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Environmental Classification of Products in a Context of Ecodesign in Small and Medium Enterprises

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Abstract:. More and more often a life cycle thinking is considered as a valuable element of environmental management. Product-based environmental management systems often refer to ecodesign, which can be used in various aspects of product management. Due to their own specificity, small and medium enterprises (SMEs) often encounter difficulties when conducting ecodesign activities. The paper presents a simplified approach based on the life cycle-based environmental classification of products intended for using in SMEs as a starting point for eco-design. A main goal of the paper is to propose such classification and discuss its role in improving the environmental performance of products. The presented analysis included 50 products classified according to the chosen criteria. As the first step, a cluster analysis has been performed and a distinction between passive and active products has been made. A main conclusion was that the information received from the cluster analysis may be insufficient to be a sole basis for ecodesign. A second classification has been performed basing on the selected environmental impact indicators (GWP100a and CED) calculated for three life cycle stages: a production, an use and a final disposal. The final products' classification reflects the differences in environmental hotspots between products and can be used for supporting the SMEs in implementation of life cycle-based eco-design processes.

Keywords: ecodesign, cluster analysis, products classification, small and medium enterprises

JEL codes: Q55,Q56

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1. Introduction

Ecodesign is understood as "the integration of environmental aspects into product design and development, with the aim of reducing adverse environmental impacts throughout a product's life

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cycle" (EN ISO 14006, 2011: 2). It is also referred to interchangeably as Design for the Environment, green design, life cycle design, and environmentally conscious design. Ecodesign and green product development are not new subject matters. According to Baumann et al. (2002: 409-425) the early 1970s saw a focus on this issue, which continued to increase, particularly during the 1990s. Over the last 20 years, a number of initiatives to develop ecodesign methodologies and tools have been undertaken (Lewis et al., 2001; Wimmer et al., 2004; Dostatni and Karwasz, 2009: 13-22; Pigosso and Rozenfeld, 2011: 136-141; Birch et al., 2011: 50-58; Poudelet et al., 2012: 192-201) such as creating of the Ecodesign Maturity Model composed of practices that can be used to improve organisation's processes in context of ecodesign (Pigosso and Rozenfeld, 2011: 136-141) or elaboration of the Business Process Reengineering (BPR) methodology for the development of suitable Decision-Support Systems (Poudelet et al., 2012: 192-201). What is more, considerable practical experience in this field has been gathered (Tukker et al., 2001: 147-161; Jincheng, 2003: 63-68; Wimmer et al., 2010; Ribeiro, 2013: 300-308).

It would seem that a number of contemporary circumstances affect an increase in the significance and popularity of ecodesign on an unprecedented scale. These circumstances include the following:

- The introduction of new pro-environmental requirements to compulsory legal regulations: for instance, with regard to energy-related products – Directive of the European Parliament and of the Council 2009/125/EC of 21 October 2009 and construction –Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011.
- The new requirements to ISO 14001:2015 that promote ecodesign as an element of the environmental management systems. It is recommended that organizations with environmental management systems (EMS) use ecodesign as a development tool (Lewandowska and Matuszak-Flejszman, 2014: 1794-1798).
- The intensification in recent years, on a European scale, of the efforts to popularize Life Cycle Thinking and Life Cycle based tools amongst small and medium enterprises (SMEs) (Kurczewski, 2014: 593-600).
- The promotion of new approaches to public procurement, and the inclusion of non-price criteria of bid assessments, with regard to the awarding of public procurement contracts – guidelines in: Ministry of Economy of Poland (2008) *The New Approach to public procurement. Public procurement and small and medium enterprises. Innovation and*

Sustainable Development; European Commission (2011) *GPP Handbook, Buying green! A handbook on green public procurement*.

- The actions of the European Commission to develop guidelines for the calculation of a Product Environmental Footprint (PEF) – guidelines in: Commission Recommendation of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organizations.

All of the above-mentioned phenomena are currently underway, making it possible to postulate that the interest in ecodesign from the perspective of business practice is likely soon to increase significantly. What's more, this interest might well be expressed by SMEs who have either implemented environmental management systems themselves or participated in a supply chain in which leading larger organizations have made suppliers comply with the pro-environmental activities.

The key issue is the question of whether ecodesign is "methodically ready" to be implemented within business practice on a wider scale. Do SMEs require a special approach to ecodesign? The opinion is often stated in the literature sources that advanced ecodesign tools — such as, e.g., detailed environmental life cycle assessment (LCA) — can be difficult to implement in SMEs (Masoni et al., 2004: 203-228; Le Pochat et al., 2007: 671-680; Chevalier, 2009; Arana-Landin and Heras-Saizarbitoria, 2011: 1007-1015; Buttol et al., 2012: 211-221; Arzoumanidis et al., 2013: 123-150). This article is intended to join this discussion by considering the life cycle-based environmental classification of products as a starting point for eco-design in SMEs. The idea is that each of the classes should contain products with similar spread of environmental burdens implicated in their life cycles. The main goal of the article is to propose a classification that would meet the needs of designers in a context of defining environmental product classes and identifying hotspots that might occur in their life cycle. Therefore, a designer's allocation of a product to a given class should allow for the identification of environmental hotspots characteristic of that class, and for the formulation of ecodesign strategy based on these, without any need to carry out a quantitative environmental life cycle assessment.

