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GWP BENEFITS FROM PAPER AND BOARD RECYCLING WITH CONSEQUENTIAL LIFE CYCLE ASSESSMENT: SPANISH CASE STUDY CONSIDERING THE INTERACTION WITH GLOBAL MARKETS

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ABSTRACT

There is a lack of data of greenhouse gases emissions (GHG) of paper recycling for Spain but they are necessary in order to guide waste management policies. The aim of this work is to calculate the environmental consequences of paper recycling in Spain. We have applied a consequential life cycle assessment (cLCA). Different scenarios were evaluated and results vary per ton of paper collected from -3 kg to -579 kg CO_2 eq., depending on the economic competitiveness of the virgin pulp producer, or if the avoided wood is used to produce bioenergy. These results show that the benefits of recycling could depend on market conditions, as markets are highly interrelated and results of one country could affect other markets.

INTRODUCTION

Different GHG savings in CO_2 eq. have been reported for paper-cardboard in the literature but none of them were calculated for Spain. In addition, several assumptions has been done but in most cases there is not provided detailed information. Recycling is methodologically a case of multifunctionality, with the product to be recycled having two functions: firstly the function the product is primarily made for and secondly the function of providing secondary resources for use in subsequent life cycles/systems (ILCD, 2011). The correct way how to model recycling has been extensively discussed over the past two decades and many approaches have been suggested. It can also be observed that most of the discussions on how to model recycling are in fact discussions on whether to use attributional life cycle assessment (aLCA) or consequential life cycle assessment (cLCA) in the first place (McMillan, 2011). A consequential approach considers that by undertaking recycling other alternative activities are not undertaken as a consequence. In other words, the cLCA is more akin to marginal economic assessment, as it looks at the consequences, in production terms and environmental

emissions, of increasing or decreasing demand for specific goods and services (Weidema, 2009). Thus, by applying a cLCA, the environmental consequences of recycling can be evaluated by analyzing market mechanism and market trends. Therefore, the aim of this study is to calculate the environmental consequences of recycling in Spain through a cLCA.

MATERIALS AND/OR METHODS

One characteristic of cLCA is that marginal technologies (those able to adjust the production capacity to new demand) are used instead of considering average technologies where constrained technologies are included. In this sense, the marginal supply of wood pulp was identified as Bleached Hardwood Kraft Pulp (BHKP) from *Eucalyptus* in Brazil or Indonesia (Reinhard et al., 2010) based on the idea that the market pulp can be considered increasing on a global scale what means that for long-term changes the most sensitive supplier is identical to the most competitive (Weidema, 2009). However, other author have pointed out that if more recovered paper is available for recycling, the avoided virgin pulp production will be the least competitive which in this case, the identified marginal supply is the Spanish BHKP from *Eucalyptus* (James, 2012). Based on this information and taken as reference Spanish data from 2011 we have considered four scenarios summarizes in Table 1 considering that the consequences of recycling are that virgin pulp production is avoided (Scenario A and B); and in addition, the avoided wood could be used for production of energy to substitute for fossil fuels in a second system expansion (scenario C and D). Besides, due to market conditions industry has changed in recent years and important quantities of waste paper are sending from Spain to China. We have quantified these impacts in all scenarios. The functional unit (FU) has been defined as the increase 1 ton of waste paper collected in Spain for recycling.

Table 1: Scenarios projected for the calculation of the recycling impacts of paper in Spain

	Avoided virgin pulp production	**Avoided energy production**
Scenario A	*Eucalyptus* BHKP Brazil	NO
Scenario B	*Eucalyptus* BHKP Spain	NO
Scenario C	*Eucalyptus* BHKP Brazil	YES
Scenario D	*Eucalyptus* BHKP Spain	YES

RESULTS

Figure 1 presents the results for scenario A and from scenario B when the system expansion to include the avoid energy production is not included and projecting same quantity waste paper collection as in 2011. GHG emissions per ton of paper collected for scenario A are -131 kg of CO_2 eq. while when the avoided virgin pulp is the BHKP from Spanish *Eucalyptus*, the GHG are -3 kg of CO_2 eq. per ton of paper collected (scenario B).

