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Life cycle perspective in design and product development

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ABSTRACT
Eco-design is one of the cornerstones of the modern economy, as reflected in the policies aimed at implementing the principles of design for the environment in the European Union legislation. A life cycle perspective is a feature of eco-design. The study aimed to determine whether and to what extent the selected companies operating in manufacturing sectors consider life cycle perspectives when designing and developing the products they offer. The main research area discussed in the following article focused on the question: What kind of activities related to the idea of life cycle thinking in product policy can be identified in the analysed enterprises? Qualitative research was conducted using the individual in-depth interview method with representatives of selected industries located in Poland. Eight manufacturer groups were invited to participate in the study. Based on the recruitment process, 24 companies were chosen for the interview. Individual in-depth interviews were conducted using Microsoft Teams, following the ICC/ESOMAR Code 2016 standards. Based on the results, most companies that participated in the study considered the life cycle perspective when designing or further developing products. However, their activities varied in scope. The activities of the ten interviewed companies could be regarded as advanced. For six companies, the advanced activities targeted the product's use phase. Two companies undertook such activities at more than one life cycle stage. The study provides evidence that the surveyed companies are beginning to think beyond operational boundaries and changing their pro-environmental orientation, albeit unimpressively. The paper provides evidence that eco-design requirements are an unquestionable driver for activities from a life cycle perspective. All surveyed manufacturers of energy-powered products are taking measures to reduce energy intensity with less activity, for example, ensuring the durability/reliability of products and finding solutions to facilitate disassembly and recycling.

KEY WORDS
life cycle thinking, eco-design, product development, Sustainable Products Initiative, sustainability, European Green Deal, EGD

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Introduction

The Corporate Sustainability Reporting Directive (CSRD) and the European Sustainability Reporting Standards (ESRS) highlight the growing importance of the circular economy (CE) in the business context. According to the EU Taxonomy (Regulation (EU) 2020/852), one of the environmental goals is the transformation towards CE. The core ESRS standards include two cross-cutting and ten thematic standards. One of them specifically focuses on resource use and circular economy (ESRS E5), where it was emphasised

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that eco-design contributes to optimising resource consumption in the whole life cycle (Commission Delegated Regulation (EU) 2023/2772). Thinking with a life cycle perspective has been gaining importance for a long time. In 2022, the European Commission prepared a proposal for a regulation on eco-design for sustainable products. It is planned to broaden the scope of the existing eco-design directive (2009/125/EC) in terms of products and requirements. The new regulations should go beyond energy-powered products and cover the broadest possible range of products to support the transition to a circular economy. A new Circular Economy Action Plan sets priorities for the Sustainable Products Initiative and recognises electronics, information and communications technologies, textiles, furniture, and products used in the construction sector (e.g., chemicals) as relevant in this context (COM(2020)98). Considering the above facts, eco-design can be expected to become more popular in practice. The issue of eco-design emerged in the early 1970s. Over the past decades, several initiatives developed this concept and gathered practical experience.

Several factors impact the environmental performance of products in the life cycle. These include durability, reliability, ease of repair and maintenance, ease of upgrading, reusability, remanufacturing, refurbishment, quality of recycling, and energy and resource efficiency (COM(2022)142). The implementation of products based on life cycle thinking concepts is a challenge. This is due to competence gaps or other organisational barriers and the specific problems faced by organisations, especially small and medium-sized enterprises (SMEs) (Witczak et al., 2014; Selech et al., 2014). Nevertheless, given the European Union's intensive efforts on sustainable products, it is expected that in the near future, companies will face the need to identify and assess the environmental aspects of their products more extensively and act in this regard. This article evaluates the status quo in this area. Although some papers investigate the product-oriented pro-environmental practices (e.g., Triguero et al., 2023; Dostatni et al., 2023; Siwiec et al., 2024), the range of actions applied by companies from different industries to reduce the impact of the product life cycle has not been studied in depth.

This research mainly aimed to determine whether and to what extent Polish producers of selected industries consider a life cycle perspective when designing or developing their products. To achieve the primary objective of the study, qualitative research was conducted using the individual in-depth interview method (Glinka & Czakon, 2021). During the interview, activities implemented by selected companies related to the idea of life cycle thinking were identified. The qualitative research allowed for deepening the knowledge of practical solutions and presenting an expanded catalogue of activities occurring at different life cycle stages. The respondents' free statements also made it possible to identify their general attitudes, opinions, and their customers' preferences for eco-design.

