To what extend does a sporting good impact on the environment and how to communicate?

A case study of a cycling product

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Abstract

In recent years, different studies have explored the environmental impacts of sport from different point of views, for instance about sporting events, recreational activities and sport facilities. However, a further area of concern exists associated with sporting in general, and it is represented by sporting goods which is still explored in a limited number of studies. In this context, the aim of this study is to quantify to what extent sporting goods impact on the environment and define how to communicate their environmental burdens to stakeholders. The final intent is to support companies in the integration of environmental impact information into their communication reporting. In order to reach our aim, a sporting good of a seldom investigated sport has been selected as case study, namely a cycling pad. The selected cycling pad weights 40 g and it is composed of a base and a cover both produced with textile and polyurethane foam. The methodology chosen to conduct this study is a combination of life cycle assessment (LCA) methodology according to ISO 14040 and ISO 14044 to quantify the impacts of the product and of ISO 14021 to identify the communication requirements. The steps of the combined methodology were: identification of the scope definition, development of the life cycle inventory, assessment of the environmental impacts and development of a self-declared environmental claim. The system boundaries for the LCA study include the process units according to a "from cradle to gate" application and the functional unit chosen for this study is: "One pad for technical cycling shorts, including primary packaging". The primary data are collected for energy and resources' consumption, waste and emissions generated during the production of the pad under study. The results show that the most significant impacts are associated with the utilization of polyurethane foam and energy consumption for the coupling and thermoforming phases. In addition, our study highlights the impact associated with distribution separately, revealing to what extent the impacts increase for all the categories, in particular for the climate change and ozone depletion. The outcome of the study was the development of a self-declared environmental claim in accordance with the requirements of ISO 14040, ISO 14044 and ISO 14021 standards. The novelty of this study is that this is the first combined analysis of LCA and self-declared environmental claims about the environmental impacts of sporting goods and can be a common practice to integrate environmental communication in companies' reporting. This abstract relates to SDG12+Target:12.6. This contribution relates to the topic of the conference because it proposes a combined methodology to encourage companies to communicate environmental impacts and see the environment as a competitive lever.

Keywords: sporting goods, cycling pad, life cycle assessment, environmental communication, sport sustainability.

1. Introduction

The European trade in sporting goods with the rest of the world reached the value of 21.3 billion Euros in 2017 showing a significant increase by 4.5 billion Euros in comparison with 2007 (Eurostat, 2020). Italy showed the largest trade surplus in Europe with export values almost twice as high as imports, associated with the export of boats and water sport equipment. Other European States recording a high export to imports ratio are Bulgaria and Hungary, due to bicycles' exports, and Romania, due to ski equipment and sport footwear. The largest European exporters of sporting goods are Germany, the Netherlands, Italy and Belgium (Eurostat, 2020). In terms of extra European imports, the main sporting goods imported are sport footwear, boats and water sports equipment, gymnastic, athletic and swimming equipment and bicycles, representing the 85% of total extra European imports (Eurostat, 2020; Eurostat 2018). Through the database developed by Andreff and Andreff (2009), it is revealed that sporting goods trade represents a range between 0.33% and 0.53% of all traded goods and that Europe is competitive in skis trade, Germany in boats, skis and table tennis trade, while Italy is competitive in sportswear, surfs, skates and gymnastic equipment trade. Based on their database, Andreff and Andreff (2009) argued that developed countries can gain advantages in sports goods trade increasing specialization in sport equipment and innovative products with improved quality. According to Subic et al. (2012) the sporting goods industry is characterized by mass volume production and distributed manufacturing across different geographical regions, with high levels of resources consumption, waste and environmental emissions. Subic et al. (2012) developed a sustainable manufacturing framework and capability assessment tool for companies producing sports apparels and footwear and identified three areas for sport sustainability, namely resource efficiency, emissions' reduction and management practices.