Firstly the cluster analysis was carried out. Selected products were classified according to the criteria such: mass, longevity, intensity of use, energy needs, water needs and environmental impact indicators – Global Warming Potential GWP and Cumulative Energy Demand CED (per the entire life cycle). Next, selected products were classified based on comparisons of the above-mentioned environmental impact indicators and a division into three life cycle stages: production, use and final disposal. Data for analysis have been derived from the author's own studies and were in part collected from LCA case studies described in the literature. LCIA calculations were carried out by using Impact 2002+ method (Jolliet et al. 2003).

2. Ecodesign in SMEs

Based on the literature review, three key directions for ecodesign implementation could be defined:

- an integration with a traditional design;
- an implementation in SMEs;
- an use in the environmental management systems.

The issue of integrating ecodesign with traditional design procedures has been the subject of literature discussions for a while, since it is necessary to practically include environmental aspects in the development and design of products. Some authors emphasize the fact that, despite many ecodesign guidelines being compliant with traditional design rules, in practice, the language of ecodesign is not clear to traditional designers (Lofthouse, 2005: 215-227; Millet et al., 2007: 335-346). Other moot points include which stage of the design the environmental aspects be included in (e.g., the strategic phase, the functional phase, the conceptual design phase, the architectural phase, the detailed phase, etc.) (Millet et al., 2007: 335-346), and what type of results achieved by using of specific ecodesign tools — such as environmental LCA, matrix methods, or other methods e.g., Material Input per Unit Service, Embodied Energy, etc. — might be useful for different types of designers (e.g., conceptual designers, core designers, design engineers, etc.) (Lofthouse, 2005: 215-227). Another issue often discussed is the too-expert character of ecodesign tools, which in practice — and without any support from external specialists — are frequently found to be too difficult to use by companies (Le Pochat et al., 2007: 671-680; Reyes and Rohmer, 2009: 173-184; Pamminger et al., 2013: 481-486).

All of the above issues are fundamentally significant from the point of view of SMEs. Researchers including Van Hemel and Cramer (2002: 439-453), Masoni et al. (2004: 203-228), Le Pochat et al. (2007: 671-680), Chevalier (2009), and the authors of this article (Witczak et al., 2014: 891-900; Selech et al., 2014; 1119-1128), have shown that for SMEs ecodesign could be difficult. It is linked to their limited resources (human, financial, technological), as well as to the split between competences and decision making. Particularly in small organizations, the executive authority is often in the hands of the owner, who singlehandedly makes decisions with regard to technology, production, purchasing, expenditure and marketing, as well as the design and development of products (Witczak et al., 2014: 891-900).

A good practice recommends establishing the eco-design teams by involving the staff coming from different departments (a cross-functional approach). In case of SMEs, this means integration of competences and individuals being responsible for a range of tasks. On the one hand, it could be argued that this shortens the decision-making time (meaning more decision-making flexibility). However, on the other hand, burdening employees with many different responsibilities may lead to lower motivation for undertaking new tasks. Engaging an external expert in the field of ecodesign can often be pricey from the point of view of SMEs, all the more because, in the case of the more advanced tools, the initial training and experience gathered during the first project are not sufficient for the independent continuation of ecodesign implementation (Masoni et al.,2004: 203-228).

So what could mobilize SMEs to engage with ecodesign activities? Van Hemel and Cramer (2002: 439-453) carried out an empirical assessment of 77 Dutch SMEs, with regard to the barriers and stimuli (internal and external) for the use of ecodesign in such organizations. The most significant internal stimuli were considered to be *environmental benefit*, *cost reduction* and *image improvement*, whilst *customer demands, government regulation* and *supplier developments* were considered the main external stimuli. The activities for the greening of public procurement, which are seen as an opportunity to open up the public procurement market to SMEs through the possibility of non-price competition (including environmental aspects) can be listed amongst the governmental directives. The other source of motivation might be the suggestion to introduce ecodesign as a solution for the development of products in EMS. In practice, this should mean the development and implementation of ecodesign procedures in order to identify and assess environmental aspects linked to products over their entire life cycles (EN ISO 14006, 2011; Lewandowska and Matuszak-Flejszman, 2014: 1794-1798). In practice it means the implementation of the POEMS concept (Rocha and Silvester, 2014; Ammenberg and Sundin, 2005: 405-415; Donnelly et al., 2006:1357-1367). It may be relevant for those SMEs that have already implemented EMS according to ISO14001. On the other hand, the motivation for it may come from outside, as the result of ecodesign being implemented by competitors. In both cases, it can be expected that the unit initiating ecodesign activities will be part of the department (or person) responsible for environmental management within the organization.