Eight groups of producers were invited to the study, with the following Polish Classification of Activities (PKD code): 14.13, 31.09, 26.20, 27.40, 27.51, 23.32, 23.99, and 20.30. The above industries were selected considering the European Union's Sustainable Products Initiative. Based on the recruitment process, 24 companies were selected to participate in the study (three producers for each selected industry). Employees with managerial positions responsible for the company's product policy participated in the survey.

The remaining paper is structured as follows. First, the theoretical and practical aspects of eco-design are briefly described. Then, the selected results of research illustrating the implementation of eco-design in enterprises are presented. Next, the research methodology is explained, and the main findings of the research are analysed. This part presents surveyed companies' actions in product policy regarding life cycle thinking. The questions focused on the various stages of the life cycle: procurement (acquisition of production materials), production, distribution, use and final disposal. In the final sections of the paper, a discussion is held, and conclusions are drawn. It was concluded that the surveyed companies are beginning to think beyond operational boundaries and changing their pro-environmental orientation, albeit unimpressively.

1. Literature review

Eco-design has various definitions. A report compiled by the European Network of Eco-design Centres (ENEC) provides 34 definitions of the term, encompassing strategic and operational aspects. According to Lindahl and Ekermann (2013), eco-design is not a specific method or tool but rather a way of better design through analysing and synthesising to reduce environmental impacts throughout

the product's life cycle (Prendeville et al., 2014, p.5). Another definition states that eco-design involves simultaneously considering the environmental impacts associated with the selection of materials, the manufacturing process, the storage and transportation phase, usage, and final disposal (Plouffe et al., 2011). According to the ISO standard, eco-design is a systematic approach that considers environmental aspects in design and development to reduce adverse environmental impacts throughout the life cycle of a product (ISO 14006:2020). Regardless of the definition, eco-design principles include many environmental issues that should be considered: avoiding toxic substances, using materials with recycled content, reducing the energy and resource intensity of the production process, minimising energy and resource consumption at the use stage of products, promoting repairability, expansion, upgrading, and extending the life of products, facilitating disassembly and recycling, etc. (Luttropp & Lagerstedt, 2006).

The greatest challenge in designing sustainable products is the selection of appropriate design strategies based on life cycle thinking (Bakker et al., 2014). Life cycle thinking means that when designing or developing a product, a company needs to consider which environmental aspect of a product is a critical point in the life cycle and implement appropriate measures for that area, even if that point is outside the "company's gate". Numerous environmental classifications of products can be found in the literature, offering insights into crucial environmental hotspots in the product life cycle (Joachimiak-Lechman et al., 2017; Joachimiak-Lechman et al., 2019). In general, a distinction is made between production-intensive, transportation-intensive, use-intensive, and disposal-intensive products.

Many papers present practical aspects of eco-design. From recent reports, it is worth mentioning the new eco-design model based on a life cycle integrated framework (Kong et al., 2022), the proposition to use Cuckoo search and life cycle assessment to support design decision-making (Ng & Tang, 2022), and the impacts of Industry 4.0 technologies on materials, products, and processes in the context of eco-design (Keivanpour, 2022). Li et al. (2024) established an eco-design performance evaluation system. A linked two-stage network Data Envelopment Analysis (DEA) model was developed, which includes Internal and Supplier Management (ISM) and Openness and Collaboration (OC). The new concept is also Eco-Design for Additive Manufacturing (EcoDfAM) using the Web Ontology Language (OWL) to model the Sustainable Design Knowledge (SDK) (Wang et al., 2024). Favi et al. (2019) described the implementation of a novel eco-design teaching approach involving the company's employees from different technical departments.

The literature also discusses the eco-design implementation in enterprises. The study presented by Dekoninck et al. (2016) addressed the problem of the slow take-up of eco-design in industry. Case studies from nine manufacturing companies from five different countries were reported based on interviews with key eco-design personnel. Challenges were identified in five areas: strategy, tools, collaboration, management and knowledge. The management category of challenges was the most frequently mentioned by the sampled companies (Dekoninck et al., 2016). Based on 61 interviews with automobile company suppliers, the interest businesses take in eco-design depends on supply chain management. It was proved that the perception of eco-design is very strong among the electric and electronic part suppliers. The perception of eco-design among other suppliers is weak (Akman et al., 2021). Another important issue is the company's level of eco-innovation. Interviews conducted with ten companies in Slovenia that actively adopt and develop eco-innovations proved that the analysed entities implement practices of the circular economy, such as open-circle recycling, recycling and reuse of materials, rental and remote monitoring of their products, and closed resource loops (e.g., materials and water) (Hojnik et al., 2023). The survey of managers from a sample of 300 manufacturing companies in Spain showed that for product design, the most frequent practice was the design for recycling, followed by the design for reuse (DfR) and the design for disassembly (DfD) (Triguero et al., 2023).