As stated by Casper and Pfhal (2015) sport creates environmental impacts like everything else in life, associated with general operations, events' hosting, sporting facilities and spectators' attendance (Casper and Pfhal, 2015). Several authors analyzed the implications of sporting on tourism, recreation and natural environment (Babi et al., 2019; Bazzanella 2019; Botella-Carrubi et al. 2019; Malchrowicz-Mośko et al., 2019) and of sport facilities (Chappelet 2008; Bunds et al., 2019; Meza Talavera et al., 2019; Triantafyllidis and Davakos 2019). Other authors analyzed the implications of sporting management in different fields, for instance McCullough et al. (2016) explored examples from different sport organizations to classify their efforts in terms of environmental sustainability proposing actions to manage environmental issues, Moser et al. (2019) explored the influence of sustainability strategies of sport clubs to motivate spectators and supporters and Orr and Inoue (2019) highlighted that sport industry, especially outdoor and winter sports, can affect climate change. In this context, Trail and McCullough (2019) highlighted that the sport industry is improving its commitment to the natural environment but sport organizations implement campaigns for sustainability in differ way not standardized. Thus, they proposed a method to evaluate sustainability initiatives within the sport industry and the response of sport participants.

If we focus on the application of methods to calculate environmental impacts related to sport, it is apparent that several authors have explored this issue, with reference to events organization, such as Dolf and Teehan (2015), Edwards et al. (2016), Triantafyllidis et al. (2018) Tòffano Pereira et al., (2019) and Wicker (2019) and sport facilities, such as Hedayati et al. (2014) and Ip et al. (2018). Karaaslan et al. (2018) performed a comparative life cycle assessment of sport utility vehicles with different fuel options and Uberti et al. (2018) applied an approach which combined eco-innovation, technical factors and life cycle assessment for designing a low environmental impact off-road motorcycle. However, if we shift the attention to technical clothing, we can find a limited number of applications. Gül et al. (2015) developed a procedure for non-leather shoes in the context of the Product Environmental Footprint using sport shoes as an example and showing that the hotspots on climate change are consumption of electricity, polyurethane and nylon and Moazzem et al. (2016) calculated the carbon footprint of a polyester sports shirt. An analysis of a sporting good was conducted by Ribeiro et al. (2019) who performed a technical, economic and environmental evaluation of a snowboard made of three alternative materials, namely carbon, glass and flax fiber reinforced plastics. They showed that life cycle evaluations can support the design and development of sporting products.

Subic et al. (2009) highlighted the need for sporting goods industry to embrace sustainable design based on the fact that sporting products have a shorter life cycle than years ago and disposal rates and waste have increased. They argued that the request of performance materials in sports equipment and apparel have increased the burdens on the environment, as also highlighted by Scherer et al. (2018).

In this context, the aim of this study is to quantify to what extent sporting goods impact on the environment and define how to communicate their environmental burdens to stakeholders. The final intent is to support companies in the integration of environmental impact information into their communication reporting.

In order to reach our aim, a sporting good of a seldom investigated sport has been selected as case study, namely a cycling pad. The cycling pad is the most important component of a cycling short as it supplies protection at a perineal and ischiatic level. Several studies about its protective functions have been conducted (Marcolin et al., 2010). The novelty of this study is that this is the first combined analysis of LCA and self-declared environmental claims about the environmental impacts of sporting goods and can be a common practice to integrate environmental communication in companies' reporting.

2. Methods

The methodology chosen to conduct our study is a combination of the life cycle assessment (LCA) methodology according to ISO 14040 (ISO, 2020a) and ISO 14044 (ISO, 2020b) and of the requirements of ISO 14021 (ISO, 2016) for self-declared environmental labels. The steps were: identification of the scope definition, development of the life cycle inventory, assessment of the environmental impacts and the elaboration of environmental claims. Figure 1 is a scheme representing the main steps for the combination of LCA with the development of self-declared environmental claims. The cycling pad selected for our study weights 40 g and it is composed of a base and a cover both in coupled material (Table 1), it is a for long distance cycling, on road.

