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The costs and benefits of packaging waste management systems in Europe: the perspective of local authorities

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The Costs and Benefits of Packaging Waste Management Systems in Europe: The perspective of Local Authorities

Abstract

Local authorities are generally in charge of household packaging waste management operations, particularly in countries with Green Dot schemes or similar extended producer responsibility systems. This leads to the need of establishing a system of financial transfers between the packaging industry and the local authorities (regarding the costs involved in selective collection and sorting). In the present study, the costs and benefits of recycling from the perspective of local authorities are compared for Portugal, Belgium and Italy (in Lombardia region), adopting the same economic-financial methodology. The results show that the industry is not paying the net cost of packaging waste management. If the savings attained by diverting packaging waste from other treatment operations are not considered, it seems that the industry should increase the financial support to local authorities. However, if the avoided costs with other treatment are considered as a benefit for local authorities, the costs are generally outweighed by the benefits and the financial support could, therefore, be reduced.

Keywords

Environmental valuation; Financial analysis; Green Dot systems, LCA, Packaging waste, Recycling

1. Introduction

The Packaging and Packaging Waste (PPW) Directive (94/62/CE) imposed the same recovery and recycling targets to all Member States (MS) of the European Union (EU). However, each country adopted different legal, economic and operational waste management strategies to achieve those targets (European Commission, 2006). In most of these countries, the public local authorities are responsible for the municipal packaging waste management operations (including collection, sorting, treatment and final disposal) (Fiorillo, 2013). Therefore, many MS adopted extended producer responsibility (EPR) systems such as the "Green Dot" scheme (Lundmark, 2003), in which the industry has to support financially the recycling systems (particularly the selective collection and sorting of packaging waste). In Germany, the EPR principle is fully respected, meaning that the packaging waste is collected under the direct responsibility of the industry (through contracts with public or private companies in a competitive market). However this is not the prevalent practice and the other MS employ different systems (in general, local authorities are in charge of collection and sorting).

If on the one hand the implementation of the PPW Directive may have had significant economic impacts (e.g. on packaged goods, waste management and recycling markets), on the other hand it is expected that it also contributed to the minimization of the environmental impacts of packaging waste management (Perchard, 1993). Environmental impacts result from the emissions released due to human activities. Some impacts can translate into benefits or costs incurred by a third party that is not involved directly in the activity (Shinkuma, 2003). If there is a gain or loss of welfare by the third party, it is usually referred to as an externality. In many cases, these externalities are not fully reflected in the economic costs and are not considered in political decisions (Nahman, 2011) because they do not have market value.

It is important for local authorities to balance the costs incurred by the waste management operations with the benefits obtained from these activities (Kinnaman et al., 2014). This is in line with the user-pays and polluter-pays principles (otherwise taxpayers have to support the net costs). Moreover, recalling that environmental protection is the main driver behind these activities, the externalities arising from the environmental impacts of the (packaging) waste management activities should also be taken into account. Some studies have monetized the environmental impacts of municipal waste strategies in order to complement the financial analyses. The advantage of monetary valuation is to express these environmental impacts in a standardized monetary value which is more easily understood by decision-makers

(Vogtländer et al., 2010). For example, Eshet et al. (2007) developed a study on the monetary valuation of externalities (in particular, disamenities) felt by the population who live near transfer stations, using the hedonic prices method (HPM). Dijkgraaf and Vollebergh (2004) estimated the external costs and benefits by comparing landfill and incineration scenarios in the Netherlands. Rabl et al. (2008) developed a similar research for French facilities based on the benefit transfer (BT) method using data from the ExternE project. Reich (2005) studied municipal solid waste (MSW) management systems combining an environmental and financial life cycle costing (LCC). Following this approach, Emery et al. (2007) analyzed four different MSW management scenarios in Wales and Massarutto et al. (2011) modelled six scenarios representing a typical region of central northern Italy. The authors focused on waste collection (source separation levels and vehicles) and different waste treatment scenarios.

This paper intends to evaluate the economic sustainability of the waste services and the implementation of the EPR principle by looking into three MS that are representative, in terms of organization of the sector, of the "typical European recycling systems": Portugal, Belgium and Italy (in specific, the Lombardia region, presented in detail in Rigamonti et al., 2015). In Portugal, the packaging waste is usually selectively collected through separate material flows (glass, paper/cardboard and plastic/metal/other packaging) and according to one of the two main collection systems: bring system (using drop-off containers, as the typical one) or kerbside system (door-to-door). This system is also applied in Italy, but the packaging waste can be collected either as a mono-material stream or as a multi-material stream. In Belgium, the packaging waste is selectively collected according the two main systems: a) kerbside collection of paper/cardboard, PMD (plastic bottles and flasks, metallic packaging and drinks cartons) and glass, depending on the agreement with the Belgian green dot company; b) collection of glass via bottle banks (differentiating colored and clear glass).

In particular, an economic-financial analysis of the recycling systems was carried out for these countries. The results from the economic-financial analysis were complemented with an environmental analysis. One may consider that the EPR is being correctly interpreted in these countries if the costs of the waste management operations aimed at the recycling of packaging waste are (at least) being covered by the industry (which means the revenues balance the costs) that introduced it into the market. This matter is being dealt with great concern by the European waste authorities (at the local, national and community levels). For instance, a recent report made for the European Commission concluded that *the design and* *implementation of an EPR scheme should at least ensure the coverage of the full net costs related to the separate collection and treatment of end-of-life products* (BIO, 2014). All the results obtained are expressed in the same unit (euros per ton of packaging waste collected) so that they can be more easily compared. The data was collected directly from the local authorities (usually, public utilities) in charge of selective collection and sorting operations for the year 2010.

After this introduction, the paper is organized as follows. All the countries studied and the methodologies applied are described in section 2. The results are discussed in section 3, whereas section 4 concludes the paper.

