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Comparative LCA of two approaches with different emphasis on energy or material recovery for a municipal solid waste management system in Gipuzkoa

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ABSTRACT

Two alternative approaches for an integrated municipal solid waste management system (MSW-MS) have been confronted in the province of Gipuzkoa, in the north of Spain, during the last decade. While one of them prioritizes energy recovery from mixed residual waste in an incineration plant, the other approach gives precedence to material recovery of separately collected waste. Which system would present a lower environmental impact and be more desirable from a sustainability perspective? Answering this question is hindered by the fact that recovered energy and materials are not directly comparable or directly substitutable with each other.

Based on the powerful framework provided by life cycle assessment (LCA) methodology, this work performs a comparative LCA of overall environmental impacts of these two alternative approaches, showing that comparisons of alternative systems in terms of direct energy recovery or direct material recovery should be avoided in favor of other indicators already proposed in the LCA framework, such as the Cumulative Energy Demand category from Ecoinvent, or the global warming potential and the Abiotic Resources Depletion categories from the CML 2001 method.

Applying the LCA framework, this work shows that when a high share of waste is collected separately, and processes assumed in the background system are adequately characterized, especially the production of the electricity mix, then prioritizing material recovery provides better results even in environmental categories tightly related to fossil energy consumption, such as the global warming potential impact category.

Contents

Abbreviations: acid, Acidification impact category from CML 2001 method; *ard*, Abiotic Resource Depletion impact category from CML 2001 method; *eutro*, Eutrophication impact category from CML 2001 method; GHG, Greenhouse Gas; *gw*, Global Warming impact category from CML 2001 method; *htox*, Human Toxicity impact category from CML 2001 method; ILCD, International Reference Life Cycle Data System; ISO, International Organization for Standardization; LCA, life cycle assessment; LCA-IWM, LCA Tools for the Development of Integrated Waste Management; MBP, mechanical biological pre-treatment; MSW, municipal solid waste; MSW-MS, municipal solid waste management systems; P, product; PE, primary energy demand; *ph-tox*, Photo-oxidant Formation impact category from CML 2001 method; RM, resource material demand; SC, separate collection; WFD, Waste Framework Directive; WP, waste prevention; WtE, Waste-to-Energy, incineration plant with energy recovery

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1. Introduction

The aim of integrated municipal solid waste management systems (MSW-MS) is to give an adequate treatment to collected waste with a minimum environmental impact under affordable costs. These systems comprise all the treatment and processing steps underwent by collected fractions of municipal solid waste (MSW) generated in a specific area, from temporary storage and collection through final disposal of secondary fluxes generated in processing plants. In order to improve sustainability and minimize impacts, some waste treatments—such as incineration or anaerobic digestion—aim at recovering energy from waste, while others are focused on preparing the waste for material recovery. In fact, integrated MSW-MS normally combine different kinds of material and energy recovery.

1.1. Waste management strategies in Gipuzkoa

Local administrations in Spain have been redefining their municipal waste-management systems for more than a decade. On one hand, they are obliged to comply with European Directives regarding minimum recovery and recycling rates for packaging wastes and closure of landfills; on the other hand, many administrations have to face up to the saturation of landfill sites. This is the case, for example, in the Basque province of Gipuzkoa, where 64% of all MSW generated in 2012 was derived to landfills. This figure, actually, is similar to the values registered in nearby provinces and regions in Spain, as can be checked in Table 1, which shows the percentages of MSW derived to final treatments that year in the three Basque provinces and Spain. There, treatment of MSW has been mainly based in landfilling and to a much lesser degree in energy recovery; material recovery, on the other hand, has remained below 40% for many years [1–4].

With a population of 731 thousand inhabitants in 2013, Gipuzkoa is administratively divided into eight municipality commonwealths. Historically, municipality commonwealths are the administrative bodies that have been in charge of the collection and treatment of municipal waste, especially through its disposal to controlled landfills. Fig. 1 shows the trend of MSW generation in Gipuzkoa between 2000 and 2013, altogether with planning objectives established by the provincial administration in 2008 (DdP-2008 Strategy, for year 2016 [5]) and in 2012 (EDDdP-2012 revision Strategy [1], for 2016 and 2020).

