Influence of Mechanical Design on the Evolution of the Environmental Impact of an Induction Hob

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Abstract

Purpose This paper studies the influence of the mechanical design of five different induction hob generations (G1 to G5), which are currently installed in several million homes, on the evolution of their environmental impact.

Methods Life Cycle Assessment (LCA) has been applied using SimaPro 7.3.3 and EcoInvent v2.2 database. Samples of each design were obtained to generate a life cycle inventory. These induction hobs have been developed and produced in Zaragoza (Spain). The functional unit has been defined as all of the components influenced by the mechanical design of a cooktop with four induction hobs and a width of 60 cm, including every component except the electronic boards and the use phase, as they are not affected by the mechanical design. The limits of the LCA model include the production of the raw materials and energy, the manufacture and production processes, the distribution and the end of life.

Results and discussion This study has revealed that the differences in mechanical design highly affect the environmental impact, especially in the environmental categories of abiotic depletion and human toxicity due to the consumption of copper, steel and plastics. The manufacturing phase highly affects human toxicity, mainly due to the variation in PPS use. There is a decreasing tendency in the environmental impact from the first (G1) to the last generation (G5), as G5 causes the lowest burden in 8 out of 11 analysed categories. The different generations analysed in this paper show that the compact designs of induction hobs help to decrease the environmental impact, especially thanks to the reduction in wiring

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lengths. It is also important to enhance the wiring separation at the end-of-life phase, avoiding designs that hinder recycling processes.

Conclusions Compact designs and reduced wiring lengths help to reduce the environmental impact. The consumption of copper, steel, aluminium and polymers creates considerable impact, although the end-of-life phase reduces the burden created by metals, thanks to recycling. Manufacturing processes such as injection moulding also produce a noteworthy impact, especially in ozone layer depletion due to the inclusion of solvents in EcoInvent's injection moulding dataset. The impact caused by the distribution phase for this product is almost negligible in most categories.

Keywords: Induction hob, LCA, Environmental impact, Evolution, Mechanical design, Home appliance

1 Introduction

The manufacture of domestic appliances has high importance in the European Union in terms of employment and revenue. This sector, including supply and retailers, employs around half a million staff. Germany, Spain and Italy are the main producers of domestic electric hobs in the European Union. In 2008, 12 million units were produced at the EU level (BIO Intelligence Service and ERA Technology, 2011).

Although there are several cooking technologies with high market shares, such as gas or radiant heating technology, induction technology grew between 2002 and 2008 with an annual increase of 24%. In 2007, 19.8% of all domestic hobs used induction technology. Approximately 2.5 million induction hobs were sold in Europe in 2010, with an expected 6.5 million units per year to be sold by 2030. In 2025, this technology is expected to be 39.3% of all domestic hobs sales.

The European Parliament has developed several laws to improve energy efficiency and the environmental protection, by energy use and energy related products, including induction hobs: EuP (European Parliament, 2005) and ErP (European Parliament, 2009). Lot 23 of the preparatory study for domestic and commercial hobs and grills showed that the hob use phase creates more environmental impact (BIO Intelligence Service and ERA Technology, 2011), which is highly dependent on the electrical mix of each country. However, according to the European Committee of Domestic Equipment Manufacturers (CECED), there is a small margin for improvement in induction hob efficiency, because most heat losses are presently produced in the RF circuitry, and induction is currently the most efficient cooking method (BIO Intelligence Service and ERA Technology, 2011). The EU requirements have focused on improving the efficiency of non-induction hobs because induction technology already meets the highest efficiency requirements. This means that the ecodesign of induction hobs should focus not only on the use phase but on the entire life cycle, including on the raw materials, the production phase, the packaging, the distribution, the end of life, etc.

The aim of this paper is to analyse the influence of the mechanical design on the environmental impact of induction hobs. As a consequence, this paper focuses on all of the components that are influenced by the mechanical design, excluding the remainder of the components (the electronics and the use phase), as these two elements are not influenced by the mechanical design. To complete this study, LCA standards

ISO 14040 (ISO, 2006) and 14044 (ISO, 2006) have been applied to several induction hobs produced in Spain, which are representative of the average induction cooktops in Europe.

The influence of the mechanical design is analysed for five different generations of induction hobs, which are currently installed in several million homes. Generations 1 and 2 (G1 and G2) are characterized by having two parts: the induction hob unit and an external metal box that houses some components; in generations 3, 4 and 5 (G3, G4 and G5) all of the components are integrated into one induction hob unit.

To quantify the environmental impact caused by a product or service, Life Cycle Assessment (LCA) is used. A wide number of researchers have applied this technique, using it to analyse products from wind turbines (Martinez et al., 2009; 2010) to polymer composites (Das, 2011). Several home appliances have also been environmentally analysed: TV sets (Hischier & Baudin, 2010), air conditioners (Grignon-Massé et al., 2011), cooker hoods (Bevilacqua et al., 2010) and refrigerators (Ma et al., 2012). The environmental burden created by the electronic boards of an induction hob was previously analysed by Elduque et al. (2014).