2. Material and methods

2.1 Characterization of the case studies

The case studies are three European MS that have to comply with the PPW Directive. These countries have Green Dot companies that manage the packaging waste recycling system in compliance with the Directive. The Green Dot companies operating in each country are identified in Table 1 along with the number of compliance schemes and the actors responsible for collection/sorting. The packaging waste systems, recycling habits, political incentives and infrastructures are all different from country to country. For more detail see da Cruz et al (2014).

Table 1

2.2 Methodological approach

The methodology applied to analyze the impacts of the packaging waste recycling systems encompasses financial, economic and environmental analyses (Porter, 2002). The economic-financial analysis compares the costs of selective collection and sorting with the respective benefits attained by local authorities, as described in da Cruz et al. (2012 and 2014). We focused our analysis on the perspective of local authorities (i.e. comparing the costs of selective collection and sorting – or preparation for recycling – activities are being covered by benefits coming from the industry) because our main concern is to discern how the EPR principle, embedded in the PPW Directive, has been interpreted and implemented on the ground. Taking this into account, there is no need to assess the financial costs and benefits of the actual recycling process, as would be required for an overall assessment of the Directive success level/impact (although, as private businesses, recyclers are expected to at least break-even).

This paper includes a LCA to evaluate the emissions related to the packaging waste collection and treatment (which are considered in the corresponding part for recycling, incineration or landfill) and a monetization of those emissions (environmental valuation). After converting the environmental impacts into the same economic unit (Euros), all costs and benefits arising from the packaging waste management operations were compared. To accomplish this, the same system boundary was assumed in both the economic-financial and the environmental analyses, as depicted in Figure 1.

Taking into account the objectives of the study and the lack of information available, the following processes were excluded from the analysis (Ferreira et al., 2016): a) The cleaning of packaging waste by the householders; b) Packaging waste materials transport from its local production (mainly households) to its delivery in the respective containers; c) Manufacturing and maintenance of drop-off containers; d) Composting process; and e) Recycling of the material (as mentioned before, assuming that the revenues balance the costs).

Figure 1

2.3 Economic-Financial Analysis

All the expenditures and revenues related to the selective collection and sorting of municipal packaging waste performed by Portuguese, Belgian, and Italian (Lombardia region) were also added. Table 2 presents the type of costs and benefits. The return on capital employed, sometimes not considered when the investments are made by public entities, was included as an economic cost. The savings arising from diverting the packaging waste flow from the refuse collection circuits and disposal operations (e.g. incineration or landfilling) were considered as “opportunity costs” and were taken into account as an economic benefit (for detail see da Cruz et al., 2014 for more details). The information used was obtained through questionnaires sent to the waste management operators and provided by the Green Dot companies, as illustrated in Table 3.

Table 2

Table 3

2.4 Environmental Analysis

The LCA was carried out using the SimaPro software (version 7.3.3) based on the ISO 14040:2006 requirements. This assessment aims to quantify the positive and negative environmental impacts[1] (particularly, the released and avoided emissions, which are detailed in the Marques and Da Cruz, 2015) arising from the operations already considered in the economic-financial analysis (as shown in Figure 1). The transport of waste to recyclers and the recycling activity itself were excluded from the system boundary because these operations are carried out by private operators and, therefore, it is difficult to gather the financial information. Nevertheless, one should note that the financial benefits of recyclers are expected to, at least, cover the costs or else the business will not be economically viable. However, these operations were analyzed under an environmental perspective (because environmental protection is the main driver behind the establishment of the recycling system). For the cases of Belgium and Italy, the pre-treatment[2] and landfill operations were excluded since organic (food) waste is usually selectively collected. In Belgium virtually all MSW (including rejected packaging waste from sorting) is incinerated. In the case of Italy, the environmental assessment only covers the packaging waste system of the Lombardia region where there is no landfilling of MSW.

As for the economic-financial analysis, the avoided impacts from the refuse collection and disposal operations ("opportunity costs") were also accounted for. The expansion of the

[1] In SimaPro, the negative values represent benefits while positive values reveal costs for the environment.

[2] Pre-treatment is the mechanical sorting process which separates the recyclable materials present in the refuse waste flow and that occurs before the actual composting process. The composting facilities in Portugal receive refuse waste. For this reason, this process was just considered for the Portuguese case-study.

system boundaries technique was adopted (Giugliano et al., 2011). Therefore, two sub-systems were defined (Clift et al., 2000): (1) the foreground system (the so called "Recycling system") and (2) the background system which includes all avoided impacts (in particular, the impacts from the raw materials production processes avoided with recycling). The foreground data (related to the main consumptions, i.e., electricity, diesel, lubricants, etc.) was collected from the waste management operators and the proper official documentation and the background data was taken from the Ecoinvent 2.2 and ELCD 2.0 databases, assuming some default values from the literature. The functional unit considered in the "recycling system" was one ton of each packaging waste flow selectively collected and sent for sorting (and recycling) in 2010. Concerning the "non-recycling system" (undifferentiated flow), the functional unit assumed was one ton of each packaging material waste (plastic, paper/cardboard, metal and glass) taking into account the respective average MSW compositions in the reference year.

