Journal of Cleaner Production xxx (2014) 1–11

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Life cycle assessment of a domestic induction hob: electronic boards

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ARTICLE INFO

Article history:
Received 21 December 2013
Received in revised form
13 March 2014
Accepted 4 April 2014
Available online xxx

Keywords:
Electronic boards
Induction hob
LCA

ABSTRACT

This study analyzes the environmental performance of the electronic boards used in the current generation of induction hob designed and assembled in Spain. A Life Cycle Assessment (LCA) has been performed, defining the functional unit as the electronic boards used in an induction cooktop with 4 hobs and 7.2 kW of nominal power. The electronic boards are two power electronic boards (ELIN PCBAs -Printed Circuit Board Assembly-), and one touch control electronic board (Touch Control PCBA). Each one has been thoroughly analysed having into account every electronic component. The software used to create the LCA model was SimaPro 7.3.3, using two databases Ecoinvent v2.2 and Chalmers CPM LCA Database.

The most relevant environmental impact in every category is caused by the two ELIN PCBAs. Touch Control PCBA has significant impact in Ozone Layer Depletion, although its value is four times lower than the emissions of one ELIN PCBA. Both ELIN PCBAs show similar environmental impact distribution. Components create between 70 and 85% of the total impact in most categories. Touch Control PCBA has a different environmental impact distribution from both ELIN PCBA.

This analysis of the environmental impact of the ELIN PCBAs and the Touch Control PCBA used in an induction hob has revealed that there are several clear areas for improvement, such as reducing the environmental impact of the components and improving its end-of-life treatment.

1. Introduction

During the last decade, the design of electronic products in Europe has been strongly influenced by new legislation. In order to lower environmental impact, the European Union has created several laws devoted to reduce the use of hazardous substances, known as RoHS (2002/95/EC) (European Parliament, 2003); the REACH (Regulation, Evaluation, Authorisation and Restriction of Chemicals) regulation to control chemicals (European Parliament, 2006); the WEEE (Waste Electrical and Electronic Equipment) directive enhances the recycling of electric and electronic equipment (European Parliament, 2012), and also introduced the ecodesign in energy-using products (EuP) (European Parliament, 2005) and energy related products (ErP) (European Parliament, 2009).

Induction hobs are affected by all these laws and are included in preparatory study of Energy-using Products, Lot 23, which focuses on domestic and commercial hobs and grills. That study shows that induction is the most efficient way of cooking commercially available. This product has an important volume in the EU market, a significant environmental impact, and great potential for improvement (BIO Intelligence Service and ERA Technology, 2011). EuP and ErP legislation has mainly focused on energy consumption, which is the main cause of environmental impact in this kind of products, and have introduced limits on standby consumption.

This study analyzes the environmental performance of the electronic boards used in the current generation of induction hob. The Spanish company which designs and assembles this induction hob sells more than half a million induction hobs per year in over 75 countries, and it is leader in Spanish home appliances sector.

An LCA allows us to identify the main types on environmental impact throughout the life cycle and find areas that can be improved in order to reduce the environmental impact. LCA has been applied to a wide range of products and services from mussel cultivation (Lozano et al., 2010) to wind turbines (Martínez et al., 2009, 2010), including food packages (Fernández et al., 2013), supply chain design (Longo, 2012; Bruzzone et al., 2009) or urban buses (García-Sánchez et al., 2012). Within the existing literature of

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http://dx.doi.org/10.1016/j.jclepro.2014.04.009
0959-6526/

Life Cycle Assessment studies, there are several based on electronic products, like TV sets (Song et al., 2012) (Hischier and Baudin, 2010) (Aoe, 2007), monitors (Kim et al., 2001), telecommunications exchange (Andrae et al., 2000), personal computers (Duan et al., 2009) cooker hoods (Bevilacqua et al., 2010). Recently Sikdar performed Life Cycle Assesment studies showing a detailed inventory of the electronic components used in Wifi Access points and Ethernet switches (Sikdar, 2011) (Sikdar, 2013). Andrae and Andersen (2010) also studied the consistency of LCA of laptops, PC, mobile phones and TV sets.

Other analysis focused on the environmental impact of printed wiring boards (PWB) (Lam et al., 2011) and also the end-of-life of PCB (Wang and Gaustad, 2012; Kasper et al., 2011; Duan et al., 2011) and also the recycling under WEEE legislation (Yamane et al., 2011). Herrmann et al. (2001) compared epoxy (FR4) based PWB against ceramic ones.

Several studies have analysed the impact of individual components, like RFID antennas (Kantha et al., 2012), integrated circuits (Taiariol et al., 2001; Andrae et al., 2004; Andrae and Andersen, 2011) and diverse semiconductor devices (Boyd, 2012). Andrae et al. (2005) also analysed a digital system telephone having into account its individual components.

