Comparative LCA of container deposit scheme and green dot system for PET bottles, cans and beverage carton waste in Spain

Eva Sevigné[1,2*], Carles M. Gasol[1,2], Jordi Oliver-Sola[1,2], Víctor Mitjans[3], Xavier Gabarrell[1,4] and Joan Rieradevall[1,4]

[1]SosteniPrA (UAB-IRTA-Inèdit), Institut de Ciència i Tecnologia Ambientals (ICTA), Universitat Autònoma de Barcelona (UAB) 08193 Bellaterra, Barcelona, Spain.
[2]Inedit Innovació S.L. UAB Research Park. Carretera de Cabrils Km2, 08348 Barcelona
[3]Fundació Privada Catalana Per a la Prevenció de Residus i el Consum Responsable (c. Balmes, 4. 08750 Molins de Rei, Spain)
[4]Chemical Engineering Department, Universitat Autonoma de Barcelona (UAB), 08193 Bellaterra, Barcelona, Spain

*Corresponding author: Tel: +34 93 581 37 60; fax:+34 93 581 33 31
E-mail address: eva.sevine@campus.uab.cat

ABSTRACT: This paper presents a comparative Life Cycle Assessment (LCA) of the collection of packaging waste (PET bottles, cans and beverage cartons) in Spain. The objective is to provide quantitative environmental data of the implementation of a Container Deposit Scheme (CDS) in Spain, adapted from German system, and its comparison with the Green Dot System (GDS) currently in operation in Spain. In addition, alternative scenarios of recovery and automation are also compared. The results show that the CDS adapted from the German model has better environmental performance than the GDS for all impact categories and when the manual return is lower than 40%, the CDS has better environmental performance than the GDS for all percentages of recovery and for all impact categories.

Key words (abstract): Container Deposit Scheme (CDS), Green Dot System (GDS), manual return, automated return, CO_2 emissions, life cycle assessment (LCA)

1. Introduction

In the 21st century, the sustainable management of municipal solid waste (MSW) will become necessary at all phases of impact from planning to design, to operation and to decommissioning [1]. In Spain, the law of packaging and packaging waste 11/1997 of 24th April (known as "LERE") [2] stated that the producers of packaging must adhere to a Green Dot System (GDS) or articulate a Container Deposit Scheme (CDS) in order to achieve the recovery targets

contained in such law. As a result of LERE, the vast majority of companies joined the packaging GDS managed by Ecoembalajes España S.A (Ecoembes) rather than created a CDS. In the context of LERE revision and the new recycling targets set by EU Directive 2004/12 [3] several studies have been commissioned for evaluating the environmental assessment of the GDS and CDS model.

LCA is a popular tool used to evaluate the environmental performance of MSW management systems [4] and in Spain several studies have been conducted in order to assess the sustainability of different MSW systems [5,6,7,8] but no one of these studies have considered CDS as an option. This study has been carried out from a life cycle approach with the aim of providing quality data of environmental performance of the potential implementation of a CDS adapted to Spain for PET bottles, cans and beverage cartons taking the German model as a reference. Another specific objective has been the quantification for 7 categories of the environmental impact of existing GDS system in Spain (only for the three fractions of packaging: PET bottles, cans and beverage cartons) to determine if replacement of the GDS for these three fractions of packaging waste could represent a potential environmental benefit in the context of Spanish territory.

2. Materials and methods

A comparative LCA has been applied to compare the two waste management systems. Such method evaluates potential impacts throughout the life cycle of a product, process or activity, from the extraction of raw materials through production and use, to final disposal [9,10].

2.1 Container Deposit Scheme (CDS)

PET bottles, cans and beverage cartons are collected manually in small shops and automatically in large commercial store through specific return packaging machines. The few waste packaging not collected selectively is managed with the rest fraction. The manually collected packaging is transported to a sorting plant where it is separated by the type of material while in the specific return machines packaging waste is separated by type of material in origin and transported and stored in the supermarket logistic centers. Finally, for both paths, the classified waste is transported to recycling centers. In both cases, the rest fraction of this phase is assumed to be transported either to landfill or to incineration plants where energy is partially recovered.

2.2 Green Dot System (GDS)

In GDS PET bottles, cans and beverage cartons are collected selectively by specific containers and through rest fraction containers. Packaging collected

selectively is transported to a packaging sorting plant. The rest fraction also from the sorting plant is managed in landfills or incineration plants where energy is partially recovered.

