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IMPLEMENTATION OF PLASTIC RECYCLING STRATEGIES IN THE REPUBLIC OF MOLDOVA. CASE STUDY

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Abstract. The present study examines the implementation of national sustainability strategies derived from European policies and global environmental concerns, focusing on ensuring a sustainable future for future generations. Given the environmental impact of plastic, as well as its non-biodegradability, the research analyzes the national and European legal framework that recommends a series of strategies and measures aimed at mitigating environmental impact while fostering a culture of sustainability from an early age at the national level. To conduct the study, multiple research methods were employed, including direct observation, systemic analysis, case studies, circular document analysis, data collection methods, and comparative analysis. The study's findings indicate that, at the national level, the first companies dedicated to recycling specific types of plastic and reintegrating them into the economic cycle as equally necessary and widely used products have been established. Additionally, various awareness and promotional campaigns highlight the importance of recycling used plastic packaging, a culture of environmental responsibility is gradually emerging among users of all age groups. The novelty of this study lies in its exploration of the interconnection between the legal, academic, and economic spheres in addressing sustainability and environmental protection. This integration positions the national approach within the broader framework of global sustainability strategies.

Keywords: *plastic, waste, recycling, recovery, sustainability, strategies.*

Rezumat. Lucrarea prezintă rezultatele studiului cu referinţă la implementarea strategiilor naţionale de sustenabilitate derivate din strategiile europene şi preocupările globale pentru protecţia mediului şi un viitor asigurat noilor generaţii. Considerând impactul plasticului asupra mediului ambiant, dar şi nebiodegradabilitatea acestuia, s-a analizat cadrul legal naţional şi european ce recomandă o serie de strategii şi măsuri implementarea cărora ar face posibilă diminuarea impactului asupra mediului, dar şi formarea culturii pentru sustenabilitate la nivel naţional încă de la cele mai fragede vârste. În vederea desfăşurării studiului au fost aplicate mai multe metode de cercetare: metoda observaţiei directe, abordarea sistemică, metoda studiului de caz, analiză documentelor circulare, metoda culegerii datelor, metoda comparativă. Rezultatele studiului au denotat, că la nivel naţional sunt atestate primele companii axate pe reciclarea unor anumitor tipuri de plastic şi

repunerea lor în circuitul uzual sub formă de produse la fel de necesare şi uzuale societăţii, sunt întreprinse diverse campanii de informare şi promovare a necesității de reciclare a ambalajelor din plastic deja folosite, este în formare cultura de sensibilitate pentru recuperarea ambalajelor la utilizatorii de toate vârstele. Noutatea studiului reflectă conexiunea societăţii la nivel legal-academic-economic în preocupările comune pentru sustenabilitate şi protecţie a mediului, înscriind-o în parcursul implementării strategiile globale pentru o viaţă sigură şi inofensivă.

Cuvinte cheie: *plastic, deșeuri, reciclare, valorificare, sustenabilitate, strategii.*

1. Introduction

The widespread use and frequency of plastic as a material with excellent mechanical properties, high resistance to various stresses, low weight, and reduced costs have made it one of the most popular materials globally. However, its non-degradability and the environmental pollution it currently generates necessitate the identification of measures that could contribute to restoring global climate balance. The pressure exerted by waste on the environment, along with the unequivocal awareness of the need to use environmentally friendly resources within the limits of necessity, has led to the adoption of the circular economy strategy. This strategy is based on the principles outlined in the international standard ISO 59004, which can be summarized as follows: Systemic approach to sustainability, Value creation, Value promotion, Resource Management, Resource monitoring, and Ecosystem resilience [1].

Accordingly, the present study outlines the findings of an analysis regarding the implementation of plastic waste recycling strategies as part of the European strategies transposed into national legislation. These strategies are reflected in the following directives: EU Directive 94/62/EC on packaging and packaging waste, Directive 2008/98/EC on waste, EU Directive 2019/904, which, since 2021, has banned several types of single-use plastic products, Directive 2018/851, which sets targets for the use of recycled materials in packaging production and establishes minimum recycling standards, Regulation (EU) No. 1169/2011 on consumer information, and the REACH and CLP Regulations, which regulate the chemical substances used in packaging to ensure they are not harmful to human health and the environment. Additionally, Regulation (EU) 2020/852 (EU Taxonomy) provides a classification system for sustainable economic activities [2].

