Reimbursement of aluminum and PET packaging project at a University Campus: a case study

Castro A.[1,*], Gomes A.P.[1], Correıa A.C.[1], Rıbeıro M.H.[4], Queırós A.[1]

[1]University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal

*corresponding author: Castro A.
e-mail: aaoliveira@ua.pt

Abstract. Deposit Return Systems were created to increase the recycling rate of single-use beverage containers and meet the recycling targets in European Union. REAP - Recycling and Reimbursement of Aluminum and PET Packaging is an initiative that took place within the scope of the sustainability policies created at the University of Aveiro, Portugal, allowing students and staff to be reimbursed for each PET beverage bottle/ aluminum can returned after consumption. This selective collection reduces the degree of contamination of the waste and increases the quality of the waste to be incorporated into the recycling industry and in the PET packaging production chain. This paper aims to promote reimbursement systems and bottle-to-bottle mechanisms as a measure for sustainability and circular economy. This article analyses the REAP case study monitoring results during the first year. The results indicate an increase in the number of returned packages during the year and return rates of 41% for PET bottles and 26% for aluminum cans in the first year of implementation. The increase in the number of users shows that the project has been a good instrument in raising environmental awareness among the academic community for the importance of packaging separation for subsequent recycling.

Keywords: Single-use Beverage Containers; Recycled PET; Bottle-to-Bottle; DRS

1. Introduction

The Covid-19 pandemic has triggered the production of plastic packaging since 2020. The intensified use of food delivery and takeaway services and the increase in online sales and e-commerce represented a significant increase in packaging and single-use plastics production. [1], [2] Packaging is the largest plastic market in the world, representing more than 40% of the plastic produced. More than 5% of plastic production is virgin PET made from fossil fuel [3]. The mechanical and thermal properties of polyethylene terephthalate (PET), such as its high tensile strength, unbreakability, clarity and good barrier properties towards moisture and oxygen, make it the most widely used plastic to produce water and carbonated beverage bottles [4], [5]. PET is a low-cost polyester polymer [6] and its very low weight compared to glass bottles with the same filling volume decreases the value of transportation significantly, which is a factor for the increase in its demand.
Even though PET recycling is increasing, [7] just a small percentage is used to produce new bottles. More than 60% of the PET packaging produced is beverage bottles, and about 50% are recycled but new bottles on the EU market contain only an average of 17% rPET. [8] To increase the percentage of rPET used in food contact packaging as beverage bottles it is mandatory to increase the amount of food-grade rPET. To achieve that, the bottles must be sorted into defined streams for recycling processes on behalf of quality purposes.

Aluminum beverage cans possess significant circularity potential. [9] When integrated into a closed-loop-supply system, their recycling yields a lower environmental impact in comparison to the production of new cans using virgin feedstock. [10] To sustain this supply chain, it is crucial to collect and acquire uncontaminated, food-grade level feedstock. Reimbursement systems have proven to be an effective measure in fulfilling this requirement [11].

1.1 Deposit Return Systems (DRS)

Directive 2019/904 [12] defined the collection target of beverage bottles at 90% and the integration of at least 30% of recycled plastic in the production of new bottles from 2030. With the European Green Deal comes the second Circular Economy Action Plan in which one of the proposed measures is the mandatory deposit return systems for plastic bottles and aluminum cans [13]. In 2018 Germany had a return rate of 97% of PET beverage bottles [11], revealing those mechanisms' promising efficiency. To produce food-grade rPET, the European Food Safety Authority (EFSA) defined that a bottle feedstock should not contain more than 5% of non-food PET plastic [14]. The implementation of a DRS for beverage bottles generates a material that automatically meets this requirement. Packaging reimbursement mechanisms prevent contamination of PET bottles by hazardous components from, for example, cleaning house products and pesticides. There are specific guidelines to produce packaging that will be in contact with food. The list of additives that can be added in the manufacture of the packages is limited and regulated. Mixing these very clean packages with other types of plastics during collection and sorting decreases their quality and value. To ensure that those contaminants don´t migrate to the food and consequently to the human body through ingestion it is required more complex and expansive recycling processes that can be avoided with more selective collecting systems [5], [15]. Bottle-to-bottle systems increase the supply of the high-quality, food-grade needed material to manufacture bottles with more recycled content, making the process more effective and less expensive.

In 2020, REAP - Recycling and Reimbursement of Aluminum and PET Packaging project, was implemented at the University of Aveiro, Portugal.

