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Comparative life cycle assessment of cooking appliances in Italian kitchens

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ABSTRACT

The paper aims to analyse and compare the environmental performances of the most widely used cooking appliances (the induction hob vs. the gas hob) considering a typical Italian scenario in terms of food, family and social habits. Cooking appliances are subject to energy labelling, and they represent the most impacting system inside households. This study was performed in accordance with the international standard, ISO 14040/14044, by using an attributional Life Cycle Assessment (aLCA). The functional unit is defined as the "preparation of a complete homemade meal (lunch) for 20 years consumed by a four-member family in Italy". This study shows the dominance, in terms of environmental impact, of the induction hob with respect to the gas hob for most of the selected midpoint indicators. In particular, the induction hob accounts for more than 60% of the climate change and ozone depletion impact categories and more than 70% of the metal depletion category. The same trend is also noticed in the end-point categories (human health, ecosystem qualities and resources) and for the Cumulative Energy Demand indicator. Based on the experimental evidence of this work, the use phase is the most important due to the different energy carriers (natural gas vs. electrical energy). This finding is the result of the nature of the energy carrier (the electricity grid mix) in the Italian scenario, which is mainly based on non-renewable sources. In addition, concerning the production phase of the two appliances, the induction hob shows a relevant dominance in terms of the human toxicity and metal depletion impact categories due to the use of rare metals and coppers in the cooktop part manufacturing. The outcomes obtained from this study may be used by household manufacturers to improve the performance and design solutions of their appliances as well as by end users in their selection of cooking technologies.

1. Introduction

Cooking appliances such as ovens, hobs and range hoods have been subjected to European (EU) energy labelling and eco-design requirements since 2015. Looking at the European energy consumption reports, household appliances represent the highest impacting system after space and water heating. This category excludes appliances for auxiliary cooking, e.g., microwave ovens, kettles, coffee makers, etc. (EC, 2013; EC, 2014a). As a consequence, the need for investigating the environmental consequences of appliances over the whole life cycle represents a significant issue and is also in accordance with the recommendations contained in the recent Circular Economy Action Plan (EC, 2014b; EC, 2015), which encourages the reduction of the environmental load of these products and the adoption of strategies for its reduction. According to the EUROSTAT definition, the products belonging to the cooking appliances are electric cookers with and without ovens, separate electric ovens, gas-only cookers, combined gas-electric cookers, and solid fuel-fired cooking stoves (EUROSTAT, 2013). Among these, by analysing statistical data (Palmer et al., 2013), electric and gas cookers were found to be the most used, and data coming from the cooking appliance producers confirm that they are intensively used in daily meal preparation. For this reason, the community interest in the environmental impact of the preparation of homemade meals has been growing over time.

Data regarding sales and production confirm the relevance of this sector. Germany, Italy, Spain and France are the main

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producers of domestic electric hobs, and approximately 12 million units are produced at the EU level (EU-25), while for gas cooking appliances, nearly 50% of their production inside the EU is represented by the UK and Italy, and approximately 2.7 million units are produced at the EU level (EU-25) (BIO Intelligence Service, 2011a). Italy is one of the European countries in which the two technologies are present. Whereas gas equipment is commonly used for meal preparation, induction hobs represent a brand-new technology in Italy. Therefore, a comparison of these technologies may shows interesting outcomes and supports responsible choices by consumers. Gas hobs are widespread in Italian kitchens due to the availability and low cost of natural gas compared with the cost of electrical energy. Induction hobs are a growing cooking technology due to their high efficiency in terms of both energy consumption and cooking performance (Villani and Presutto, 2012).