2.4.1 Inventory for modelling the waste management recycling operations

The Ecoinvent data sets were used to model the selective collection process. A different approach based on the "GERLA" Project[3] was adopted for the Italian case (Lombardia region). The collection model was divided into bring system collection and kerbside system collection according to different percentages for each material flow. The data used is reported in Rigamonti et al. (2013). For Portugal and Belgium, selective collection was modelled considering the emissions released mainly by the fuel combustion (Spielmann et al., 2007). The emissions were calculated according to the Tier 1 methodology from EEA (2012), based on the fuel consumption and specific-fuel emission factors from the literature. After collection, packaging waste is sent to sorting facilities in Portugal and Belgium. For these cases, the consumption of electricity, diesel and lubricants as well as the separation efficiency were considered in the modelling process. In Portugal, different sorting processes were modelled for each material flow (paper/cardboard, glass and other packaging), including the landfilling of rejected packaging waste as the final disposal operation. In Belgium, only the sorting of the Plastic, Metal and Drinks (PMD) flow was considered (including the

[3] The "GERLA" project has been developed by the Department of Civil and Environmental Engineering of the Politecnico di Milano providing a valuable and updated set of primary data on the overall waste management scheme (Rigamonti et al., 2013).

incineration of rejected waste as disposal operation) since paper/cardboard and glass waste are directly sent to the recyclers. The data is given in Table 3.

For Italy (Lombardia region), the packaging waste selectively collected is grouped in a certain location and then delivered to the sorting facility using a different vehicle. The distance of this transport was assumed to be 10 km and was modelled by Ecoinvent data sets (50% Transport, lorry >32t, EURO3/RER and 50% Transport, lorry >32t, EURO4/RER). Only the sorting of ferrous metals and the separation of multi-material fraction were modelled since these are the activities actually paid by local authorities. The electricity consumption was assumed (see Table 4) and the incineration of rejected waste was considered as the final disposal operation.

The different packaging waste materials sorted are transported to the recyclers. In the recycling processes, the functional unit was one ton of each packaging material (differentiating the plastic and metal materials) delivered in the recycling facility. Since the recycling operation allows replacing (partially or totally) the primary raw materials in the manufacture of new packaging or other products, the avoided materials production had to be considered, assuming a certain substitution ratio (Rigamonti et al., 2009). The substitution ratio is related to the quality of the secondary products compared to the corresponding primary ones. A substitution ratio of 1:1 means that 1 unit of secondary packaging material replaces 1 unit of the corresponding primary material while a substitution ratio of 1:<1 means that 1 unit of secondary material replaces less than 1 unit of the corresponding primary material (Rigamonti et al., 2010). The data for modelling the primary production processes and recycling of materials was obtained from the Ecoinvent 2.2 (2007) database and the relevant literature. The recycling and avoided processes modelled are provided in Table 5 for Portugal and Belgium and in Table 6 for Italy.

Table 4

Table 5

Table 6

2.4.2 Inventory for modelling the waste disposal operations

The refuse collection (operation of emptying the drop-off containers and transporting the undifferentiated waste flow) was modelled based on the same methodology used for modelling the selective collection process in Portugal and Belgium. In Italy (Lombardia region), the undifferentiated waste is collected through a kerbside system (70.8%) or a bring system (29.2%), with an average mileage of 15.4 and 7.4 km per ton collected, respectively. The kerbside system collection was modelled by Ecoinvent datasets *Transport, lorry > 16t, fleet average/RER* (40.9%) and *Transport, van <3,5t/RER* (59.1%), whereas the bring system collection was modelled by Ecoinvent dataset *Transport, lorry, >16 t, fleet average/RER*. After collection, we assumed that the undifferentiated waste is delivered in a incineration facility located, on average, 18.3 km away, by means of trucks modelled by Ecoinvent datasets *Transport, lorry >32t, EURO3/RER* (50%) and *Transport, lorry >32t, EURO4/RER* (50%). For Portugal and Belgium, the undifferentiated waste was assumed to be transported directly to the treatment/disposal facilities.

In Belgium and Italy, incineration was the only disposal facility considered for undifferentiated waste. Although, this assumption is not valid for all the Italian regions, it is valid for the Lombardia region. In Portugal, the disposal operation was modelled by combining composting (specifically pre-treatment)[4], incineration and landfilling taking into account the quantities of undifferentiated waste sent for each of these operations in 2010. The pre-treatment operation was modelled considering the consumption related to the equipment use, such as electricity, diesel and lubricants (10.34 kWh/ton, 0.11 L/ton and 0.04 L/ton, respectively). To model the incineration process, the data used for Portugal and Belgium was collected from the several incineration facilities, the environmental annual reports and relevant literature. For Italy, the data used is reported in Turconi et al. (2011).

It should be noted that the incineration and landfilling of packaging waste contributes to energy production in the facilities with energy recovery. In fact, the energy produced has an economic value (because this energy is sold by the local authorities). It also avoids the environmental impacts associated with energy production through other sources. For this reason the energy mix (of sources) is very important to evaluate the environmental impacts

[4] The consumptions regarding the composting operations were excluded because the packaging waste materials are recovered in the pre-treatment operation. The packaging materials are not effectively composted and thus do not contribute for compost production.

associated with the process of energy production. The different sources of energy, called "energy mix", are indicated in Table 7.

Since incineration is a multi input-output allocation process where several inputs (different packaging waste fractions) and outputs (energy recovery, ash, slag and scrap generation and emissions) coexist, the allocation method was adopted. Following an attribution approach, the electricity produced by the incineration facility substitutes the electricity mix for each country considering the losses of distribution and transmission of the national grid (7.8% in Portugal, 4.6% in Belgium and 6.2% in Italy). This electricity corresponds to the real mix production in 2010 (average approach, see Table 7).

Landfilling (only applicable to Portugal) was modelled using the ELCD 2.0 databases and default values were assumed according to IPCC (2006). Landfills with and without energy recovery (72% and 28%, respectively) were considered. In the landfills with energy recovery, the electricity produced from landfill gas (LFG) combustion substitutes the electricity mix production in the country (see Table 7).