Several authors have used Life Cycle Assessment to compare and analyse the differences between products or production processes: different mobile phone network generations were compared by Scharnhorst et al. (2006). Two different viticulture activities, biodynamic and conventional, were analysed by Villanueva-Reya et al. (2014). Copper recycling strategies were assessed by Rubin et al. (2014). Cofiring versus biomass-fired power plants were compared by Sebastián et al. (2011). The environmental impacts of two packaging options were analysed by Dhaliwal et al. (2014). The use of recycled natural fibres was compared in the Brazilian automotive sector (Pegoretti et al., 2014). Hydrogen production alternatives have also been compared by Cetinkaya et al. (2012) and Hajjaji et al. (2013). Recently, Hischier (2015) compared different television display technologies.

2 Methods

2.1 Goal and scope definition

To analyse the evolution of the different designs and compare them, a LCA model was developed. Samples of each design were obtained to generate a life cycle inventory. These induction hobs have been developed and assembled in Zaragoza (Spain).

The aim of this study is to assess the influence of the mechanical design on the evolution of the environmental impact caused by induction hobs. Although these induction hobs were produced in different years, the designs have been compared as if they were currently produced in the factory, as the aim is to compare the designs. This means that, although they were produced in the same factory in different years, the current auxiliary production consumptions and electrical mix have been used.

The LCA study includes the following stages: material production and manufacture, distribution, and end-of-life (Figure 1).

2.2 Functional Unit

The functional unit is defined as all of the components (the use phase is not included) influenced by the mechanical design in a cooktop with 4 induction hobs and a width of 60 cm. This definition includes every component, except the electronic boards, as they are directly influenced by the electronics and are not affected by the mechanical design.

2.3 System boundaries

As the aim of this study is to analyse the impact of the mechanical components of an induction hob; the limits of the LCA model include the production of raw materials and energy, the manufacture and production processes, the distribution and the end of life. Outside the limits of the system fall the electronic boards and the use and maintenance phases, as induction hobs are expected to be free of maintenance.

2.4 Inventory data and cut-off criteria

The mechanical design of an induction hob is mainly composed of a housing, four inductors, one vitroceramic glass, wiring and packaging.

As this study has been performed in collaboration with the company that designs, manufactures and sells these products, most information was obtained from internal data. An inventory was created for each design, identifying and weighing each component. Transportation between the suppliers and the factory has also been included using internal data. Distribution has been analysed using real European sales data.

The Life Cycle Inventory was developed using EcoInvent v2.2, one of the most used databases. Assignation between the inventory data and the EcoInvent datasets has been performed following the EcoInvent guidelines (Frischknecht & Jungbluth, 2007).

2.5 Assumptions

SimaPro 8.0.3.14 (Pré Consultants), has been used to create the LCA model (Goedkoop et al., 2013). The environmental impact has been calculated with CML LEIDEN 2000 v3.01 methodology (PRé Consultants, 2013). End point approaches have not been used to avoid subjectivity (Guinée, 2002). The following midpoint impact categories have been used: abiotic depletion, acidification, eutrophication, global warming (GWP100), ozone layer depletion (ODP), human toxicity, fresh water aquatic ecotoxicity, marine aquatic ecotoxicity, terrestrial ecotoxicity and photochemical oxidation. Although the use of this methodology is widespread, in recent studies some authors have shown that this methodology may underestimate the influence of CO_2 and N_2O in Acidification and Ozone layer depletion (ODP) categories (Andrae, 2012).

As instructed by ISO 14044 (ISO, 2006), allocation has been avoided using information directly related to the studied products. The 62635 IEC Technical Report (IEC, 2012) has been used to analyse the end of life phase. This product is under the WEEE directive (Waste of Electrical and Electronic Equipment) (European Parliament, 2012), meaning that it must be collected at the end of its life. It is assumed that every induction hob will be shredded in a WEEE plant, recycling the metals with high recovery yields (steel, aluminium and copper).

2.6 Life Cycle Inventory

To compare the mechanical design of different induction hobs and determine their environmental impact, a significant amount of inventory data were gathered. This information was divided as displayed in Figure 2:

- 2.6.1 Manufacturing: Components manufacturing and assembly
- 2.6.2 Distribution to consumers
- 2.6.3 End-of-life data

Although a detailed inventory was generated for each generation and was used in the LCA model, only the simplified inventory is shown because there are several hundred components.

2.6.1 Manufacturing: Components manufacturing and assembly

An induction hob has a wide range of components, such as the housing, the wiring, the inductors, the vitroceramic glass, etc. All of the parts included in the functional unit have been analysed. A summarized inventory of all generations is shown in Table 1, where the weight of all parts of the same material has been aggregated. Table 2 displays the EcoInvent datasets used for the most relevant materials.

