycled materials for SMEs, and misinformation about biodegradation. Suarez asserts that a lack of citizen education, the absence of separate collection, and citizen disappointment at seeing mixed waste are significant barriers. The lack of reliable data also limits planning. The mixing of waste in compaction trucks and the lack of infrastructure discourage citizens, hindering circularity.

Among the main weaknesses identified by companies in this transition are the lack of recycling infrastructure, limited availability of food-grade recycled materials, and a lack of clear guidelines for implementing legislation. Carvajal Empaques, for example, highlights that the recycling chain is weak and that available recycled materials do not meet standards for certain uses. Esenttia and Sun Chemical indicate that incentives and regulatory frameworks are needed to promote the incorporation of non-PET resins.

The lack of financial resources, as in the case of OCADE and Grupo Plásticos de Colombia, also hinders progress in this transition. World Compost identifies fear and misinformation about compostable products as barriers. In general, greater institutional and educational coordination is needed to enable companies to adopt sustainable and circular economy practices more clearly, efficiently, and profitably.

- Key players for companies in the transition

The key stakeholders are the government (for regulations and resources), academia (for R&D), professional recyclers (for reverse logistics), and consumers (to change perceptions and habits). According to Ruje, "Further formalizing recyclers, I think that has to be almost like sponsoring them." Multi-stakeholder collaboration is essential, with Acoplásticos playing a role as a liaison between these groups.

Companies agree that the transition to a circular economy is only possible with the coordinated participation of multiple stakeholders. They particularly highlight the State, ministries, recyclers, cleaning companies, end-user brands, processors, and suppliers of recycled raw materials. Companies such as Esenttia and Sun Chemical identify the entire value chain as key, which includes not only the State but also consumers and academia.

Intecplast and Carvajal Empaques highlight the role of the Ministry of the Environment and PCR suppliers as key players. OECD mentions the importance of having responsible companies that properly dispose of their waste, and World Compost emphasizes that manufacturers and customers must have a common vision. This multiplicity of actors reflects the need for shared governance to achieve sustainable and systematic progress.

- Business support strategies

Acoplásticos provides support through training, technical support, promotion of calls for proposals, and certifications. It offers digital tools to collect data and improve processes. Some projects, such as Colombia Productiva, offer technical assistance to companies to incorporate recycled materials and optimize processes. ICIPC offers training, certifications, and technical sheets for recycled materials. It promotes awareness among users and companies about separation and eco-design. According to Óscar Suárez, training recyclers, optimizing industrial processes, and developing waste generation maps for management planning can be strategies to support industries.

The support received by companies has been mixed, and many express the need to strengthen it. Some, such as Esenttia and Empaques Transparentes, have created their own internal strategies or collaborated on public-private initiatives. Carvajal Empaques and World Compost are developing sustainable schemes based on material and product innovation, but are seeking greater institutional support. Grupo Plásticos de Colombia emphasizes the importance of receiving financing and technical advice.

OECD, for its part, has worked with international organizations such as GIZ and the United Nations, which has allowed it to formalize processes for hazardous waste management. Even so, many companies state that current support is insufficient and that incentives should be better distributed to encompass both large, medium-sized, and small businesses. This suggests the need to strengthen public policy, cooperation, and technical financing mechanisms.

- Solutions or improvements implemented in your company

Companies have implemented various solutions to improve their environmental performance and transition toward a circular economy. Intecplast has adopted eco-design, the use of three-layer dies, and life-cycle analysis. Sun Chemical has increased its investment in technology and improved resource consumption tracking and CO_2 control. Carvajal Empaques has worked on material changes, recycling projects, and the use of food-grade PCR.

Empaques Transparentes leads the way with 100% PCR packaging, while Esenttia promotes chemical recycling and 100% recycled resins. OCADE contributes with its WEEE separation model and safe disposal of brominated plastics. World Compost has developed compostable designs internally, and Avient offers products that facilitate reduction, reuse,

and recycling. Together, these solutions reflect a growing commitment from the sector, although many initiatives still require greater scalability.

- **Relations with Universities**
    - Types of relationships

On the Acoplásticos side, the relationship includes joint projects, technical training, and participation in calls for proposals. However, collaboration is limited and requires more structure, such as applied theses or long-term projects. The organization acts as a bridge, but resource limitations and a lack of clear mechanisms hinder deeper collaboration. The Plastics and Rubber Training and Research Institute has served as a bridge, focusing on ecodesign and energy efficiency, but academia tends to conduct research that is largely unimplemented. The lack of connection is due to the perception that academia produces utopian research, while companies seek practical solutions. The ICIPC welcomes students for internships and collaborates on projects, but academia focuses on long-term research, while industry seeks immediate solutions.