Table 7

The electricity produced in these landfills was estimated according to the IPCC methodology (IPCC, 2006). This methodology is based on the First Order Decay (FOD) method which assumes that the degradable organic carbon (DOC) in waste decays slowly throughout a few decades during which methane (CH_4) and carbon dioxide (CO_2) are formed. Therefore, the impacts cannot be immediately evaluated, corresponding to a 100 years forecast (short term).

2.4.3 Life cycle impact assessment (LCIA)

In SimaPro, the impact categories with more relevance for the system boundary were selected in order to be comparable when converted into monetary values (through three environmental valuation methods). To monetize these categories, three valuation methods were used since the LCA modelling is subjective and involves a high degree of uncertainty. Hence, the following impact categories, common to these three methods, were analyzed: climate change, human toxicity, photochemical oxidant formation and acidification, according to the recommendations of the European Commission (EC, 2011).

2.4.4 Environmental valuation methods

The monetization of environmental impacts was carried out based on the benefit transfer method (Eshet et al., 2007b). Three monetary valuation methods were used: Eco-costs2012 (Vogtländer et al., 2001, TU Delft, 2013), Stepwise2006 (Weidema, 2013) and Ecovalue08 (Ahlroth and Finnveden, 2011) and the results were compared. Since the reference year is 2010, the eco-costs in Eur2012 were translated into Eur2010, assuming the European (EU27) inflation rates between those years (1 Eur2012 = 0.94535 Eur2010; Eurostat, 2013c). The same approach was taken for the monetary values obtained with the Stepwise method (1 EUR2003 = 1.17234 Eur2010). Ecovalue08 was developed by Ahlroth and Finnveden (2011) based on stated preference methods (contingent valuation and market prices). The monetization of the impact categories selected reflects the damage costs incurred (measured by welfare loss). In this case, the characterization of impact categories was firstly done according to the LCIA methods used by the authors (in particular, the Case Method Learning (CML) method). Then, the impact categories quantified were multiplied by the weighting factors, which are presented in the following table.

Table 8

2.5 Cost-Benefit Analysis

To compare all (economic-financial and environmental) costs and benefits of the packaging waste recycling systems of Portugal, Belgium and Italy in 2010, the results of the two types of analyses were illustrated in a graph, as depicted in Figure 2 (and also presented in Marques and Cruz, 2015, Ferreira et al., 2014 and Ferreira et al, 2016). On the costs side, the environmental costs related to the emissions released in the transport of packaging waste and sorting operations were added to the financial costs incurred in the same operations. The benefits considered were the avoided emissions by recycling the packaging waste instead of incinerating or landfilling it, along with the financial revenues generated by the packaging waste management operations (selective collection and sorting). The environmental results obtained for the "Non-Recycling scenario" (composed of refuse collection and other waste treatment or disposal) correspond to the environmental opportunity costs.

Figure 2

3. Results and discussion

3.1 Economic-financial costs and benefits

The results obtained for Portugal, Belgium and Italy are depicted in Figure 3. As far as we were able to determine, in Belgium and Italy, subsidies to the investment in selective collection and sorting activities are not relevant.

In Portugal, on average, local authorities enjoy a benefit of about 260€ per ton of packaging waste collected. However, if a strictly financial perspective is adopted, the benefits are significantly reduced to 158€ per ton of waste collected. Regarding the cost perspective, selective collection and sorting of packaging waste represent 204€ per ton collected for local authorities in this country. Therefore, the cost coverage is around 128% under an economic perspective but only 77% if the cost savings arising from recycling are not taken into account.

Belgian local authorities benefit around 286€ per ton of packaging waste collected in 2010, considering the opportunity costs. In a strictly financial perspective, the benefits represent 126€ per ton. Since the financial benefits cover the costs of the service (in fact, the cost coverage is around 90% from a financial perspective – this is mainly because some local authorities decide to provide quality of service levels above the mandatory requirements). One may conclude that, currently, the Belgian recycling system is financially sustainable and has no public money subsidizing it.

Finally, the Italian case presents the lowest financial cost coverage (48%). Financially, local authorities benefit around 58€ per ton of packaging waste selectively collected whereas the service cost is 121€ per ton collected. The economic analysis shows that the benefits increase significantly to 249€ per ton and the cost coverage is 207%.

From this analysis, we can realize that the adequacy of the financial transfers for local authorities depend on the (economic or financial) perspective adopted. Assuming that the savings by diverting waste from landfills (and incineration, etc.) should be accounted for as a benefit of local authorities, the financial support paid by the industry could be reduced or even eliminated in some cases, as shown in Figure 3. In contrast, if the EPR principle was strictly followed, the transfers would possibly increase globally.

Figure 3

In summary, the cost coverage of packaging waste recycling systems differs widely among the countries. This was somehow expected. For example, in Belgium, the collection frequency (per flow) is around two times per month, while in Portugal this increases to twice per week (mainly due to the differences in terms of average temperature between the two countries). In fact, collection costs vary significantly with the type and frequency of collection (Cossu and Masi, 2013). The Italian case Rigamonti et al. (2013), where several packaging waste collection flows coexist, provides a good illustration of this circumstance. Moreover, in some countries, as in Portugal, some public money is involved in the packaging waste market.

3.2 Environmental costs and benefits

In the environmental analysis, the impacts are related to the waste management activities (selective collection and sorting) and the recycling of the packaging waste materials. Moreover, similarly to the economic methodology, the avoided impacts (opportunity costs) accounted for in the economic-financial analysis were also considered in the environmental analysis. These opportunity costs correspond to the refuse collection and disposal operations. Note that, in Belgium and Italy (more specifically, in the Lombardia Region), only incineration was considered in this scenario.[5] The environmental negative (good for the

[5] Since virtually no waste is sent to landfill.

environment) and positive (bad for the environment) impacts of each scenario were assessed and converted into monetary values with the Eco-costs2012, Stepwise2006 and Ecovalue08 valuation methods for each case study (Portugal, Belgium and Italy – the Lombardia Region).[6] Note that the economic-financial components were adjusted for the specific case of Lombardia.