The mechanical design varies in each generation, as shown in Figures 2 and 3, which show a comparison of the weight of the main materials of each design. Some of the key characteristics of these designs are:

- G1 and G2 are bulkier as they have two separate parts (the induction hob unit and the external steel box). These also create higher packaging volumes and wiring lengths.
- G2 also has a more complex design, with a higher number of parts that increase the material consumption. Its external control module also increases the overall wiring.
- G3, G4 and G5 have an integrated design but use different internal configurations.
- G3 has different type of inductors, copper wiring embedded in epoxy resin, which hinder recycling processes.
- G4 has a plastic housing that significantly reduces steel consumption in this design.

To assess the environmental burden created by the ceramic glass, as it is not currently available in EcoInvent, composition data were obtained from the manufacturer. The vitroceramic glass used is based on SiO_2, Al_2O_3 and Li_2O. Although a complete list of the composition percentages and chemical substances was obtained, these are not shown due to confidentially reasons. In spite of the inventory data being confidential, the vitroceramic glass inventory has been included in the study, and therefore, its environmental impact has been integrated in the calculations.

Production processes performed by suppliers outside the assembly factory have been calculated using the EcoInvent datasets, as displayed in Table 3.

The assembly of the components is carried out in Zaragoza. This assembly process has been included in the LCA model, taking into account the direct energy consumption and the auxiliary consumptions of the factory. The actual layout of the factory was used to study the assembly processes. A simplified flow chart is shown in Figure 4.

Travel distances for the raw materials and components have also been taken into account. A milk run truck is used to gather most supplies, reducing transportation distances. Other components are also transported to the factory by truck. The freight ship alternative is only used for the parts produced in China.

2.6.2. Distribution

The induction hobs produced in Zaragoza are mainly sold in the European market. Using internal sales data, a distribution scenario of 1800 km has been defined. The weight of the appliance directly affects the environmental impact of the distribution phase. Euro IV logistic trucks (Transport, lorry >32t, EURO4/RER U) have been used to model this phase.

2.6.3 End of life

As most induction hobs are sold in Europe, these are expected to end its life in a WEEE treatment plant, where the hobs will be dismantled and treated. Recycling has been considered following the EcoInvent guidelines, considering the avoided material and assuming that it will be used in new products. Table 4 displays the EcoInvent datasets used for land filling and the recycling percentages.

3 Results

After performing the Life Cycle Inventories, these were introduced in SimaPro to quantify and compare the environmental impacts using the characterization factors of the CML method.

The global environmental impacts of the five generations are shown and compared. Then, the influence of each LCA phase (raw materials and manufacturing, distribution and end of life) is also studied in detail.

3.1 Global environmental impact and comparison between the generations

The global environmental impact results are displayed in Table 5 for each impact category according to CML methodology. The G1 design is used as the benchmark, or base impact (100%), showing its overall impact in each category. The results of the remainder of the designs (from G2 to G5) are shown perceptually (refer to G1).

3.2 Manufacturing phase

The impacts created in the manufacturing phase are shown in the following table (Table 6).

3.3 Distribution phase

The environmental impacts created in the distribution phase are directly related to the weight of the appliance because the distribution scenario is the same for all designs, as shown in the LCI section. As the weight changes between the generations, the relative importance of the distribution phase on the global impact is shown in Table 7.

3.4 End-of-life phase

The end-of-life phase results are shown in Table 8. As this phase is directly related to the materials used in each design, instead of comparing this phase to G1, it is analysed showing the environmental impact reduction achieved by the end-of-life treatments in each design.

4 Discussion

The next subsections discuss the global environmental impact, the comparison between designs and the different LCA phases.

4.1 Discussion of the global environmental impact and comparison between generations

In most environmental categories, the G2 induction cooktop creates the highest environmental impact as it uses more materials than the rest of the designs, as previously shown in the inventory section. There is a decreasing impact tendency from G2 to G5. The G5 cooktop creates the lowest environmental impact in 8 out of 11 cases, as shown in Figure 5.

- Abiotic depletion: This impact category is especially relevant in G1 and G2 with a higher overall copper consumption and in G3 where copper in the inductor wiring has not been considered recyclable. On the other hand, G5 has an 89% lower impact than the first generation, thanks to reduced material consumption.
- Abiotic depletion (fossil fuels) and Global warming (GWP100a): The differences between the designs in these impact categories are smaller. G3 and G5 show the lowest environmental impact (-7.6% and -18.2%).
- Ozone layer depletion (ODP) and Human toxicity: G4 and especially G2 show a higher impact (344% higher than G1 in Human toxicity) than the rest of the designs due to the higher use of injected plastics.

- Fresh water aquatic ecotoxicity and Marine aquatic ecotoxicity: From G2 to G5 there is a clear decreasing tendency as G2 creates the highest impact and G5 creates the lowest in both categories because the use of copper highly influences these results.
- Terrestrial ecotoxicity: This impact is higher in G2 and G3 (+7.5% and + 33.7%). In this case, the latest design (G5) does not have the lowest impact, due to the consumption of aluminium.
- Photochemical oxidation: Photochemical oxidation is especially high in G2 due to copper and PPS use (+60% higher than G1). The lowest value is obtained in G3 (-16.7%).
- Acidification and Eutrophication: As in both of the aquatic ecotoxicity categories, there is a clear decreasing tendency from G2 to G5, thanks to copper use reduction.