Taking into account the fact that small companies in particular often do not have separate design, research and development departments, do have limited financial and technological resources, the question is how to manage ecodesign in such organizations. In the literature it is proposed to use generic ecodesign guidelines (golden rules) (Luttropp and Lagerstedt, 2006: 1396-1408) or introduce the ecodesign process on the basis of the "Trojan horse method" (Reyes and Rohmer, 2009: 173-184) or use the semi-quantitative or qualitative approaches such as the ERPA matrix and MECO methodologies (Hochschorner and Finnveden, 2003: 119-128; Hur et al., 2005: 229-375). In the literature, there is also a number of solutions proposed involving drawing up quantitative approaches based on a simplified LCA (Soriano, 2004; Pamminger et al., 2013: 481-486; Okrasinski et al., 2013: 750-755) or support for organizations via the formulation of ecodesign strategies based on the classification of products (Sousa and Wallace, 2006: 228-249).

3. The environmental classification of products

There are some analytical models that provide the designer with a product classification that identifies critical features of the product form and considers consumer needs (Mahmud et al., 2014: 775-781; Xu, 2009: 87-110). However, it should be noted that product designers require tools that focus on the consumer but also support a pro-environmental decision-making process (Chandrasegaran, 2013: 204-228). A number of different product classification approaches can be found in the literature, depending on the adopted environmental criteria (Table 1). When comparing the quoted classifications, it can be seen that in some sense they are mutually exclusive, namely, the same products are in different environmental classes and, consequently, different hotspots and development recommendations are suggested with respect to them.

Table 1. The environmental classification of products — a comparison of approaches

	Hanssen, (1996)	**Akermark (1999)**	**Kaebernick and Soriano (2000)**	**Sousa(2003)**	**Ecodesign Pilot**
Classification criteria	Product's functional and life-cycle properties related to significant environmental impacts	Role of energy in the product's function	Distribution of environmental burdens during the product life cycle	Product descriptors (e.g. lifetime, energy source, mass)	Environmental significance of life cycle stages
Identified classes (chosen)	1.Stationary inert products without energy consumption in use 2.Stationary products with internal energy consumption in use 3.Transportable products without internal energy consumption in use 4.Transportable products with internal energy consumption in use	1. Active (necessary) 2. Passive (redundant)	1. Products where the most of environmental impact is caused by the production of the material (90%) 2. Products where the most of environmental impact is caused by usage (89%) 3. Products where both material and usage phases contribute significantly to the total environmental impact	1. Durable, high-mass household appliances, with efficient energy consumption during use 2. Durable, low-mass consumer products, with a significant amount of plastic materials, and with energy consumption during use 3. Non-durable, low-mass consumer products, with no energy consumption during use 4. Durable, low-mass, recyclable products, with a significant amount of metals, and with external energy consumption for maintenance during the use phase	1. Raw Material Intensive 2.Manufacturing Intensive 3.Transportation Intensive 4.Use Intensive 5. Disposal Intensive
Examples of products	1. Electric cables 2. Lighting Armature 3. Food Package 4. Boat with outboard motor	1.Washing machine 2. Food packaging	1. Paper bag 2. Coffee makers 3. Hydraulic Activation Unit	1. Refrigerators 2. Coffee makers 3. Paper bags 4. Sauce pans	1. Computer 2. Furniture 3. Packaging 4. Washing machine 5. Battery

Source: the authors' own elaboration, based on: Sun, 2004: 56-57;Wimmer et al., 2004

The environmental classification of products represents a significant simplification compared with other approaches but, in light of SME constraints, it seems to be a valuable alternative allowing the identification of disjoint classes of products, with clearly defined characteristics (so that a designer can classify a tested product without much doubt), and indicating environmental hotspots (so that they constitute a prerequisite for the designer to implement an eco-design strategy).

From the point of view of the designers selecting an ecodesign strategy seems to be essential to answer the following two questions:

1. What selection criteria should be followed in order to classify a product?
2. Do construction and technological differences (production or final disposal processes) influence the classification of a given product or not?

In order to answer these questions, 50 products were identified and grouped with the use of a cluster analysis: a collection of grouping methods based on the taxonomic similarity of multi-feature objects.

3.1 Material and methods

The main aim of a cluster analysis is to divide a collection *n* of objects, described by a number of features, into two or more separable, homogeneous groups (Stanisz, 2007; Norusis, 2012; Sarstedt and Mooi, 2014). For this purpose a set of diagnostic variables should be created including these variables which have been acknowledged as potentially significant criteria for selecting objects. In the presented study, an assessment of variables' discriminating potential has been performed (amongst other related to the completeness of data, the degree of the internal differentiation of features and their reciprocal correlation) allowing to distinguish the following diagnostic variables:

- unit mass [kg],
- usage time [years],
- usage intensity [hours/lifetime],
- use of electrical energy during usage [kWh],
- use of energy other than electrical during usage [kWh],
- use of water [m3],
- Global Warming Potential (GWP 100a) [kg CO_2 eq.] — per the entire life cycle
- Cumulative Energy Demand (CED) [MJ] — per the entire life cycle

There are several environmental impact categories whose importance depends on the specific product into consideration. However, GWP represents the problem of emissions (i.e., an output-oriented impact category) and CED involves the use of resources (i.e., an input-oriented impact category), which means that the environmental aspects coming from both sides of product system are represented. Such indicators have also been selected in view of their increasing practical importance. Data for analysis were in part collected from LCA case studies described in the literature. Because many reports contain only GWP and CED results, selecting only these indicators made it possible to collect more research objects.

