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ScienceDirect
Waste Management 27 (2007) 989–996
wasteWmanagement
www.elsevier.com/locate/wasman

What life-cycle assessment does and does not do in assessments of waste management

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Accepted 16 February 2007
Available online 16 April 2007

Abstract

In assessments of the environmental impacts of waste management, life-cycle assessment (LCA) helps expanding the perspective beyond the waste management system. This is important, since the indirect environmental impacts caused by surrounding systems, such as energy and material production, often override the direct impacts of the waste management system itself. However, the applicability of LCA for waste management planning and policy-making is restricted by certain limitations, some of which are characteristics inherent to LCA methodology as such, and some of which are relevant specifically in the context of waste management. Several of them are relevant also for other types of systems analysis. We have identified and discussed such characteristics with regard to how they may restrict the applicability of LCA in the context of waste management. Efforts to improve LCA with regard to these aspects are also described. We also identify what other tools are available for investigating issues that cannot be adequately dealt with by traditional LCA models, and discuss whether LCA methodology should be expanded rather than complemented by other tools to increase its scope and applicability.

1. Introduction

1.1. Background

Waste management is a complex phenomenon with a range of consequences for the involved stakeholders and the society. One of the many parameters to evaluate is the environmental impact of different treatment options or technical solutions. There are many tools for assessment of environmental impact, but one of the most commonly used is life-cycle assessment (LCA). It helps expanding the perspective beyond the waste management system. This is important since the environmental consequences of waste management often depend more on the impacts on surrounding systems than on the emissions from the waste management system itself (Ekvall, 1999). In particular, the broad perspective of LCA makes it possible to take into account the significant environmental benefits that can be obtained through different waste management processes:

- waste incineration with energy recovery reduces the need for other energy sources,
- material from recycling processes replaces production of virgin material,
- biological treatment may reduce the need for production of artificial fertilisers and vehicle fuel[1],

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[1] It may also help improving the quality of soils, but this is difficult to take into account in LCA.

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doi:10.1016/j.wasman.2007.02.015

- residues from waste incineration may replace gravel at road constructions (Birgisdottir, 2004), etc.

The broad system perspective makes LCA a powerful tool for environmental comparison of different options for waste management of a specific product, a material, or a complex waste flow. Because of this, LCA has gained in acceptance as a tool for waste management planning and policy-making. It is now being used in various contexts, ranging from local planning to policy making at national and international levels. An example of this is the recent thematic strategy on waste management presented by the European Commission.

An international standard for LCA has been developed, and handbooks are available (e.g., Guinée, 2002), as well as scientific reviews of recent developments (Rebitzer et al., 2004; Pennington et al., 2004). Separate publications describe how to apply the method on waste management systems (Finnveden, 1999; Clift et al., 2000). However, to be able to make sustainable use of LCA in the waste management, it is important to be aware of the limitations of the methodology and to understand that the environmental information it generates is neither complete, nor absolutely objective or accurate. The international standardisation process helps to reduce what can appear to be arbitrariness of the methodology, but important methodological choices still remain free to be made in each separate study. The LCA results therefore depend on methodological decisions, for example:

- choice of time perspective (Finnveden et al., 1995; Obersteiner et al., 2007),
- assumptions made in the study,
- sources of input data,
- allocation of environmental burdens to different life cycles (Ekvall and Tillman, 1997; Winkler, 2007), and
- modelling of environmental impacts.

These methodological choices may be influenced by the values and perspectives of the LCA practitioner and the LCA commissioner. This means that an LCA typically does not yield objective answers. The methodology also suffers from large uncertainties (Huijbregts, 1998a,b). As indicated by the references above, the subjective and uncertain aspects of the answers given by LCA have been thoroughly discussed elsewhere. These limitations are also not unique to LCA. Several methods for environmental systems analysis have been developed to support different types of decisions (Wrisberg et al., 2002; Finnveden and Moberg, 2005). Similar problems occur in most of them.

A limitation that has not been much discussed, however, is the fact that a traditional LCA model has several inherent characteristics that prohibit it from giving adequate answers to many significant questions. This is the focus of our paper.

1.2. Aim of the paper

In order to contribute to the awareness of the limitations of LCA, the aim of this paper is to discuss the restrictions in the applicability of LCA as a decision-support tool in waste management planning and policy-making. We do this by identifying certain characteristics of LCA, discuss how these may restrict the applicability of LCA, efforts made to improve LCA methodology with regard to these characteristics, and what other tools are available that cover issues currently not adequately dealt with in LCA. We also discuss whether LCA methodology should be expanded rather than complemented by other tools to increase its scope and applicability. Most of the discussion is valid also for LCA applied outside the waste management sector, and to a large extent it is also valid for other tools for environmental systems analysis.

The advantages and disadvantages of LCA applied to waste management can be discussed at three conceptual levels. The discussion can focus on the characteristics of LCA as a scientific method, on methodological applications of LCA in computer models or methodological guidelines, or on the practical applications of LCA in actual case studies. Our discussion aims at the most general level. The purpose is to shed light on the characteristics of LCA as a scientific method. However, we use examples of methodological applications as well as practical applications as illustrations.

2. Functional unit and system dynamics

2.1. Restrictions in applicability

LCA models of waste management often calculate the environmental burdens per kg or tonne of waste generated. It implies that the quantity of waste is unaffected by the management measures investigated. Having identical amounts of waste treated in different scenarios makes it possible to simplify comparative analyses by neglecting the production and use of the materials (Finnveden, 1999). This simplification is sometimes called the "zero burden assumption", suggesting that the waste carriers none of the upstream burdens into the waste-management system.

LCA models that calculate the environmental burdens per kg or tonne of waste generated allow for environmental comparisons of different options for dealing with this waste, but not for analyses of changes in the quantities of waste generated. They are inadequate for the identification and assessment of waste prevention strategies. They also fail to account for the serious challenges posed by a continuation of the short-term and long-term trends of increasing waste flows, and consequently do not give information on how large capacity for waste treatment is required.

Traditional LCA models are also static. In the context of waste management, this implies that they cannot give