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# DEVELOPMENT OF LCA BASED MODEL FOR ASSESSING CITIZEN'S WASTE DISPOSAL PRACTICES

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## ABSTRACT
The present paper describes the work carried out under the project *simRecicla*, namely the development of one of three simulators which aims to provide the citizens with information regarding the best practices for waste packaging disposal and the environmental impacts associated with such practices. The scope of the citizen simulator includes the municipal solid waste processing value chain, namely collection, sorting, organic recovery, recycling, waste-to-energy and landfill. The modelling is based on a detailed technical, environmental and economic characterization of the technological processes of waste management, resorting to scientific approaches such as Material Flow Analysis and Life Cycle Assessment. The simulator allows to determine the environmental impacts of over 50 types of packaging and provide that information to the citizens through a simple web application.

**Keywords:** Municipal Solid Waste, Life Cycle Assessment, citizen awareness

## INTRODUCTION
The current legal and strategic framework for municipal solid waste (MSW) management sets ambitious targets aimed at increasing preparing for re-use and recycling of waste. The citizens play a vital role in the pursuit of these goals as they ultimately are responsible for the correct disposal of their household waste. It is therefore important to bring awareness to citizens regarding the correct waste disposal practices and inform them about the impact of their actions. This is one of the main goals of the *simRecicla* project which consists of a set of simulators for different processes of the waste management value chain. This paper describes the work developed in the project for a specific simulator aimed towards the citizens in which information is presented regarding the best disposal practices and the environmental and economic impacts of their choices. This simulator, which was developed as a web application to be made public in 2023, aims to promote the adoption of the best waste disposal practices, fostering greater knowledge and transparency about the potential environmental impacts associated with the collection and treatment of packaging waste through the different waste management pathways.

## METHODOLOGY

The modelling of the simulator involved a detailed technical and environmental characterization of the MSW processing value chain, which included (i) the development of technical models of unit processes, from collection to treatment; (ii) the mass balance, by type of material, for each stage of the value chain, according to a Material Flow Analysis (MFA) approach; and (iii) the development of life cycle inventories of unit processes and assessment of environmental impacts according to a life cycle assessment (LCA) approach. The modeling of the waste management technological processes required the collection and consolidation of detailed operational and economic information from the responsible entities. Given the geographic scope of the project, information was collected from TRATOLIXO's technical teams, and through interactions with various stakeholders, namely the municipalities and municipal companies in its area of operation. Whenever the available information proved to be insufficient, complementary information was collected through bibliographic sources and references in the scientific literature. The scope of the simulator includes the MSW processing value chain, as depicted in Fig. 1.

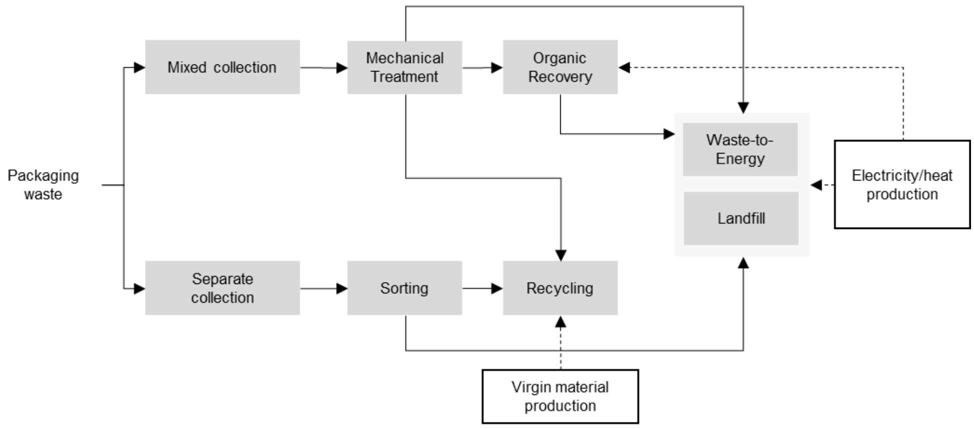


Figure 1. MSW management value chain considered in the simulator

The simulator consists of a packaging database, impact allocation matrices and an environmental and economic indicators database, the latter developed resorting to MFA and LCA. Even though the model also calculates the economic impacts associated with the waste packaging collection and treatment options, that analysis component is not addressed in this paper. The packaging database includes a set of 50 of the most representative types of packaging put in the market, with specific information regarding its material composition and the best practices for disposal, defined according with the recommendations from Producer Responsibility Organisation (PRO) *Sociedade Ponto Verde* (e.g. emptying the packaging, flattening it, separating the lid or keeping the label). To create this database, the defined universe of packaging was characterized, which involved weighing and defining their material composition by packaging components. The categories of materials that were modeled were: paper, cardboard, beverage cartons, plastic film (LDPE), PET, HDPE, EPS, mixed plastics, ferrous metals, non-ferrous metals and glass.