It should be noted, however, that a number of data have been derived from the author's own studies. In order to keep the system boundaries consistent, the following assumptions were made when collecting quantitative information:

- for the production stage, basic materials/construction materials consumption and energy consumption in the production process have been taken into account;
- for the use stage, data were collected based on a scenario underlying the formulation of a functional unit. Assumptions in the author's own research were made following consultations with manufacturers;
- final disposal scenarios are based on the legal requirements for waste management that are in force in Poland.

The selected research set contains products that represent entirely different product categories, including packaging. The specificity of the life cycle of individual packages is based mainly on the fact that they play an important role in trade. The life cycle of packaging involves two "users": the manufacturer of products (for which the packaging is intended) and the consumer of these goods. The role of the consumer of goods is reduced to opening package and emptying it, which is done with practically no environmental intervention. The manufacturer of products, for which a package is designed, "uses" this package through filling and sealing it and distributing goods. It is this latter aspect that was taken into account in the "use"-of-packaging stage, which is consistent with the guidelines of PN-CR 13910: 2002, which recommend taking into account the stage of transportation of a packaged product in the lifecycle of packaging.

It is worth noting that the products identified for the cluster analysis differ not only in functionality but also in unit mass, longevity, usage intensity and demand for energy during the usage phase. When it comes to the final criterion, the identified products can be divided into two generic groups: “active” products, which require energy to fulfill their function (e.g., bar furniture, desktops, laptops, fridge-freezers, vacuum cleaners, biomass boilers, passenger cars, buildings, etc.) and “passive” products, which do not need energy (e.g., milk, packaging, tiles, etc.).

Amongst the passive products are also some that don’t physically require being powered with energy or another medium as a constructional requirement to fulfill their function, yet the commonly accepted method of fulfilling this function requires additional materials, which may include the need for energy. These can be described as “accompanying environmental interventions” and are well exemplified by washing detergent or textiles. In both cases, “interventions associated with” carrying out the product’s functions are linked with the activity of washing and are inseparable elements of their lifecycle (water and energy consumption, generating wastewater). The weight of a product, its service life and the intensity of use determine the importance of the role that the accompanying interventions play in the passive product life cycle.

The next element taken into account while formulating the list of products for the cluster analysis were technological differences. LCA analyses (here limited only to the values of GWP and CED) were carried out for different material solutions (e.g., cotton and polyester t-shirt; timber, aluminum and PVC window frames; masonry and wooden buildings), different recycling rates and waste management scenarios (e.g., window frames were recycled, incinerated or landfilled), different production technologies (e.g., milk from an organic and a conventional manufacture) and different usage scenarios (e.g., vacuum cleaners used in domestic and commercial conditions). Such a large differentiation of products was supposed to answer the question as to whether these differences should influence the products’ classification. The cluster analysis should therefore also be treated as a kind of sensitivity analysis to measure the differences in material solutions and usage, the production as well as the final disposal conditions of the analysed products.

4. Cluster analysis for 50 selected products

A cluster analysis was carried out based on the final collection of normalized diagnostic variables, using Ward’s method. The reason behind selecting this method, highlighted in the literature, was the efficiency produced by its estimation of the distance between clusters using an analysis of variance (Hair et al., 2009; Sarstedt and Mooi, 2014). The resulting Euclidean distance was used to create a matrix of distances between the analysed objects.

4.1 Results

The first step involved a cluster analysis for all (50) products from the inventory, which made it possible to distinguish two clear clusters, which were defined as A (29 products) and B (21 products). It is possible to further disaggregate the products according to the clustering structure for both groups. In case of class A, three subclasses were suggested: A1 (dishwashers, washing machines, office lighting units and bar furniture), A2 (vacuum cleaners, TV sets, lighting systems, hand dryers, laptops, desktops and mobile phones), and A3 (paper towels, packaging materials (laminates), milk, cotton towels and t-shirts). In the case of class B, three subclasses were also suggested: B1 (insulation material (Rockwool), window frames, roofing tiles and trapezoidal metal roofing sheets), B2 (biomass boilers and passenger cars), and B3 (buildings).

Looking at the characteristics of the products, each of the classes could be assigned the following characteristic features, which are common for all products allocated to a given subclass:

- A1 – large unit mass, long use period, very high intensity of use, and the need for the product to be powered with energy during usage;
- A2 – medium unit mass, medium use period, high intensity of use, and the need for the product to be powered as a condition of starting its function;
- A3 – small unit mass, short use period, low or moderate intensity of use, and no constructional requirement for powering the product;
- B1 – large or very large unit mass, very long use period, very high intensity of use, and no constructional requirement for powering the product;
- B2 – very large unit mass, medium use period, high intensity of use, and the need for the product to be powered as a condition of starting its function;
- B3 – very large unit mass, very long use period, very high intensity of use, and the need for the product to be powered as a condition of starting its function.

