Science of the Total Environment 559 (2016) 192–203

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Life cycle environmental impacts of vacuum cleaners and the effects of European regulation

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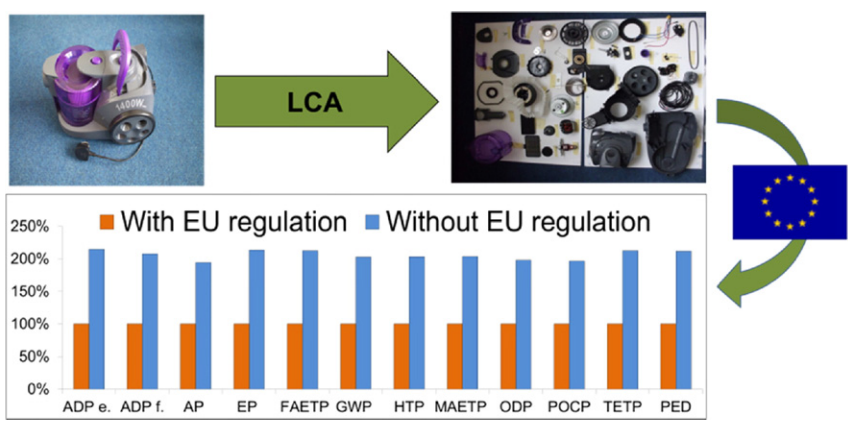
HIGHLIGHTS

- Over 200 M domestic vacuum cleaners in the EU consume 18.5 TWh electricity annually.
- First comprehensive LCA of vacuum cleaners to estimate the effects of EU regulation
- The eco-design regulation will reduce the EU impacts by 37%–44% by 2020.
- The WEEE directive will have a moderate effect, reducing the impact by <1%.
- Decarbonisation of electricity would decrease most the impacts by 6%–20% by 2020.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 21 December 2015
Received in revised form 15 March 2016
Accepted 20 March 2016
Available online 7 April 2016

Editor: Simon Pollard

Keywords:
Eco-design
Energy efficiency
Life cycle assessment (LCA)
Electricity decarbonisation
Waste electrical and electronic equipment (WEEE)

ABSTRACT

Energy efficiency of vacuum cleaners has been declining over the past decades while at the same time their number in Europe has been increasing. The European Commission has recently adopted an eco-design regulation to improve the environmental performance of vacuum cleaners. In addition to the existing directive on waste electrical and electronic equipment (WEEE), the regulation could potentially have significant effects on the environmental performance of vacuum cleaners. However, the scale of the effects is currently unknown, beyond scant information on greenhouse gas emissions. Thus, this paper considers for the first time life cycle environmental impacts of vacuum cleaners and the effects of the implementation of these regulations at the European level. The effects of electricity decarbonisation, product lifetime and end-of-life disposal options are also considered. The results suggest that the implementation of the eco-design regulation alone will reduce significantly the impacts from vacuum cleaners (37%–44%) by 2020 compared with current situation. If business as usual continued and the regulation was not implemented, the impacts would be 82%–109% higher by 2020 compared to the impacts with the implementation of the regulation. Improvements associated with the implementation of the WEEE directive will be much smaller (<1% in 2020). However, if the WEEE directive did not exist, then the impacts would be 2%–21% higher by 2020 relative to the impacts with the implementation of the directive. Further improvements in most impacts (6%–20%) could be achieved by decarbonising the electricity mix. Therefore, energy efficiency measures must be accompanied by appropriate actions to reduce the environmental impacts of electricity generation; otherwise, the benefits of improved energy efficiency could be limited. Moreover, because of expected lower life expectancy of vacuum cleaners and limited availability of some raw materials, the eco-

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http://dx.doi.org/10.1016/j.scitotenv.2016.03.149

design regulation should be broadened to reduce the impacts from raw materials, production and end-of-life management.

