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Environmental evaluation of municipal waste prevention

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ABSTRACT

Waste prevention has been addressed in the literature in terms of the social and behavioural aspects, but very little quantitative assessment exists of the environmental benefits. Our study evaluates the environmental consequences of waste prevention on waste management systems and on the wider society, using life-cycle thinking. The partial prevention of unsolicited mail, beverage packaging and food waste is tested for a "High-tech" waste management system relying on high energy and material recovery and for a "Low-tech" waste management system with less recycling and relying on landfilling. Prevention of 13% of the waste mass entering the waste management system generates a reduction of loads and savings in the waste management system for the different impacts categories; 45% net reduction for nutrient enrichment and 12% reduction for global warming potential. When expanding our system and including avoided production incurred by the prevention measures, large savings are observed (15-fold improvement for nutrient enrichment and 2-fold for global warming potential). Prevention of food waste has the highest environmental impact saving. Prevention generates relatively higher overall relative benefit for "Low-tech" systems depending on landfilling. The paper provides clear evidence of the environmental benefits of waste prevention and has specific relevance in climate change mitigation.

1. Introduction

The amounts of municipal solid waste have been increasing for years in many countries. In the European Union (EU27), a 15% increase between 1995 and 2008 was observed with an annual increase of 1% in recent years (Eurostat, 2010). In the Organisation for Economic Co-operation and Development (OECD) countries, an increase of 18% has been reported between 1995 and 2007 (OECD, 2010). Many governmental agencies and international organisations have established waste related policies to reduce the environmental impacts of waste management, including reducing the amounts of waste. Studies of the relationship between quantity of waste generated and economical growth indicators have suggested that a decoupling is needed in order to reduce the increasing burden from waste management (OECD, 2002; Jacobsen and Kristoffersen, 2002). Waste prevention has the highest priority in waste policy in several regions, including the European Union, as stated in Directive 2008/98/EC (The European Parliament and the Council of the European Union, 2008), but so far, absolute decoupling between waste growth and economical growth has not been demonstrated in Europe, in absolute terms, as indicated by Mazzanti and Zoboli (2006, 2008).

Prevention of waste is generally considered to be good for the environment and society at large, but there is little quantitative evidence assessing the environmental aspects of waste prevention. Most current assessments focus on the amount of waste that potentially could be prevented (Mazzanti and Zoboli, 2006; EEA, 2009). The objective of this paper is to devise an environmental quantification methodology of household waste prevention, using life cycle thinking, in order to address the significance of prevention, depending on the type of prevention activity, the type of waste and the type of waste management system.

2. Background

In Europe, waste prevention has been a key part of waste management policy. In 2008, it was integrated in the legislation (waste framework directive 2008/98/EC (The European Parliament and the Council of the European Union, 2008)) and stated that prevention is the first priority of waste management, being at the top of the waste hierarchy, with a requirement from European member states to produce waste prevention plans.

In the UK, the Government has funded a large research program in waste prevention. It includes a review of evidence analysing the behavioural opportunities and barriers in household waste prevention, associated with the effectiveness of various policy measures (Cox et al., 2010). The impact of waste prevention campaigns (Sharp et al., 2010a), and methods to monitor and evaluate waste prevention through mass reduction and behavioural studies (Sharp et al., 2010b), were also developed. Current decoupling indicators of waste prevention were reviewed (Fell et al., 2010). This

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unprecedented government led research initiative has demonstrated the key issues of waste prevention from a behavioural perspective. It is, however, quite critical also to assess the environmental significance of waste prevention as this can reinforce evidence for policy development.

In the United States, the US EPA has undertaken a program to support local authorities and waste management organisations to quantitatively assess the consequences of waste prevention on global warming potential (GWP) reduction with the WAste Reduction Model (WARM) but does not include other environmental impact categories (USEPA, 2006).

Some countries, such as Taiwan (Young et al., 2010), South Australia (Zero Waste South Australia, 2007) and New Zealand (Ministry for the Environment, 2007) have adopted the target of "zero waste" as a form of strategic waste prevention. Regrettably, zero waste is usually interpreted as zero waste to uncontrolled disposal or landfill, mostly includes recycling and generally excludes environmental assessment.