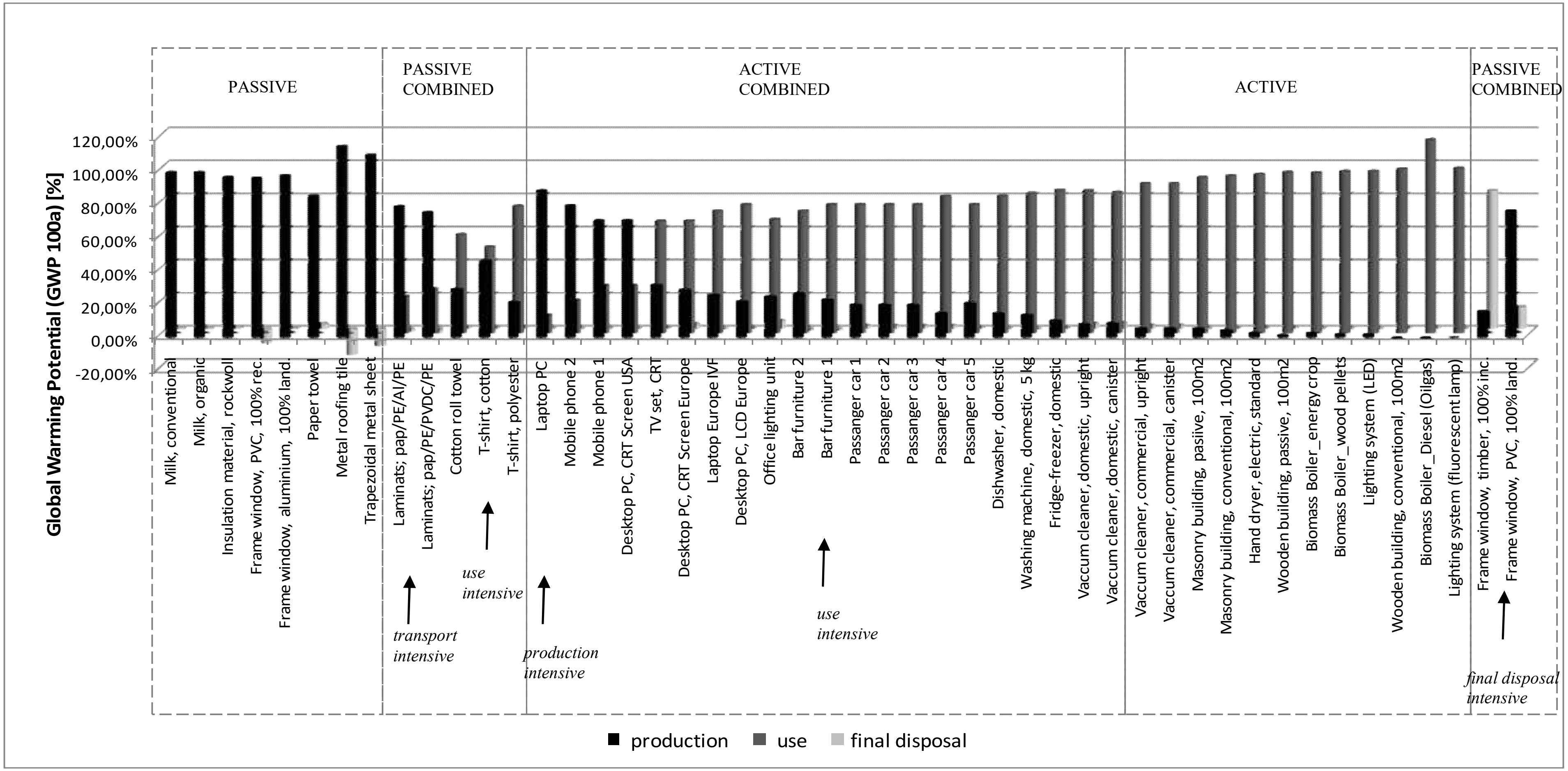
Looking at the classification achieved as the result of the cluster analysis, it can be seen that all the varieties of each product type are contained in the same class, regardless of the adopted material solutions, production technology or the final disposal. Taking into account the fact that the cluster analysis included the cumulative impact of the product on the environment (GWP 100a per life cycle), the resulting classification of the products does not refer to the contribution of each of the individual life cycle stages to the formation of the total environmental impact. However using a percentage contribution of each of the life cycle stages to the overall environmental impact as diagnostic variables is not possible. It is linked with the fact that the environmental indicators may take both positive and negative values and it would entail dividing two intervals.

Accordingly, the selected products[1] were classified based on comparisons of environmental impact indicators: GWP 100a (Figure 1) and CED (Figure 2) and a division into three life cycle stages: production (black), use (dark grey) and final disposal (light grey). In this way, it was determined whether the classification of a products depends on the type of environmental impact indicators.

The left side of the diagram 1 — from “Milk, conventional” to “Trapezoidal Metal Sheet”— includes products for which the production stage has the predominant role (over 90%) in their global warming impact, which can be recognized as fully *passive products*. The section from “Laminates, PAP/PE/Al/PE” to “Vacuum Cleaners (domestic, upright)” includes products whose production and use stages both play significant roles, which can be defined as *combined products*. Because “Laminates”, “Cotton Roll Towels” and “T-Shirts” are passive products, they are defined as *passive combined*. The first subgroup includes products with increased susceptibility to transport and the stage of use equated with distribution processes (hence *passive combined, transport-intensive*). In the case of this products, the contribution of the production stage is higher than the other stages; however, it is still below 90%.

[1]For three products were available only the cumulative values of CED. This products were omitted in the classification that takes into account CED.