The relationship between the National University and the external sector is good when there is direct collaboration, but it is limited by mutual misgivings and a lack of trust. The university offers technical solutions, but industry does not always take advantage of them. Collaboration occurs on specific projects, but there is no structured relationship. Large companies (Nutresa or Enka, for example) have established relationships with specific universities (such as EAFIT and the University of Antioquia), but SMEs have less contact due to a lack of resources and time. The university faces bureaucratic barriers to technology transfer. Relationships with large companies are more fluid, but with SMEs they are limited and require greater effort.

The level of engagement with universities and research centers is uneven, according to company responses (see Figure C.12). Some, such as Esenttia, Empaques Transparentes, and both Sun Chemical locations, have established clear links through innovation projects, academic events, and university internships. These collaborations allow for the development of sustainability-aligned solutions and the training of technical personnel in circular economy issues. In these cases, academia plays an active role in supporting business transformation processes.

In contrast, companies such as Avient, Intecplast, Carvajal Empaques, and Grupo Plásticos de Colombia do not report any current links with universities. This reveals a gap in the coordination between the productive and academic sectors, which could be limiting the capacity for innovation and adaptation. Collaboration channels need to be strengthened to leverage applied research in the development of circular solutions.

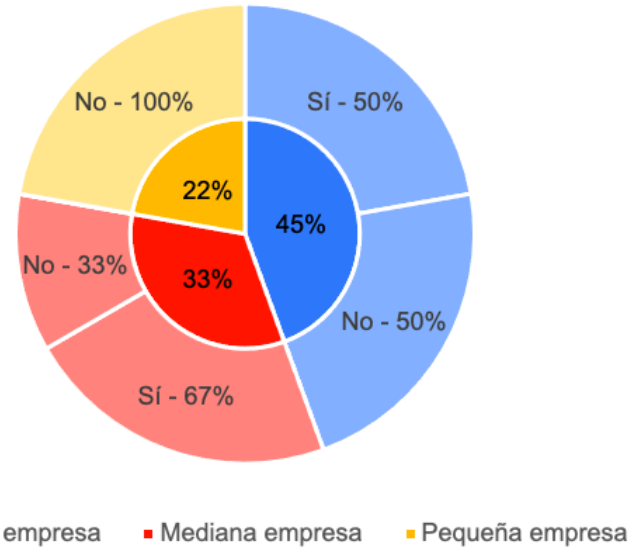

Figure C.12 Percentage of companies that reported having some type of relationship with academia, according to their classification, for companies that responded to the survey.

- Examples of projects or collaborations

Acoplásticos is working on specific projects, including the replacement of glass fibers with natural fibers (Jorge Tadeo University) and studies on the recycling ecosystem (Pilot University). These projects are in their infancy but show potential for addressing industry-specific problems. Some examples include collaborations with the National University of the Andes and EAFIT through the ICIPC, focused on training, research in polymers and biomaterials, and the development of sustainable solutions. The projects focus on sustainability and the circular economy, but are primarily led by the Institute, not through direct relationships between companies and universities.

From the Circular Alliance, some projects include a returnable pilot with Ciclo and the Medellín City Hall, the development of a water filter using flexible plastics (initially with Nutresa), and digital tools for logistics and traceability. These collaborations involve external resources and master's degree students.

Among the most notable examples of corporate responses is the EnCadena Transparent Packaging project, in collaboration with ICIPC and Colombia Productiva. Esenttia has also worked with universities on innovation exercises for their sustainability initiatives, while Sun Chemical has actively participated in academic events and training programs. These experiences demonstrate how collaboration can translate into concrete results such as new products, waste identification, and sustainable action plans.

World Compost also mentions that it works with academia, developing plans under the law to dispel misinformation about compostable products. In contrast, companies such as Grupo Plásticos de Colombia, OCADE, and Carvajal Empaques do not report specific

projects, although in some cases they collaborate with institutional actors such as the United Nations or ministries. This suggests that there is still great potential to be tapped in terms of collaborative research.

C.2.3 Key players in the transition to the circular economy

The key players in the circular plastics economy are:

i) The national government, through agencies such as the National Planning Department, CONPES, the Ministry of Environment and Sustainable Development, the Ministry of Commerce, Industry and Tourism, the Ministry of Science, Technology and Innovation, the Superintendency of Public Services, etc., responsible for promulgating policies, approving and regulating laws, and implementing them, will make it possible to achieve the goals proposed in the ENEC.

ii) Companies producing plastics in primary and basic forms are responsible for their plastic products through ecodesign and Extended Producer Responsibility.

iii) Municipal governments and local legislative bodies responsible for providing sanitation and waste collection services must implement policies and issue decrees that facilitate the incorporation of recyclable plastic waste into the EC.