1. Introduction

Several studies have assessed life cycle environmental impacts of different electrical appliances and electronic products (Andrae and Andersen, 2010; Song and Li, 2015). The former include refrigerators (Monfared et al., 2014), dishwashers (Johansson and Björklund, 2010), ovens (Mudgal et al., 2011) and washing machines (Ardente and Mathieux, 2014). The impacts of electronic products studied in the literature include plasma TVs (Feng and Ma, 2009; Hischier and Baudin, 2010), computers (Choi et al., 2006; Duan et al., 2009; Teehan and Kandlikar, 2012) and monitors (Zhou and Schoenung, 2007), mobile phones (Andrae and Vaija, 2014) and e-books (Jeswani and Azapagic, 2015). However, the analysis of the life cycle environmental performance of vacuum cleaners has received little attention in literature with few studies available. For example, Lenau and Bey (2001) and Hur et al. (2005) proposed and tested different simplified life cycle assessment (LCA) methodologies using semi-quantitative inventory data of unspecified models of vacuum cleaners as examples. In both studies, the main objective was to compare the proposed methodologies and, therefore, these studies did not provide specific conclusions related to the environmental performance of these devices. A screening LCA on vacuum cleaners (AEA, 2009) was also performed as part of preparatory documents for the development of the European Union (EU) eco-design regulation for vacuum cleaners (European Commission, 2013a). The main objective of this study was to assess the environmental performance of different types of vacuum cleaner and to identify improvement opportunities. The study was performed with aggregated inventory data provided by manufacturers and specific data obtained by disassembly of certain elements (AEA, 2009). Only three environmental impacts were considered (global warming, eutrophication and acidification), in addition to some air emissions and heavy metals which were estimated at the inventory level only. The findings indicated that use of vacuum cleaners was the main hotspot and identified various alternatives to improve their energy efficiency and cleaning performance. However, as far as we are aware, a comprehensive LCA study of vacuum cleaners has not been carried out yet so that it is not known how the use stage affects other impacts and how much the other life cycle stages, such as raw materials and waste management, contribute to these. This is particularly pertinent in light of the European strategy on circular economy which promotes resource efficiency and waste minimisation (European Commission, 2014).

The power rating of vacuum cleaners has increased markedly since the 1960s, from 500 W to over 2500 W, persuading consumers that a "powerful" cleaner will perform better (AEA, 2009; Biček et al., 2014; Dyson, 2011). However, higher power does not necessarily lead to a better cleaning performance but does mean a lower energy efficiency, which dropped from 30–35% in the 1970s to below 25% in recent years without noticeable improvements in the cleaning performance (AEA, 2009).

More than 200 million of domestic vacuum cleaners are currently in use in the European Union (EU), with around 45 million sold annually and a market growth of 9% per year (European Commission, 2013b). The average annual electricity consumption by these devices in the EU was estimated at 18.5 TWh in 2010 (European Commission, 2013b), representing 0.6% of the total EU consumption (ENTSO-E, 2011) and equivalent to the annual electricity generation by five gas power plants (DECC, 2015). Vacuum cleaners, therefore, represent an important area of action to help reduce the environmental impacts from households. For that reason, the European Commission (EC) has recently developed an eco-design regulation to encourage manufacturers to produce more energy efficient vacuum cleaners without compromising product performance and economic feasibility (European Commission, 2013a). The regulation considers only most widely used domestic vacuum cleaners (i.e. upright and canister/cylinder) and excludes others, such as dry and/or wet, robot, battery-operated and floor-polishing devices.

Another important aspect considered by the EC to improve the environmental performance of household appliances is the recycling of waste electrical and electronic equipment (WEEE). The generation and treatment of WEEE is currently a rapidly growing environmental problem in many parts of the world. As the market continues to expand and product innovation cycles become shorter, the replacement of electric and electronic equipment accelerates, making electronic devices a fast-growing source of waste (Kiddee et al., 2013; Premalatha et al., 2014; Robinson, 2009; Song and Li, 2014; Widmer et al., 2005). To help address this problem, the WEEE directive aims to prevent, re-use, recycle and/or recover these types of waste (European Parliament, 2012). It also seeks to improve the environmental performance of all players involved in the life cycle of electrical and electronic equipment (producers, distributors and consumers) and, in particular, those involved directly in the collection and treatment of WEEE. Waste prevention and minimisation also contribute directly to improving resource efficiency which is at the core of the European 2020 strategy for creating a smart, sustainable and inclusive economy (European Commission, 2010).

Therefore, considering these policy drivers, the main objectives of this study are:

- to evaluate life cycle environmental impacts of vacuum cleaners and identify opportunities for improvements; and
- to assess the effects at the EU level of the implementation of the eco-design and WEEE regulations related to vacuum cleaners and provide recommendations for future research and policy.

As far as we are aware, this is the first study of its kind for vacuum cleaners internationally.

2. Methods

The LCA study has been conducted according to the guidelines in ISO 14040/44 (ISO, 2006a, 2006b), following the attributional approach. The assumptions and data are detailed in the following sections, first for the reference vacuum cleaner considered here and then for the study at the EU level.

2.1. Reference vacuum cleaner

2.1.1. System description and boundaries

Vacuum cleaners can be broadly categorised as upright and canister/cylinder type. In the upright design, the cleaning head is permanently connected to the cleaning housing, whereas in the cylinder type, the cleaning head is separated from the vacuum cleaner body, usually by means of a flexible hose. Cylinder vacuum cleaners represent 85% of the European market (AEA, 2009). Vacuum cleaners can have a disposable bag or they can be bagless with a reusable dust container. The European market shows an upward consumer trend towards low-cost bagless vacuum cleaners with high power rating, most of which are produced in China (AEA, 2009). Therefore, this study focuses on a