The study investigating the adoption of green supply chain management in developing countries proved that eco-design and green marketing coupled with eco-innovation assisted in enhancing environmental image. Hence, the active involvement of organisations in innovation processes and the implementation of green management practices drive success (Bashar et al., 2023). Research efforts in Poland on the implementation of sustainable development patterns (e.g., Sikorska et al., 2005; Anuszewska et al., 2011a; Anuszewska et al., 2011b; Zuzek & Mickiewicz, 2014; Suzuki & Gemba, 2022; Słupik, 2014; Kubicka & Kupczyk, 2016) have not addressed eco-design. The most extensive report resulted from a qualitative study commissioned by the Polish

Agency for Enterprise Development, published in 2011. It was noted that few of the analysed companies had declared eco-design practices (Annuszewska et al., 2011b). Considering that many eco-design stimulants have emerged since then, eco-design can be expected to become more popular in practice. However, it seems that most SMEs are still reluctant to adopt eco-design initiatives. SMEs need to adapt to the economic model and have appropriate knowledge of production and management processes and their relationship with product innovation and the environment (Siwiec et al., 2024 cit. per Ali et al., 2021). Other analyses also confirmed the vital role of the owner and the internal corporate organisation and the barriers faced by SMEs in acquiring the necessary knowledge, thus making internal training of existing resources a key factor for them (Rodríguez-Rebès et al., 2024).

In 2023, a survey was conducted on the qualitative environmental aspects of product improvement in SMEs from the Visegrad Group countries (Czech Republic, Poland, Hungary, and Slovakia). A research sample consisted of 379 companies from the electrical machinery industry. The analysed companies focused their activities on improving products to improve their quality rather than limiting their negative environmental impact (Siwiec et al., 2024). According to the study, the most frequently used measures of environmental activity in SMEs from the V4 countries are waste generated per unit of finished product, the percentage of recycled waste, efficiency in the use of materials and energy, environmental failures (e.g., exceeding the established pollution limits and unplanned releases) and the number of incidents (Siwiec et al., 2024). Important conclusions illustrating the approach of companies to product-oriented environmental aspects also emerge from a study conducted by researchers from the Poznan University of Technology. The study focused on different manufacturing companies operating in the Greater Poland Voivodship. The main objective was to compare the involvement of manufacturing companies in environmental activity at various stages of the product life cycle. It was observed that large companies applied numerous pro-environmental solutions and continuously improved their processes. It was also concluded that in the context of SMEs, many areas require improvements; however, the willingness of SMEs to develop their environmental activities was also demonstrated (Dostatni et al., 2023).

2. Research methods

As mentioned, qualitative research was conducted using the individual in-depth interview method with representatives of selected manufacturers located in Poland (PKD codes:14.13, 31.09, 26.20, 27.40, 27.51, 23.32, 23.99, 20.30). The choice of industries was dictated by the EU initiative on sustainable products. In the clothing and furniture industry, the survey included representatives of the most numerous manufacturer groups (according to the Polish Statistical Information Centre https://bip.stat.gov.pl/dzialalnosc-statystyki-publicznej) belonging to the class "Manufacture of other outerwear" and "Manufacture of other furniture". In the electronics and electrical engineering industry, interviews were conducted with representatives of the most numerous classes ("Manufacture of computers and peripheral equipment" and "Manufacture of electric lighting equipment") and producers of household appliances, which had a significant production increase in 2020. The construction industry is the most diverse manufacturer group that belongs to different classes of the Polish Classification of Activities; thus, the qualitative study included representatives of manufacturers with a significant production increase in 2020 (more than 10%), i.e., building ceramics, insulation materials and paints and varnishes.