iv) Garbage collection companies are responsible for collecting recyclable plastics.

v) Recycling associations play a fundamental role in the country's collection of recyclable plastic waste. In some cases, these associations create an intangible link between consumers and companies that can recycle plastic waste.

vi) Consumers, who through appropriate product selection, responsible use, and proper disposal, will facilitate the segregation and incorporation of plastic waste into the EC.

vii) Companies that recycle plastic waste, as it is at the heart of their economic activity.

viii) Plastics industry associations, especially ANDI, Acoplásticos, sector development clusters of chambers of commerce (for example, the packaging and printing cluster, the water and circular economy cluster in Bogotá), and even the National Chamber of Plastics, are acting as facilitators of relations between companies, the national government, and legislative bodies at the municipal and national levels.

ix) Multi-stakeholder public-private alliances aimed at articulating efforts in the circular economy, such as Bogotá Circular Region (Bogotá Circular Region, 2024), ANDI Circular Vision (ANDI, 2025i).

x) Oversight institutions and environmental NGOs must monitor and audit the results of the implementation of the ENEC.

xi) Universities and research institutes, generating the knowledge and technologies necessary for the use of plastics through CE, or facilitating the adaptation of acquired technologies by companies.

xii) Primary and secondary education institutions, training young people in a CE culture.

xiii) International entities that promote the circular economy, such as the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (giz, 2025).

C.2.4 Relationship between factors and actors

The interaction of stakeholders in the circular economy in Colombia is complex and depends on several regulatory, economic, technological, and social factors. Five main groups of stakeholders can be identified:

The State (National and Local Government)

- It regulates the production, use, and disposal of plastics through regulations such as Law 2232 of 2022, which establishes goals for the reduction of single-use plastics.
- It promotes circular economy policies, such as the National Circular Economy Strategy (ENEC), and coordinates incentives for recycling and sustainable production through the Ministry of Environment and Sustainable Development, the Ministry of Commerce, Industry and Tourism, and the National Planning Department.
- Implements programs to formalize recyclers and improve infrastructure for source separation.

Companies and Industrial Sector

- Major companies such as Enka of Colombia, Esenttia, Postobón, and Mexichem Resinas have developed recycling and sustainable production models.
- Industries must implement Extended Producer Responsibility (EPR), as is the case with Grupos Retorna and RecoPET, which work on the recovery of post-consumer plastic packaging.
- Others have opted for compostable, bio-based materials and new mechanical and chemical recycling technologies.

Recyclers (or waste pickers) and Recycling Cooperatives

- They are key to the plastic waste recovery chain and represent more than 60,000 professional recyclers in the country.
- Cooperatives such as ARB (Bogotá Recyclers Association) and Cooperativa Planeta Verde have formalized their operations and are working with businesses and the government to improve recycling efficiency.
- However, they still face challenges such as a lack of job recognition, informality, and a lack of access to technologies that could increase their cost-effectiveness, especially due to technical and financial deficiencies.

Academia and Research Institutions

- Universities such as the National University of Colombia have developed projects in recycling and biodegradable materials in partnership with companies and the government.
- The Central University and other institutions have worked to include recyclers in circular economy models and environmental education strategies.
- Research programs have been created in new materials, waste management efficiency, and energy recovery.

Consumers and Civil Society

- Consumer behavior is a critical factor in the circular economy, as recycling and source separation depend on environmental education and awareness.
- Movements such as Bogotá Basura Cero and Greenpeace Colombia have promoted campaigns against single-use plastics and sustainable alternatives.

The implementation of circular economy in Colombia depends on a balance between clear regulations, economic incentives, and technological advancements. Although investment in machinery for the plastics industry is increasing, it is essential that this growth be aligned with sustainable production models. Furthermore, digitalization and cross-sector collaboration can accelerate the adoption of circular practices.

ANDn an initial analysis of the influences between actors and factors mentioned in Dayana Luque Avendaño's work (see Table C.6), a network diagram is proposed, Figure C.13, which seeks to visualize the interaction between the different actors and factors that make up the circular economy in the country. To better understand its dynamics, three key elements are analyzed: (i) the hierarchy of influence between actors, (ii) the role of structural factors and their impact, and (iii) critical interactions and their effect on the transition towards the circular economy.