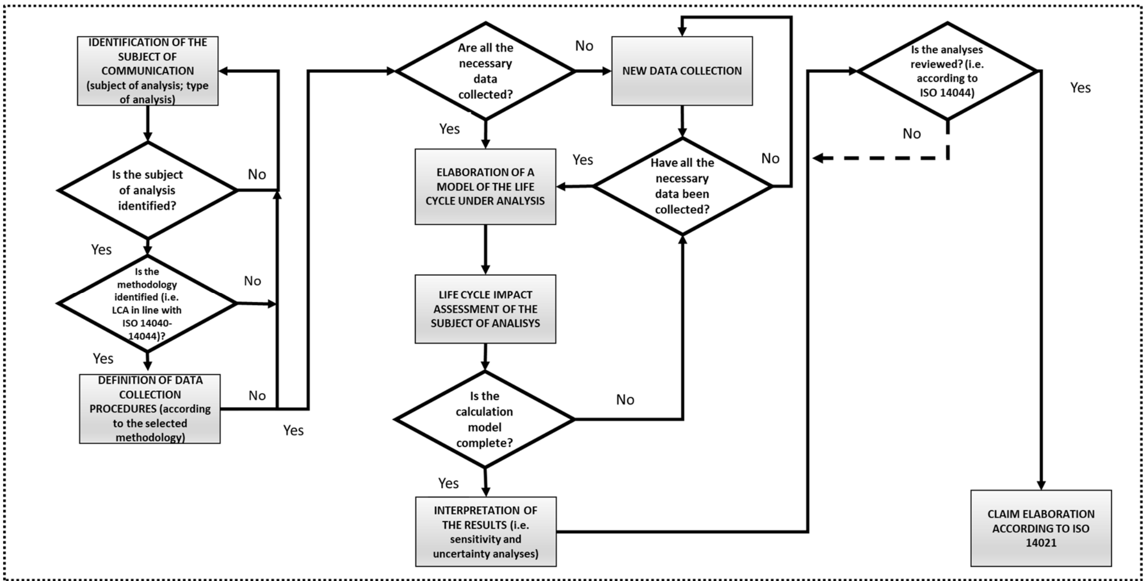

Figure 1. *Scheme representing the main steps for the combination of LCA with the development of self-declared environmental claims*

Table 1. *Composition of the pad under study*

Component	Material	Type of material
Base	Textile and foam	Textile: Polyamide 80% and Elastane 20% Polyurethane foam
Cover	Textile	Polyamide 100%

The production process consists of the following phases: shearing of the base and cover, skiving of the base, thermoforming, cooling and packaging. The shearing phase has the aim of giving shape to the base and the cover; the skiving phase eliminates excess foam from the base and avoid the formation of uncomfortable compressions; the thermoforming process consists in the union of the cover and the base through a special mold. The system boundaries for this study include the process units according to a "from cradle to gate" application as reported in Figure 2.