Purposive sampling was used in the study. The sample selection criteria were based on production activities in selected industries and involvement in product-oriented pro-environmental initiatives. Recruitment was made using databases provided by Dan & Bradstreet (https://www.dnb.com) and the Central Economic Information Service. Dun & Bradstreet supplies a reputable company database that collects and provides comprehensive information on companies in various industries and regions. It ensures that the list of companies is comprehensive and covers a variety of companies, which allows for a reliable sample for qualitative research.

In the first stage of selection, 50 companies were recruited for the study according to the indicated PKD code. In the next stage, a trained recruiter contacted the enterprises, asking whether the company takes any pro-environmental initiatives related to the products they offer (the word "eco-design" was deliberately avoided so that companies would not assume in advance that they were not active in this area). In the case of a positive answer, the recruiter asked to

Tab. 1. Number of companies invited to participate in the study

Industry	Number of companies
Manufacture of other outerwear (PKD code:14.13)	3
Manufacture of other furniture (PKD code: 31.09)	3
Manufacture of computers and peripheral equipment (PKD code: 26.20)	3
Manufacture of electric lighting equipment (PKD code: 27.40)	3
Manufacture of household appliances (PKD code: 27.51)	3
Manufacture of building ceramics (PKD code: 23.32)	3
Production of insulating materials (PKD code:23.99)	3
Production of paints and varnishes (PKD code:20.30)	3

contact the appropriate employee, noting that a person with a managerial position responsible for product policy should participate in the interview. Recruitment was carried out until interviews were successfully arranged with representatives of companies in a given industry (three producers for each selected industry). Finally, 24 companies were selected (Table 1). The most common reason for disqualifying a company was the lack of contact (e.g., an inactive number) or refusal (due to the lack of time/ the lack of willingness to participate in the interview or a declared lack of interest in the environmental aspects of the offered products).

The study was attended by nine production managers, five product managers, five owners, four environmental specialists, and one ESG coordinator. Almost half of the surveyed businesses were limited liability companies. Most of the surveyed companies (18) belonged to the SME sector, with the largest group being small entities (13). Four companies had foreign capital. Eight of the surveyed companies had formalised management systems, usually a quality management system based on ISO 9001 (as a standalone system or in integration with other management systems ISO 14001 and ISO 45001).

Individual in-depth interviews were conducted following the standards set by the ICC/ESOMAR Code 2016, using Microsoft Teams. The individual in-depth interview was based on a structured interview scenario. The interview was prepared following an in-depth review of the eco-design requirements for the analysed products included in EU Commission Regulations (EU Commission Regulations: 666/2013, 66/2014, 2019/424, 2019/2019, 2019/2020, 2019/2021, 2019/2022, 2019/2023, 305/2011, EC Regulation 1907/2006, EU Commission Decision of May 28, 2014) and proposals presented in publications of various institutions (European Environmental Bureau 2017, Nordic Council of Ministers 2018, Public Waste Agency of Flanders 2021, Environmental Coalition on Standards 2021).

Interviews were recorded, and a transcription of the content was made. The interview transcriptions went through content analysis using a predefined set of categories. The first step in the content analysis was coding. This procedure involves generating categories (codes) that conceptually cover the area under study, assigning properties to them, and linking them together to look for relationships (Glinska-Neweś & Escher, 2018). A code, therefore, in qualitative data analysis is a designation or label assigned to units of text, and it is assumed that these units can include individual sentences, statements, or sequences of statements (Kowalik & Baranowska-Prokop, 2013). The set of obtained categories was supplemented based on statements that emerged in the interviews. Finally, they were divided into smaller units, so-called subcategories. The coding of the interview resulted in a set of 268 citations. The analysis of the results of individual in-depth interviews is presented below.

3. Research results

3.1. Supply

The most important part of the study dealt with product design and development actions by the surveyed companies and focused on the various stages of the life cycle. The first question concerned the material supply process. Three areas of activities in supply were identified from analysed responses (Table 2):