National-level concerns for a healthy and sustainable environment have been specifically regulated through: Government Decision No. 323 of 30.04.2024 (MO 202-204/10.05.24, Article 410, in force from 27.07.24), Government Decision No. 561 of 31.07.2020 approving the Regulation on packaging and packaging waste, Law No. 247 of 31.07.2023, amending Law No. 1540/1998 on environmental pollution charges, Law No. 231 of 23.09.2010 on domestic trade (amended by LP373 of 30.11.23, published in MO 492-494/22.12.23, Article 871, in force from 22.02.24), and Law No. 209 of 29.07.2016 on waste management, with modifications published on 20.06.2024 in Official Gazette No. 260-263, Article 373.

2. Materials and Methods

The documentary study focused on analyzing national and European laws, regulations, and standards concerning the circular economy, packaging waste, and recycling. Within the framework of this research, the review of specialized literature, including academic research papers, was also undertaken.

Several methodological approaches were employed: the cross-sectional method-observation-to identify the relationship between theoretical and practical research competencies, and the longitudinal method—case study—to achieve research objectives by analyzing a specific case and presenting concrete findings relevant to the research theme.

A qualitative and quantitative analysis was conducted on Type 2 (HDPE) and Type 5 (PP) plastic packaging, facilitating direct observation of the recycling process and its integration into industrial product manufacturing through experimental methods.

All collected and analyzed data underwent a structured processing methodology, while data interpretation methods were applied to identify best practices in plastic recycling in the Republic of Moldova. The study ultimately generated conclusions regarding this topic, contributing to the ongoing discourse on sustainable waste management.

3. National Recycling Strategies: Results

Plastic recycling represents one of the core objectives of the European Union's circular economy policy. Several directives and strategies addressing plastic waste have been implemented to facilitate the transition toward a circular economy. In this context, as part of efforts to combat plastic pollution, the European Commission proposed a Plastics Strategy in January 2018, aiming to ensure that by 2030, all plastic packaging can be either reused or recycled while simultaneously reducing the consumption of single-use plastics and microplastics. The Republic of Moldova has aligned with these objectives by integrating them into its National Sustainable Development Strategy "Moldova 2030" [3].

Waste management, including plastic waste, remains a significant environmental challenge for the Republic of Moldova. The issue of waste is becoming increasingly acute due to the rising volume and diversity of waste, as well as its growing negative impact on the environment [4].

There is no single ideal solution for addressing plastic waste management challenges. Instead, a wide range of measures can be implemented. One such measure entails the recycling and reprocessing of existing packaging materials to generate new packaging or alternative products. According to the United States Environmental Protection Agency (EPA), recycling is defined as "*the process of collecting and processing materials that would otherwise be discarded as waste and transforming them into new products*" [5]. Furthermore, Law No. 209 of 29.07.2016 (amended on 20.06.2024), in Article 2 "Definitions", defines recycling as "*any recovery operation through which waste materials are transformed into products, materials, or substances to fulfill their initial function or for other purposes. This includes the reprocessing of organic materials but excludes energy recovery and conversion for fuel use or backfilling operations*" [6].

Certain materials are highly suitable for recycling, while others, despite being theoretically recyclable, require costly procedures. In this regard, Table 1 presents an overview of different types of plastics and their recyclability within the Republic of Moldova. The conclusions are from a review of many bibliographic sources, collaboration with local recycling firms, and independent research investigations.

The recycling strategy aims at the following main objectives specific to the national waste management hierarchy (Law No 209/2016, Article 3, Paragraph 1) (Figure 1):

1. Preventing waste formation by promoting clean technologies and organic products.
2. Waste recovery through optimization of selective collection and sorting systems: preparation for reuse, recycling, and other recovery operations – including energy.
3. Final disposal of waste that has not found a recovery solution.