1.2 Project REAP

Project REAP initiative took place within the scope of the sustainability policies created at the University of Aveiro (UA). [16] This project allows students and staff from UA to be reimbursed for each PET beverage bottle/ aluminum can returned after consumption. This return is made through reverse vending machines spread throughout the UA Campus. The amount of the refund must be credited to the University's Single Card, which is already associated with the institution's access and payment systems [17].

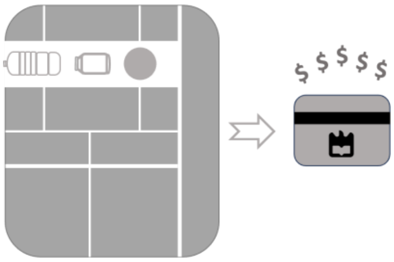

Figura 1. RVMs mechanism.

The product derived from the collection has two distinct paths. The first one is the obtainment of a high-grade and food-grade product that is used in different research projects at UA, the main one being the study of new packaging produced through the recycling of this product and its study regarding the physical, chemical, and thermal quality in relation to packaging produced with virgin material. This project allows the study of the effects of multiple cycles of recycling of the same packaging. Those results have a major importance to the recycling industry and the new obstacles that this industry has ahead with the new legislation. The second destination of this product, through the UA waste management system, is the incorporation of the post-consumption material directly into the recycling chain of PET and aluminum to produce new packaging, enhancing the value of residues with a minimal level of contamination. Additionally, it is to promote innovation in waste collection and recycling processes, thereby mitigating environmental impacts, particularly through reduced washing requirements and enhanced recycling efficiency [18].

This paper aims to promote reimbursement systems and bottle-to-bottle mechanisms as a measure for sustainability and circular economy capable of responding to various waste management problems and showing the main benefits of their implementation.

2. Methodology

The methodology used in this article is the analysis of a case study of the implementation of a reverse vending system for PET and aluminum packaging in a Portuguese University. This article follows the period of the first year of operation of the reverse sale system implemented at the University of Aveiro which extends from April 2022 to April 2023. During this period the system was monitored and data as the number of collected bottles/cans and deposits value were gathered. For analysis of the operation of the system and presentation of results, data was provided by the UA.

3. Case Study

This case study analyzes a pioneering project involving the implementation of a reimbursement system on a University Campus in Portugal, specifically designed for PET bottles and aluminum cans. The system is accessible to students, teachers, researchers, and other staff members. The project features seven reverse vending machines (RVMs) strategically positioned throughout the UA campi, with varying capacities. The capacity and quantity of RVMs were determined considering the density of students and staff, as well as the proximity to surrounding buildings. These machines were strategically placed in common areas within specific buildings that are exclusively accessible to the academic community [18]. The implementation of the system was assisted by an experienced company in the sector, Infinitum. Additionally, two external companies were involved, responsible for programming the machines and customizing the system to meet the specific requirements of the campus. They also ensured the seamless integration of the machine system with the University's Single Card, optimizing its functionality. The machines were programmed to accept PET bottles and aluminum cans ranging in capacity from 0.1L to 2L. For packaging with a capacity between 0.1L and 0.5L (inclusive), a reimbursement of 0.02€ is credited to the card. For packaging with a capacity between 0.5L and 2L (inclusive), the reimbursement amount is 0.05€. The key aspects of system monitoring are managed through a mobile application, which provides notifications for machine maintenance requirements such as cleaning or when they reach full capacity and need to be emptied. The collected batches from the machines are stored in the UA's dedicated waste park, segregated from other waste types, for further processing and onward handling.

4. Results and Discussion

The data gathered during the monitoring period indicate an increased tendency in the number of collected packages since the system's implementation on UA's campi. This tendency is perceptible for both PET and aluminum cans (dotted lines in Figure 1). The only exceptions to this upward trend are temporary declines coinciding with academic breaks, including summer holidays, Christmas, Easter, and the transition between semesters. These periods are characterized by a notable decrease in campi activity and population, leading to reduced package collection (Figure 1).

