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Allocation solutions for secondary material production and end of life recovery: Proposals for product policy initiatives

K. Allacker, F. Mathieux*, S. Manfredi, N. Pelletier, C. De Camillis, F. Ardente, R. Pant

European Commission – Joint Research Centre, Institute for Environment and Sustainability, Via E. Fermi 2749, 21027 Ispra, Italy

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ABSTRACT

This paper aims at analysing how secondary materials production and end of life recovery processes are modelled in life cycle-based environmental assessment methods in order to discuss their suitability in product policy-support contexts, with a focus on Sustainable Consumption and Production (SCP) policies. The equations prescribed in three published, widely recognised standards are evaluated. In addition, more recent modelling approaches that have been adopted in the context of two EU product policy initiatives (the Product Environmental Footprint (PEF) and the Resource Efficiency Assessment of Products (REAPro)) are similarly analysed. All of the methods are scrutinised against eight criteria which we deem to be important in product policy-support contexts, including comprehensiveness, accommodation of open-loop and closed-loop product systems, and consideration of recyclability/recoverability rates, to name a few. Based on this analysis, it is suggested that the PEF and REAPro modelling approaches appear to be better suited for use in product policy-support contexts than do the currently widely endorsed methods that we considered.

1. Introduction

1.1. Modelling secondary material production and end of life stages in Life Cycle Assessment

Allocation issues arise in life-cycle based environmental accounting exercises when a system produces multiple product outputs or uses inputs stemming from another product's life cycle. The related input flows and emissions occurring across the life cycle must then be attributed to the co-products in a principled manner. Similarly, allocation is needed when modelling end of life (EoL) processes, including recycling, reuse, energy recovery and disposal in case more than one product is involved. The former instances are particularly challenging in that the environmental benefits and burdens associated with input and output flows must potentially be assigned in relation to multiple product systems both upstream and downstream of the product life cycle of concern. The term "allocation" as it is used in this paper refers to allocating the environmental impacts tied to secondary materials production and EoL processes when several 'subsequent' products are involved. It does not cover allocation between two 'simultaneous' products from the same production process.

Defining system boundaries related to recycled product or recycling at EoL and related allocation methods have been long-debated in the life cycle assessment (LCA) community. Klöpffer (1996), for example, provides an overview of different allocation rules and discusses these in terms of mathematical "neatness", feasibility, and justice/incentives for both producers and users of secondary raw materials. Different allocation approaches related to recycled products were proposed by different researchers such as a market-based approached (Ekvall, 2000), the EVR model of Vogtländer et al. (2001) and a material-quality-based approach by Kim et al. (1997). The ISO 14044:2006 standard for LCA describes this issue in general terms, and provides a conceptual framework to guide practitioners in modelling EoL processes (ISO, 2006b). This conceptual framework distinguishes between open-loop product systems (material from one product system is recycled in a different product system) versus closed-loop product systems (material from a product system is recycled in the same product system). In addition to the allocation solution hierarchy and requirements for general allocation problems specified in ISO 14044:2006, practitioners are required to take into account any changes in the inherent properties of materials. Still, the framework is general and leaves room for interpretation (Ardente and Cellura, 2012; Pelletier and Tyedmers, 2011).

Since the publication of ISO 14044 in 2006, the issue of EoL modelling has continued to receive significant attention amongst practitioners of LCA and comparable methods, with numerous

* Corresponding author. Tel.: +39 0332 789238; fax: +39 0332 786645.
E-mail address: fabrice.mathieux@jrc.ec.europa.eu (F. Mathieux).

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approaches to modelling allocation at EoL described in the literature to date. Methodological aspects such as the definition of system boundaries for recycling and incineration and the related allocation issues have been extensively discussed for several cases, including waste paper (Merrild et al., 2008), recycling of PET bottles into fibres (Shen et al., 2010) and cement (Chen et al., 2010). Frischknecht (2010) also recently discussed two intensely debated approaches on modelling the recycling of materials in LCA: the recycled content approach and the EoL recycling approach. The author concluded that harmonisation of the two approaches is unlikely, mainly due to the value assumptions underpinning these alternative strategies, and that there is actually "*no need to reach consensus in this respect*" (Frischknecht, 2010, p. 6). The author moreover concluded that the appropriate modelling approach should be defined by the commissioner of the study.

