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Implementation of the Selective Collection in Small Villages of less than 50 Inhabitants in Cantabria Region (Spain): Preliminary Viability Study

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This project develops an algorithm for allowing municipalities of dispersed villages of Cantabria, an Autonomous Community situated in the north coast of Spain, to check the environmental feasibility of extending the selective collection in their municipalities. The algorithm will allow these municipalities to introduce their own data and compare two waste management systems (Scenario A and B). Scenario A is referred to the current waste management system in which no selective collection is being carried out. Consequently, light packaging material (LP) and paper and cardboard (P/C) are collected together with the municipal solid wastes (MSW), following the same path. Scenario B is the hypothetic new waste management system in which selective collection is introduced. To determine the environmental preference of these scenarios, an algorithm based on Life Cycle Assessment (LCA) has been developed. Only if environmental impacts in Scenario B are lower than in A when running the model the extension of the selective collection for each individual municipality should be recommended.

1. Introduction

The selective collection of light packaging (LP) and paper and cardboard (P/C) presents an environmental benefit from the society and material recovery point of view, because avoids the resource extraction to manufacture new materials. However, the implementation of this collection system involves the manufacture of new containers, an additional transport and the manufacture, operation and maintenance of the treatment plants. This is even more relevant when population is distributed in dispersed areas such is the case of Cantabria, an Autonomous Community situated in the north coast of Spain, where a great amount of people live in population centres of less than 50 inhabitants. So to justify the implementation of a selective collection system in a determined area the balance between the environmental benefit generated by the material recovery and the environmental burdens associated to the process must be positive. The best approach to determine this balance is the life cycle thinking

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methodology. Life Cycle Assessment (LCA) is a powerful tool for assessing the environmental performance of a product, process or activity from “cradle to grave”. It can be used to support the decision making in order to identify the clean and sustainable alternatives in the process design activity (Azapagic et al., 1999; Cerdan et al., 2009).

2. Objective

The objective of this study is to build a mathematical model for checking the environmental performance of extending the selective collection of LP and P/C waste dispersed areas of Cantabria. The model will allow each particular municipality to introduce their particular data and assess if the environmental impact associated to the selective collection infrastructure is higher or not to the environmental benefit due to the treatment and recovery of LP and P/C respect to the actual management system. The model will allow the users to compare two different scenarios:

Scenario A: describes the actual LP and P/C waste collection system in dispersed villages of Cantabria. There is no selective collection and these fractions are collected together with the mixed municipal solid waste (MSW). Afterwards they are transported to MSW facilities in which the recyclable fractions are manually separated and sent to a recycler. The non recovery fractions are sent to an incineration plant.

Scenario B: describes the hypothetical situation of extending the selective collection in dispersed villages of Cantabria. In fact, this scenario means a double waste collection system, as far as not all LP and P/C are collected separately. Part of the packaging residues will be collected thought the new battery of containers and the rest will follow the actual system (scenario A).

3. Methods

All this study has been conducted under the LCA methodology approach regulated by ISO 14.040 and 14.044. To build the model for comparing the current situation (scenario A) and the hypothetical extension of selective collection (scenario B), software GaBi 4.3 and GaBi i-report application (an extension of the LCA software Gabi) have been used (Gabi 4, 2007).

3.1 Development of the model

To simplify the study, keeping the life cycle perspective, the model has been developed based on the energy and material balance of all the processes involved the global life cycle of the waste. Three environmental impact categories are considered: Primary Energy Consumption (PEC, MJ); Global Warming Potential (GWP, emissions of CO_2 equivalent) and Abiotic Resources Consumptions (ARA, kg de Sb equivalent). The model has been created using open parameters in order to allow the final users to modify and/or introduce their real data (variables). For doing so, the GaBi i-report application has been used, as it is suitable for being used by people with no experience in LCA. To justify the implementation of a selective collection system, the environmental performance of scenario B should be better to scenario A for all the impact categories analysed. In the following sections the equations of the model for calculating the material balance in each step of the life cycle of the waste are detailed.

3.2 Waste disposal in the container

The amount of LP and P/C collected is described in equations (1) to (3):

$$M_{ERS} = (M^* \beta_E^* \alpha_E) + IMP_{EJ} \quad (1)$$
$$M_{ERM} = M^* \beta_E^*(1-\alpha_E) \quad (2)$$
$$IMP_{EJ=} (M_{ERS*}P_{Ej}) / (1-P_{Ej}) \quad (3)$$

where M_{ERS} is the amount of LP waste selective collected per year [ton]; M_{ERM} amount of LP collected together with the MSW per year [ton]; M total amount of waste generated per year [ton]; β_E is the LP wastes fraction in the waste [%/100]; IMP_{EJ} the amount of no LP material disposal in the selective collection containers (j [1-2] depending of the container) and α_E efficiency of the selective collection, defined as the amount of packaging waste that is collected selectively (a number between 0 and 1). The rest is supposed to be collected jointly with mixed MSW and.
The same type of equations has been proposed for the P/C.