Table 1

Types of plastic and their possibility of recycling in the Republic of Moldova [7-10]

Polymer type	Abbreviation and code	Example of packaging, containers	Recyclable or not
Polyethylene terephthalate	PET, 1	Containers for liquids; food packaging.	Yes
High density polyethylene	HDPE, 2	Cosmetic containers; pipes; toys; in agriculture.	Yes
Polyvinyl chloride	PVC, 3	Blister packaging; shrinkable packaging for food and industrial products; pipes; cable insulation.	Difficult
Low density polyethylene	LDPE, 4	Simple packages; barrier layer in multistate packaging; food packaging.	Difficult, Yes
Polypropylene	PP, 5	Flexible packaging for food and non-food products; chemical, cosmetic, food and industrial containers.	Yes
Polystyrene	PS, 6	Floating for meat, fruit, vegetables; Compact Discs; homes for food and industrial.	No
Elastomer, polymethyl methacrylate, composite.	Others, 7		Not most of the time

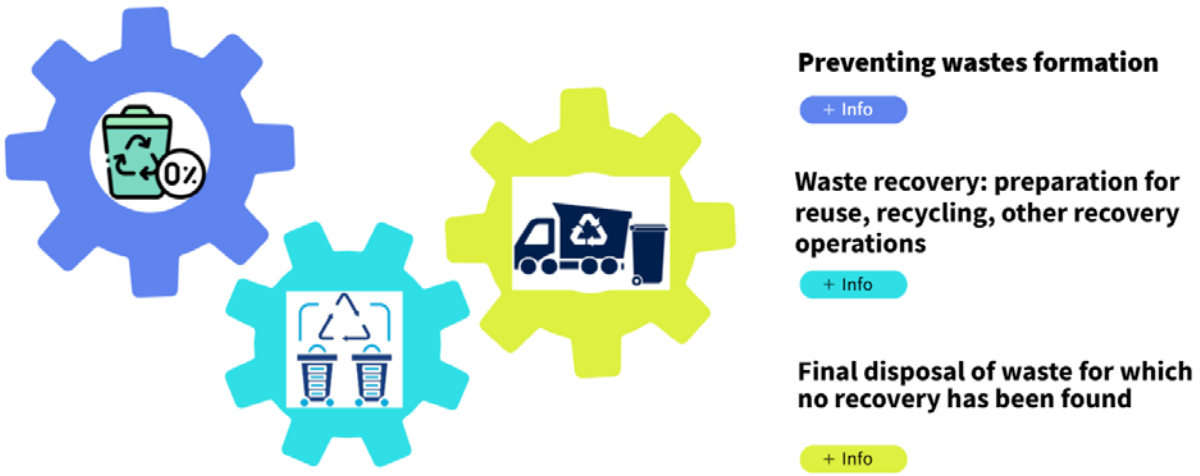


Figure 1. Main objectives of waste recovery.

The National Sustainable Development Strategy "Moldova 2030" supports the Republic of Moldova's involvement in the global fight against plastic pollution by advocating for a global treaty, the key aspects of which were negotiated during the roundtable discussions organized by the United Nations Environment Programme (UNEP) from November 23 to December 2, 2024, in Busan, South Korea [3,11].

3.1. National actions aimed at forming a culture of sustainability and preventing waste formation

The Republic of Moldova is among the countries committed to sustainability, initiating a series of measures aimed at this goal. Consequently, as a result of direct observation and analysis of the strategies developed and implemented at the national level, the launch and operation of the following actions were identified [12-15]:

• The concept of *"Zero Waste Communities"* for three beneficiary localities: the municipality of Strășeni/ Mănăstirea Căpriana, Orhei (Trebujeni village)/Orheiul Vechi, and the municipality of Soroca/Soroca Fortress. Each of these localities, in addition to expanding the infrastructure for separate plastic waste collection, will actively participate in identifying and implementing efficient solutions to prevent plastic pollution, regarded as the most effective, healthy, and economic tool in the fight against such waste.

• *"Criuleni without Waste"* aims to carry out a media and advocacy campaign in the city of Criuleni, seeking to improve waste management by informing the population about the need for selective collection and enhancing local policies in this regard.

• The "Solid Waste Awareness and Collection Campaign" in six beneficiary localities of the project “Solid Waste Management with Community Involvement” in Strășeni district – Strășeni municipality, Lozova commune, Negrești village, Scoreni village, Sireți village, and Vorniceni village.

• The project *"Say No to PLASTIC: Informed Communities with Fewer Waste Generated"* aims to inform the population of various ages about the impact of plastic on the environment and health, and consequently reduce the quantity of plastic waste generated nationwide, including the costs related to the management of these wastes. This is a priority project for Waste Management Region 5 (Nisporeni, Călărași, and Ungheni districts).