2.3 Comparative environmental assessment: Life Cycle Assessment

This environmental tool follows ISO 14040 [10] guidelines, according to which, LCA is divided into four steps: (1) goal and scope definition, (2) inventory analysis, (3) impact assessment, (4) interpretation. The environmental analysis was developed using the software program SimaPro 7.1.8 by Pré Consultants.

2.3.1 Functional unit

In this study the functional unit is: to generate a ton of PET bottles, cans and beverage cartons ready to enter a recycling process, considering the efficiency of GDS in Spain and a CDS with automation levels adapted from German model.

2.3.2 System description of CDS adapted from German model

The CDS adapted from German model is characterized by a level of 80% of automation in collection and the remaining 20% is recovered through a manual process. The system boundary includes the stages presented in figure 1:

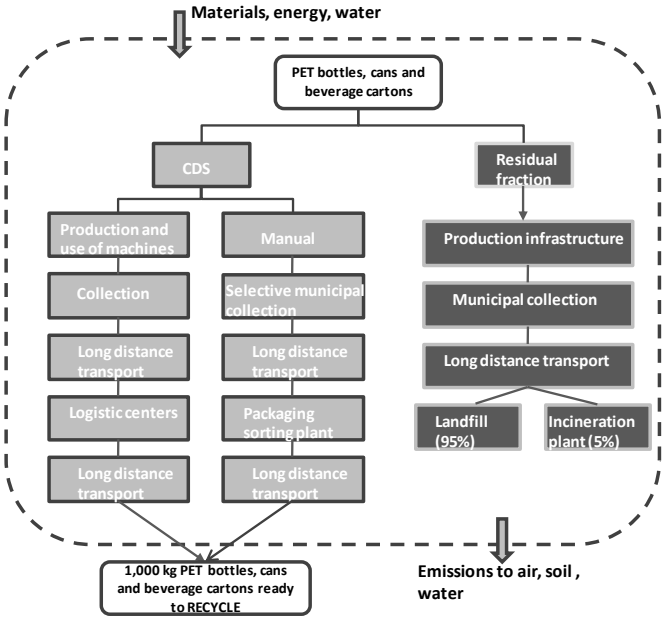

Fig. 1: Limits of CDS management system

2.3.3 System description of GDS in Spain

PET bottles, cans and beverage cartons account for the largest share of packaging waste in the current GDS in Spain. The boundary systems include the stages presented in figure 2. The stage of PET bottles, cans and beverage cartons recycling in plants is excluded from the study. However, the system includes transportation from packaging sorting plants to recycling plants and also the rest fraction from the packaging sorting plants to landfill or incineration.

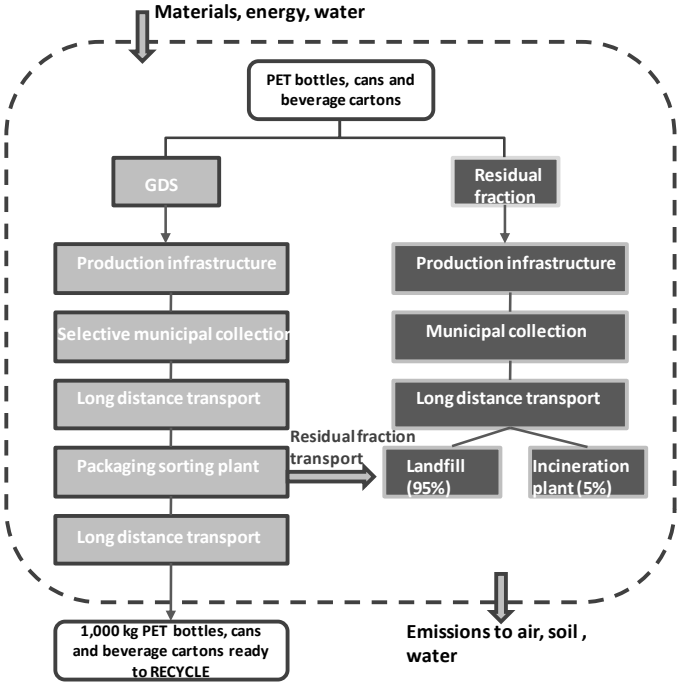

Fig. 2: Limits of GDS system management

2.3.4 Proportion by weight of packaging waste considering in the study

The three fractions studied account for 45% of the total packaging waste generated in Spain [11] distributed as follows:

- PET bottles: 21%
- Cans:16%
- Beverage cartons: 8%

From all environmental impacts associated to packaging GDS in Spain, it has only considered the proportion, by weight, for these three fractions of packaging. With respect to the functional unit distribution shall be distributed according to:

- PET bottles: 47%

- Cans:36%
- Beverage cartons: 17%

The amount of PET bottles, cans and beverage cartons collected separately that should be managed for both systems is determined by; the collection rate (from 10% to 100%) and efficiency of Spanish packaging sorting plant (67%) [11]. These variables determine the total amount of packaging waste collected separately required to satisfy the functional unit. Table 1 presents the total packaging waste in tones to manage in both systems in different cases of rate collection:

Tab.1 Quantity of waste to manage in CDS and GDS with a percentage of selective collection of 55%

	Selective collection (%)	Tones to manage (T)
CDS	10	10,000
	100	1,000
GDS	10	14,870
	100	1,487

2.3.5 Life cycle inventory/Quality of data

This assessment requires having quality inventory data of the most relevant inputs and outputs of the system under study. Primary data has been collected from various sources: Waste Agency of Catalonia [12-15], Ecoembes [11,16,17], Waste Prevention and Responsible Consumption Foundation [18], Ministry of Environmental, Rural and Marine of Spain [19,20], the Polytechnic University of Catalonia [21], Tomra [22], Rhenus Logistic [23], Volvo [2424]. In addition databases such as ecoinvent 2.0 (2007) have been used as background data [25].

Recovery of PET bottles, cans and beverage cartons in solid waste treatment plants has not been accounted for due to the lack of quality information. Nevertheless, not considering this stage does not affect the final comparison between CDS and GDS since for a same percentage of collected MSW impacts on both systems would be the same.

2.3.6 Life Cycle Impact Assessment (LCIA) methodology

The LCIA methodology used has been "CML baseline 2001". The impact categories included are: abiotic depletion (AD); acidification (A); eutrophication (E); global warming (GW); ozone layer depletion (ODP); human toxicity (HT) and photochemical oxidation (PO). According to ISO 14.040, only classification

and characterization phases have been used, excluding the optional phases of normalization and weighting in order to avoid subjectivity in the analysis.

3. Results and discussion

3.1 Results of the comparison between CDS adapted to German model and Spanish GDS for global warming category (GW)

Figure 3 shows results for different collection rates between 10% and 100% and different scenarios for the CDS according to the manual collection and automatically collection rates:

- CDS 1: 20% manual collection and 80% automatic collection
- CDS 2: 50% manual collection and 50% automatic collection
- CDS 3: 80% manual collection and 20% automatic collection

The results obtained in CDS 1 show that the selective collection with this system has fewer CO_2 eq. emissions that the GDS regardless of the collection rate. The impact avoided, compared to GDS, is highest when rate collection in both systems is 10% (or lower) achieving a saving of 642.2 kg of CO_2 eq. for every ton of PET bottles, cans and beverage cartons recovered for recycling. For CDS 2 the environmental performance follows the same trend as in CDS 1 but as the amount of packaging waste collected manually and therefore not compacted, is higher, this scenario has higher environmental impacts. For a 10% rate collection 505.2 kg of CO_2 eq. could be avoided. Finally, in CDS 3 when the selective collection is higher than 40% the environmental impacts for GDS are lower than for CDS 3. For this scenario, a 100% collection rate of PET bottles, cans and beverage cartons with GDS would save 128.1 kg of CO_2 eq. with respect to CDS 3.

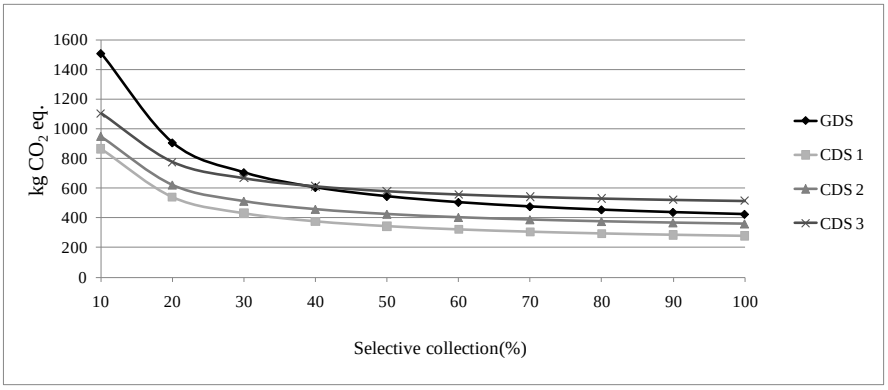

Fig. 3: Environmental comparison between CDS 1, CDS 2, CDS3 and GDS for selective collection range 10-100% for GW impact category

3.2 LCA results for life cycle stages for a rate collection of 55% for CDS and GDS

To assess the environmental impacts of the different life cycle stages, a collection percentage should be fixed for the two systems compared. This percentage has not relevant effect on the results presented here, however to avoid arbitrariness, the reference value of minimum recycling packaging waste of 55% established by Directive 2004/12/EC [3], has been chosen. CDS results vary significantly depending on the percentage of packaging waste recovered manually or automatically. This section presents the values adapting German reality to Spain (20% manual and 80% automatic collection).