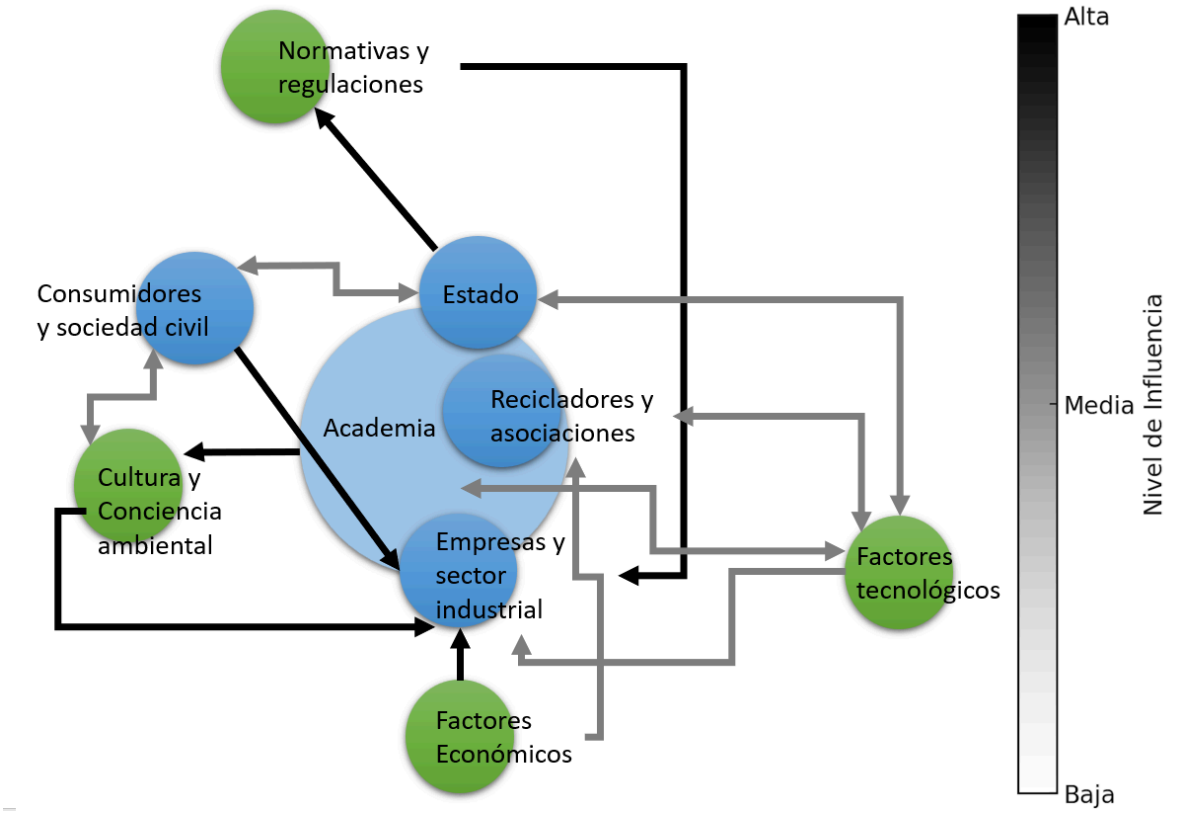

Figure C.13 Network diagram - Interaction and influence between actors and factors influencing the transition to the circular economy. Created by the authors.

The intensity of the connections between actors is represented in Figure C.13 with line thickness and grayscale, allowing us to visualize the actors that most influence the structure of the plastics circular economy. The results show the following:

Actors with the greatest structural influence

State (Government and Regulatory Entities)

- Its influence is direct and decisive due to its ability to issue regulations, environmental regulations, and establish economic incentives.
- Example: Law 2232 of 2022 on single-use plastics, which requires companies to redesign packaging and materials (straws, swabs, disposable party items, etc.).
- Relationship with factors: Main impact on regulation and market.

Industrial Sector and Processing Companies

- They represent the productive and technological capacity that defines the economic viability of recycling, eco-design, and the incorporation of circular economy models.
- Example: Enka of Colombia has promoted the transformation of recycled PET into textile fibers and resins, which reinforces the economic viability of recycling.
- Relationship with factors: Mainly affects technology and innovation and market demand.

Actors with intermediate influence

Academy and Research Centers

- Its influence lies in the development of knowledge and technologies, but its impact depends on effective transfer to industry and state support.
- Example: Some research at the National University on biopolymers and biodegradable plastics has generated alternatives to conventional polymers, but they require business support for their scalability.
- Relationship with factors: It affects technology and innovation, but with an indirect connection to the market.

Professional Recyclers and Solidarity Economy Organizations

- Their impact is key in the logistics of waste collection and separation, but they depend on regulations and market conditions.
- Example: The formalization of recyclers in Bogotá has improved the efficiency of plastic waste recycling, but economic barriers still exist.
- Relationship with factors: It affects the efficiency of waste management, but is subject to state regulations and market conditions.