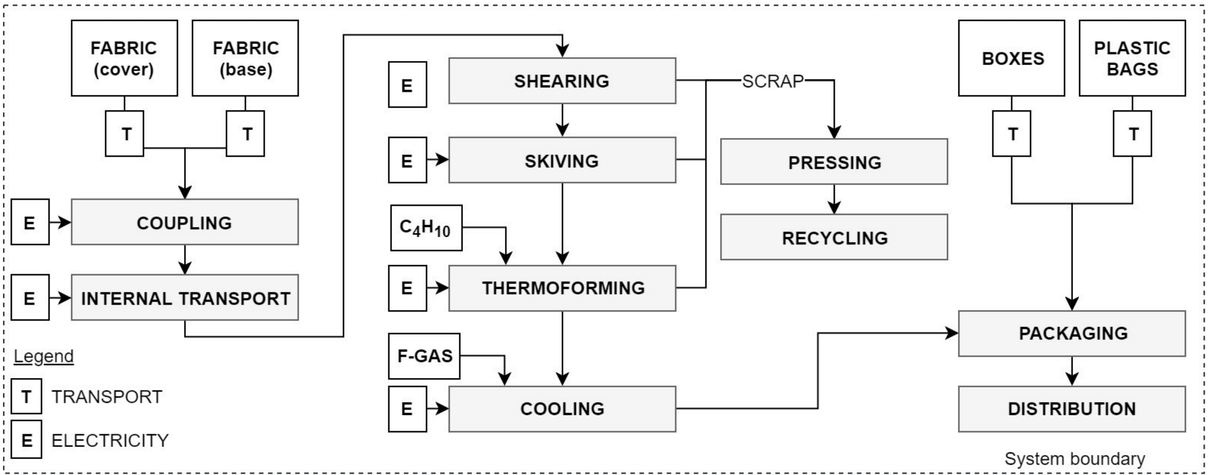

***Figure 2**. System boundaries.*

The functional unit was defined by the function of the examined product, i.e. providing support on a saddle. Consequently, the functional unit chosen for this study is: "One pad for technical cycling shorts, including primary packaging". The pads have different weights and different thicknesses in general. However, despite the differences they maintain the same function. For this reason, a defined weight or thickness is not indicated within the definition of the functional unit. A pad is not a product intended to be sold to the consumer directly, but to companies that sew one pad in each short. Even if it is therefore a component of a finished product, a pad has a specific function. However, for "from cradle to gate" LCA studies a declared unit is defined rather than a functional unit usually, because at the gate of the manufacturing company it is generally not possible to know what will happen next. From this perspective, it was decided to refer also to a declared unit defined as: "1 kg of pads for technical cycling shorts, including primary packaging". Therefore, the results relating to 1 kg of pads were also calculated.

The primary data were collected at the company producing the pad in 2019. Table 2 shows the primary information collected and the data sources. In the event that primary data were not available, secondary data obtained through the consultation of scientific literature and internationally recognized databases were used (Table 3).

As regards the textiles used for the base and the cover, it was necessary to conduct a study of the scientific literature to understand the main processes of polyamide production and the related energy consumption. This information was obtained from the study of van der Velden et al. (2014), as reported in Table 4. As regards the coloring of textiles, it was assumed that that the color constitutes 2% of the textile composition. In this study, the allocation intended as "co-product allocation" was avoided as follows: the consumption of raw materials regards only the product under study, the energy consumptions of the different process steps were measured and then compared to invoices, regarding the consumption of packaging materials the final sales unit contains only the products under study. It was necessary to proceed with the allocation intended as "co-product allocation" in the following cases: the consumption for lighting and heating was allocated by comparing the total plant consumption with the total quantity of pads produced in 2019; the consumption of the forklift for the products under study was allocated by comparing the total hours of work with the total quantity of pads produced.

The methodology chosen to evaluate the potential environmental impacts is the ReCiPe Midpoint (H) method, described by Goedkoop et al. (2013). The results are calculated with reference to the functional unit (one pad) and the declared unit (1kg) and the main contributors are identified. The distribution phase, even if outside the defined system boundaries, is analyzed through a sensitivity analysis to investigate to what extent it can affect the obtained results.

Table 2. *Primary data and primary sources used for this study.*

Process units	Primary data	Primary sources
Transport of input materials	Distance travelled, type of fuels	Purchase invoices and interviews to suppliers
Materials used for base production	Quantity and type	Operating control documents
Materials used for cover production	Quantity and type	Operating control documents
Packages	Quantity and type	Operating control documents
Manufacturing	Input flows, output flows, waste produced, energy consumption	Operating control documents and invoices Energy supplier documents
Internal transport with electric forklift	Worked hours	Operating control documents
Distribution	Distance travelled, type of fuel	Sales invoices and interviews to clients

Table 3. *Secondary data and secondary sources used for this study.*

Process units	Secondary data	Secondary sources
Transport of input materials	Vehicle combustion processes: emissions, maintenance, use of the road network, fuel consumption	Transport freight lorry 7.5-16 metric ton EURO3 RER transport freight lorry 7.5-16 metric ton EURO3 (Ecoinvent 3.2)
Materials used for base production	Textile production process and foam production processes	Nylon 6 {RER}| production Nylon 6-6 {RER}| production Polyurethane, flexible foam {RER}| production (Ecoinvent 3.2)
Materials used for cover production	Textile production process	Nylon 6 {RER}| production Nylon 6-6 {RER}| production
Packages	Packaging production	Corrugated board box {RER}| production Polyethylene, low density, granulate {RER}| production (Ecoinvent 3.2)
Manufacturing	Energy production process	Electricity, low voltage {IT}| electricity voltage transformation from medium to low voltage (Ecoinvent 3.2)
Internal transport with electric forklift	Energy production process	Electricity, low voltage {IT}| electricity voltage transformation from medium to low voltage (Ecoinvent 3.2)
Distribution	vehicle combustion processes: emissions, maintenance, use of the road network, fuel consumption	Transport, freight, aircraft {RER}| intracontinental (Ecoinvent 3.2)