- purchasing eco-friendly production materials (29 statements),

Tab. 2. Actions in the field of supply

Industry	Major category	Frequency of occurrence	Subcategory	Frequency of occurrence
Manufacture of other outerwear	We buy eco-friendly production materials	5	Fibers with content of raw materials of natural origin	2
			Fabric with content of natural dyes	2
			Fabric produced with the use of organic methods	1
Manufacture of other furniture	We buy eco-friendly production materials	3	Furniture materials with recycled content	2
			Ecological paints	1
	We consider additional supplier qualification criteria	1	Supplier location	1
Manufacture of computers and peripheral equipment + Manufacture of electric lighting equipment + Manufacture of household appliances	We buy eco-friendly production materials	14	Components that ensure the energy efficiency of a product	8
			Construction materials with recycled content	4
			Construction materials with the content of raw materials of natural origin	2
	We consider additional supplier qualification criteria	6	Supplier location	2
			Supplier eco-friendly activities	1
			Possibility of order commingling	1
			ISO 14001 certification	2
	We pay attention to transportation packaging	1	Use of reusable packaging	1
Manufacture of building ceramics + Production of insulating materials + Production of paints and varnishes	We buy eco-friendly production materials	7	Production materials with recycled content	3
			Production materials with low content of hazardous chemicals	3
			Production materials with the content of raw materials of natural origin	1
	We consider additional supplier qualification criteria	2	Supplier location	1
			Possibility of order commingling	1

- considering additional pro-environmental criteria when qualifying suppliers (nine statements),
- paying attention to transport packaging (one statement).

The category "Actions in the field of supply" was assigned 39 citations, which accounted for less than 15 % of the citations in the database. This means that the surveyed companies are not particularly interested in sourcing eco-friendly production materials or considering additional pro-environmental criteria when qualifying suppliers. One surveyed company from the apparel industry admitted not considering any environmental aspects in their purchasing process, as they were only guided by price. Other surveyed apparel companies paid attention to the content of natural raw materials in fabrics and the content of natural dyes when purchasing production materials. It was indicated that they looked for the optimal composition of fabrics/dyes so that the designed/developed product was sufficiently durable. One manufacturer from the furniture industry admitted not being guided by environmental aspects when purchasing production materials. The remaining companies said they bought materials with recycled content. One respondent indicated that this was not their regular practice as "few customers have such expectations".

The next three industries manufacture energy-powered products. The most frequent pro-environmental purchasing criterion was "energy efficiency of components" (eight statements). One company representing the computer and peripheral manufacturing industry neither indicated this nor other environmental aspects as important in their purchasing process. Only one representative of this industry admitted to buying engineering plastics with recycled content. The others were not interested in this practice, focusing only on the best quality of materials. One of the respondents made the following statement: "Primarily, the utmost importance lies in the product's functionality, followed by the choice of components and materials that are more or less environmentally friendly". The remaining statements made by electrical lighting equipment and home

appliance manufacturers indicated an interest in materials with recycled content (three statements).

The last three industries operate in the construction sector. One of the analysed companies from the building ceramics industry strongly denied buying materials with recycled content, explaining that "they are only interested in the best quality raw materials". The other two companies bought materials with recycled content but made it clear that the technology allowed for their use. In the case of manufacturers of insulation materials, each of the surveyed entities pointed to only one (each time different) environmental aspect related to purchasing ("production materials with low content of hazardous chemicals"/"production materials with recycled content"/"production materials with the content of raw materials of natural origin"). One of the surveyed companies from the paints and varnishes industry admitted that it did not consider any environmental aspects in the purchasing process, as price was the most important criterion. Other surveyed entities indicated making purchases by considering the content of chemicals and whether they posed a general threat to the environment.

3.2. Production processes

The second question of the interview concerned production processes. Three areas of action in the field of production processes were identified during the statement analysis (Table 3):

- lowering the level of production materials consumption (31 statements),
- lowering the level of conventional energy consumption (31 statements),
- lowering the level of water consumption (one statement).

The category "Actions in the field of production processes" was assigned 63 citations, accounting for just under 24 % of the citations in the database, indicating that, in general, aspects related to production (e.g., material consumption) were more important than aspects occurring in the supply chain (e.g., recycled content). Regarding the reduction of the consumption of production materials, respondents most often described the reuse of waste in the production process (14 statements). Although much less frequent, another activity in this area was using IT tools to facilitate the optimal usage of materials (six statements). To optimise the use of production materials, a few entities (four companies) produced products from waste, thus diversifying their activities. In the area of energy consumption reduction, two dominant activities were noted: the "use of photovoltaic panels" (12 statements) and "investment in machinery with low energy demand" (ten statements). One of the companies surveyed uses professional software that collects data on material and energy consumption and emissions to help control production performance. This is the only example of comprehensive monitoring of resource consumption in business operations. More often than not, companies could