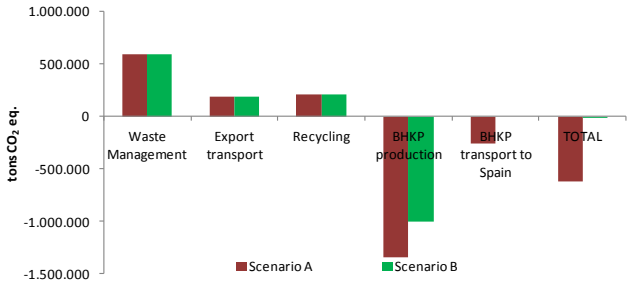

Figure 1: Total GHG emissions for scenario A and scenario B for Spain

As shown in Figure 1, the environmental benefits of recycling are considerably higher when the assumption of virgin pulp from Brazil is considered. In this case, total GHG emissions avoided to Spain would be around 618,000 tons of CO_2 eq. of which 60% of emissions correspond to waste management stage while 84% of the avoided emissions would be due to the production of virgin pulp. In Scenario A when we have considered that virgin pulp is produced in Spain, global GHG emissions avoided would be around 13,000 tons of CO_2 eq. In both scenarios the emissions due to waste management, recycling and transportation of waste to China are the same as we have used same data. The following Figure 2 presents the results for scenario C and scenario D. As collection, export transport, recycling and sorting are equal as in scenario A and scenario B, these stages are summarizes as waste management & recycling. In these scenarios the GHG emissions avoided are per ton of paper collected -579 kg CO_2 eq. and -383 kg CO_2 eq. for scenario C and scenario D, respectively. Avoided emissions are higher than in the previous scenarios and when we expanded the system to include energy production, the total difference between the two scenarios decreases. However, when considering that the virgin pulp production in Brazil is avoided; more emissions are avoided because the production in that country has higher energy consumption. In addition, international transport from Brazil is also avoided.

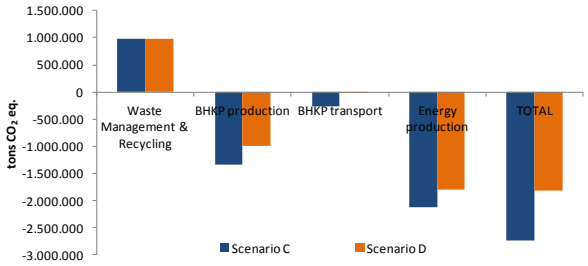

Figure 2: Total GHG emissions for scenario C and scenario D for Spain

DISCUSSION

The results show that the market perspective is very important and can affect the results obtained. In this sense, there is no study in Spain which analyzes the environmental impacts of recycling paper from a consequential perspective. In other international sources, we can found very different results ranging from -3,100 kg of CO_2 eq. per ton in the U.S. (US EPA, 2006) to -0.3 kg of CO_2 eq. per ton when the study is developed by the Bureau International

Research (BIR, 2008). In addition to the methodological assumptions existing between these methodologies, the differences due to different management systems and data by country indicate that it is necessary to calculate these impacts by countries and that the use of these data in countries with different waste management profiles can lead to erroneous results. On the other hand, to the knowledge of the authors, in no case the origin of virgin pulp or the destination of the export flows due to market conditions were evaluated. In this sense, the cLCA allows the inclusion of the influence of markets by establishing that the consequences resulting will affect one production system or another depending on for instance, their economic competitiveness.

CONCLUSION

The results show that the benefits of recycling could vary between years and countries, and could depend on market conditions, as markets are highly interrelated and that the results of one country could affect other markets. All this shows that in general, we need more information and research on the influence of international markets on recycling processes. In this sense, the market based approach methodology (Ekvall, 2000) which considers that the consequences of recycling can be evaluated depending on the price elasticity of supply and demand of recovered material, could be evaluated in future research. Besides, in the case of paper recycling in Spain, we still needs to improve our inventory in order to have quality data to calculate the environmental impacts of recycling related to international markets and to use these results to conduct our waste management policies.

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