• The *"July without Plastic"* campaign (an international campaign initiated in 2011 in Australia) in the Republic of Moldova is implemented by the Public Association E-Circular and supported by several state institutions (Ministry of Environment, Ministry of Health, National Public Health Agency, "Autosalubritate" Enterprise (Figure 2), Environmental Agency), non-governmental organizations, and private companies. This campaign took place from July 1-31, 2023.

• The national campaign *"Support Moldova, Refuse Plastic, I Am Europe"* was conducted from July 1-31, 2023.

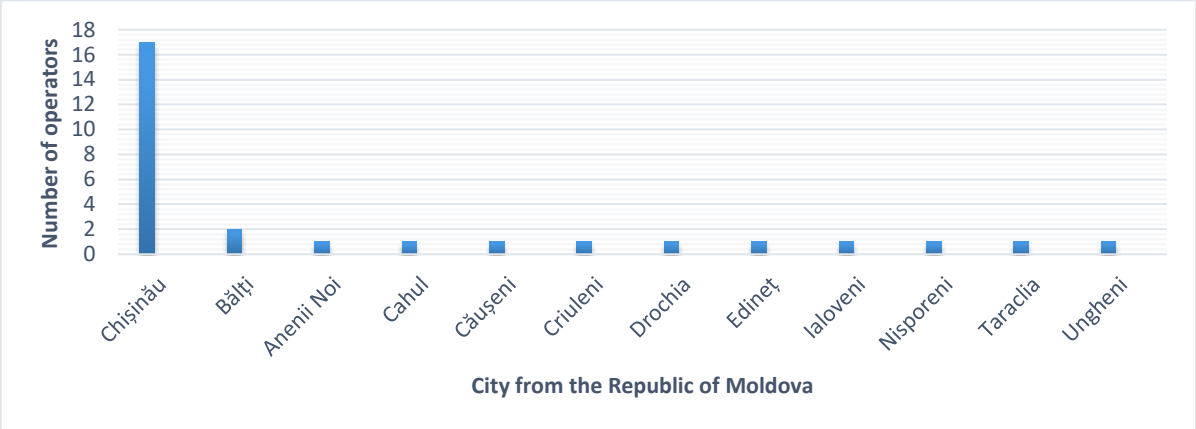


Figure 2. Number of authorised operators for the collection, transport and recycling of plastic waste [16].

• The project *"Run from PLASTIC"* was designed by the NGO "EcoDigital" in partnership with the NGO Training and Consulting Center "E-CIRCULAR", NGO Run Moldova, and the Association of Manufacturers and Importers of Packaging in Moldova (APIAM), with financial support from the GEF SGP Moldova Small Grants Program, implemented by UNDP.

• The awareness and information campaign *"Without PLASTIC I Feel FANTASTIC"* is an information and awareness project launched by the NGO Association for Waste Valorization, with financial support from the European Union under the "Development of Civil Society Organizations' Capacities" project, which is a regional project implemented by ERIM (formerly IREX Europe).

• The campaign for collecting bottle caps in schools in Chișinău, implemented by Recycline in 2024.

• The national campaign *"Plastic Collected, Clean Environment,"* initiated by the Environmental Protection Inspectorate and the National Environmental Center, on the eve of World Cleanup Day, held in the city of Bălți on September 14, 2023.

In the context of enhancing and aligning the institutional academic environment, the team of faculty members and researchers from the Department of Industrial and Product Design, the Design and Printing Technologies program, in collaboration with several companies focused on packaging recycling, launched a campaign to raise awareness among younger generations represented by students of the "Design and Printing Technologies" and "Industrial Design" study programs within the Faculty of Design at the Technical University of Moldova. The campaign, titled "Let's Recycle Together," included a series of actions aimed at:

• Providing information about the need for environmental protection and its long-term impact.

• Promoting the concept of sustainability through: Rethink, Refuse single-use products, Reduce consumption, Reuse the products you already have, Recycle, Recover, and Reintroduce into circulation.

• Promoting the concept of collecting plastic packaging waste types 2 and 5 within the environment, society, family, academic group, building, etc., through the development of posters and verbal dissemination of the established objectives, including on the DTP program's page (https://www.facebook.com/share/p/1X3bssGZ4B/).

• Accumulating waste with student participation (collecting 5 kg of type 2 plastic (HDPE) and 3 kg of type 5 plastic (PP)).

• Transmitting the collected waste to companies specialized in packaging recycling (Recycline SRL in Chisinău).

