Selecting representative products for quantifying environmental impacts of consumption in urban areas

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1. Introduction

Populations are becoming more urban than rural, creating concentrated areas with high consumption of products. Understanding and influencing the environmental impact of consumption within cities becomes therefore increasingly important. Although there have been several studies evaluating the environmental impact of consumption at the global, national, and regional scale, there are few methods currently available to estimate impact at the urban level. There is therefore a need for a systematic approach to select appropriate, region-specific representative products. This study combines material flow analysis with life cycle assessment to select representative products that can be used as proxies to assess the environmental impact of urban areas using life cycle impact factors. The selection was based on the following criteria: the top consumed products within a product category, consistent products with respect to time and geography, and product types with known high environmental impact. The representative products were identified for three Swedish cities: Stockholm, Gothenburg and Malmo, using sixteen years of annual urban-level material flow analysis data (1996–2011). A total of 71 products across 44 categories, were identified as representative of the 10,000 product types consumed in the urban areas analyzed. The method described in this study can be used by practitioners to identify representative products in any urban area with material flow data and allows for a more comprehensive and tailored analysis that what has been previously available.

Although there have been several studies evaluating the environmental impact of consumption at the global, national, and regional scale, (e.g. Bruckner et al., 2012; Giljum et al., 2014; Turner et al., 2007; Wiedmann et al., 2007), there are few methods currently available to estimate impact at the urban level. Consumption data is often applied to one of three main approaches to quantify the subsequent impact: ecological or carbon footprint, environmentally extended input-output tables, or life cycle assessment (LCA) coupled with various methods such as input-output tables (e.g., Munksgaard et al., 2005; Larsen and Hertwich, 2010). Life cycle assessment is a popular tool used to quantify the potential environmental impacts products in a life cycle perspective, from the “cradle” (e.g., resource extraction, production) to “grave” (e.g., disposal) (Bruijn et al., 2002). Several impact categories can be evaluated, such as climate change, resource depletion, toxicity, acidification, eutrophication, etc. Life cycle assessments have increasingly been used in connection with methodologies like IO as...
Several studies have called for a combination of MFA and LCA (Pincetl et al., 2012; Voet et al., 2004), which has already been applied for example at a university campus (Lopes Silva et al., 2015), at the European Union level (European Commission, 2012), but to a lesser extent at the urban level. However, the analysis is often limited to certain aggregated consumption categories, such as food and electricity (Lopes Silva) and food, water, transport fuels, building energy, metals, plastics, paper, glass, rubber, electronics, and construction materials (Goldstein et al., 2013). The Lopes Silva et al., 2015 study uses “bottom-up” data based on interviews and university documents while the Goldstein et al. uses data from previous urban metabolism studies. The urban metabolism data was obtained by both bottom-up data and assuming national average values (Goldstein et al., 2013). The European Commission Joint Resource Centre has also linked MFA and LCA in the European and national scale (European Commission, 2012; Huysman et al., 2016).

Due to recent advances in urban MFA, specifically the UMAN model (Rosado et al., 2014) that provides product-level consumption data for 10,000 product types, a comprehensive description of environmental impacts at the product-level in urban areas is possible. Life cycle impact profiles for all of the 10,000 products quantified with UMAN are, however, not available and there is a need to improve the possibility of using LCA profiles to describe an entire urban-system.

This study further develops the hybrid MFA-LCA approach by investigating the level of detail that LCA profiles need to have to combine with the UMAN model detailed consumption at production level. A new method for selecting representative products to support the quantification of consumption-driven environmental impact at the product level is suggested, based on the combination of product-level resolution of MFA and LCA profiles in order to evaluate the environmental impact of total (i.e. including all sectors: industry, public and private) consumption while providing the level of detail necessary for effective local policy decisions. The method can be used at any scale for which product-level consumption data is available, but is illustrated here at an urban scale. Sixteen years of urban MFA data obtained with the UMAN tool was used (Rosado et al., 2014). Therefore, the aims of this article are twofold: (1) to describe an integration procedure for the MFA and LCA data; (2) to define criteria for selection of representative products that allow for a satisfactory description of the environmental impact of consumption in urban areas.

In the next chapters, the method for selecting representative productions will be provided, focusing on the criteria selection process and the results of the selection of representative products will be presented and discuss using Swedish MFA data for the three largest metropolitan areas: Stockholm, Gothenburg and Malmo.

2. Method

The steps described in this study are presented in Fig. 1. Criteria for selecting representative products were developed by first analyzing MFA data to find potential representative product categories by weight, evaluating annual data for trends, then matching the data with relevant LCA profiles, followed by a preliminary LCA test which led to the final product list presented in Section 3.

2.1. Data integration

The connection between MFA and LCA at the product-level allows for the combination of physical quantities to LCA profiles. In this study, the combined nomenclature (CN) was used to connect the product types found in the MFA to LCA profiles. The CN is a publicly available system of codes used to classify goods for import and export and is used for both trade statistics and custom duties (The Combined Nomenclature, n.d.). This system comprehensively identifies all the material flows in an economy, increasing in complexity from natural resources and materials (for example an ore, stone etc.) to intermediate products and parts used in production as well as final products. The CN codes have multiple levels of detail, specified by the number of digits. The CN-8 (eight digits) is the most detailed level. As an example, the CN-2 code for dairy is 04, the CN-4 code for butter is 0405, and the CN-8 code for a dairy spread with a fat content greater than 60% but less than 70% is 04052030. An LCA profile can for instance be matched to the CN-4 product type, like “butter”. The CN is divided into 95–99 CN-2 product categories where the number of categories may vary slightly from year to year. Each CN-2 category is comprised of an average of 13 CN-4 product types (also depending on the year), which are then comprised of an average of 129 CN-8 products per CN-4 subcategory. Combined nomenclature is generally accepted for the MFA methods architecture, as for example in Economy-wide MFA method used by Eurostat for statistics on material consumption of EU states and the urban metabolism MFA model UMAN

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![Diagram](https://example.com/diagram.png)

**Fig. 1.** Overview of Data Integration and Representative Product Selection steps.
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