Table 2 shows total environmental impact associated with the management of PET bottles, cans and beverage cartons for CDS and GDS in Spain. The results show that for all impact categories GDS has more impact than the considered CDS. The impact avoided ranges from 32.8% for EP to 63.0% for PO.

Tab.2 Characterization of LCA results with a 55% of selective collection

Impact category	CDS[1]	GDS	% Impact reduction
AD (kg Sb eq.)	1,90E+00	2,90E+00	34,5%
AC (kg SO_2 eq.)	1,52E+00	2,34E+00	35,0%
EP (kg PO_4^{-3} eq)	2,54E-01	3,78E-01	32,8%
GW (kg CO_2 eq)	3,32E+02	5,22E+02	36,4%
ODP (kg CFC-11 eq)	4,63E-05	7,96E-05	41,8%
HT (kg 1,4-DB eq)	9,38E+01	1,43E+02	34,4%
PO (kg C_2H_4)	1,10E-01	2,97E-01	63,0%

[1] *20% manual and 80% automatic*

Figures 4 and 5 present for each impact category the relative contributions of different stages. These figures identify that long distance transport of PET bottles, cans and beverage cartons collected selectively has the greater contribution to environmental impacts for both management systems. In addition, although in CDS system only 20% of packaging waste is collected manually, the contribution of this manually collection stage accounts for 24 to 40% of the impacts of long distance transport. This is because compaction is not made in origin as in automatically collection. However, CDS, either manual or automatic, has positive effect in packaging sorting plants, where there is no waste rejected and the recovered material has higher quality than in GDS.

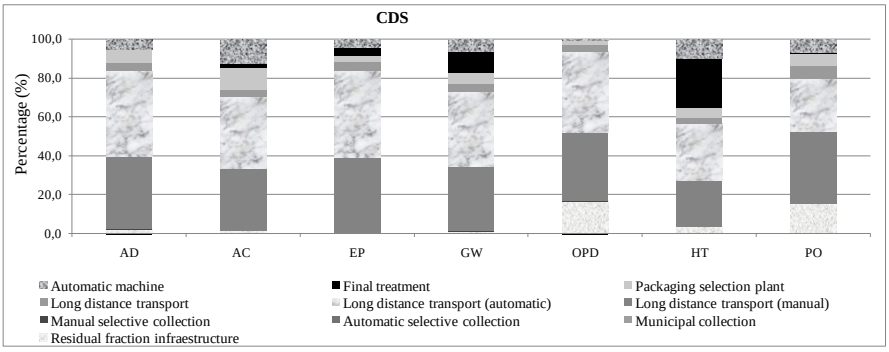

Fig. 3: Relative contributions of life cycle stages of CDS system for 55% selective collection

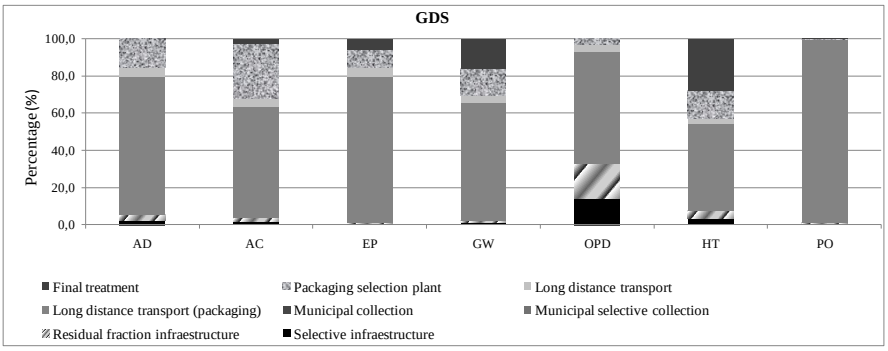

Fig. 4: Relative contributions of life cycle stages of GDS system for 55% selective collection

4. Conclusions

Comparative LCA results indicate that the introduction of CDS system in Spain, with manual and automatic collection percentage similar to Germany (20% manual and 80% automatic), would save environmental impacts for all categories compared to current GDS Spanish system. For CDS, the stage with the greatest impacts is long distance transport. Therefore, compaction at origin through automatic collection machines decreases significantly the impact of transport stages. That is the reason why when the automatic collection is over 40%, the CDS has lower carbon footprint for any selective collection percentage.