Actors with less direct influence, but relevant to the sustainability of the system

Consumers and Civil Society

- Its impact is indirect but growing, as changing consumption patterns can put pressure on the industry to adopt circular practices.
- Example: Responsible consumption initiatives in Medellín and Bogotá have promoted the reduction of single-use plastics.
- Relationship with factors: It affects the market and environmental awareness.

Each actor interacts with factors that determine the circular economy. In Figure C.13, these factors are represented as nodes that connect various actors with different levels of influence.

Regulatory Factors: Regulation and Public Policies:

- Main driver of structural change.
- It directly impacts the industrial sector, recyclers, and the market.
- Example: The ban on single-use plastics in certain sectors has forced the industry to look for alternatives.

Factors associated with Technology and Innovation:

- Key to improving the viability of recycling, bioplastic production, and the development of circular models: ecodesign, reuse, and reconditioning.
- Its impact depends on investment from the industrial sector and academia.
- Example: The development of biodegradable polymers in universities requires business support for scaling.

Economic factors: Market and Demand:

- Factor that can accelerate or slow down the transition to the circular economy.
- Dependent on business decisions and consumer behavior.

- Example: Growing demand for recycled resins is driving the recycling industry, but cost barriers remain.

Factors associated with culture, awareness and environmental education:

- Its effect is long-term and depends on government campaigns and private initiatives.
- Example: School recycling programs have improved source separation in some cities.

From the analysis of the network diagram, Figure C.13, key relationships emerge that will determine the effectiveness of the EC in Colombia:

State → Regulation and Public Policies → Industrial Sector:

- Regulation creates incentives or barriers to the transformation of plastic waste.
- Stricter policies without adequate incentives can slow down the industry, while well-designed regulations can boost investment in recycling and eco-design.

Academy → Technology and Innovation → Industrial Sector:

- Technological innovation depends on knowledge transfer, but there are still gaps in implementation.
- Need to strengthen the connection between universities and businesses to improve the competitiveness of the circular economy.

Recyclers → Waste Management → Industry and Market:

- The efficiency of plastic recovery depends on the formalization and working conditions of recyclers.
- Greater government and private sector support can increase the volume and quality of recycled plastic available.

Consumers → Market and Demand → Industry:

- Increased consumption of recycled or sustainable products could pressure the industry to adopt circular economy models.
- Environmental education strategies can accelerate this transition.

As a summary of the network diagram presented in Figure C.13, it can be concluded that:

- The state and the industrial sector are the main agents of change, as regulations and business decisions determine the viability of the circular economy.
- Academia plays a fundamental role in innovation, but its impact depends on technological adoption by industry.
- Recyclers are essential to recycling logistics, but they require better conditions and formalization to improve their impact.
- Consumers can influence the circular economy through their purchasing decisions, but they require greater environmental education.
- The diagram shows that, to accelerate the transition to a circular economy, it is necessary to strengthen the interaction between regulations, technological innovation, and the market, reducing gaps between academia, industry, and recyclers.

Now, to strengthen the relationships between actors and factors in the CE ecosystem in Colombia, the following policies and strategies are proposed, supported by international experiences and proposals from national entities such as Acoplásticos, ANDI and the Bogotá Chamber of Commerce (Acoplásticos, 2023) (CCB, 2024) (ANDI, 2025):

Strengthening Regulation and Public Policies:

- **Implementation of Extended Producer Responsibility (EPR):**Requiring producers to take responsibility for the entire life cycle of their products, from manufacturing to final disposal. This policy has been effective in countries such as Chile and Mexico (Ministry of the Environment, 2024) (International Alliance of Waste Pickers & WIEGO, 2023).
- **Tax Incentives for Sustainable Practices:**Offer tax exemptions or tax reductions to companies that adopt circular economy practices, similar to the policies implemented in Brazil (Cezar & Balaguer, 2025).

Promotion of Technology and Innovation:

- **Creation of Innovation Centers in the Circular Economy:**Establish laboratories and research centers dedicated to the development of sustainable technologies, such as the laboratory inaugurated by SENA in Bogotá (SDA, 2022).
- **Public-Private Partnerships for Innovation:**Promote collaborations between the public and private sectors for the development of innovative solutions, following the example of the alliance between CAF and Tetra Pak in Latin America (CAF, 2025).

Market Development and Demand:

- **Public Awareness Campaigns:**Launch educational initiatives to raise consumer awareness about the importance of the circular economy, inspired by campaigns carried out in cities such as Córdoba and Fortaleza (Lecumberri, 2025).
- **Certifications and Green Labeling:**Implement certification systems for sustainable products, incentivizing companies to adopt circular practices and enabling consumers to make informed choices.

Improving Environmental Awareness and Education:

- **Incorporating the Circular Economy into Educational Plans:**Integrate concepts of sustainability and the circular economy into school and university curricula, following ECLAC recommendations (ECLAC, 2021).
- **Training Programs for Recyclers:** Offer training and certification to professional recyclers to improve their skills and working conditions, as promoted by the Bogotá Recyclers Association (ARB, n.d.).