It is also important to notice that when the industry is not paying the effective cost of packaging waste adequate treatment, instead of trying to reduce the costs of service, it means that there is public money in this market, which is not right and, according to the EU legislation, this must be changed.

3.3 Economic and environmental balance

The environmental results were added to the financial-economic ones and the global balance for each valuation method and country are illustrated in Figure 4. The results are expressed in tons of packaging waste selectively collected. The environmental results for the "Non-Recycling scenario" (mainly related to the emissions avoided by diverting packaging waste of the refuse collection and waste treatment/disposal) prove to be a benefit in Portugal and Belgium; however, in Italy, these represent a cost (in Lombardia the incineration with energy recovery of the packaging waste selectively collected would be globally positive from an environmental point of view).

The magnitude of the results varies significantly with the valuation method considered. Moreover, these methods are based on different LCIA methods and different weighting sets for the several environmental impact categories. Nevertheless, all (economic and environmental) benefits outweigh all the costs of the packaging waste recycling system in the three countries, even if the environmental benefits of the recycling activity are not considered.

In Portugal, the total benefits (including recycling) represent 220%, 199% and 144% of the total costs for the Ecocosts2012, Stepwise2006 and Ecovalue08 methods, respectively. If the economic and environmental opportunity costs are not considered, the cost coverage is lower (89%, 86% and 82%) and the packaging waste recycling system would seem unsustainable.

[6] In SimaPro a negative sign represents a positive impact and a positive sign represents the opposite.

The benefits from recycling represent 60 €, 35 € and 15 € per ton of packaging waste selectively collected in each method (in the same order).

In Belgium, the recycling system seems to be sustainable both from the financial and environmental perspectives. In this case, the benefits cover 142%, 124% and 115% of the costs, according to the Ecocosts2012, Stepwise2006 and Ecovalue08 methods, respectively. Taking into account the opportunity costs, the cost coverage is higher (301%, 275% and 233%). The benefits from the recycling represent 98 €, 60 € and 38 € per ton of packaging waste selectively collected in each method (in the same order).

In Italy, the recycling system is sustainable from the economic and environmental perspectives (including the benefits from the recycling). In this case, the benefits cover 197%, 218% and 202% of the costs based on Ecocosts2012, Stepwise2006 and Ecovalue08 methods, respectively. Excluding the opportunity costs, the benefits fall below the costs (65%, and 80% for the Ecocosts2012 and Ecovalue08 methods, respectively). For the valuation with the Stepwise2006 method, the benefits surpass the costs even if the opportunity costs are excluded. The benefits from the recycling activity are much higher in the valuation with Stepwise2006 (63 € per ton of packaging waste selectively collected) than in the other valuation methods (22 € and 36 € per ton of packaging waste with Ecocosts2012 and Ecovalue08, respectively).

Figure 4

Table 9 summarizes the results obtained for the three environmental valuation methods applied to the three case studies under an economic and financial perspective. The goal of the local authorities is to achieve financial cost coverage. From this perspective, the results point out cost coverage between 70-89% for Portugal, 80-124% for Belgium and 47-50% for Italy.

Table 9

4. Conclusions

In this study the economic-financial and environmental analyses were performed from the local authorities' perspective. The main reason behind this research effort was to assess how the EPR principle embedded in the PPW Directive has been interpreted in practice. Therefore, the operations under scrutiny were refuse and selective collection, sorting, pre-treatment, incineration and landfilling. From the financial results obtained, we can conclude that the EPR principle does not seem to be strictly respected for most of the case studies, since there is public money directly (subsidies to the investment) and/or indirectly (paid by citizens through the local taxes) involved in the funding of the recycling systems.

From the economic analysis conducted for Portugal, Belgium and Italy, some wide-ranging implications can be drawn. Considering the opportunity costs, the packaging waste management systems revealed a cost coverage of 128% and 135% and 207% in 2010 for Portugal, Belgium and Italy, respectively. Therefore, according to these results, the financial support coming from the Green Dot companies to the local authorities could be reduced and the system would still be sustainable. In Belgium, the recycling system seems sustainable, even from a strictly financial perspective, because Fost Plus covers the total costs of the packaging waste selective collection and sorting (through different funding systems established with the local authorities).

Considering the environmental costs and benefits for Portugal, Belgium and Italy (in particular, the Lombardia region), we can conclude that routing the packaging waste for recycling is less costly for the environment than the other disposal operations. When one adds these costs and benefits to the economic-financial ones, the Portuguese and Italian recycling systems prove to be sustainable (i.e. the benefits are higher than the costs) if the environmental and economic opportunity costs are taken into account. In the Belgian case, considering the opportunity costs seems to be irrelevant in terms of the sustainability of the recycling system. However, this component could be assumed as an efficiency promoter, reducing the financial costs and the environmental disamenities.

When analyzing the results from the financial perspective, including the environmental costs and benefits, some improvement are observed in the costs' coverage since the benefits from the recycling of the sorted materials overcome the costs derived from the selective collection and sorting activities.

In this regard, the conclusions drawn from this study can be taken to some of the countries but they cannot be applied to all Member States. That is why we must be prudent about generalizations. There are countries that are completely sustainable and the industry supports the system (financially and economically speaking), following the guidelines of the EU legislation.

In Europe, Germany and Belgium are two of the very few cases for which the EPR principle seems to be strictly respected through quite different waste management models (private and public, respectively). Nevertheless, it should be noted that the implementation of a pay-as-you-throw (PAYT) scheme is a common feature in these two countries Moreover, in these countries the "recycling behaviors" have been promoted for decades and reinforced by these economic incentives.