Figure 1. Environmental impact (as GWP 100a) of various life cycle stages for the 50 analysed products



Source: the authors' own elaboration

The second subgroup contains products for which the commonly accepted way of implementing their functions requires additional materials, such as energy (e.g., textiles). With regard to this products, the usage stage is predominant in terms of impact; hence, these products are described as *passive combined, use-intensive*.

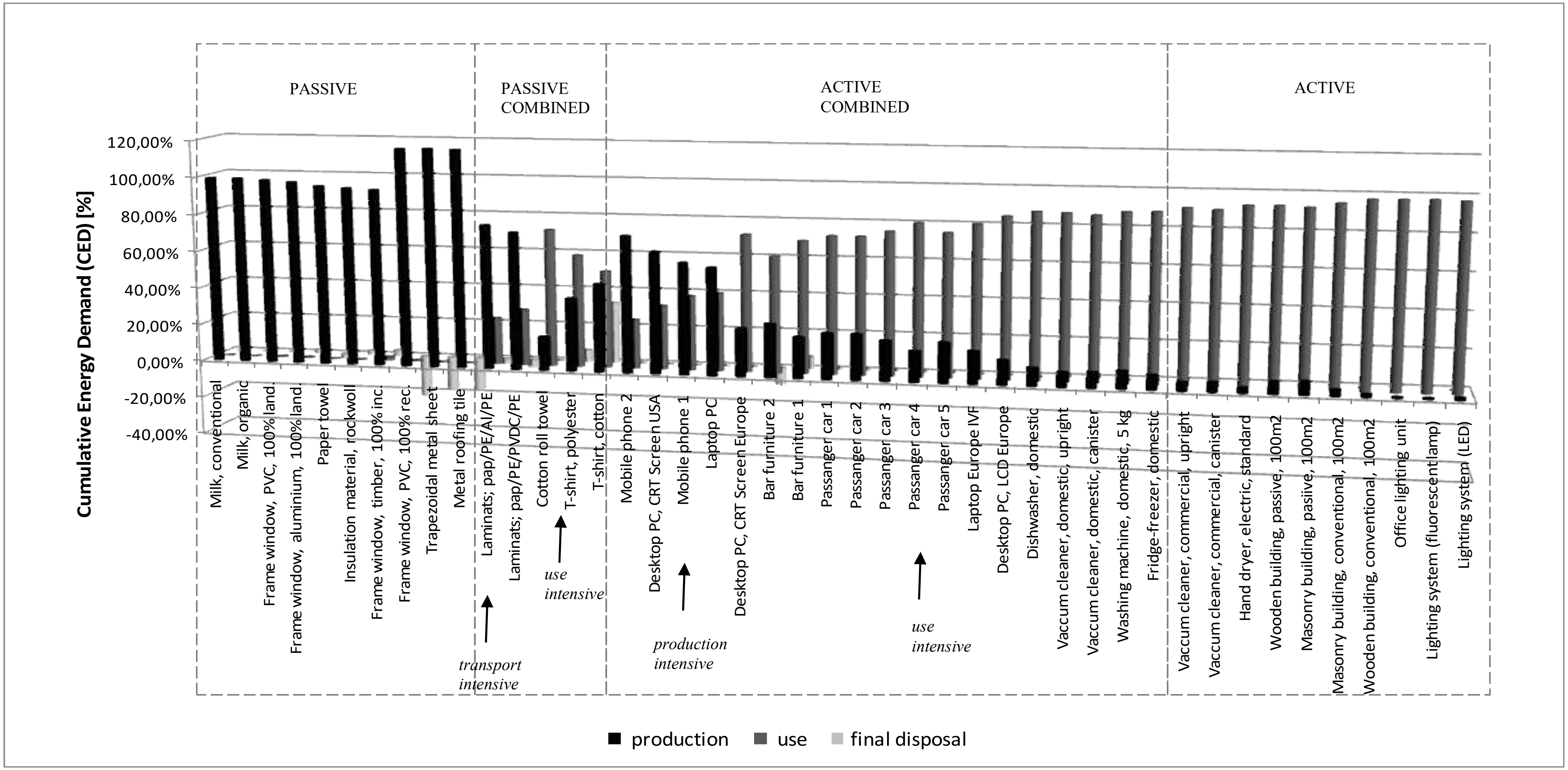
Moving further along, the section from "Laptop PCs" to "Vacuum Cleaners (domestic, canister)" includes powered (electric/thermal) products that are active, but whose usage stage contributes below 90% of its GWP 100a, which leads to their being described as *active combined*. The range of these products includes those with a lower unit mass (up to 25kg) and a medium usage period (a few years). In the case of these products, the shorter usage period moves the impact towards the production stage, that is why they are described as *active combined, production-intensive*. These products are followed by the ones with a larger unit mass and a clearly longer usage period, which are described as *active combined, use-intensive*. Among others, these include "Washing Machines", " Dishwashers" "Cars" and "Domestic Vacuum Cleaners".