Strengthening Infrastructure and Logistics:

- **Development of Recycling Infrastructure:** Invest in efficient recycling plants and collection systems, taking as a reference the initiatives of leading European cities in the circular economy.
- **Reverse Logistics Optimization:** Implement systems that facilitate the return and reuse of products, reducing waste and promoting circularity.

Promoting Intersectoral Collaboration:

- **Creation of Circular Economy Networks:**Promote collaboration between companies, governments, and civil society organizations to share best practices and resources, similar to the networks established in countries such as the Netherlands (European Union, 2021).
- **Active Participation of Guilds and Chambers of Commerce:**Involve entities such as Acoplásticos, ANDI and the Chamber of Commerce in the promotion and adoption of circular practices, aligning with national strategies (ANDI, 2025).

These policies and strategies, based on international experiences and national proposals, can strengthen relationships between key stakeholders and factors, accelerating the transition to a circular economy in Colombia.

C.2.5 Policies and strategies to strengthen relationships between stakeholders

According to Acoplasticos, it is estimated that around 350,000 tons of post-consumer plastic waste are recycled in Colombia each year. The results of the Survey on the Characterization and Growth of Plastics Recycling in Colombia show that recycled plastic grew 19% in tons and 145% in sales in 2021. This growth rate implies that Colombia can double its plastics recycling in just five years. At the same time, between 2019 and 2021, the installed capacity of the plastics recycling industry grew by 40%, with a 120% increase in investments. This has led to more than 60,000 registered professional recyclers currently benefiting from the dynamism generated by this sector.

On the other hand, the Ministry of Environment and Sustainable Development stated that “Colombia recycles 163,000 tons of plastic waste per year and that Bogotá and Medellín process 13,000 tons of plastic waste per month, supported by the work of professional recyclers and the network of nearly 260 processing industries. In 2019, the Single Information System for Household Services identified that 15.09% of the recycled materials, that is, 212,434 tons, correspond to the plastics family” (MinAmbiente, 2021).

According to Statista, the percentage distribution of plastic waste worldwide between 2020 and 2060, according to its final destination, will be as shown in Figure C.14. As can be seen, approximately 65% of plastics will be taken to landfills or mismanaged, up to 17% recycled, and a similar percentage incinerated. Furthermore, the OECD estimates that by 2040, only 6% of plastics will be well managed, and that inappropriate management and incineration will account for 50% and 20%, respectively (OECD, 2024). Thus, the situation in Colombia is similar to that of the rest of the world, but faces structural challenges in waste collection, separation, and transformation. Unlike countries like Brazil and Chile, which have more successfully implemented Extended Producer Responsibility (EPR) systems and energy recovery strategies, Colombia still lacks large-scale incineration plants as a management alternative. These types of plants are essential for managing contaminated, highly heterogeneous, and difficult-to-recycle plastic materials.