MSW generation in Gipuzkoa increased since 2000 until 2006, when a peak of 411 thousand metric tons was generated. During that period around 80% of the MSW was mixed residual wastes derived to landfills, as most of the waste was not separately collected—from 15.3% in 2000 up to 25.5% in 2006. In order to reduce environmental impacts related to such a big waste flux being derived to landfill sites, during those years the provincial administration made a strong commitment to energy recovery of the mixed residual waste. This commitment was materialized in the DdP-2008 Strategy, approved in the beginning of 2008. This planning projected a progressive increase in waste generation and recycling until 2016. According to it, in that year 57% of the generated waste would be separately collected and 53.3% could be recycled [5]. Most of the resting mixed residual waste (213 thousand metric tons, annually) would be incinerated with energy recovery. This strategy would have required the installation of at least one new incineration plant in Gipuzkoa, although up to three new plants were eventually considered [5,7]. It must be emphasized that the DdP-2008 Strategy was established previous to the approval of the European Waste Framework Directive (WFD), which sets a minimum target of 50% for re-use and recycling of MSW by 2020 [8]. That target could be tightly achieved inside the DdP-2008 Strategy by 2016, but some serious problems arise when the evolution of MSW generation in Gipuzkoa after 2006 is considered.

Since 2007 the MSW flux generated in Gipuzkoa has diminished steadily, as can be checked in Fig. 1. This reduction in waste generation seems to be due, partially at least, to a social context more sensible every year with recycling, re-use and environmental impacts derived from landfilling, as the decline started before the economy got into recession by the end of 2008. At that moment, MSW generation in Gipuzkoa had already diminished by 15% when compared to 2006 levels. By 2013 the reduction was 22%, and 35% less than the forecast for 2016.

After the approval of the DdP-2008 Strategy and the WFD in 2008, some municipalities boosted an alternative approach in order to avoid the installation of any new incineration facility in the province. This alternative strategy was mainly based on a

Table 1
Final treatments of MSW in 2012 in Gipuzkoa and nearby regions (other Basque Provinces and Spain).

Final treatment	Gipuzkoa (%)	Bizkaia (%)	Araba (%)	Spain (%)
Landfilling	64	28	63	63
Energy recovery	0	36	2	10
Material recycling	29	36	34	17
Composting	7	< 1	1	10

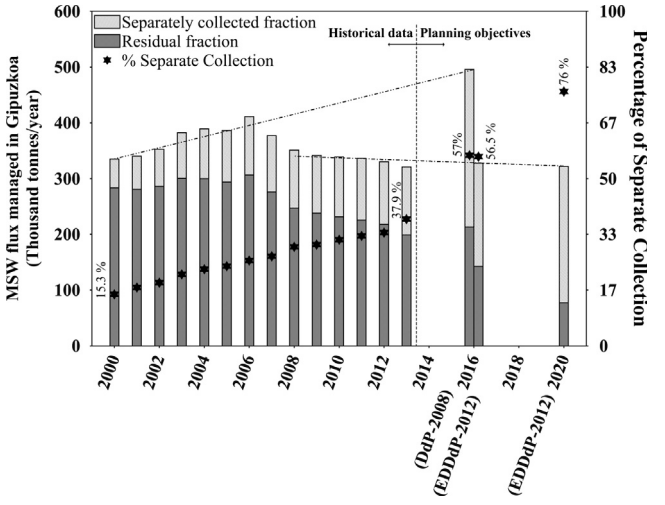

Fig. 1. Historical evolution of the MSW flux in Gipuzkoa, and planning objectives established by the DdP-2008 Strategy (for year 2016) and those established by the EDDdP-2012 revision Strategy (for years 2016 and 2020). Broken lines are eye guides. Source: [1,5,6].