Table 4. *Secondary data for textile manufacturing processes.*

Process units	Primary data	Primary sources
Materials used for the production of the base	Spinning and weaving processes: 0.5 + 2.56 kWh / kg Textile colouring: 3.75 kWh / kg Extrusion for elastane: 1.7 kWh / kg Quantity and type	van der Velden et al. (2014) Operating control documents
Materials used for the production of the cover		

The environmental claims were developed according the requirements of ISO 14040, ISO 14044 and ISO 14021. The objective identified for the environmental claims are: i) provide accurate and verified environmental information that does not lead to misinterpretations; ii) improve the image on the market, iii) stimulating environmental improvements. The following requirements were considered according to ISO (2016):

- The claims must be clear and specific,

- The claims will not contain information relating to sustainability in general terms,

- The life cycle of the products will be considered (according to the LCA study),

- No comparative assertions will be made.

3. Results and Discussion

Table 5 shows the results of the impact assessment for one pad, identifying the contribution of the process units on the total overall environmental impact for each category.

The groups identified in Table 5 are:

• Textiles. The impacts associated with the use of polyamide and elastane are grouped here.

• Foam. The impacts associated with the use of polyurethane foam are included in this group.

• Transportation. The impacts associated with the transport of raw materials and auxiliary materials (boxes and bags for packaging) and internal transport by electric forklifts are grouped.

• Manufacturing: The impacts associated with the energy consumption of the coupling phase, but also of the previous weaving, colouring and finishing phases of the textiles are grouped. This analysis group covers also the impacts due to the shearing, skiving, thermoforming, cooling, packaging and the waste produced during the manufacturing process, the consumptions for lighting and heating.

The results for each impact category are illustrated below, highlighting the main responsible processes.

For the Climate change (CC) impact category, a value of 9.47E-01 kg CO2 eq is obtained due to the emissions of cabon dioxide equal to 7.74E-01 kg CO2 eq and methane equal to 1.30E-01 kg CO2 eq mainly due to the production processes of polyol and toluene diisocyanate for the production of the polyurethane foams with which the fabrics are coupled. These processes contribute more than 50% of the impact. The textile production processes, i.e. polyamide production, contribute to 12% of the total impact; while electricity consumption contributes to 17% of the impact.

Table 5. *Environmental impacts of the product analysed (1 pad).*

Impact category	Unit	Total	Textiles	Foam	Transport	Manufacturing
Climate change	kg CO2 eq	9.47E-01	1.86E-01	5.36E-01	6.35E-03	2.18E-01
Ozone depletion	kg CFC-11 eq	4.34E-08	3.76E-09	1.37E-08	3.82E-09	2.21E-08
Terrestrial acidification	kg SO2 eq	3.57E-03	6.05E-04	2.10E-03	5.84E-05	8.15E-04
Freshwater eutrophication	kg P eq	1.36E-04	1.42E-05	6.64E-05	1.06E-06	5.47E-05
Marine eutrophication	kg N eq	6.88E-04	9.21E-05	5.58E-04	1.50E-06	3.63E-05
Human toxicity	kg 1,4-DB eq	1.11E-01	9.60E-03	5.30E-02	2.47E-03	4.56E-02
Photochemical oxidant formation	kg NMVOC	2.78E-03	5.33E-04	1.72E-03	4.07E-05	4.93E-04
Particulate matter formation	kg PM10 eq	1.55E-03	2.13E-04	1.03E-03	2.13E-05	2.87E-04
Terrestrial ecotoxicity	kg 1,4-DB eq	4.37E-05	2.94E-06	2.49E-05	2.75E-06	1.31E-05
Freshwater ecotoxicity	kg 1,4-DB eq	8.76E-03	8.05E-04	2.42E-03	7.84E-05	5.45E-03
Marine ecotoxicity	kg 1,4-DB eq	7.92E-03	7.18E-04	2.32E-03	8.87E-05	4.79E-03
Ionising radiation	kBq U235 eq	3.43E-02	4.37E-03	5.09E-03	4.86E-04	2.44E-02
Agricultural land occupation	m2a	5.09E-02	5.72E-03	3.18E-03	1.06E-04	4.19E-02
Urban land occupation	m2a	3.11E-03	2.82E-04	8.60E-04	3.36E-04	1.63E-03
Natural land transformation	m2	4.55E-05	4.81E-06	7.67E-06	2.30E-06	3.07E-05
Water depletion	m3	2.40E-02	2.74E-03	1.34E-02	2.97E-05	7.89E-03
Metal depletion	kg Fe eq	1.44E-02	1.07E-03	6.97E-03	6.76E-04	5.69E-03
Fossil depletion	kg oil eq	3.33E-01	5.44E-02	2.10E-01	2.20E-03	6.58E-02