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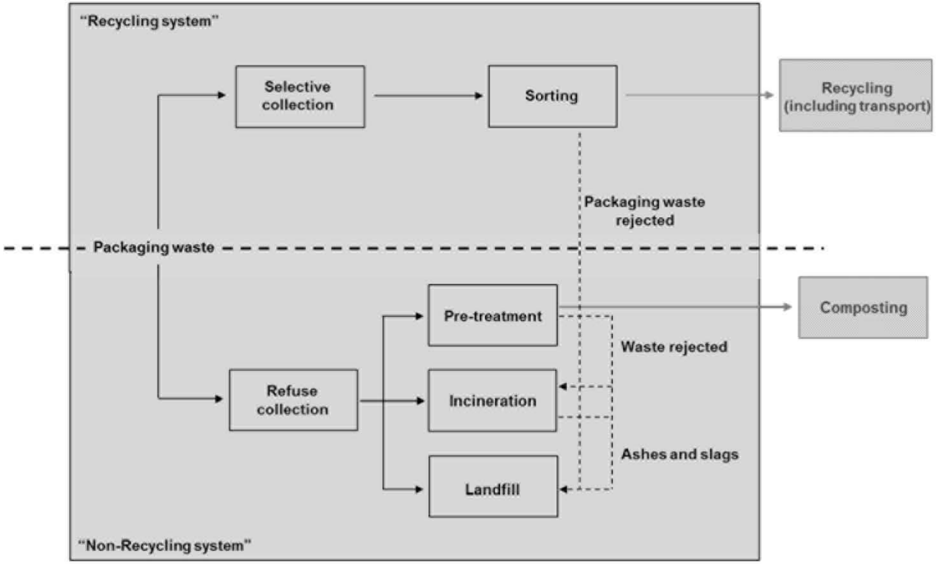

Figure 1: System boundary defined for economic-financial and environmental analyses

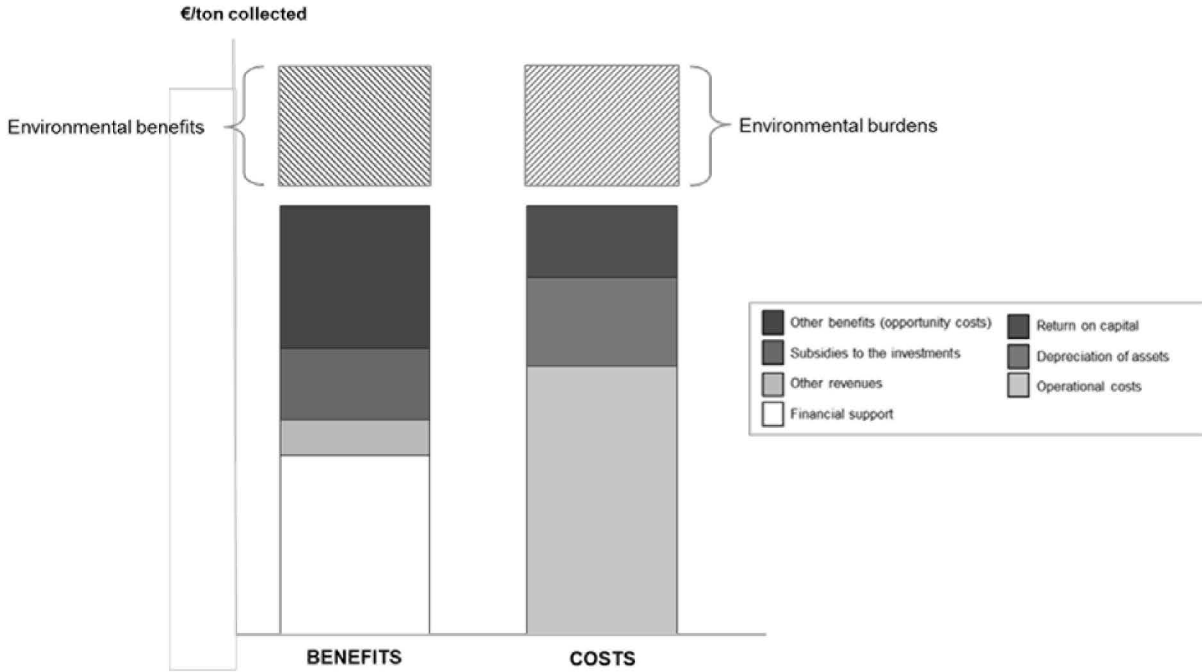

Figure 2: Comparison of the costs and benefits of packaging waste recycling systems