• Involving students in the redesign of new products.

• Translating the concepts created by students and approved into manufacturing and new concept products.

Figure 3. Company promotion poster „Let's recycle together" (author: student gr. DTP-223, Pavlina Burlakova).

This campaign facilitated the involvement of most students from all four years of the Bachelor's program from the mentioned study programs and made it possible to raise their awareness by engaging them in the creation of social posters (Figure 3) focused on the theme of plastic waste collection, which was later recycled by the company Recycline in Chisinău.

3.2. Making use of plastic waste. Case study

The waste from hard, recyclable plastic is collected through the yellow containers installed by the Municipal Enterprise „Regia Autosalubritate" (for the inhabitants of mun. Chisinau), as well as in the yellow nets installed by ABS Recycling Moldova, 12% of the total plastic waste (mainly plastic containers) are transported to the recycling station in Peresecina, where they are transformed by crushing into granules, and then from them are produced sewer pipes or containers for cosmetic products.

Another option for plastic recycling is the startup generically called Recycline. This small company has as its main objective the collection and recovery of type 2 plastic (HDPE) and type 5 (PP) (Figure 4), being the most widespread material from which the caps for various containers for cosmetics are made and not only.

Figure 4. Types of containers and packages made of type 2 and type 5 plastic [17].

The company Recycline has its own equipment for the mechanical shredding of plastic into plastic flakes of different colors, subsequently transformed by a string of technological steps into „precious plastic" – decorative objects, household items, as well as jewelry and accessories (Figure 5).

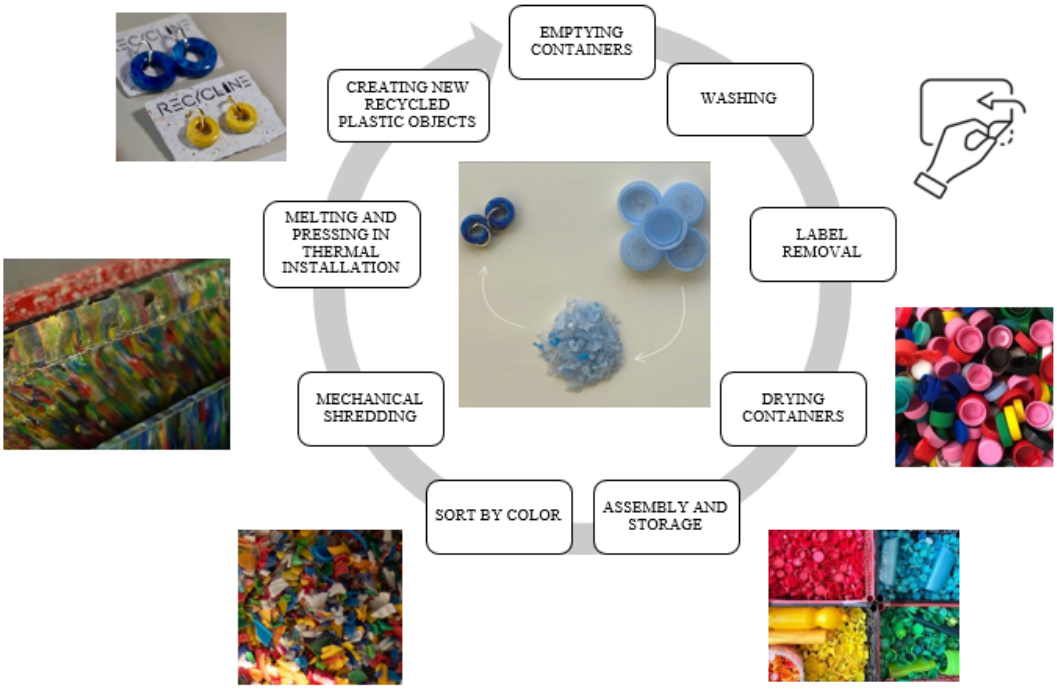


Figure 5. Stages of recycling and recovery of plastic type 2 and type 5 within Recycline.

The process of collecting plastic as a primary source for obtaining materials can be ensured from physical sources, representing personal or industrial use products, as well as from sources with different legal statuses that use containers of various volumes made of different materials in their activities.