Building on this research and on the ISO framework, existing guidelines, technical specifications, and methods for environmental assessment of products – including carbon footprinting (e.g. WRI/WBCSD, 2011) and category rules for Environmental Product Declarations (EPD) (e.g. EN:15804, 2012) – have heterogeneously adopted these competing approaches. As a result, there is currently no single, widely accepted approach to modelling EoL and related secondary material production. This seems to be justified as long as different goal and scope of approaches and their application require different approaches to these allocation problems. More consistency seems to be desirable, however, if product policies within the Sustainable Consumption and Production (SCP) context are the focus.

1.2. EU policy initiatives for resource efficiency

A central aim of the European Commission's "Europe 2020 Strategy", as described in the "Roadmap to a Resource Efficient Europe", is to increase resource productivity and to decouple economic growth from resource use and its environmental impact (European Commission, 2011). Several strategies linked to "*transforming the economy onto a resource-efficient path that will bring increased competitiveness and new sources of growth and jobs through cost savings from improved efficiency, commercialisation of innovations and better management of resources over their whole life cycle*" have been identified. These include: "*sustainable consumption and production*" and "*turning waste into a resource*" (European Commission, 2011, p. 7).

In support of the sustainable production and consumption objective, the European Commission is currently engaged in two policy initiatives. The first is to: "*Establish a common methodological approach to enable Member States and the private sector to assess, display and benchmark the environmental performance of products, services and companies based on a comprehensive assessment of environmental impacts over the life-cycle ('environmental footprint')*" (European Commission, 2011, p. 7). The resulting Environmental Footprint (EF) Guides (Product Environmental Footprint – PEF, Organisation Environmental Footprint – OEF) provides a method for modelling the environmental impacts of the flows of material/energy and the emissions and waste streams associated with a product or organisation throughout its life cycle (European Commission, 2013a). The second initiative, the REAPro method, has been specifically developed to be used in the framework of various product policies, including the EcoDesign Directive (European Union, 2009), EU Ecolabel (European Union, 2010) and Green Public Procurement (European Commission, 2008). These two life cycle-based methods developed for product policy support necessarily includes specifications for modelling EoL and secondary material production processes.

1.3. Aims of the paper

This paper aims at analysing how EoL and secondary material production processes are modelled in environmental assessment methods of one product through its life cycle. The overall aim of this analysis is to discuss the suitability of different modelling approaches in product policy-support contexts. Towards this end, Section 2 introduces a subset of widely recognised methods (and associated equations) that were evaluated, along with the PEF and REAPro methods. In this section, the general approach for comparison of the methods is also presented. In Section 3, the original equations are re-expressed using a set of common terms in order to enable comparison. Section 4 presents the analysis and comparison of the equations prescribed in each of these methods against a set of relevant criteria. Section 5 discusses the relative merits and limitations of the PEF and REAPro methods compared to the other methods. Section 6 draws conclusions and provides perspective on future research needs.

2. Presentation of the methods and parameters

2.1. Selection of the methods

Three methods (and seven associated equations) which constitute a representative sample of recent international methods, as well as the PEF and REAPro methods (and four associated equations) were considered in our analysis.

The first method, called PAS2050:2011 (Publically Available Specification – Specification for the assessment of the life cycle greenhouse gas emissions of goods and services) was developed in the UK, co-sponsored by several departments of the UK government and published by BSI in September 2011 (BSI, 2011b). The method is an attempt to define an integrated and consistent approach for assessing the life cycle greenhouse gas emissions of products for use in the broad community and industry (BSI, 2011b; Sinden, 2009).

The second method, called BP X30-323, was developed in France under the laws Grenelle I of 2009 and Grenelle II of 2010 and was published in June 2011 (AFNOR, 2011). The method aims at defining harmonised practices when implementing the legislative request of quantifying environmental impacts of products throughout their life cycle, with the aim of declaring them to consumers.

The third method, defined in the ISO/TS 14067 Technical Specifications, aims at establishing internationally recognised principles, requirements and guidelines for the quantification and the communication of the carbon footprint of products (ISO, 2013). The method aims, in particular, to allow industries, governments, communities and other parties to consistently and transparently quantify emissions.

For the PEF Guide and REAPRO methods we refer to the ones in the introductory section (Section 1.2).

2.2. General approach of comparison

In the subsequent section, each of these selected methods is described in terms of (a) the objectives and scope of the method (including the system boundaries and specifically targeted products if any) and (b) the modelling approach for the production (i.e. use of virgin and recycled materials) and EoL stages (including the mathematical representation, i.e. "production/EoL" equations).

It should be pointed out that the analysis considers recycling and energy recovery but not (partial) re-use. The possibility to address re-use is, however, mentioned in the scope of each method, where relevant. The impact categories accommodated by each of the methods (and the related characterisation factors) are not addressed, neither is the required data type (i.e. generic or