The section from "Vacuum Cleaner, commercial, upright" to "Lighting System, fluorescent lamp" includes the products for which the usage stage contributes over 90% of their GWP, hence classifying them as *active*. These include products classified in the cluster analysis as subclass A2 ("Lighting Systems", "Hand Dryer" and "Vacuum Cleaners"), as well as B3 ("Buildings"). Commercial and domestic vacuum cleaners are of similar weight and durability; however, the former are characterized by a much higher intensity of use, which in turn translates into a higher involvement of the stage of use, thus moving these products from *active combined* to *active.*

The last group of products are "Window Frames", the final disposal of which (incineration, disposal in landfill) — and the resulting high impact on the environment with regard to global warming — classifies them as *passive combined, final disposal-intensive.*

A comparison of Figures 1 and 2 showed that treating CED as the explanatory variable changed the classification of certain products under analysis. Three out of 47 products, classified according to cumulative energy requirements, were moved to another group. This applies to the following products: "Frame Window, PVC, 100% land", "Window Frame, timber, 100% inc." and "Office Lighting Unit". The above-mentioned window frame was originally in a group of products whose environmental significance was determined by two life cycle stages: production and final disposal. In the current CED classification, however, it belongs, along with the other frames, to the group of products with a clearly important production stage (above 90%). Consequently, the class of products with a relatively high significance of the final disposal has been eliminated. "Office Lighting Unit" was moved from *active combined* to *active* products and thus it joined the other lighting systems. Importantly, the vacuum cleaners under analysis differ in the intensity of use and belong to different environmental classes.

Figure 2. Environmental impact (as CED) of various life cycle stages for the 47 analysed products



Source: the authors' own elaboration

4.2 Discussion

It can be concluded that the consideration of each of the life cycle stages, in terms of their environmental impact as GWP100a and CED (Figure 1 and 2), changed to some degree the classification achieved in the cluster analysis. Above all, in one case, functionally identical products (vacuum cleaners) were split. Taking into account the cluster analysis, all of the vacuum cleaners ended up in the same subclass A2. In the case of classification in order to GWP 100a and CED, the lower intensity involved in their use at home (compared to commercial settings) resulted in an increase of the relative contribution of the production stage, and the reallocation of these products to *active combined*.

Another interesting example includes "Office Lighting Unit", "Lighting System, fluorescent lamps" and "Lighting System, LED". These products are very similar in terms of functionality, but they differ from vacuum cleaners in durability and design. In the cluster analysis, the lighting systems were classified into the same subclass (A2), while "Office Lighting Unit" was put into another one (A1). In a sense, this is consistent with the classification that takes into account GWP. The lighting systems were included in the *active* product group, contrary to the "Office Lighting Unit" (*active combined*). In the classification that takes into account CED, all these products were in the same class of active products. Another interesting example is that of "Window Frames, timber, 100% incinerated" and "Window Frames, PVC, 100% landfilled", which — on the far right side of Figure 1 — were the only products whose final disposal had a significant role in GWP. In the cluster analysis, they were classified as B1, alongside other window frames, because they showed a similar unit mass, longevity, usage, intensity of use and a lack of power requirements in the usage stage. In Figure 1, both these types of window frames were classified as *passive combined,* and not purely *passive*, as in the case of "Window Frames, Al., 100% landfilled" and "Window Frames, PVC, 100% recycled". In Figure 2, all window frames were placed in the same group of products (*passive*), regardless of the final disposal, which is in a way consistent with the classification obtained in the cluster analysis.

Importantly, in the classification resulting from both the cluster analysis and the comparison of GWP and CED, there was no breakdown of other functionally equivalent products, characterized by a different composition of materials (milks, T-shirts, packaging materials, buildings). It can be concluded, however, that differences in construction/material and technology (the intensity of use, the form of the final disposal) most affect the classification of a product type into a specific class of eco-design when the share of various life stages in the creation of the environmental impact is analysed through the prism of GWP. It seems, therefore, that designers should also, at least qualitatively, take into account material and technological solutions rather than just the weight of products. It is possible that assuming a different scenario of the final disposal or other conditions of use (the intensity of use, durability) will move the product from one class to another and change the eco-design recommendation.

In the face of the issues outlined above, it should be considered how the use of the environmental classification of products can help SMEs implement eco-design processes, as they can face difficulties in applying advanced eco-design tools, such as the LCA, due to limited human and financial resources. The proposed classification combines two criteria for the distribution of products: the "energy" functional dependency and the importance of various life cycle stages. On this basis, eco-design classes were selected, their characteristics were determined, hotspots were pointed out and guidelines for environmental improvement were proposed (Table 2). These issues should provide key information for designers taking eco-design steps.