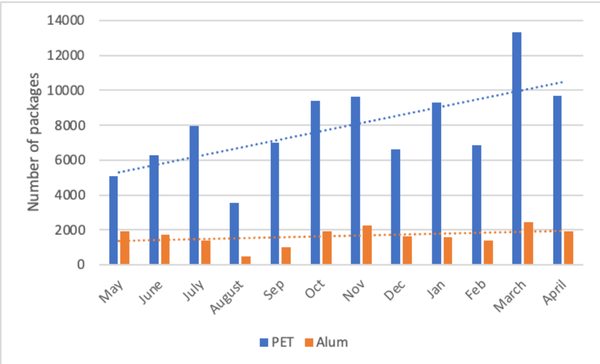

Figure 1. Monitoring results of the RVMs at UA (Dotted lines are just for the purpose of showing the tendency).

With a total of 114351 packages collected during the period of this study and a total of 19032 (Table 1) potential users of the system, the number of collected packages per capita is 6 in the first year of the implementation of the project.

Table 1. Academic Population in 2022 at UA *(available at https://indicadores.ua.pt)*

Students	16432
Professors	1250
Researchers	505
Staff	845
Total	**19032**

The consistent promotion of the system within the UA Academy has led to an increase in the number of users, and this upward trend is expected to persist and further expand, leading to higher values for the number of collected packages per capita.

Figure 2 illustrates the comparison between the packages collected in the RVM system and the packages sold on the UA campus, which corresponds to the fractions of 41% in the PET packages and 26% in the aluminum cans. As illustrated, the sales of aluminum cans are three times lower than the number of PET packages sold. This disparity provides justification for the observation made in Figure 1, where the average number of aluminum cans collected by RVMs is five times lower than PET packages.

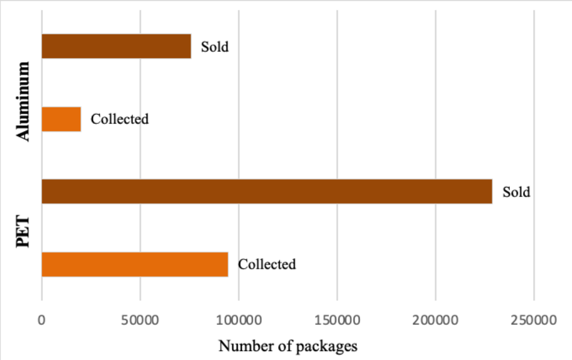

Figure 2. Number of packages sold at UA vs. collected in the RVMs.

The packages collected from the RVMs between April 2022 and April 2023 correspond to approximately 2Mg, accounting for 7% of the plastic and metal waste (EWC: '150102', '150104', '200139', '200140') handled by UA's waste management system for recycling. (Figure 3).

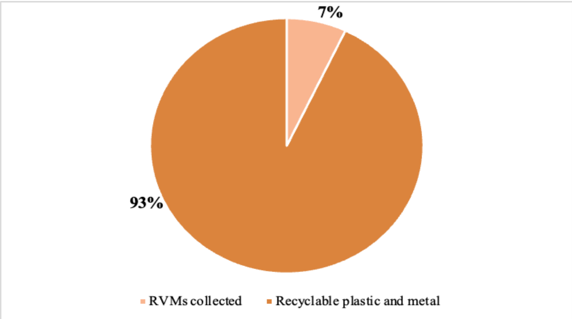

Figure 3. Recyclable plastic and metal waste produced at UA.

Only in one year UA managed to generate 2Mg of recyclable waste with food-grade level of quality, giving rise to a positive economic return. This waste has more value than the remaining 93% of plastic and metal collected by the UA's waste management system.

The DRS for single-use beverage containers has been implemented in ten European countries. In 2021, the return rates ranged from 70% (in The Netherlands) to 90% (in Germany) [11]. These rates are not comparable with the results of REAP Project where the maximum return rate was for PET, 41%, since in those countries the DRS was implemented from 1984 (in Sweden) till 2016 (in Lithuania)[11]. Portugal is currently preparing its own DRS legislation (Decreto-Lei nº69/2018) which establishes incentives for the implementation of a DRS and some awareness projects, similar to REAP, have been implemented since then. This kind of initiative is fundamental for the success of the future DRS program that is expected to roll out in Portugal by 2023/24.

Recent reports have indicated that higher deposit values are associated with increased return rates. Therefore, it is crucial to evaluate the deposit values of the REAP project. In European countries where a DRS system is implemented through RVMs, the deposit values could be ten or five times higher (as seen in Germany) compared to the deposit value established by REAP, which adheres to Portuguese legislation (Despacho Nº 6534/2019). Understanding and considering these deposit value differences is essential in analyzing and comparing return rates between different countries.