Tab. 3. Actions in the field of production processes

Superior category	Major category	Frequency of occurrence	Subcategory	Frequency of occurrence
Actions in the field of production processes	We reduce the consumption of production materials	31	Reuse of waste (closed loop)	14
			Use of IT tools to facilitate optimal use of materials	6
			Investment in machinery to allow the most efficient material consumption	3
			Selection of materials to allow the most efficient use of them	3
			Monitoring of processes for waste minimisation (not IT-assisted)	2
			Preparation of intermediates to ensure efficiency in their use	1
			Processes improvement to eliminate non-conforming products	1
			Miniaturisation of product components	1
	We reduce the consumption of conventional energy	31	Use of photovoltaic panels	12
			Investment in machinery with low energy demand	10
			Optimisation of machine park working time	3
			Heat recovery	3
			Use of standby mode of machines and equipment	1
			Education of employees on energy-saving	2
	We reduce the consumption of water	1	Investment in machinery with low water demand	1

not describe in detail how they tracked materials used. One statement read: "From an economic perspective, everyone seeks to use as little energy, gas, or other things as possible. It is not written down or supervised in any way".

3.3. Distribution

The next question addressed the distribution topic. Two areas of action were identified in this field based on respondents' statements (Table 4):

- implementing pro-environmental solutions in the area of packaging (32 statements),
- implementing pro-environmental solutions in the area of transportation (23 statements).

The category "Actions in the field of distribution" was assigned 55 citations, accounting for about 21 % of citations in the database. To reduce the impact of the product distribution stage, most of the surveyed companies used packaging made of environmentally friendly materials (17 statements). In the second area of action in this field, the most popular was "optimisation of transport routes and cargo" (11 statements), followed by the "use of environmentally friendly fleet" (seven occurrences).

3.4. Product performance parameters

The next question concerned performance parameters for designed/developed products. Respondents were asked to describe actions they take to reduce the environmental impact of the product at the use stage. Two areas of activities were identified based on the responses (Table 5):

- implementing solutions to increase the durability/reliability (including extending the life of products) (68 statements),
- implementing solutions to reduce the intensity of resource use (19 statements).

The category "Actions in the field of a product's performance parameters" was assigned 87 citations, accounting for more than 32 % of the citations in the database and ranking this stage in the first place in terms of the number of actions taken to reduce the environmental impact of the products. One apparel company admitted to not having taken any actions to increase the durability/reliability of its products. The respondent's statement reads: "This may sound a bit brutal, but we don't care about using our products for as long as possible. It's not a priority for someone to use a garment for 20 years". Other apparel companies implement valuable activities leading to an increase in the durability/reliability of the products they offer, leading to an extended life cycle ("providing an offer for refresh/repair", "providing classic form and universal design", etc.). In the case of furniture manufacturers, each of the surveyed companies takes specific measures to increase the durability/reliability of the products, for example, "use of low-failure connection systems", "use of readily available damage-prone components or their provision at the point of sale".

Each of the surveyed companies in the computer and peripherals industry takes measures to reduce energy consumption while the product is active and/or in standby mode (they vary, e.g., installing motion sensors or using efficient batteries). Each of the surveyed companies also provides spare parts and has a product repair service on offer (beyond the warranty period). As in the case of computers and peripheral equipment manufacturers, the surveyed lighting producers try to reduce the energy intensity of their products. However, manufacturers in this industry are less active in the field of durability/reliability of their products than the previously analysed entities.

The surveyed household appliance manufacturers implement a wide variety of measures to reduce the resource intensity of their product use, and this applies to a broad range of products (e.g., providing

Tab. 4. Actions in the field of distribution

Superior category	Major category	Frequency of occurrence	Subcategory	Frequency of occurrence
Actions in the field of distribution	We implement pro-environmental solutions in the area of packaging	32	Use of packaging made of environmentally friendly materials	17
			Avoiding repackaging	8
			Reducing the weight of the packaging	1
			Giving up disposable packaging (partial)	6
	We implement pro-environmental solutions in the area of transportation	23	Optimisation of transport routes and cargo	11
			Use of an environmentally friendly vehicle fleet (electric cars or hybrids)	7
			Selection of courier company considering environmental aspects	3
			Transportation by rail	2