Very scarce literature is found on the quantitative environmental assessment of waste prevention. A notable exception is presented by Laner and Rechberger (2009), for the environmental assessment of waste prevention projects implemented by small and medium size enterprises, using GWP, acidification potential and cumulative energy demand. Salhofer et al. (2007) have also undertaken quantitative environmental assessment by ranking waste prevention measures for specific waste streams using waste reduction indicators (mass of waste reduced) and life-cycle assessment (LCA) indicators (LCA impacts of waste prevented). They concluded that while the ranking of prevention measures were similar among the two methods, LCA provides more detailed information that cannot be assessed by the waste reduction indicators alone. Salhofer et al. (2008) studied the potentials for municipal solid waste (MSW) prevention and concluded that the prevention potential of a single fraction could represent up to 10% of that fraction. They also indicated that the prevention potential appeared to be small, but not insignificant, in comparison with the overall MSW produced. In Sweden, Olofsson (2004) evaluated that the prevention of 4% of MSW at national level, could reduce greenhouse gas emissions by 5–9%.

3. Methodology

A more detailed methodology is provided in the Supporting information.

3.1. Scope and limitations

This study is an environmental system analysis using LCA methodology as prescribed by Finnveden et al. (2009). It is based on a consequential approach using system expansion for a fictional European municipality. The focus is on waste prevention at the municipal solid waste stage, with main interest in the reduction of the environmental impacts with the introduction of waste prevention. The objective of the assessment is to compare different waste prevention options with a baseline scenario.

Non municipal household waste, such as hazardous waste, commercial and industrial waste and mining waste, is excluded from the scope. The paper also excludes the following waste prevention approaches:

- prevention by reduction of the hazardousness properties of the waste;
- prevention from redesign of product (light-weighting of packaging);
- manufacturing chain waste prevention;
- behavioural change (consumption is assumed constant);
- material exchange scheme and second hand shops; and
- rebound effect, where prevented waste is associated with the generation of another waste.

3.2. Choice of preventable waste fractions

Three waste fractions, food waste (meat and vegetables), unsolicited mail and beverage packaging (plastic and glass), were selected for this study. Prevention of food waste was chosen because a significant amount of food is wasted (Scott et al., 2009). Unsolicited mail waste was retained because it is considered to be relatively easy to prevent. In contrast, beverage packaging was selected because its prevention depends on the efficiency of relatively complex take back schemes, involving integrated policy and legal framework, logistics and support from industry, as well as acceptance from the public (Salhofer et al., 2007, 2008). The three selected fractions thus represent not only different types of materials but also different types of prevention schemes. Food waste, unsolicited mail waste and beverage packaging represented, respectively the prevention of food surplus, the direct reduction of unsolicited mail service or the reuse of beverage packaging. The prevention of each of these materials was not considered to be replaced or substituted by other products or service (no rebound effect was assumed in our study).

Based on Salhofer et al. (2008), it was assumed that the prevention potential was 20% for both food waste and unsolicited mail and 60% for beverage packaging. In our view, it was important to use realistic prevention potential to evaluate the effect of prevention measures.

3.3. Functional unit and system boundaries

The functional unit (FU) has been defined as the service of managing 100,000 metric tonnes of average MSW from a fictional European municipality. However, waste prevention cannot be modelled on a tonne basis, because waste prevention inherently changes the functional unit and therefore makes it impossible to compare results (Ekvall et al., 2007). To avoid this limitation in LCA methodology, we have considered that the quantity of prevented waste is a virtual waste flow (a quantity of waste that has no environmental burden and is subject to no transformation within the waste management system). This enables us to quantify the consequences of reducing a waste fraction on the existing MSW system and, in addition, assess the avoided production impacts from the quantity of prevented products, without affecting the FU. The FU is effectively composed of waste FU and prevented waste or 'virtual' waste FU. A similar approach has recently been proposed by Cleary (2010), where the author proposes a primary and a secondary FU for the environmental assessment of waste prevention, using LCA.

The system boundaries have been defined by the quantity of household waste, whether real or virtual, entering the MSW system, corresponding to a baseline case (Fig. 1a). The operating system includes all the waste management activities and related environmental impacts of two typical MSW management systems. These systems are defined by a high technology system (high incineration level, in-vessel tunnel composting, good recycling level and low landfilling), and a low technology system (no incineration, in-vessel tunnel composting, lower recycling and high landfilling). These two MSW systems are referred to as "High-tech" and "Low-tech", and their respective waste management proportions are available in the Supporting information. Recycling includes plastic, glass, paper and ferrous fractions (the residual aluminium fraction is, in this context, considered insignificant, constituting only 1–2% of the MSW in Europe).