Several European countries have implemented the CDS and they reach up to 95% of waste packaging recovery. If this share was achieved in Spain through a CDS

for PET bottles, cans and beverage cartons the system would emit 429.266 tones of CO_2 eq. but it would also generate an annual saving of 226,685 tones of CO_2 eq. respect to the current GDS.

5. References

1. Pires A., Martinho G., Chang N.B. Solid waste management in European countries: A review of systems analysis techniques. Journal of Environmental Management 92 (2011); 1033-1050
2. Law 11/1997, of 24th of April, of Packaging and Packaging Waste
3. Directive 2004/12/EC of the European Parliament and of the Council of 11 February 2004 amending Directive 94/62/EC on packaging and packaging waste-Statement by the Council, the Commission and the European Parliament
4. Cleary J. life cycle assessment of municipal solid waste management systems: A comparative analysis of selected peer-reviewed literature. Environmental International 35 (2009); 1256-1266
5. Bovea M.D., Powel J.C. Alternative scenarios to meet the demands of sustainable waste management. Journal of Environmental Management 79 (2006); 115-132
6. Bovea M.D., Flores V.I., Gallardo A., Colomer-Mendoza F.J. Environmental assessment of alternative municipal solid waste management strategies. A Spanish case study. Waste Management 30 (2010); 2383-2395
7. Fragkou M.C., Vicent T., Gabarrell X. A general methodology for calculating the MSW management self –sufficiency indicator: Application to the wider Barcelona area. Resources, Conservation and Recycling 54 (2010); 390-399
8. Rieradevall, J., Munoz, I., Domenech, X., Rabella, R., Cucurull, D., 2005. LCA of different solid waste management systems applied in municipalities of the Barcelona region. In: LCM 2005, Innovation by Life Cycle Management, International Conference, Proceedings, vol. II. Centre per a l'Empresa i el Medi Ambient, Barcelona, Spain.
9. AENOR. Environmental Management. Life Cycle Assessment. Evaluation of life cycle impact. ISO 14042:2000.
10. ISO 14040: Environmental management—life cycle assessment—principles and framework. Geneve, Switzerland; 2006.
11. http://www.ecoembes.es (Acceded 06/06/2010)
12. Program of Municipals Waste Management of Catalonia 2007-2012. Department of Environmental and housing.
13. Report of Environmental Sustainability of the Program of Municipals Waste Management 2007-2012. Waste Agency of Catalonia.

14. Waste Agency of Catalonia. Personal communication with Jordi Picas Contreras. Head of Selective Collection and Packaging. Tfno: 0034 93 567 33 00
15. Waste Agency of Catalonia, Urban Ecology Agency of Barcelona (2006). Modeling by applying SIMUR Waste management systems of municipalities of Catalonia (dates from the program)
16. Annual report 2009. Ecoembalajes España S.A
17. Study to determine the payment formula applicable to the collection of waste packaging (2007). Ecoembalajes España S.A
18. http://www.residusiconsum.org (Acceded 08/06/2010) *Els sistemes de dipòsit, devolució i retorn d'envasos*. *La solució de gestió dels Residus d'envasos més ecològica i eficient* (2010). Waste Prevention and Responsible Consumption Foundation. Version 1.5.
19. Spain's environmental profile. Report based on indicators (2009). Ministry of Environmental, Rural and Marine of Spain
20. National Waste Plan 2007-2015. Annex I. Ministry of Environmental, Rural and Marine of Spain
21. Alvárez del Castillo D., Pla Carles J., Ruiz Ortiz V, Sans Fonfria R. Study of the composition by weight and unit of municipal waste packaging of Catalonia (2006). Polytechnic University of Catalonia
22. http://www.tomra.com (Acceded 06/06/2010)
23. http://es.rhenus.com/index.php?id=1146&L=5 (Acceded 09/06/2010)
24. http://www.volvotruck.com (Acceded 08/06/2010) Volvo Truck. Emission from Volvo's Truck emissions, standard diesel fuel.
25. Frischknecht R, Jungbluth N, editors. Ecoinvent project. Swiss Centre for Life Cycle Inventories, Du¨ bendorf, Switzerland, 2004. Available from http://www.ecoinvent.ch/S