The next subsections show the environmental impact analysis of the manufacturing phase.

4.2 Discussion of the manufacturing phase

These impacts are primarily caused by the consumption of raw materials, especially by the use of copper in wiring, aluminium and steel in the chassis, and by nylon and PPS in the plastics parts.

- Abiotic depletion: The most significant impacts in this category are created by copper consumption, which is highest in G2 due to longer wiring (+6.16%).
- Abiotic depletion (fossil fuels) and Global warming (GWP100a): These impacts are mainly generated by steel and aluminium consumption in the first two generations due to the external box and by aluminium in G3, G4 and G5. High PPS use is also relevant in G2.
- Ozone layer depletion (ODP): The organic solvents used in injection moulding and the production of PPS and aluminium generate high impacts in this category. The highest impact is created by G2 (+41%).
- Human toxicity: This impact is mainly caused by the use of PPS plastic in the inductor supports. This is especially significant in G2, generating the highest impact (+285.1%).
- Fresh water aquatic ecotoxicity and Marine aquatic ecotoxicity: Copper generates most of the environmental impact in both of these categories. As G2 uses the highest quantity of copper, it also creates the highest impact (+26.2% and + 24.7%).
- Terrestrial ecotoxicity: This is mainly caused by aluminium and steel consumption, which is the highest in G2 (+23.2%).

- Photochemical oxidation: Photochemical oxidation is mainly created by PPS, copper, steel and aluminium, thus G2 also creates the highest impact (+52.5%).
- Acidification and Eutrophication: These effects are mainly produced by the consumption of copper, thus G1 and G2 show the higher environmental impacts.

4.3 Discussion of the distribution phase

The environmental impacts created in the distribution phase are directly related to the weight of the appliance because the distribution scenario has been considered the same for all designs, as shown in the LCI section. In most environmental categories, the distribution phase creates between 0.27 % and 6.14%. The impact is lower than the range in human toxicity (between 0.06% and 0.25%), and higher, up to 8.85%, in ozone layer depletion impact category.

4.4 Discussion of the end-of-life phase

The end of life treatment reduces the environmental burden of every studied impact category because the recycling processes a percentage of the materials that are recycled to produce a decrease bigger than the impact created by the materials that are landfilled. However, due to the diversity between the designs, there are significant differences in the reductions. The impacts are mainly reduced with the recycling of copper and aluminium, meaning that the overall environmental impacts are highly sensitive to improper end of life treatments.

- Abiotic depletion: Copper recycling particularly reduces the environmental effects in this category, especially in G4 and G5 (-81.7% and -91.5%). On the other hand, in G3, the copper in the inductors is embedded in epoxy resin and is considered non-recyclable; there is only a small reduction in the environmental burden.
- Abiotic depletion (fossil fuels) and Global warming (GWP100a): As the steel and aluminium consumptions are quite relevant in G1 and G2, they also create significant impact reductions when recycled at the end-of-life phase (-23.6% and -22.9%).
- Ozone layer depletion (ODP): Low environmental impact reductions (between -7 % and -13%) are achieved in the end of life phase as the impacts in the manufacturing phase are mainly caused by the solvents used in the injection production processes.
- Human toxicity: This impact is mainly caused by the use of PPS plastic. Because this plastic is not recycled, this environmental burden is not significantly reduced in most designs.

- Fresh water aquatic ecotoxicity and Marine aquatic ecotoxicity: The ecotoxicity impacts show a similar tendency in the end-of-life phase, thanks to copper recycling. The lowest reduction is achieved in G3 as copper from the inductors is not recycled.
- Terrestrial ecotoxicity: The terrestrial ecotoxicity impact is reduced by the recycling of aluminium and steel, achieving a 52.1% reduction in G5.
- Photochemical oxidation: This impact is diminished thanks to recycling of the copper, steel and aluminium. Significant reductions are achieved in all designs (between -14.3% and -23.1%).
- Acidification and Eutrophication: These effects are lessened by copper recycling. The lowest reduction is again achieved in the G3 design.

5 Conclusions

The environmental burden created by the mechanical design of five different induction cooktop generations has been assessed. There is a decreasing tendency in the environmental impact, meaning that the last generation, G5, creates the lowest burden in 8 out of 11 analysed categories.

The mechanical design especially influences the global impact in the environmental categories of abiotic depletion and human toxicity, as both categories showed higher variations between designs due to the differences in the consumption of copper, steel and plastics. The manufacturing phase highly affects human toxicity, mainly due to the variation in PPS use.

The different generations analysed in this paper show that the compact design of induction hobs helps to decrease the environmental impact, thanks to the reduction in wiring lengths. It is also important to enhance wiring separation at the end-of-life phase, avoiding designs that hinder recycling processes.