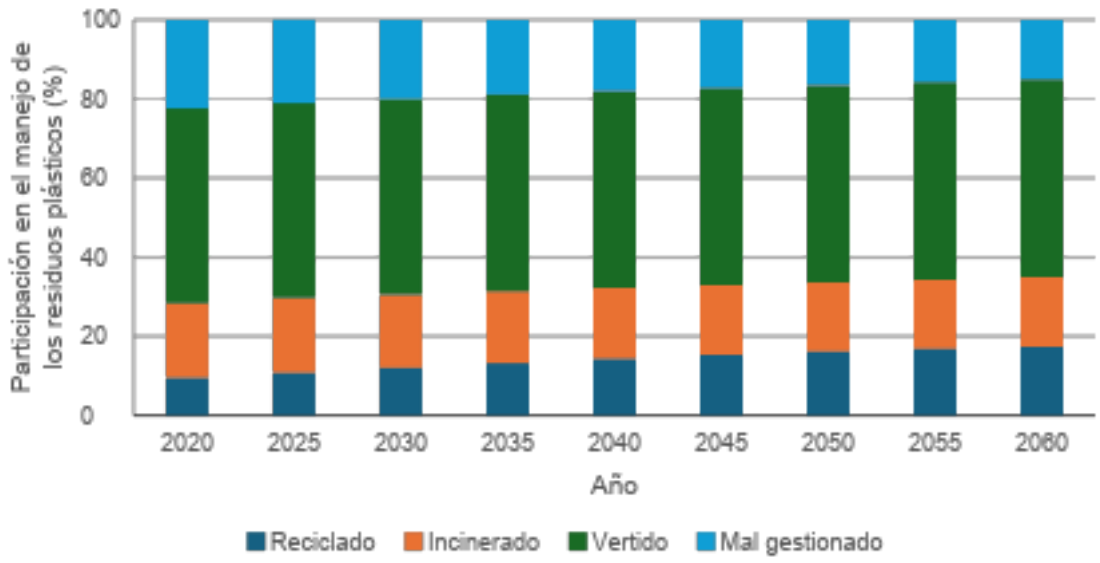

Figure C.14 Percentage distribution of plastic waste worldwide between 2020 and 2060. Constructed with data available at https://es.statista.com/estadisticas/1484226/distribucion-de-los-residuos-plasticos-a-nivel-mundial-segun-destino-final/. Accessed March 13, 2025.

C.2.6 Plastic recycling in Colombia

From the partial understanding of the situation at the National University of Colombia, Bogotá campus, the relationship is limited to the proposal and, if approved, the implementation of research and extension projects for the development of products and processes that use biobased waste or raw materials for the production of polymers or finished products within the CE philosophy. In the case of the Chemical and Biochemical Processes Research Group, since the late 20th century, projects have been developed for the production of polyols from palm and soybean oils, and later from used cooking oils (UCO), which have subsequently been evaluated in the production of polyurethanes. The projects have been carried out in conjunction with companies such as Espumlatex and Espumados, and associations such as Fedepalma. Table C.7 presents a partial list of these research projects.

Table C.7 Research projects carried out by the Chemical and Biochemical Processes Research Group of the Department of Chemical and Environmental Engineering on the project topic.

Project	Year	Company the financier
Study of the stages of recycling post-consumer plastics	1996	National University of Colombia
Polymer blends: morphology and structure	1998	National University of Colombia
Synthesis of biodegradable polymers and copolymers based on lactic acid for pharmaceutical applications	2005	National University of Colombia – Chalver Laboratories
Production of polyester polyols from palm oil for the manufacture of flexible and rigid polyurethane foams	2006	Colciencias – National University of Colombia - Espumlatex
Production of polyurethane foams from soybean oil	2006	National University of Colombia
Development of bioadhesive and biodegradable materials from copolymers derived from lactic acid	2007	National University of Colombia
Scaling up the production process of biodegradable plastics using renewable carbon sources with native microorganisms	2007	National University of Colombia
Study of miscible blends of thermoplastic polymers and thermosetting polymer precursors	2007	National University of Colombia
Design of biodegradable packaging for cosmetic products in solid presentation.	2009	National University of Colombia
Development of a prototype reactor for microwave depolymerization of polyurethane	2015	National University of Colombia
Reuse of used vegetable oil in the production of epoxidized oils	2017	National University of Colombia
Production of polyols from palm oil	2020	Fedepalma - Foamed

The Central University (Bogotá) has developed a series of initiatives related to the circular economy, recycling, and support for professional recyclers. Below are some of its main initiatives in these areas:

Training and Capacity Building for Professional Recyclers

Diploma "Managing and Recycling": Since 2017, the Central University, in collaboration with Gerdau Diaco, has offered this diploma program for professional recyclers. To date, more than 300 recyclers have benefited, strengthening their skills in areas such as tax regulations, RUT management, office tools, proper waste management, and structuring recycling associations.

Entrepreneurship Course: In 2017, a 30-hour course focused on innovation, marketing, finance, and entrepreneurial models was offered, with the goal of improving the productivity and business management of participating recyclers.

Strategic Alliances with Recycling Associations

Puerta de Oro Recyclers Association of Bogotá: Since 2019, Universidad Central has worked with this association to improve waste management within the institution. Between 2018 and 2021, 8,673.8 kg of PET and 2,876.3 kg of low-density plastic were collected and delivered for transformation into new products, thus promoting the circular economy.Events and Awareness Activities

University Recycling Fair "Diverciclaje": In September 2021, the first edition of this fair was held with the aim of raising awareness among the university community about the importance of recycling in everyday life.

Celebration of National Recycler's Day: The university has recognized the work of professional recyclers, highlighting their importance in the waste management chain and their contribution to environmental sustainability.

Promotion of the Circular Economy

Forums and Publications: The Central University has organized events and published articles highlighting the importance of the circular economy as a model for a sustainable future, promoting new forms of waste management and more environmentally friendly production processes.

These initiatives reflect the Central University's commitment to sustainability, social inclusion, and the promotion of responsible waste management practices, strengthening its role as an agent of change in society.

In addition to the universities involved in the project, other institutions are developing research and technological development projects with companies and institutions on innovative projects involving biodegradable plastic materials, mechanical and chemical recycling, and plastic waste recovery. Some examples are presented below:

University of the Andes

Through its Advanced Materials and Energy Research Center, the Universidad de los Andes has worked on projects involving biopolymers, chemical recycling, and new materials from plastic waste. Companies in the sector have funded research into compostable materials and sustainable packaging.