For the impact category ozone depletion (OD), a value of 4.34E-08 kg CFC-11 eq is obtained mainly due to the emissions of Halon 1211 (38%), chlorinated hydrocarbons (20%) and Halon 1301 (20%) into the air. Halon 1211 emissions are mainly associated with the coupling and thermoforming phase and the related energy consumption. The emissions of chlorinated hydrocarbons and Halon 1301 are mainly caused by the foam production processes.

For the terrestrial acidification (TA) impact category, a value of 3.57E-03 kg SO2 eq is obtained mainly due to the emissions of sulfur dioxide and nitrogen oxides in the air associated with the processing of the expanded polyurethane of which the foam is composed.

For the freshwater eutrophication (FE) impact category, a value of 1.36E-04 kg P eq is obtained due to the phosphate emissions in water associated with the polyurethane foam and the coupling process because of the energy consumption.

For the marine eutrophication impact (ME) category, a value of 6.88E-04 kg N eq is obtained due to the emissions of nitrates (38%) and nitrogen (37%) in water associated with the production of the expanded polyurethane of which the foam is made (75%) and the production of textiles (10%).

For the human toxicity impact (HT) category, a value equal to 1.11E-01 kg 1.4-DB eq is obtained due to the emissions of manganese (49%) and mercury (10%) in water. Manganese emissions are mainly associated with the foam production process (33%) and the coupling phase (40%); while mercury emissions are associated almost entirely with the foam manufacturing process (88%).

For the photochemical oxidant formation (POF) impact category, a value of 2.78E-03 kg NMVOC is obtained due to the nitrogen oxides (64%) emitted into the air associated with the polyurethane of which the foam is made and the polyamide of the base.

For the impact category particulate matter formation (PMF), a value of 1.55E-03 kg PM10 eq is obtained due mainly to the emissions of sulfur oxides (32%) and nitrogen oxides (25%) in air associated with the use of foam.

For the terrestrial ecotoxicity impact category (TET), a value of 4.37E-05 kg 1.4-DB eq is obtained due to the release of chlorine (37%) and copper (15%) into the air. Chlorine releases are mainly associated (96.5%) with the use of polyurethane foam; while copper releases are also associated with transport, in particular the wear of vehicles.

For the freshwater ecotoxicity impact category (FET), a value of 8.76E-03 kg 1.4-DB eq is obtained due to the emissions of copper (71%) and nickel (10%) in water. Copper emissions are mainly due to coupling (45%); while nickel emissions are mainly due to foam (36%) and coupling (38%).

For the marine ecotoxicity impact category (MET), a value of 7.92E-03 kg 1.4-DB eq is obtained mainly due to the emissions of copper (68%) and nickel (11%) in water. Copper emissions are mainly associated with coupling (45%); the nickel emissions to the foam (36%) and to the coupling (38%).

For the ionising radiation (IR) impact category, a value of 3.43E-02 kg Bq U235 eq is obtained due mainly to the emissions of Radon-222 (60%) in the air associated with the coupling processes.

For the agricultural land occupation (ALO), urban land occupation (ULO) impact categories and natural land occupation, the impacts obtained are mainly due to the coupling phase.

For the water depletion impact category (WD), a value of 2.40E-02 m3 is obtained due to the use of polyol for polyurethane foam and the coupling of fabrics with foam.

For the metal depletion (MD) impact category, a value of 1.44E-02 kg Fe eq is obtained due to the consumption of nickel and chromium in the life cycle of textiles and foam.