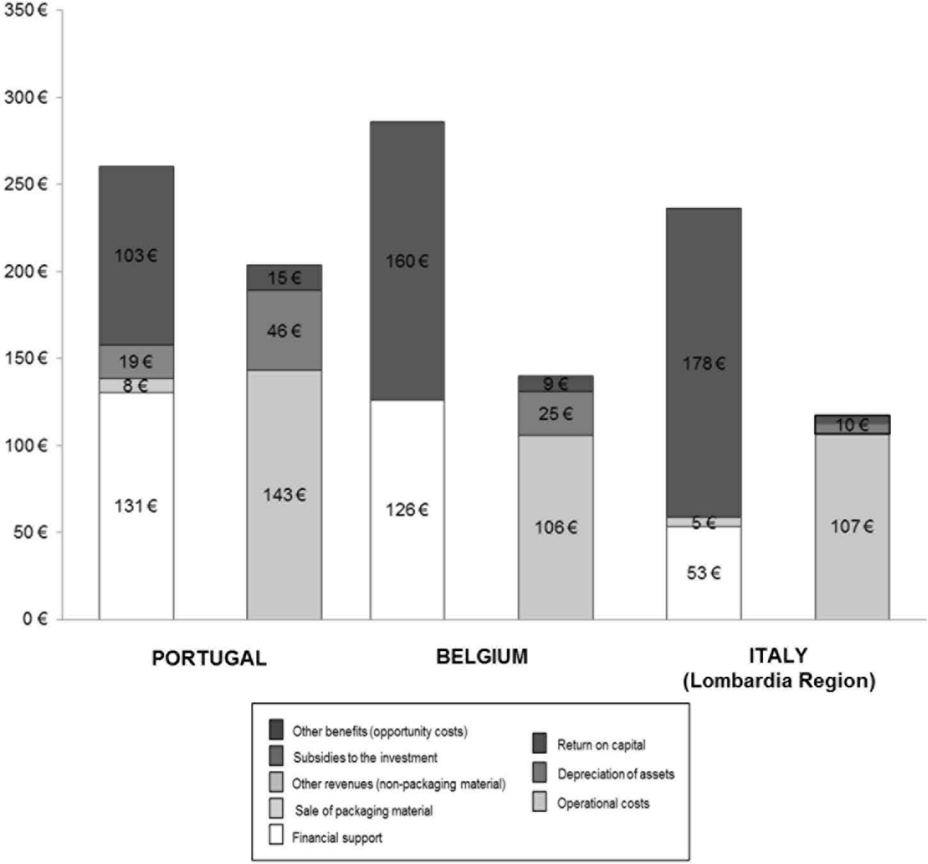

Figure 3: Cost coverage in the packaging waste recycling systems in 2010

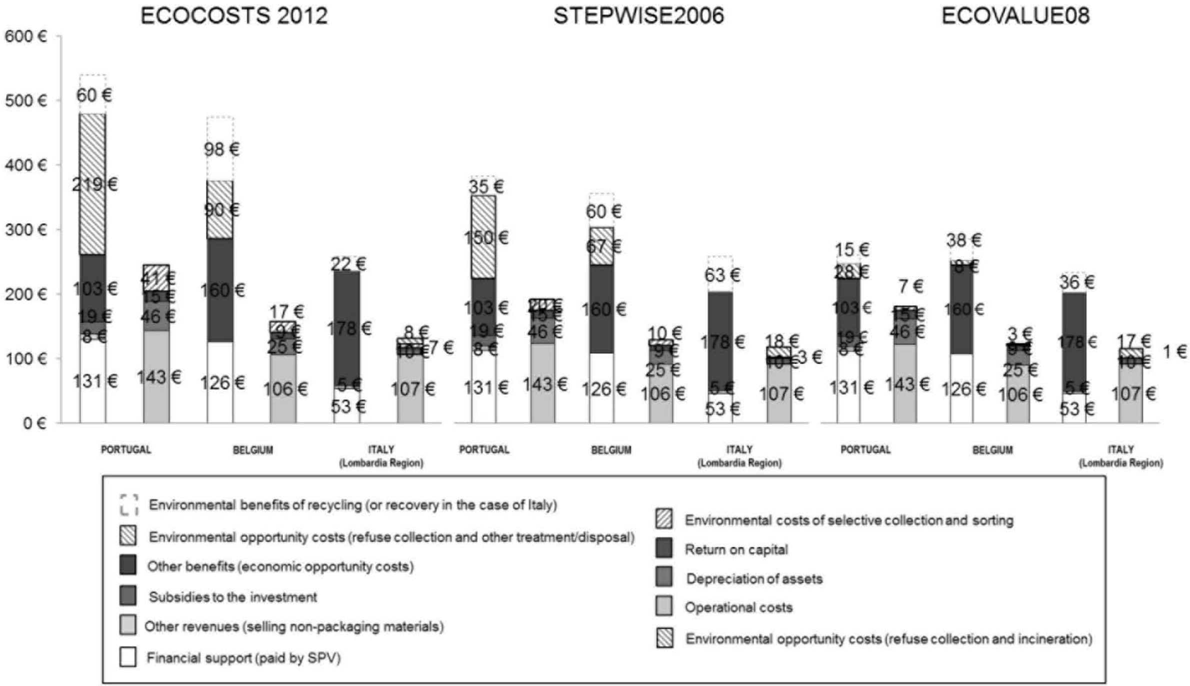

Figure 6: Economic and environmental results achieved with the Eco-costs2012, Stepwise2006 and Ecovalue08 methods per ton of packaging waste selectively collected in each country

Table 1: The case studies

Country	Green Dot Company	Number of Compliance Schemes	Responsability of the operations	Population (10^6)	GDP (10^3 € per capita)
Portugal	SPV	1	Municipalities	10,4	~20
Belgium	Fost Plus	1	Municipalities/Private operators	11,2	~39
Italy (Lombardia region)	Conai	1	Municipalities	10,0	~34

Table 2: Expenditures and revenues considered in the economic-financial analysis

Economic-financial components	**Sources**
Expenditures	
Operational/maintenance costs	Survey (local authorities)
Depreciation of fixed assets	
Return on capital employed	Calculated
Revenues	
Financial support paid by Green Dot companies	Survey (local authorities and Green Dot companies)
Sale of packaging materials	Survey (local authorities)
Other benefits (sale of non-packaging materials)	
Subsidies to the investment	
Opportunity cost	Calculated

Table 3: Variables used in the economic analysis in the case studies

Variable	**Portugal**	**Belgium**	**Italy**
Useful life of the assets (years)	9.6	9.6	(-)[a]
Cost of equity (%)	6.0	6.0	
Equity in the capital structure (%)	19.0	19.0	
Marginal corporate tax (%)	20.3	34.0	
Cost of debt (%)	4.6	4.6	
Unit costs of refuse collection, €/ton	49	60	191
Unit costs of other treatment (landfill, incineration, etc.), €/ton	54	101	
Efficiency of collection (%)			
Glass	97	100	90 – 99.5
Paper/cardboard	90	100	
Other packaging	61	84	

[a] The value of 14.3€/ton was estimated by "Rapporto Rifiuti 2013" (ISPRA, 2013) taking into account the depreciation costs of the waste bins and collection trucks, the depreciation for relinquished financial assets and others, cost of accruals and costs related to the return on invested capital.