The consumption of copper, steel, aluminium, nylon and PPS create significant impacts, although the end-of-life phase significantly diminishes the burden created by metals, thanks to recycling. Manufacturing processes such as injection moulding also produce a noteworthy impact, especially in ozone layer depletion due to the inclusion of solvents in EcoInvent's injection moulding dataset.

The impact created by the distribution phase is almost negligible in most environmental categories, except for ODP, GWP and both of the abiotic depletion categories.

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Compliance with Ethical Standards

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Tables

Table 1 Inventory of materials per design

Material Weight (g)	G1	G2	G3	G4	G5
Steel	7480	6874	2466.1	457	2688
Copper	1440	1865	801.7	1125	825
Aluminium	1205	1644	1655	1519	1360
Ferrite	636	864	718	496	721
Vitroceramic glass	2500	2968	2986	2903	2986
PA66	56	0	707	1999	1022
PET	0	0	1116	0	0
PPS	0	1559	0	760	648
PVC	368	443	103.8	161	106
Epoxy	0	120	96	0	0
LDPE	0	0	86	86	86
ABS	244	0	0	0	0
PP	56	0	0	0	0
Paper	360	360	360	345	360
Cardboard	1051	1051	570	285	285
EPS	853	853	466	466	467

Table 2 EcoInvent dataset selection for materials

Material	EcoInvent
ABS	Acrylonitrile-butadiene-styrene copolymer, ABS, at plant/RER U
Steel	Steel, low-alloyed, at plant/RER U
Aluminium	Aluminium, production mix, at plant/RER U
Cardboard	Packaging, corrugated board, mixed fibre, single wall, at plant/RER U
Copper	Copper, at regional storage/RER U
EPS	Polystyrene, expandable, at plant/RER U
Ferrite	Ferrite, at plant/GLO U
LDPE	Polyethylene, LDPE, granulate, at plant/RER U
Nylon 66	Nylon 66, glass-filled, at plant/RER U
PPS	Polyphenylene sulfide, at plant/GLO U
PVC	Polyvinylchloride, at regional storage/RER U

Table 3 EcoInvent dataset selection for production processes

Process	EcoInvent dataset
Injection moulding	Injection moulding/RER U
EPS moulding	Foaming, expanding/RER U
Plastic film extrusion	Extrusion, plastic film/RER U
Steel sheet rolling	Sheet rolling, steel/RER U
Aluminium sheet rolling	Sheet rolling, aluminium/RER U
Aluminium extrusion	Section bar extrusion, aluminium/RER U
Copper wire drawing	Wire drawing, copper/RER U
Welding	Welding, arc, steel/RER U
Energy consumption	Electricity, medium voltage, production ES, at grid/ES U

Table 4 End-of-life scenario and EcoInvent dataset selection

Material	% Recycling	Landfilling dataset
Steel	93	Disposal, inert material, 0% water, to sanitary landfill/CH U
Stainless steel	93	
Aluminium	90	
Copper	93	
Paper	65	Disposal, paper, 11.2% water, to sanitary landfill/CH U
Cardboard	65	Disposal, packaging cardboard, 19.6% water, to sanitary landfill/CH U
Glass	0	Disposal, glass, 0% water, to inert material landfill/CH U
Filled plastics	0	Disposal, plastics, mixture, 15.3% water, to sanitary landfill/CH U
PS	0	Disposal, polystyrene, 0.2% water, to sanitary landfill/CH U
PP	70	Disposal, polypropylene, 15.9% water, to sanitary landfill/CH U
PE	70	Disposal, polyethylene, 0.4% water, to sanitary landfill/CH U
PVC	0	Disposal, polyvinylchloride, 0.2% water, to sanitary landfill/CH U
Wood	0	Disposal, wood untreated, 20% water, to sanitary landfill/CH U

Table 5 Global environmental impacts

Impact category	Unit	G1	G1	G2	G3	G4	G5
Abiotic depletion	kg Sb eq	1,167E-03	100%	108,12%	100,30%	32,29%	10,51%
Abiotic depletion (fossil fuels)	MJ	7,874E+02	100%	118,59%	92,39%	100,62%	81,81%
Global warming (GWP100a)	kg CO2 eq	5,474E+01	100%	114,57%	92,64%	98,01%	82,63%
Ozone layer depletion (ODP)	kg CFC-11 eq	5,878E-06	100%	142,43%	96,44%	108,36%	81,98%
Human toxicity	kg 1,4-DB eq	1,373E+02	100%	443,87%	75,42%	209,25%	94,31%
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	8,608E+01	100%	131,40%	86,83%	74,17%	52,46%
Marine aquatic ecotoxicity	kg 1,4-DB eq	2,113E+05	100%	126,65%	95,93%	76,87%	53,74%
Terrestrial ecotoxicity	kg 1,4-DB eq	1,355E-01	100%	107,47%	133,74%	75,16%	78,71%
Photochemical oxidation	kg C2H4 eq	2,117E-02	100%	159,76%	83,28%	97,89%	86,39%
Acidification	kg SO2 eq	6,568E-01	100%	77,75%	53,82%	55,49%	44,71%
Eutrophication	kg PO4--- eq	3,620E-01	100%	115,03%	74,80%	71,46%	49,85%