For the fossil depletion (FD) impact category, a value of 3.33E-01 kg oil eq is obtained due mainly to the consumption of natural gas (49%) for the production of polyurethane foam.

Analyzing the contributions associated with the product under study as reported, it is clear that the most important factors that emerged from the evaluation are the use of polyurethane foam, of textiles and the coupling phase. It should be noted that the coupling phase also groups the spinning, finishing and coloring processes.

Table 6 shows the impact values calculated for 1 kg of bottoms. The main contributors to the impact are those reported for the analysis of 1 pad.

The results of the sensitivity analysis including the distribution of the pad to the clients are showed in Figure 2. It emerges that the impacts increase for all categories, in particular for climate change and ozone depletion.

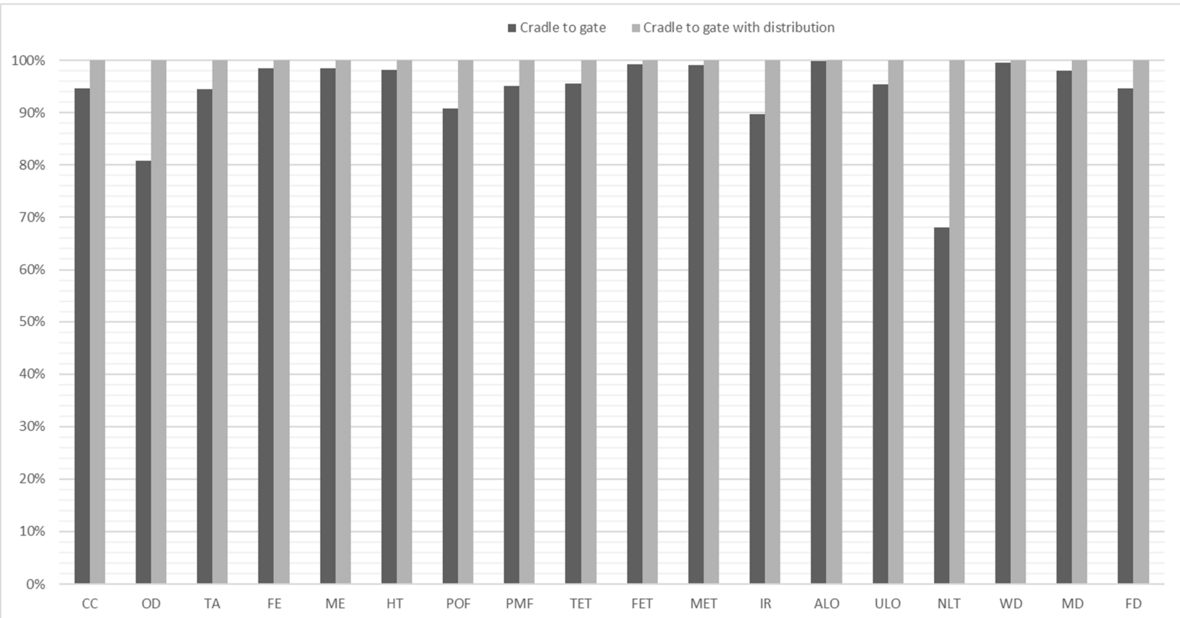

***Figure 2**. Comparison of the impacts calculated applying the system boundaries "from cradle to gate" and the impact calculated adding the distribution phase.*