3.3 Containerization and selection of the type of wastes collection

In the model a specific process for each type of container has been developed. This process includes the manufacture, maintenance and end of life of the containers.

3.4 Collection and transport of the LP and P/C selective collected

The environmental impact of this process depends on the amount of collected waste, the covered distance and the emissions associated to the garbage collection truck. The amount of transported waste corresponds to the collected ones M_{ERS} and M_{PRS}. To calculate the emissions associated to truck generic data from the ELCD/PE-Gabi database have been used. The emissions depends on the useful load and velocity of the vehicle, the type of combustible and the type of transport way.

3.5 Collection and transport of the LP and P/C collected together with the MSW

For this process a similar model to the selective collection one has been applied. The main difference is that two types of trucks are considered. The first one transports the waste to the transfer plant and the other one goes from this plant to the MSW plant.

3.6 MSW Plant

The amount of LP and P/C recovered is described in Equations (4) to (6):

$$M_{TREC} = M_{EREC} + M_{PREC} \quad (4)$$

$$M_{EREC} = \sum_{i=1}^{i=7} M_{ERM}^* \beta_{Ei}^* \eta_{Wi} \quad (5)$$

$$M_{PREC} = M_{PRM}^* \eta_{Wp} \quad (6)$$

Where M_{TREC} is the total amount of materials recovered in the MSW plant [ton]; M_{EREC} the amount of LP materials recovered [ton]; M_{PREC} amount of recovered P/C [ton]; M_{ERM} amount of LP collected together with the MSW [ton]; M_{PRM} amount of P/C collected together with the MSW [ton]; β_{Ei} fraction of the i material in the LP waste [% / 100] i[1-7], being 1=PET, 2=PEAD, 3=PEBD, 4=Plastic mix, 5=Bricks, 6=Steel, 7=Aluminium (Al); η_{Wi} recovery material efficiency of the i material present in the LP[1]

[1] Amount of each individual material present in LP flow (PET, PEAD, PEBD, plastic mix, bricks, steel and aluminum) that is recovered in the sorting plant (number between 0 and 1)

and η_{Wp} the recovery material efficiency of the i material presents in the P/C wastes.

3.7 LP selection plant

Equation (7) describes the amount of LP recovered:

$$M_{EREC}= \sum_{i=1}^{i=7} M_{ERS} * \beta_{Ei} * \eta_{SEai} \quad (7)$$

Where M_{EREC} is the amount of LP recovered [ton]; M_{ERS} amount of LP collected selectively per year [ton]; η_{SEai} recovery material efficiency of the i material in the plant. i[1-8], 1=PET, 2=PEAD, 3=PEBD, 4=Plastic mix, 5=Bricks, 6=Steel, 7=Al, 8=P/C.

3.8 P/C treatment plant

At this plant arrives the P/C from the selective collection (M_{PRS}). In this case all the collected P/C is recovered in this plant (M_{PREC}).

3.9 Recycling materials

In equations (8) to (10) the amount of recovery and no recovery materials and avoided raw materials are described:

$$M_{TREC}= M_{EREC} + M_{PREC} \quad (8)$$

$$M_{EVT}= \sum_{i=1}^{i=8} M_{TREC} * \eta_{Ri} * \varphi_i * \lambda_i \quad (9)$$

$$M_{VT}= \sum_{i=1}^{i=8} M_{TREC} * (1-\eta_{Ri}) \quad (10)$$

Where M_{TREC} is the total amount of materials recovered [ton]; M_{EVT} amount of avoided raw materials due to the waste recycling [ton]; M_{VT} amount of materials no recovered [ton]; η_{Ri} recovery material efficiency of the i material in the recycling plant [% / 100]; φ_i: substitution factor of the raw material i by the recycled material and λ_i the purity factor of the recovered material i.

3.10 Incineration

The LP and P/C waste that arrives to the incinerator is described in equations 11 to 13:

$$M_{IRMP} = M_{PRM} * (1-\eta_{Wi}) \quad (11)$$

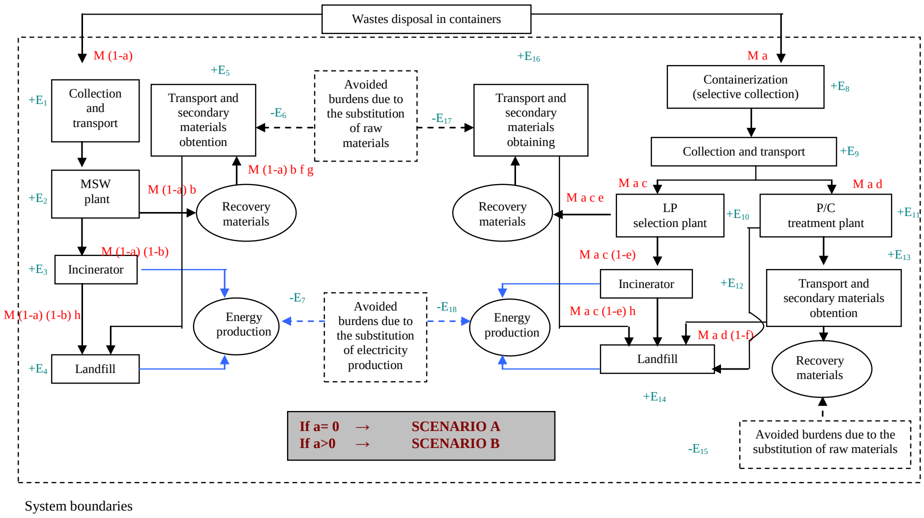
$$M_{IRME}= \sum_{i=1}^{i=8} M_{ERM} * \beta_{Ei} * (1-\eta_{Wi}) \quad (12)$$

$$M_{IRSE}= \sum_{i=1}^{i=8} M_{ERS} * \beta_{Ei} * (1-\eta_{SEi}) \quad (13)$$

Where M_{IRMP} is the amount of P/C that comes from the MSW plant to the incinerator [ton]; M_{IRME} amount of LP that comes from the MSW plant to the incinerator [ton]; M_{IRSE} amount of the LP that comes from the selection plant to the incinerator [ton]; η_{Wi} the recovery material efficiency of the i material in the MSW plant and η_{SEi} the recovery material efficiency of the i material in the sorting plant.

4. Results and discussions

The results of the study are a model and an i-report template that could allow the users to assess the environmental convenience of extending the selective collection in their area. In Figure 1 a diagram of the model is shown.



M = amount of LP and P/C in the MSW; E_x = Input (+) or output (-) of energy; a = efficiency factor of the selective collection; b = efficiency recovery factor of the MSW plant; c = amount of LP in the MSW; d = amount P/C in the MSW; e = efficiency of the LP selection plant; f = efficiency of the recycling process; g = substitution factor of the recycled material by the raw material; h = reduction mass factor in the incinerator.

Figure 1: Developed model.

Particular results will depend on the variables that could be modified by the user. Thus, the algorithm is an open model that could be adapted to different realities. All the parameters refer to the selective collection system depend on the efficiency factor of the selective collection (a). This parameter refers to the percent of the L/P and P/C collected in the specific containers for the selective collection of this type of wastes. This way the developed model allows comparing two different scenarios:

Scenario A: If a=0, all the selective collection impacts will be cancelled and only the impacts associated to collection and treatment of the LP and P/C collected together with the MSW are considered.

Scenario B: If a>0, the environmental impacts of the selective collection system are considered. So the impacts associated to the selective collection of the LP and P/C and the impacts of the LP and P/C collected together with the MSW are considered. As it shown in Figure 1 containerization, collection and treatment of waste are considered as positive impacts. On the contrary, energy and material recovery that correspond to environmental benefits are negative values. Bearing this in mind, the more negative the results are, the more environmental friendly they are.

5. Conclusions

The implementation of the selective collection means the manufacture of new containers, an additional transport and the manufacture and maintenance of the recovery material fractions. On the other hand some environmental benefits are obtained: the materials recovery that avoid the raw materials extraction to manufacture new materials and the increase of the collection ratio and recovery material quality, decreasing the amount of LP and P/C that arrives to the landfill and incinerator.

A mathematic model to determine the environmental viability of extending the selective collection in dispersed population centres of Cantabria has been developed. The model has been developed using the software tool GaBi i-report. This model will allow the final users to introduce their own data in order to assess if in their particular area is convenient or not to implement a selective collection system.

The main variables of the model are the amount of LP and P/C waste collected and the selective collection efficiency for each fraction. Other important parameters that could be modified are the type of container used or the distances travelled to collect or transport these waste types to different treatment plants. It is foreseen that this tool will be useful for local municipalities in the decision making process, when they will have to decide if implementing a separate collection system for LP and P/C.

References

Azapagic A., 1999, Life cycle and its applications to process selection, design and optimisation. Chemical Engineering Journal 73, 1-21.

Cerdan C., Gazulla C., Raugei M., Martinez E. and Fullana P., 2009, Proposal for new quantitative eco-design indicators: a first case study, Journal of Cleaner Production 17, 638-1643.

Reques, P., 1998, Population and territory in Cantabria. Regional Assembly of Cantabria (in Spanish).

Institute of Statistic of Cantabria (ICANE). Municipal Registry 2007 (in Spanish).

Waste Plan of Cantabria 2006-2010. Government of Cantabria 2006 (in Spanish).

LBP & PE, GaBi 4, 2007, Software-System and Databases for Life Cycle Engineering, Department of Life Cycle Engineering, Chair of Building Physics, Stuttgart University & PE International GmbH, Echterdingen, Germany.

ISO 14044: 2006. Environmental management –LCA - Requirements and guidelines.