The mechanics of the simulator, namely the pathway of sending a type of packaging for treatment along the MSW processing chain, as well as the attribution of environmental and economic impacts related to the different unit operations, is associated with matrices of allocation. These matrices consist of technical coefficients that allocate the mass flow of the packaging waste to the different operations of the MSW management system, according to the technical characteristics of the waste management system considered. As an example, if the user chooses to dispose of a PET bottle in the plastic recycling bin, the simulator assigns the value 1 to the plastic/metal separate collection operation for the PET material and to the sorting operation (plastic/metal line), allocating the impacts of these processes to 100% of the PET material. After the sorting operation, this material is allocated to the different treatment options. Assuming that 80% of the amount of PET entering the sorting operation is sent to the recycling operation, the PET recovery efficiency in the sorting process is defined by a coefficient of 0.8, with the remainder corresponding to the fraction that is rejected by the process and ends up being sent to landfill and waste-to-energy. The efficiencies of the different recycling processes are also modelled in the simulator (e.g. 1 kg of PET waste results in 0.8 kg of recycled PET).

The environmental performance of MSW collection and treatment technologies was determined based on a streamlined LCA approach. As is characteristic of studies focused on waste treatment, for the purpose of defining the boundary of the system, it is considered that the production of waste itself does not entail any environmental impact (assumption typically referred to as zero burden). The life cycle inventories of the processes included in the system presented in Fig. 1 were developed based on the collected data from municipalities and TRATOLIXO. For the modelling of landfill, waste-to-energy and recycling processes, information from LCA database Ecoinvent (3.8) was used and adapted.

## RESULTS

The model allows for the calculation of the environmental and economic impacts of different management pathways for around 50 types of packaging waste. As an example, the results for the disposal of a PET water bottle (1.5 liter), in terms of carbon dioxide equivalent emissions, are presented in Table 1, considering different disposal scenarios.

Table 1. Environmental impact results for the management of one waste PET bottle.

| | $CO_2$e emissions from waste PET bottle processing [kg CO2e/packaging unit] | | | | | | |
|---|---|---|---|---|---|---|---|
| **Scenarios** | **Collection** | **Sorting** | **Recycling** | **Waste-to-Energy** | **Landfill** | **Material substitution** | **Total** |
| All bottle components sent to the plastic recycling bin | 0,00186 | 0,00066 | 0,01192 | 0,00487 | 0,00213 | -0,049866 | -0,02843 |
| Bottle label sent to the paper recycling bin; bottle and lid sent to the plastic recycling bin | 0,00184 | 0,00065 | 0,01192 | 0,00487 | 0,00213 | -0,049866 | -0,02845 |
| All bottle components sent to the mixed waste bin | 0,00006 | 0,00011 | 0,00174 | 0,01700 | 0,00405 | -0,007279 | 0,01579 |

The obtained results allow the user to compare and analyze the impacts associated with different disposal practices. The correct disposal pathway of a water bottle is the plastic recycling bin, including its paper label. If a paper label is separated from the bottle and disposed of in the paper recycling bin, it will not be recovered in the paper/cardboard sorting process due to its small dimensions. The simulator takes this into consideration in the allocation matrices as the results for recycling and material substitution are the same for each of these scenarios. If the waste bottle is incorrectly placed in the mixed waste bin, there will be a reduction of emissions related to the collection, sorting (mechanical and biological treatment instead of a material recovery facility) and recycling, however, since the material recovery is significantly lower in this pathway, there will be increased impacts associated with the landfilling and energy recovery of the waste PET and considerably lower benefits associated with the avoidance of virgin material production.

## CONCLUSIONS

The work developed under the *simRecicla* project involved the detailed and robust modelling of the technological processes for the MSW management value chain, taking into consideration the different material waste fractions. This allowed the simulator to present reliable and transparent information for citizens, not just regarding the recommendations for correctly disposing of waste but also quantitative data regarding the environmental and economic impact of their choices. There is added value in the simulator as its modelling was based on standardized and transparent scientific approaches which means that the information can also be used for a more systematic assessment of MSW management systems, namely LCA studies.


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