Thus, from individuals, through personal visits to the company's collection point, the following plastic waste is collected:

- Single-use containers, packaging from dairy products (plastic type 5).
- Caps from water, juices, dairy products, carbonated beverages (plastic type 2).
- Packaging from hygiene products (plastic type 2).
- Packaging from detergents (plastic type 2 and type 5).
- Household products marked with labels (toys, vitamin packaging, cosmetic product packaging).
- From legal entities, by requesting a company representative to collect the plastic, the following plastic waste is collected:
    - Caps from milk and carbonated drinks (from cafes).
    - Packaging from care products (from beauty salons).
    - Caps from beverage containers (from educational institutions).
    - Containers of cheeses (from restaurants).
    - The collected plastic is sorted by color (Figure 6).

Figure 6. Chromatic diversity of plastic collected and recycled by Recycline.

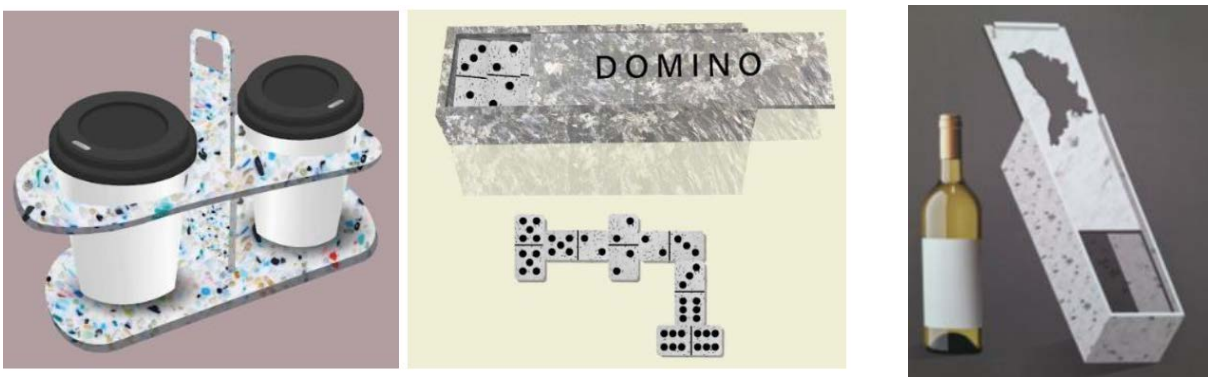
In order to increase the efficiency of plastic waste recovery, the research team has been involved in ensuring the connection between Recycline and small printing companies (up to 49 employees), where various supplies supplied in type 2 plastic containers (HDPE) are involved, which can serve a permanent source for recycling activity recovery and disposal of waste from companies in this industrial field (Table 2).

Table 2

Recycable plastic that can be collected from a small printing company

Packaged product	Volume of container, L	Quantities used
Cleaning Solutions	20	2 pieces/month
Alcoholic Solutions	20	2 pieces/month
Varnish	25	1 piece/half a year
Moistening Solution	10	2 pieces/month
Gumming Solution	10	1 piece/half a year
Developing Solution	10	1 piece/half a year

Recycline is open for active collaboration on the implementation of its own design, recycled plastic packaging projects. Students have developed their own projects (Figure 7) to be implemented in the manufacturing.



a) b)

Figure 7. Concepts of redesign of the products to be made from recycled plastic by students of the Design and Polygraphic Technologies program: a) Cosonea Iulia; b) Rudaia Irina.

4. Conclusions

The case study conducted allowed for the following findings to be made:

- Strategies related to the circular economy should be focused on: Systemic approach to sustainability, Value Creation, Value promotion, Resource Management, Resource monitoring, and Ecosystem resilience.
- Encouraging young people to start up businesses focused on recycling all types of plastic used in daily life.
- Continuous motivation and promotion of the sustainability concept at all levels of children's education, simulating through various methods of care for the environment, protection of natural resources, recycling, and reintroducing existing resources into circulation through: Rethink, Refuse single-use products, Reducing consumption, Reuse the products you already have, Recycle, Recover, and Reintroduce into circulation.
- Intergenerational connection between young people and adults in the joint implementation of promotion actions, tree planting, waste collection, etc.
- Involvement and stimulation of companies in the economic environment focused on waste recycling to visualize the results of their work and engage the entire society in recycling activities and reintroducing waste into circulation, including organizing work visits within companies for children to understand the process well.
- Designing new products and packaging based on sustainability principles.

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