Table 4: Inputs of waste sorting (weighted averages) for the year 2010

Variable	**Paper/cardboard waste**	**Glass waste**	**Plastic/metal/other packaging waste**
	Portugal		
Electricity (kWh/ton)	14.57	----	53.05
Diesel (L/ton)	1.62	----	5.59
Lubricants (L/ton)	0.03	----	0.08
Water (m^3/ton)	0.11	----	0.14
Rejected waste (ton/ton)	0.10	0.03	0.39
Rejected disposal		Landfill	
	Belgium		
Electricity (kWh/ton)	----	----	32.22
Diesel (L/ton)	----	----	3.52
Lubricants (L/ton)	----	----	0.04
Rejected waste (ton/ton)	----	----	
Rejected disposal		Incineration	
	Italy		
Electricity consumption (kWh/ton):			
Ferrous metal sorting		47.5	
Multi-material separation		15.9	
Rejected waste (ton/ton)		0.096	
Rejected disposal		Incineration	

Table 5: Recycling process and avoided product considered for Portugal and Belgium

Packaging material		**Recycling process**	**Avoided Product**	**Substitution ratio**
Plastics	PET	PET granulate	PET granulate	1:1
	EPS	Recycled EPS	EPS from virgin materials	1:1
	Mixed plastics	Furniture to use outdoor from plastic recycled	Furniture to use outdoor from wood (Plywood)	1:1
	Plastic film	LDPE granulates	LDPE granulates from virgin materials	1:1
	HDPE	HDPE granulates	HDPE granulates from virgin materials	1:1
Glass		Glass from cullet	Glass from virgin materials	1:1
Paper/cardboard		Corrugated board, from recycling fibers	Sulphate pulp	1:0.83
Aluminum (non-ferrous)		Secondary aluminum from old scrap	Primary aluminum	1:1
Steel (ferrous)		Ferrous scrap	Pig iron	1:1

Table 6: Recycling process and avoided product considered for Italy (Lombardia region)

Packaging material	**Recycling product**	**Avoided product**	**Substitution ratio**
Ferrous metals	Liquid secondary steel from iron scraps	Liquid primary steel from pig iron	1:1
Aluminium	Secondary aluminium ingots from aluminium scraps	Primary aluminium ingots from bauxite	1:1
Glass	Generic glass container from cullet	Generic glass container from raw materials	1:1
Wood	Particle board from recovered wood	Plywood from virgin wood	1:0.6
Paper	Non-deinked pulp from wastepaper	Virgin thermo-mechanical pulp	1:0.8
Plastics	Granules of recycled PET	Granules of virgin PET	1:0.8
	Granules of recycled HDPE	Granules of virgin HDPE	1:0.8
	Flakes of mix of polyolefin	50% Wood	1:1
		50% nothing	-

Table 7: Electricity mix in 2010 for Portugal, Belgium and Italy

Energy Mix	**Portugal**[a]	**Belgium**[b]	**Italy**[c]
Hydropower	29.5%	----	15.6%
Nuclear	-----	45 %	----
Coal	12.6%	2.8 %	,11.9%
Natural gas	20.5%	29 %	45.8%
Other fossil fuels	0.09%	5.1 %	8.8%
Biomass	4.2%	3.4 %	----
Other renewable sources	44.2%	3.2 %	4.7%
Imported	5.0%	12 %	13.2%

[a] REN (2010); REN (2013); DGEG (2013a); DGEG (2013b)

[b] Spitzley and Najdawi (2011); Eurostat (2013a); Eurostat (2013b)

[c] Terna (2013)

Table 8: Weights considered in Ecovalue08 database

Impact category	**Unit**	**Value in SEK**	**Value in EUR**[a]
Climate change (GWP), Min.	Per kg CO_2 eq.	0,10	0,01050
Climate change (GWP), Max.		2,00	0,20991
Human Toxicity, Min.	Per kg 1,4-DB eq.	0,004	0,00042
Human Toxicity, Max.		12,00	1,25946
Photochemical oxidant formation, Min.	Per kg C_2H_4	14,00	1,46937
Photochemical oxidant formation, Max.		40,00	4,19820
Aquatic eutrophication	Per kg PO_4 eq.	218,00	22,88017
Acidification	Per kg SO_2 eq.	30,00	3,14865
Depletion of abiotic resources, Min.	Per MJ	0,004	0,00042
Depletion of abiotic resources, Max.		0,24	0,02519

[a] Considering 1 SEK = 0,10495 EUR in 2010 (ECB, 2013)

Source: Ahlroth and Finnveden (2011)

Table 9: Costs and benefits according the financial and economic perspective

	PORTUGAL			BELGIUM			ITALY		
	Benefits	Costs	Costs' coverage	Benefits	Costs	Costs' coverage	Benefits	Costs	Costs' overage
ECOCOSTS 2012									
Economic	539 €	245 €	220%	376 €	157 €	239%	258 €	123 €	209%
Financial	217 €	245 €	89%	126 €	157 €	80%	58 €	123 €	47%
STEPWISE2006									
Economic	410 €	224 €	183%	413 €	150 €	275%	299 €	137 €	218%
Financial	158 €	224 €	70%	186 €	150 €	124%	58 €	119 €	49%
ECOVALUE08									
Economic	303 €	211 €	144%	294 €	143 €	206%	273 €	118 €	232%
Financial	173 €	211 €	82%	126 €	143 €	88%	58 €	118 €	50%