Recently, a standard to carry out LCA of electronic product was published (ETSI, 2011). Focussing on ICT Equipment, Networks and Services. This Technical Specification has been used as a guide.

This paper focuses on the environmental impact of the electronic boards used in induction hobs, a high technology product with hundreds of different electronic components. The electronic boards are two power electronic ELIN(ELectronic INduction) PCBA (Printed Circuit Board Assembly), called ELIN Right PCBA and ELIN Left PCBA (ELINRPCBA and ELINLPCBA) and one Touch Control PCBA (TCPCBA). Each one has been thoroughly analysed having into account every electronic component.

Induction heating technology is not a recent development, as it is currently used in a wide range of applications, like cooking (Acero et al., 2008), welding (de Santana et al., 2006), sealing (Babini et al., 2003) and melting, hardening or brazing of metals (Fujita and Akagi, 1996; Kristoffersen and Vomacka, 2001; Noda et al., 1997).

The use of induction technology in cooking has been commercially available since the early 1990s. An induction hob uses cutting-edge electronic technology, employing high frequencies to generate an oscillating magnetic field, which heats ferromagnetic vessels through two effects, Foucault currents and magnetic hysteresis. Each burner has a spiral coil, known as inductor, which is operated from 20 kHz to 100 kHz, higher than audible range, and up to 5.5 kW (Acero et al., 2008). These currents are supplied by IGBT half-bridge series resonant inverter controlled. The resonant load is composed of the inductor wiring, the vessel, and a resonant capacitor.

The aim of this paper is to quantify the environmental impact of the ELINRPCBA, ELINLPCBA and TCPCBA used in an induction hob which belong to a representative example of an induction hob produced in Europe, by applying the ISO 14040 and 14044 standards of Life Cycle Assessment (ISO, 2006a) (ISO, 2006b).

This paper analyzes a product that is installed in several million homes worldwide, having into account each individual component, allowing us to understand its environmental behaviour and how each component affects the overall result.

2. Materials and methods

2.1. Goal and scope definition

The LCA models of ELINRPCBA, ELINLPCBA and TCPCBA have been developed with the help of producer's electronic design team. This company has provided samples of the PCBAs and components and has also helped contacting with some of the main product providers.

The main objective of this Life Cycle Assessment is to identify the main environmental impacts of the electronic components in an induction hob. This study has focused on analysing the electronic components used in the current induction hob generation that is commercialized. This product is completely developed and assembled in Spain. The research and development of this product has been carried out for 30 years, and currently the fifth generation of induction hobs is being sold.

Individual electronic components are produced in a wide range of countries by several suppliers: the ELIN PCBAs printed wiring boards are produced in China and assembled in Zaragoza, whereas the TCPCBA is produced in Germany. All these components are finally assembled in the Montaña factory (Zaragoza, Spain) to create the complete induction hob.

2.2. Functional unit

The functional unit has been defined as the ELINRPCBA, ELINLPCBA and TCPCBA used in a cooktop with 4 induction hobs. This induction ceramic hob has a width of 60 cm, and 7200 W of power at a voltage of 220–240 V and a frequency between 50 and 60 Hz. This induction hob is currently sold worldwide and the functional unit is used in a wide range of models. The main characteristic of this induction hob is the presence of 4 cooking zones, each one with variable 17-stage power settings. The dimensions, rated power and maximum power of each hob are shown in Table 1.

The main features of the PCBAs are automatic pan recognition, timer with buzzer, heat indicator for each zone, childproof lock, safety time switch off, small cookware detection and anti overflow protection.

2.3. System boundaries

As the goal of this paper is to analyse the environmental impact of the PCBAs, within the limits of the LCA model fall the production of the electronic components and PWBs, the transportation to Spain, the assembly, use stage and the end-of-life of the product (see Fig. 1). Outside the limits of the system fall the distribution to consumers. Although the aim of this study is to analyse the environmental impact of the PCBAs, following ETSI guidelines, the use phase have been included inside the limits of this study.

2.4. Inventory data and cut-off criteria

Each PCBA consists of a PWB and several hundred electronic components. Those components have a wide range of functions: resistors, inductances, capacitors, transistors, microcontrollers … There are two mounting technologies for those components: SMD (Surface-mount device) in which the components are placed onto the PCB's surface, and Through-hole, when leads are inserted into holes drilled in the PCB.

This study has been performed with internal data from the manufacturer. A detailed list of every electronic component was

Table 1
Dimensions and power characteristics of cooking units in hob.

Units	Diameter (mm)	Nominal power (kW)	Booster power (kW)
1	150	1.4	1.8
2	180	1.8	2.5
1	210	2.2	3.3