University of Valle

The Polymer Research Group has worked with the industrial sector on mechanical recycling of post-consumer plastics and the formulation of recycled materials for applications in the construction and automotive industries.

Regarding academic programs, universities such as the National University, the University of Antioquia, and the Pontifical Javeriana University have incorporated modules and specializations in waste management and the circular economy into their chemical, environmental, and materials engineering programs. The Central University offers the subject "Circular Economy and Green Business" as an elective in the Faculty of Engineering. The Plastics and Rubber Research and Training Institute (ICIPC) provides training on plastics issues, with the circular economy as one of its focuses.

These institutions train professionals capable of implementing sustainability strategies in the plastics industry.

Likewise, some universities have promoted entrepreneurship in the plastics recycling sector through incubators and innovation programs. One example is Bio'Kim, a startup founded in Bogotá that has developed deinking technologies to recover post-industrial plastic materials.

In summary, although the relationship between universities and the industrial sector in Colombia regarding plastics recycling has been growing, driven by the need for sustainable solutions and the circular economy, and there has been progress in research,

technological development, and training, there is a need to further strengthen the connection between academia and business, promoting the effective transfer of knowledge and the industrial application of innovations in recycling and new materials.

C.2.8 Innovations in the plastics industry

The plastics industry in Colombia is evolving with a strong focus on innovation and sustainability. Below are some of the key advances and examples of companies leading this transformation.

Circular Economy and Recycling

Companies have adopted circular economy strategies to reduce the use of virgin plastics and promote recycling.

Enka from Colombia: Founded in 1964, this company has been a pioneer in recycling in the country. In 2009, it opened a PET recycling plant, and in 2018 and 2023, it launched plants for recycling caps and labels for polyolefin production. Its approach has allowed it to close the loop on these materials and reduce dependence on virgin plastic resins (Enka, 2018).

Recycle (Plastilene Group): Specializing in post-consumer plastic recycling, it produces high-quality recycled resins for flexible packaging, promoting the reuse of materials in the packaging industry (Reciclene, 2020).

Mexichem Resinas S.A.S. (VESTOLIT): It promotes PVC sustainability in Latin America through its "Vinyl in Motion" program, which promotes the recycling of post-industrial and post-consumer PVC waste. The initiative empowers recyclers and connects key players in the value chain to integrate recycled PVC into new products under a circular economy model. The program is currently recognized for its consumer focus and for transforming more than 3,000 tons of PVC annually into new applications (Acoplásticos, 2024c).

Andercol: It works in the transformation of collected material, especially transparent PET, oil-impregnated PET and amber-colored PET (Andercol, 2024).

Investments in Technology and Modernization

The sector has modernized its infrastructure with advanced machinery to improve efficiency and sustainability.

Rambal: It has developed quality control systems with artificial vision and dosing solutions for flexible packaging, improving the precision and efficiency of production processes (La Nota Económica, 2024).

Bio'Kim:A Bogotá-based company that has innovated with technology for deinking plastic films, enabling the recovery of high-quality post-industrial materials for reuse.

ESTRA Industries S.A.: The production of their products includes PCR, and they are pioneers in the incorporation of Industry 4.0 technologies focused on energy efficiency and productivity (Estra, 2024).

Sustainable Product Development

Innovation in materials and processes has driven the creation of biodegradable or recyclable products.

Green Plastic Colombia SAS: It is dedicated to the recovery and transformation of plastic waste into new products, promoting the closing of the plastic cycle within the circular economy (Green Plastic, 2021).

ProUSAR: Initiative that supports sustainability and innovation in the plastics industry, promoting responsible and efficient practices in the production and use of plastics.

Community and Social Projects

Companies are engaging with the community to promote a culture of recycling and sustainability.

Bottles of Love: An initiative that encourages the community to collect hard-to-recycle plastics in bottles, which are then used to make plastic lumber for street furniture. (Bottles of Love, 2023)

Specialized Fairs and Events

> **COLOMBIAPLAST:** Key event presenting advances in chemical recycling, eco-design, and bioplastics, connecting companies and professionals with innovative solutions for the industry (Colombiaplast, 2025).

In conclusion, the Colombian plastics industry is transitioning toward a more sustainable model through circular economy strategies, technological innovation, and the development of products with a lower environmental impact. Companies such as Enka, Reciclene, Bio'Kim, and Green Plastic Colombia are leading the way with initiatives that not only optimize industrial processes but also generate a positive impact on plastic waste management. This transformation not only responds to environmental regulations but also to a growing market and societal demand for more sustainable solutions.

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