Table 6 Manufacturing phase environmental impacts

Impact category	Unit	G1	G1	G2	G3	G4	G5
Abiotic depletion	kg Sb eq	2,429E-03	100%	106,16%	48,52%	84,60%	59,33%
Abiotic depletion (fossil fuels)	MJ	1,031E+03	100%	117,48%	82,15%	90,45%	80,51%
Global warming (GWP100a)	kg CO2 eq	6,729E+01	100%	115,88%	85,92%	95,17%	83,58%
Ozone layer depletion (ODP)	kg CFC-11 eq	6,588E-06	100%	141,54%	92,43%	106,50%	83,91%
Human toxicity	kg 1,4-DB eq	1,665E+02	100%	385,09%	64,64%	193,24%	111,20%

Fresh water aquatic ecotoxicity	kg 1,4-DB eq	1,105E+02	100%	126,15%	72,35%	79,62%	63,61%
Marine aquatic ecotoxicity	kg 1,4-DB eq	2,897E+05	100%	124,68%	78,33%	85,41%	65,33%
Terrestrial ecotoxicity	kg 1,4-DB eq	2,420E-01	100%	123,22%	104,18%	83,87%	91,97%
Photochemical oxidation	kg C2H4 eq	2,708E-02	100%	152,46%	75,93%	96,98%	87,85%
Acidification	kg SO2 eq	7,490E-01	100%	82,81%	51,71%	61,26%	51,34%
Eutrophication	kg PO4--- eq	4,428E-01	100%	112,93%	64,25%	76,22%	56,20%

Table 7 % of impact of the distribution phase in the global environmental impact

Impact category	Unit	G1	G2	G3	G4	G5
Abiotic depletion	kg Sb eq	0,82%	0,86%	0,60%	1,75%	5,91%
Abiotic depletion (fossil fuels)	MJ	6,14%	5,91%	4,91%	4,22%	5,71%
Global warming (GWP100a)	kg CO2 eq	5,77%	5,75%	4,60%	4,07%	5,32%
Ozone layer depletion (ODP)	kg CFC-11 eq	8,85%	7,09%	6,78%	5,65%	8,23%
Human toxicity	kg 1,4-DB eq	0,25%	0,06%	0,24%	0,08%	0,20%
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	0,35%	0,31%	0,30%	0,33%	0,51%
Marine aquatic ecotoxicity	kg 1,4-DB eq	0,35%	0,32%	0,27%	0,32%	0,50%
Terrestrial ecotoxicity	kg 1,4-DB eq	1,07%	1,14%	0,59%	0,99%	1,04%
Photochemical oxidation	kg C2H4 eq	1,97%	1,41%	1,75%	1,39%	1,74%
Acidification	kg SO2 eq	1,90%	2,79%	2,61%	2,37%	3,24%
Eutrophication	kg PO4--- eq	0,94%	0,93%	0,93%	0,91%	1,43%

Table 8 Reduction of the overall environmental impact due to the end of life phase

Impact category	Unit	G1	G2	G3	G4	G5
Abiotic depletion	kg Sb eq	-51,98%	-51,09%	-0,73%	-81,67%	-91,49%
Abiotic depletion (fossil fuels)	MJ	-23,65%	-22,93%	-14,13%	-15,06%	-22,42%
Global warming (GWP100a)	kg CO2 eq	-18,65%	-19,57%	-12,29%	-16,22%	-19,57%
Ozone layer depletion (ODP)	kg CFC-11 eq	-10,78%	-10,22%	-6,91%	-9,22%	-12,82%
Human toxicity	kg 1,4-DB eq	-17,54%	-4,96%	-3,79%	-10,71%	-30,07%
Fresh water aquatic ecotoxicity	kg 1,4-DB eq	-22,07%	-18,83%	-6,47%	-27,41%	-35,74%
Marine aquatic ecotoxicity	kg 1,4-DB eq	-27,06%	-25,91%	-10,68%	-34,36%	-40,01%
Terrestrial ecotoxicity	kg 1,4-DB eq	-44,02%	-51,18%	-28,14%	-49,84%	-52,10%
Photochemical oxidation	kg C2H4 eq	-21,84%	-18,10%	-14,28%	-21,11%	-23,14%
Acidification	kg SO2 eq	-12,31%	-17,66%	-8,73%	-20,58%	-23,63%
Eutrophication	kg PO4--- eq	-18,23%	-16,71%	-4,80%	-23,34%	-27,47%