The Life Cycle Assessment (LCA) literature about household appliances is broad, e.g., TV sets (Hischier and Baudin, 2010), air conditioners (Grignon-Massé et al., 2011), cooker hoods (Bevilacqua et al., 2010) refrigerators (Ma et al., 2012), kettles (Ayoub and Irusta, 2014) and vacuum cleaners (Gallego-Schmid et al., 2016). Now, with the advent of the IoT (Internet of Things), such analyses have been coupled with the use of smartphones as household appliances auxiliaries for management, monitoring and additional aspects (e.g., recipes, alarms, etc.) (Andrae and Vaija, 2017). Several authors have used LCAs to compare and analyse the differences between products or production processes. As an example, regarding product technologies, Vignali (2017) has analysed different domestic boilers, Scharnhorst et al. (2006) have compared different mobile phone generations and Andrae (2015) have compared different office computing systems. However, few of these investigations were focused on cooking appliances such as induction or gas hobs. The study conducted by Pina et al. (2015) analysed the influence, in environmental terms, of five different induction hob configurations; this study had a very specific objective, and for this reason, it excluded from the analysis the electronic boards, as well as the use and maintenance phases, focusing only on those components affected by mechanical design. In line with the objectives of that study, the environmental analysis of the use phase was excluded, thus limiting the research due to the highly significant importance of this phase in the entire product life cycle impact. The long product lifetime and the relatively high energy consumption create, indeed, a massive environmental impact, and therefore, their quantification becomes interesting. The study of Elduque et al. (2014) analysed the environmental burden created by the electronic boards of an induction hob; in this case, the analysis was limited to this specific element of the product, and consequently, the study does not allow for a clear picture of the environmental impact related to the meal cooking with hobs. Jungbluth (1997) presented a comparison of different cooking alternatives by means of an LCA. In particular, attention was focused on the energy vector used to produce the heat needed to cook by means of a gas stove and an oven using natural gas or liquefied gas, an electric range and oven, a microwave oven and a wood stove in Switzerland. This study presents a very interesting analysis; however, this paper is now nearly 20 years old, and consequently, in addition to a supersized database and method used to model and to quantity a product's environmental impact, the evolution of technologies makes the results not applicable for current cooking solutions.

The current work attempts to overcome these limits and has the objective to analyse the environmental performance of the most commonly used cooking appliances (the induction hob vs. the gas hob). This study uses the guidelines outlined by the attributional LCA (aLCA) approach. The aLCA system modelling approach has been chosen with the aim to make a comparative analysis of both types of equipment by using the inputs and outputs attributed to the functional units of a product system (Baitz, 2016). In this case, the attributional approach allows for the estimation of the environmental load of the two cooking alternatives in the same scenario, highlighting the differences in the results (e.g., climate change). This study does not consider the effect in terms of environmental impacts caused by the replacement of one technology (e.g., a gas hob) with a new one (e.g., an induction hob), which is a typical consequential life cycle analysis.

The goal of this analysis is to provide another decisional support parameter in the selection of the most sustainable system for meal preparation and to create consumer awareness of the technology used for food cooking, which is considered one of the most important points of heat/energy consumption in residential buildings. This analysis has been performed considering a typical Italian scenario in terms of food, family and behaviours. Whereas the hobs belong to energy using product category, the use phase assumes a relevant role and was modelled using real consumption data that have been directly derived from measured product test cases.

2. Methods

According to the normative (ISO, 2006a; ISO, 2006b), an attributional LCA comparison analysis requires a clear and fair definition of the goal and scope of the study (Schmidt Rivera et al., 2014). In particular, the comparison is made on two products capable of fulfilling the same function (what), for the same time period (when) and for the same quantity of food (how much) (EC, 2016). The functional unit selected for the comparison is defined as “the preparation of a complete homemade meal (lunch) for 20 years that would be consumed by a four-member family in Italy”. The “typical” Italian meal represents the average amount of food consumed on a normal working day by an average Italian family. Specifically, the meal is composed of the following:

- 350 gr of pasta (spaghetti);
- 100 gr of tomato sauce as a condiment;
- One (1) omelette made out of three (3) eggs; and
- Four (4) boiled zucchini.

This menu can be prepared by the following procedure:

- Boil approximately 3 L of water in a large pot; once the water boils, place 350 gr of spaghetti into the water and let it cook for approximately 10 min;
- Cook four slices of tomato in a small pan for 20 min;
- Cook 3 eggs in a small pot for 5 min; and
- Boil approximately 1 L of water in a medium pot, and then place 4 zucchini into the water and let them cook for 5 min.

A large heat supply is needed for the pasta, while both the vegetables and the tomato sauce require a medium heat flow. The eggs could be easily cooked using a small heat supply. Thus, the preparation of such a meal implies the use of a cooking area equipped with at least four heat sources.

Obviously, the Italian and the Mediterranean cultures in general are characterised by a large variety of “typical” meals; however, the one previously described appropriately represents the food habits of Italy (Guerrero et al., 2010; Nuvoli, 2015; Renna et al., 2015; Sahyoun and Sankavaram, 2016).

The functional unit refers to a lifespan of 20 years, which