Table 6. *Environmental impacts of the product analysed (1 kg).*

Impact category	Unit	Total	Textiles	Foam	Transport	Manufacturing
Climate change	kg CO2 eq	2.37E+01	4.64E+00	1.34E+01	1.59E-01	5.46E+00
Ozone depletion	kg CFC-11 eq	1.08E-06	9.41E-08	3.42E-07	9.55E-08	5.52E-07
Terrestrial acidification	kg SO2 eq	8.94E-02	1.51E-02	5.24E-02	1.46E-03	2.04E-02
Freshwater eutrophication	kg P eq	3.41E-03	3.55E-04	1.66E-03	2.64E-05	1.37E-03
Marine eutrophication	kg N eq	1.72E-02	2.30E-03	1.40E-02	3.75E-05	9.08E-04
Human toxicity	kg 1,4-DB eq	2.77E+00	2.40E-01	1.33E+00	6.17E-02	1.14E+00
Photochemical oxidant formation	kg NMVOC	6.96E-02	1.33E-02	4.29E-02	1.02E-03	1.23E-02
Particulate matter formation	kg PM10 eq	3.88E-02	5.33E-03	2.58E-02	5.32E-04	7.17E-03
Terrestrial ecotoxicity	kg 1,4-DB eq	1.09E-03	7.36E-05	6.23E-04	6.88E-05	3.28E-04
Freshwater ecotoxicity	kg 1,4-DB eq	2.19E-01	2.01E-02	6.06E-02	1.96E-03	1.36E-01
Marine ecotoxicity	kg 1,4-DB eq	1.98E-01	1.79E-02	5.81E-02	2.22E-03	1.20E-01
Ionising radiation	kBq U235 eq	8.59E-01	1.09E-01	1.27E-01	1.22E-02	6.10E-01
Agricultural land occupation	m2a	1.27E+00	1.43E-01	7.95E-02	2.66E-03	1.05E+00
Urban land occupation	m2a	7.78E-02	7.04E-03	2.15E-02	8.39E-03	4.09E-02
Natural land transformation	m2	1.14E-03	1.20E-04	1.92E-04	5.74E-05	7.68E-04
Water depletion	m3	6.01E-01	6.85E-02	3.35E-01	7.44E-04	1.97E-01
Metal depletion	kg Fe eq	3.60E-01	2.67E-02	1.74E-01	1.69E-02	1.42E-01
Fossil depletion	kg oil eq	8.32E+00	1.36E+00	5.26E+00	5.50E-02	1.65E+00

The environmental claims based on the results obtained through the LCA study, in line with the requirements of ISO 14040, ISO 14044 and ISO 14021 are reported in Table 7.

Table 7. *Final environmental claims.*

First claims	The environmental impacts along the "from cradle to gate" life cycle were accounted through a Life Cycle Assessment (LCA) study compliant with International Standards
Second claim	Through a Life Cycle Assessment (LCA) study compliant with ISO International Standards 14040 and ISO 14044 it was possible to quantify the impact of the pad under study on climate change equal to 947 g CO2eq. The quantification is based on system boundaries "From cradle to gate" and on data for the year 2019.

4. Conclusions

Our study investigates to what extent a component used for technical clothing impacts on the environment and explores the main contributors. The study was conducted analysing the consumption of resources, waste and materials for the different phases of the product life cycle from cradle to gate, such as the extraction and use of raw materials, the production process of the product, the waste produced. For the data collection, the period January-December 2019 was covered and specific data were collected for the product system analysed. In particular, the main data from primary sources concern the quantity of raw and auxiliary materials used, the energy consumption, the transport, the waste produced, the fate of these waste, internal transport and the energy mix of the plant. What the results tell us is the environmental impact of one pad or of 1 kg of pads with "a cradle to gate" perspective. The results also show that the most significant contributors are associated with foam and energy consumption for the coupling and thermoforming phases. In addition, our study highlights the impact associated with distribution separately, it is apparent that the impacts are increased for all categories, in particular for the climate change and ozone depletion categories.

Our results contribute advancing the discussion about the application of environmental impacts' quantification methodologies in the sporting sector and the progressive achievement of valuable sustainability assessment of sporting goods. Our study is a starting point for the development of studies of cycling technical apparel adding information to the environmental analyses of bicycles' production or surveys about cyclists' attitudes towards sustainability. Our study also led a development of a self-declared environmental claim in accordance with the requirements of ISO 14040, ISO 14044 and ISO 14021 standards showing a methodology to include the environmental profile of a product in companies' reporting.

The main limitations of this study were related to the fact that the system boundaries are "from cradle to gate", thus the impacts due to further processing of the pad, its utilization and disposal are not included. To face this limitation, a further phase namely the distribution was analysed in a sensitivity analysis. Another limitation regards the production of the foam, which was revealed to be one of the most significant contributors and for which it was necessary to use secondary data in place of primary information. A further development of this study will be to explore how to include quantified economic and social profiles of different products in companies' reporting.

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