PRELIMINARY ASSESSMENT OF PLASTIC WASTE VALORIZATION VIA SEQUENTIAL PYROLYSIS AND CATALYTIC REFORMING

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Abstract

A lice cycle approach is followed to carry out a preliminary assessment of the energy and global warming performance of a specific feedstock recycling alternative. Thus, cumulative energy demand and global warming potential indicators are computed for a production system that involves the supply of gasoline blending components from waste agricultural polyethylene films through sequential pyrolysis and catalytic reforming. Energy and global warming results suggest the suitability of this system for plastic waste valorization, though actions to reduce the thermal energy demand are required.

Keywords: *allocation; cumulative energy demand; feedstock recycling; global warming; life cycle assessment*

1. Introduction

The wide range of applications for plastics has led to high consumption levels of plastic materials worldwide. As a result, the management of plastic wastes has arisen as a key environmental issue that should be addressed on the basis of a well-balanced choice of options, including re-use, mechanical recycling, chemical recycling (depolymerization), feedstock recycling, and energy recovery [1]. In particular, feedstock recycling refers to a valorization strategy based on chemical and thermal processes for the conversion of waste polymers into hydrocarbon products to be used as petrochemical feedstocks [2]. Although only a low percentage of plastic wastes are sent to feedstock recycling (due mainly to unfavorable investment costs), this management alternative is expected to play a leading role in the future owing to the potential attainment of economic and environmental advantages [3].

The present work uses a life cycle approach in order to assess the energy and global warming performance of a specific feedstock recycling system based on the sequential pyrolysis and catalytic reforming (SPCR) of waste agricultural polyethylene films to yield hydrocarbon products [2].

2. Materials and Methods

Comprehensive environmental analyses of energy systems require the use of environmental management tools provided with a life cycle approach. Among these, Life Cycle Assessment (LCA) is a standardized methodology to assess the environmental aspects and potential impacts associated with a product [4]. LCA methodology was used herein to evaluate the production of gasoline blending components through SPCR of waste agricultural low density polyethylene (LDPE) films. Fig. 1 summarizes the scope of the analysis, from waste plastic reception to gasoline blendstock production. The functional unit (FU) –i.e. quantified performance of the product system for use as the reference unit in the LCA study– was defined as 1.00 kg of gasoline product for blending. Although this study focused on the gasoline fraction, other energy co-products derive from the SPCR system, viz. gas fraction (C_1-C_4 compounds), diesel fraction, and char.

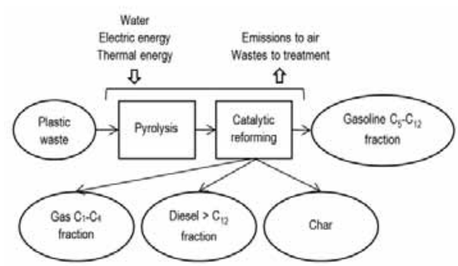

Fig. 1. Case study: SPCR of waste agricultural LDPE films.

Table 1 gathers the main inventory data for the SPCR system subject to evaluation. These data were adapted from specific scientific literature [1,2], while secondary data for background processes such as electricity production or water supply were taken from the ecoinvent database.

Two relevant categories were evaluated in this preliminary LCA study: cumulative energy demand (CED) and global warming potential (GWP). The term CED refers here to the cumulative non-renewable fossil and nuclear energy demand computed according to Hischier et al. [5], while GWP was quantified by using the CML method [6]. PRé Consultants' SimaPro 7 software was used for the computational implementation of the inventory.

Table 1. Simplified life cycle inventory for the SPCR system.

Inputs from the technosphere		
Waste LDPE film	2.94	kg
Water	5.88	kg
Electricity energy	0.17	kWh
Thermal energy	17.52	MJ
Outputs to the technosphere: products		
Gasoline fraction	1.00	kg
Diesel fraction	0.09	kg
Gas fraction	1.50	kg
Char	0.03	kg
Outputs to the technosphere: wastes to treatment		
Ash to landfilling	0.05	kg
Solid waste to incineration	0.14	kg
Outputs: direct emissions to air		
CO_2	1.01	kg
NO_x	0.88	g
SO_2	5.88	g

3. Results and Discussion

Since this case study involves a multifunctional system, allocation was needed to distribute the CED and GWP results among the different products in Table 1. A system expansion approach based on the concept of avoided burdens was followed [1]. Hence, -62.64 MJ eq (CED) and 1.61 kg CO_2 eq (GWP) were attributed to the gasoline product per FU. Turning to a whole system perspective, a promising net energy ratio of 4.69 was estimated according to the potential energy output of all the products as a whole.

As shown in Fig. 2, a total negative CED value was computed for the gasoline product. This favorable result is closely linked to the avoided burdens approach, which considers co-products as substitutes for conventional refinery products. The CED category was extremely influenced by the energy discounts for the co-products.

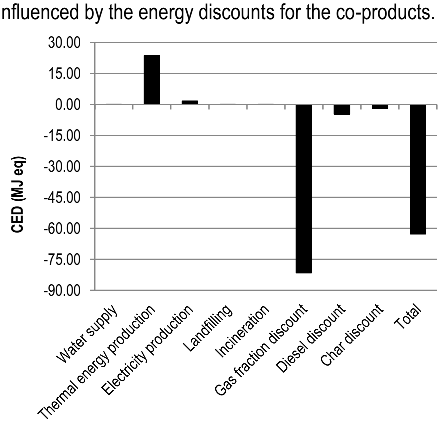

Fig. 2. Contributions to CED (results per FU).

As observed in Fig. 3, thermal energy production and direct emissions to air arose as the main sources of GWP. On the other hand, GWP discounts associated with the co-products significantly offset the greenhouse gas emissions brought about by the assessed system.

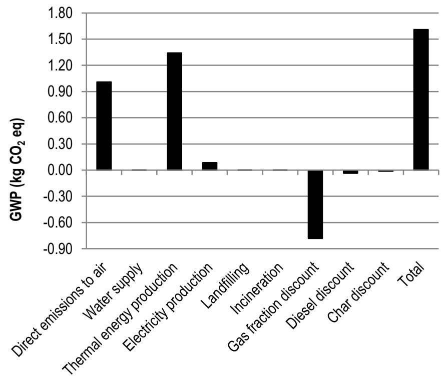

Fig. 3. Contributions to GWP (results per FU).

Even though this preliminary assessment led to encouraging values for the CED and GWP indicators, further aspects need to be evaluated. For instance, if a more thorough environmental assessment is desired, additional impact categories should be comprised (e.g. ozone layer depletion, acidification, eutrophication, etc.).

4. Conclusions

The processing of waste agricultural LDPE films through SPCR to produce gasoline blending components was evaluated in terms of its life-cycle CED and GWP indicators. An appropriate energy and global warming performance was concluded, though improvement actions are needed to minimize the thermal energy demand. Further efforts are required to (i) gather specific inventory data from industrial or pilot scale experiences, (ii) evaluate alternative methodological choices, and (iii) include additional impact categories.

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