Table 2. The characteristic of selected classes of products

Environmental type of product	The key features		Environmental hot spots	Recommendations for improvement
	General features	Detailed features		
Passive	No structural adaptation to energy consumption – the implementation of the product's essential function without energy supply	- high/moderate unit weight - a long service life	Material consumption during production	Using production materials that ensure longer service life
		- low unit weight - a short period of use (disposability)		
Passive Combined-transport intensive	No structural adaptation to energy consumption – the product's function is to enable the distribution of another product	- low unit weight - a short period of use (disposability)	Material consumption during production Distribution	Reducing unit weight
Passive Combined-use intensive	No structural adaptation to energy consumption – the adopted method of accomplishing the product's function requires energy supply	- low unit weight - a relatively short life cycle with an intensive period of use	Material consumption during production Energy consumption during use	Using production materials that ensure the reduction of "energy consumption" during use
Active Combined-production intensive	Structural adaptation to energy consumption – the implementation of the product's function requires energy supply + intensive use	- low unit weight - a relatively short life cycle - operation possible without constant power supply	Material consumption during production Energy consumption during use	Reducing energy consumption while prolonging the service life
Active Combined-use intensive	Structural adaptation to energy consumption – the implementation of the product's function requires energy supply + intensive/ moderate use	-high/moderate unit weight -operation possible with a steady power supply or as a result of the burning of a specific energy source	Material consumption during production Energy consumption during use	Reducing energy consumption while prolonging the service life
Active	Structural adaptation to energy consumption – the implementation of the product's function requires energy supply + very intensive use	- low/moderate unit weight - a relatively short life cycle	Energy consumption during use	Reducing energy consumption
		- high/very high unit weight -a relatively long/very long life cycle		

Source: the authors' own elaboration

5. Conclusions

The article highlights the growing role of eco-design for SMEs and discusses the use of the environmental classification of products as a starting point for eco-design. The goal of the article is to propose a products' classification that would meet the needs of designers in a context of identifying the hotspots that might occur in the products' life cycle. The analysis included 50 products, which were classified according to the adopted criteria (mass, longevity, intensity of use, energy needs).

The cluster analysis classified the products based on the above-listed criteria and generally distinguished between passive and active products. However, because the cumulative values of GWP and CED were used as diagnostic variables in the classes created through the cluster analysis, it was not possible to further distinguish between *active*, *active combined*, *passive* and *passive combined* products, nor to identify further subgroups (e.g., *passive combined, production-intensive*; *passive combined, transport-intensive*; *passive combined, use-intensive*; and *passive combined, final disposal-intensive*). Theoretically, from the point of view of interpretation, the best solution for designers would be to use diagnostic variables based on the percentage contribution of each of the stages of the products' life cycles in the cluster analysis. In such a case, the products could be classified according to the spread of environmental burdens throughout their life cycles. However, because the results of the environmental indicators could take either positive or negative values, and because this would imply the need to divide two interval values, which is an unacceptable statistical operation, such a solution would not be possible.

For this reason, the selected products were classified based on comparisons of selected environmental impact indicators (GWP 100a and CED) and a division into three life cycle stages: production, use and final disposal. The presented classification makes it easier to take up eco-design activities in the context of specific product groups. It can also have a more extensive use, for example in a situation where, in addition to ready-made eco-design solutions, a designer would like to determine to what extent the proposed solutions potentially reduce the environmental impact of the products under analysis. The environmental classification of products and the resulting knowledge of the sources of environmental impacts may become the basis for the development of a simplified LCA inventory model that would cover the most important environmental issues.

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Środowiskowa klasyfikacja produktów w kontekście ekoprojektowania w małych i średnich przedsiębiorstwach

Streszczenie

Od pewnego czasu kreowane jest podejście do zarządzania środowiskowego bazujące na cyklu życia wytwarzanych produktów i usług oraz ich wpływie na środowisko. W tak zorientowanym systemie zarządzania ważną rolę pełni ekoprojektowanie, które może mieć zastosowanie w różnych aspektach zarządzania produktem. Specyfika małych i średnich przedsiębiorstw powoduje jednak, że realizowanie w ich przypadku procesów ekoprojektowych może być problematyczne. W artykule podkreślono wzrastające znaczenie ekoprojektowania w kontekście tej grupy podmiotów oraz przedyskutowano wykorzystanie w tym obszarze środowiskowej klasyfikacji produktów. Głównym celem było zaproponowanie klasyfikacji, która pozwalałaby na zdefiniowanie środowiskowych klas produktów oraz identyfikację przyczyn negatywnego oddziaływania ich cyklu życia. Dla ustalenia jakimi kryteriami należy się kierować klasyfikując dany produkt wykonano analizę skupień na grupie 50 wyselekcjonowanych obiektów badawczych. Uzyskana jednak klasyfikacja produktów nie pozwoliła na kontrybucję poszczególnych etapów cyklu życia w tworzeniu wpływu na środowisko, a jedynie na wyróżnienie zasadniczo dwóch grup produktów typu *active* oraz *passive.* W rezultacie uznano, iż analiza skupień z racji, iż nie pozwala na identyfikowanie środowiskowych punktów krytycznych, może być traktowana przez projektantów jedynie jako źródło informacji uzupełniających, a nie jako główne podejście do podziału produktów. Z tego względu dokonano podziału analizowanych produktów według udziałów procentowych wartości wskaźnika Potencjału Globalnego Ocieplenia (GWP100a) oraz Skumulowanego Zapotrzebowania na Energię (CED) w trzech etapach cyklu życia: produkcji, użytkowania oraz końcowego zagospodarowania. Otrzymana klasyfikacja stanowi wytyczne w zakresie doskonalenia produktów w oparciu o proponowane strategie ekoprojektowe i może być pomocna zwłaszcza małym i średnim przedsiębiorstwom.

Słowa kluczowe*:* ekoprojektowanie, analiza skupień, klasyfikacja produktów, małe i średnie przedsiębiorstwa.