5. Conclusions

In order to improve the rates of returns, a reassessment of the project should be made, namely in terms of the value of the deposit so it becomes more appealing, simultaneously should be created mechanisms of dissemination in the Academy.

The increase in the number of users shows that the project has been a good instrument in raising environmental awareness among the academic community, specifically for the importance of packaging separation for subsequent recycling.

6. Acknowledgments

The authors acknowledge the financial support through the Environment Programme of the Multi-Annual Financial Mechanism (EEA Grants), established under the Agreement on the European Economic Area.

References

[1] W. Q. de Oliveira, H. M. C. de Azeredo, I. A. Neri-Numa, and G. M. Pastore, “Food packaging wastes amid the COVID-19 pandemic: Trends and challenges,” *Trends Food Sci Technol*, vol. 116, pp. 1195–1199, 2021, doi: https://doi.org/10.1016/j.tifs.2021.05.027.

[2] K. Graulich, “Impact-of-COVID-19-on-single-use-plastics-and-the-environment-in-Europe,” 2021.

[3] Plastics Europe, “Plastics-the Facts 2022 OCTOBER 2022,” Nov. 2022.

[4] M. Chanda, *Plastics Technology Handbook*, Fifth Edition. CRC Press, 2018.

[5] F. Welle, “Twenty years of PET bottle to bottle recycling - An overview,” *Resources, Conservation and Recycling*, vol. 55, no. 11. pp. 865–875, Sep. 2011. doi: 10.1016/j.resconrec.2011.04.009.

[6] W. Thodsaratpreeyakul, P. Uawongsuwan, and T. Negoro, “Properties of Recycled-Polyethylene Terephthalate/Polycarbonate Blend Fabricated by Vented Barrel Injection Molding,” *Materials Sciences and Applications*, vol. 09, no. 01, pp. 174–190, 2018, doi: 10.4236/msa.2018.91012.

[7] EUNOMIA, “Pet Market In Europe State Of Play 2022 Productıon, Collectıon And Recyclıng,” 2022.

[8] A. Grant, V. Lahme, T. Connock, and L. Lugal, “How Circular is PET?,” Feb. 2022.

[9] R. Stewart, M. Niero, K. Murdock, and S. I. Olsen, “Exploring the Implementation of a Circular Economy Strategy: The Case of a Closed-loop Supply of Aluminum Beverage Cans,” *Procedia CIRP*, vol. 69, pp. 810–815, 2018, doi: https://doi.org/10.1016/j.procir.2017.11.006.

[10] M. Niero, M. Z. Hauschild, S. B. Hoffmeyer, and S. I. Olsen, “Combining Eco-Efficiency and Eco-Effectiveness for Continuous Loop Beverage Packaging Systems: Lessons from the Carlsberg Circular Community,” *J Ind Ecol*, vol. 21, no. 3, pp. 742–753, 2017, doi: https://doi.org/10.1111/jiec.12554.

[11] Reloop, “Global Deposit Book 2022: An Overvıew Of Deposıt Return Systems For Sıngle-Use Beverage Contaıners,” 2022.

[12] Official Journal of the European Union, *Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment*. 2019.

[13] European Comission, “European Green Deal: Putting an end to wasteful packaging, boosting reuse and recycling,” Nov. 30, 2022.

[14] M. T. Brouwer, F. Alvarado Chacon, and E. U. van Velzen, “Effect of recycled content and rPET quality on the properties of PET bottles, part III: Modelling of repetitive recycling,” *Packaging Technology and Science*, vol. 33, no. 9, pp. 373–383, 2020, doi: https://doi.org/10.1002/pts.2489.

[15] F. Awaja and D. Pavel, “Recycling of PET,” *European Polymer Journal*, vol. 41, no. 7. pp. 1453–1477, Jul. 2005. doi: 10.1016/j.eurpolymj.2005.02.005.

[16] “Universidade de Aveiro.” https://www.ua.pt/pt/noticias/11/64063 (accessed May 31, 2023).

[17] “REAP.” https://www.eeagrants.gov.pt/pt/programas/ambiente/projetos/projetos/reap-reciclagem-e-reembolso-de-embalagens-de-aluminio-e-pet-sistema-piloto/ (accessed May 31, 2023).

[18] I. Gonçalves, “Sistema piloto de reembolso de depósito, para embalagens de bebidas (de PET e alumínio), na Universidade de Aveiro,” Universidade de Aveiro, 2021.