Figure Captions

Fig. 1 Life Cycle Assessment boundaries

Fig. 2 Cutaway images of the analysed induction hobs

Fig. 3 Comparison of the material weight distribution between designs

Fig. 4 Simplified flowchart of the assembly process

Fig. 5 Comparative global environmental impact results

Figures

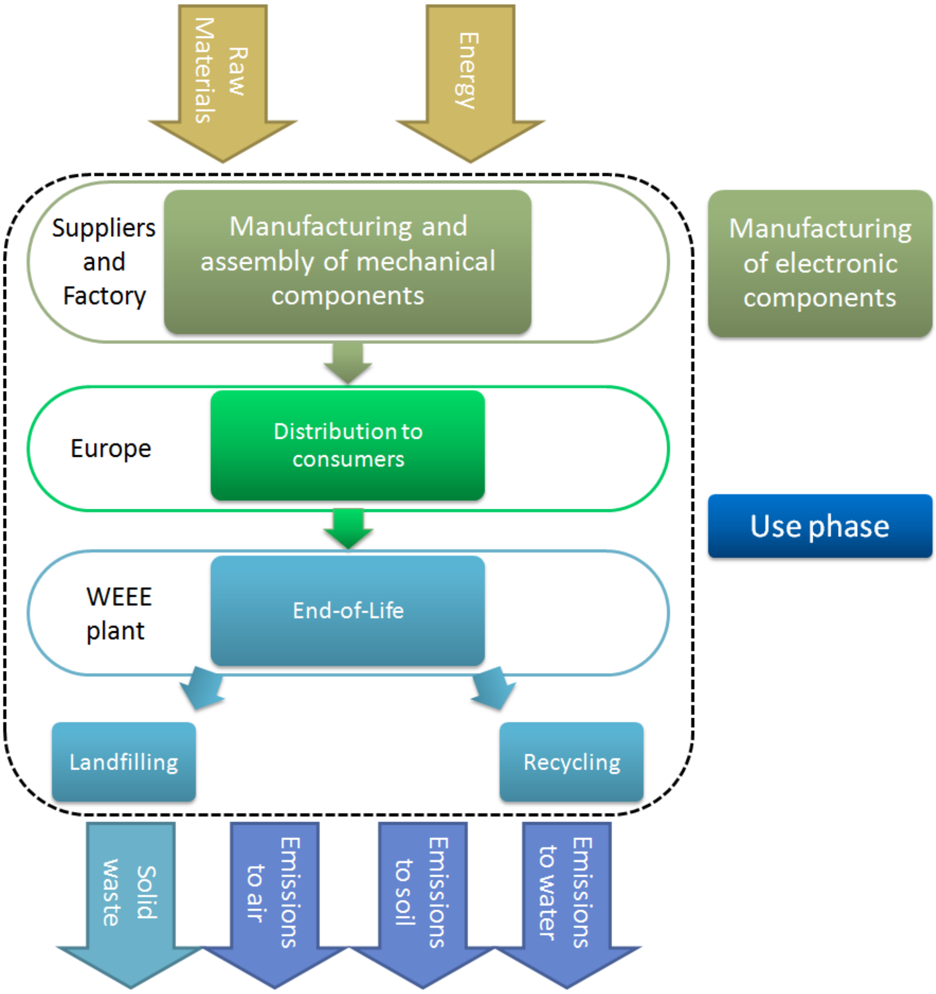

Fig. 1 Life Cycle Assessment boundaries

Fig. 2 Cutaway images of the analysed induction hobs

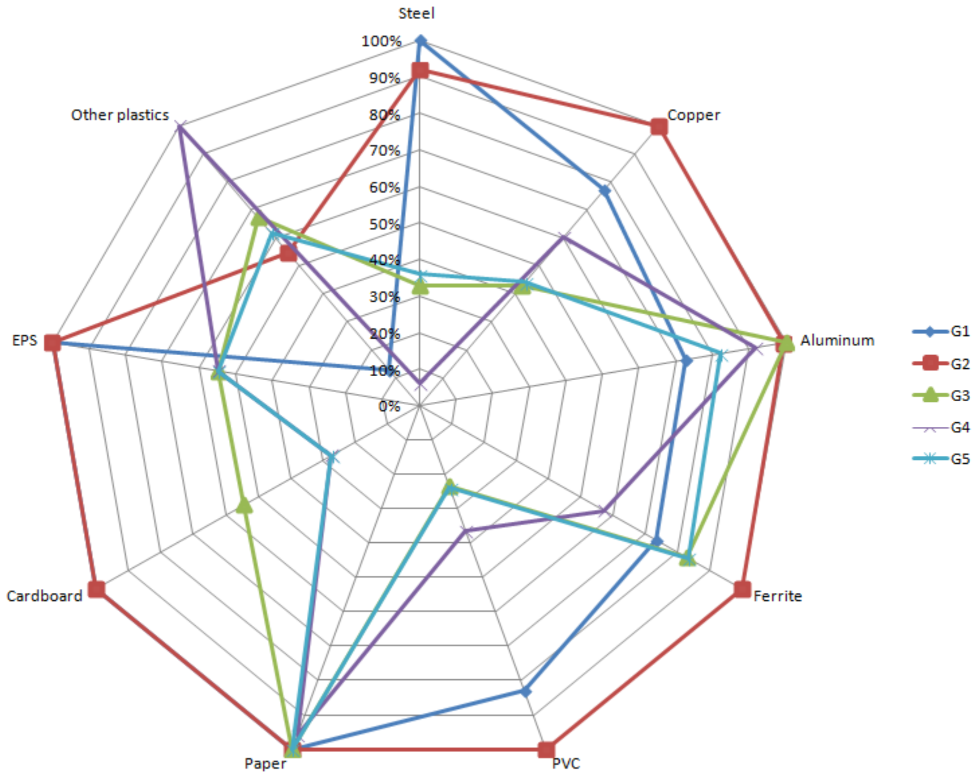

Fig. 3 Comparison of the material weight distribution between designs

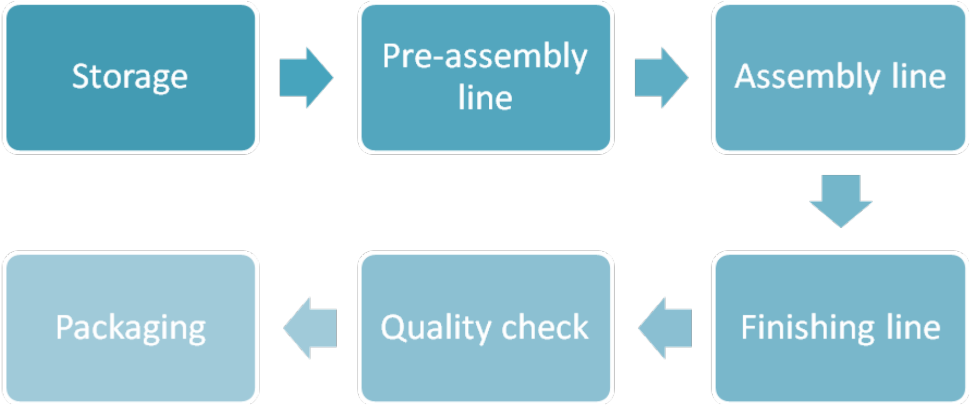

Fig. 4 Simplified flowchart of the assembly process

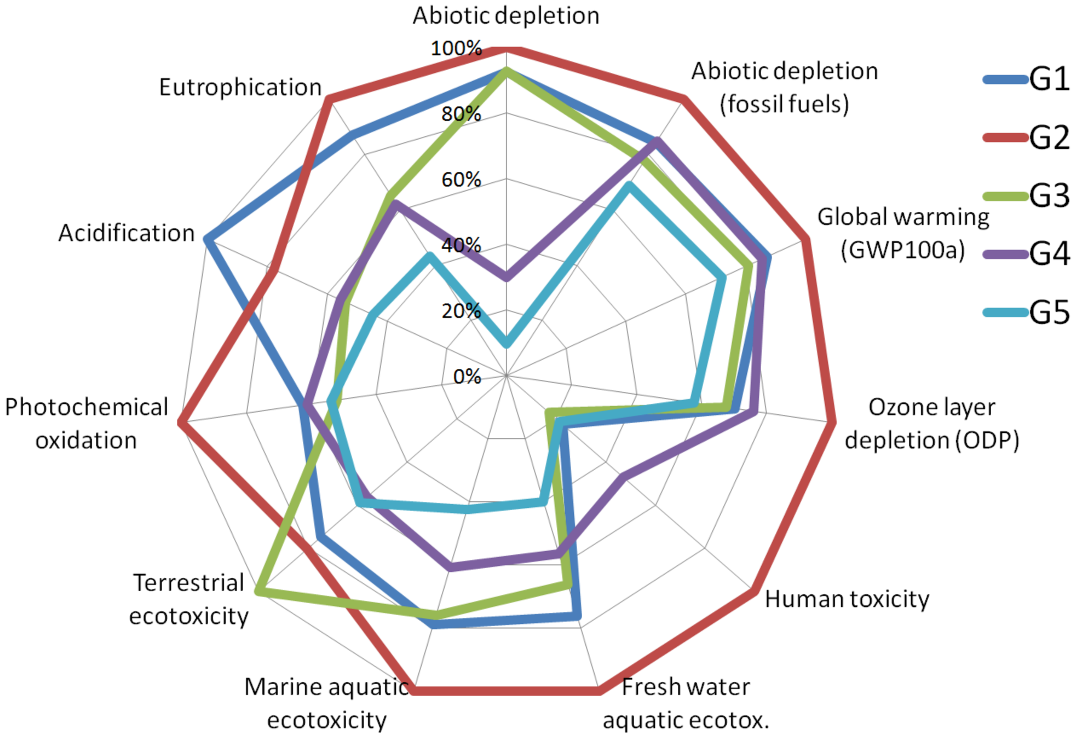

Fig. 5 Comparative global environmental impact results