Tab. 5. Actions in the field of product performance parameters

Industry	Major category	Frequency of occurrence	Subcategory	Frequency of occurrence
Manufacture of other outerwear	We implement solutions to increase durability/reliability	17	Ensuring an optimal composition that gives the possibility of longer use	2
			Ensuring classic form and universal design	2
			Formulation of detailed instructions for care	2
			Providing a refresh/repair offer	2
			Providing models that adjust to buyers' size	2
			Use of modern print fixation technologies	1
			Strict control of the strength of the fabric and seams	2
			Use of readily available accessories or providing them at the point of sale	1
			Supporting actions of second-hand clothing resale	1
			Supporting the collection of unshredded clothing	1
			Organising post-season fairs (selling off old collections and unneeded fabrics)	1
Manufacture of other furniture	We implement solutions to increase durability/reliability	14	Use of low-failure connection systems	3
			Use of modern technology for the preparation of semi-finished products	1
			Ensure modularity of furniture	1
			Stability check after disassembly and reassembly	1
			Use of readily available damage-prone components or their provision at the point of sale	3
			Formulation of detailed maintenance instructions	3
			Providing a refresh/repair offer	2
Manufacture of computers and peripheral equipment + Manufacture of electric lighting equipment + Manufacture of household appliances	We implement solutions to increase durability/reliability	29	Increasing the efficiency of ventilation	2
			Use of technology that extends mechanical durability	5
			Ensuring the highest quality components	2
			Ensuring ease of upgrade/replacement	2
			Ease of repair and maintenance	1
			Detailed product testing and control of performance parameters	4
			Providing spare parts	6
			Providing a repair offer (beyond the warranty period)	7
	We implement solutions to reduce the resource intensity of use	13	Reducing energy consumption at usage	9
Manufacture of building ceramics + Production of insulating materials + Production of paints and varnishes	We implement solutions to increase durability/reliability	8	Use of modern material-strengthening technologies	3
			Use of modern technology that provides additional protection	3
			Use of materials that ensure a long shelf life	1
			Strict quality control of raw materials	1
	We implement solutions to reduce the resource intensity of use	5	Use of modern technology to ensure high insulation parameters	3
			Use of materials that ensure high product yield	1
			Training for wholesalers and contractors	1

a modern oven design to optimise operating time, providing a system to automatically set optimal freezing parameters, a function to retain water from the last rinse in the dishwasher, etc.). One company pointed out that "there will be something in each product range so that the customer can choose an even greener option for themselves than the regulations require". Manufacturers of household appliances indicated numerous measures to increase the durability/reliability of their products. One company's statement said: "We also don't care about introducing something that will break down immediately. We check everything down to the last detail, and we even do it with care, so to speak".

A surveyed manufacturer of building ceramics did not indicate specific measures leading to reducing the environmental impact of their product's use phase. Other companies used technology that pro-

vided increased insulation parameters. One statement was made regarding the use of material reinforcement technology and strict control of the raw material's quality, which, according to the respondent, is the most important in ensuring the durability of ceramic products. One insulation manufacturer said that they did not take additional measures to improve the product's performance aspects. According to the respondent, the way forward for the industry would be to develop a biodegradable product, but this is beyond the "capabilities of a small company". The second surveyed manufacturer of insulation materials takes steps to improve its insulation performance, ensuring that products are continuously developed in this regard. This company also uses innovative additives to improve the strength of materials. The third company implements technological solutions to improve insulation parameters in addition to using technology that increases the durability of the offered product. In the statements of the surveyed paint and varnish manufacturers, the use of technology to ensure high product durability came up twice. Each of the surveyed companies reiterated the importance of reducing harmful air emissions during product application and ensured that this aspect is considered when purchasing production materials.

3.5. Final disposal

The last question concerned reducing the environmental impact of the product's final disposal. Two areas of action were identified in the responses of the surveyed companies (Table 6):

- implementing solutions to facilitate disassembly and recycling (20 statements),
- taking additional organisational measures (four statements).

There were 24 citations assigned to the overarching category "Actions in the field of final disposal", which accounted for less than 10 % of the citations in the database. This is certainly the most difficult stage for the surveyed companies to counteract environmental damage. Seven surveyed companies did not take any initiatives to reduce the environmental impact of their product's end-of-life (no such far-reaching passivity was noted for the other stages). Among the identified activities, it is worth noting the possibility of returning used products and their recycling/recovery within the scope of the manufacturer's operations (five statements). Seven respondent statements also included the issue of ensuring that disassembly can be carried out using common hand tools and unskilled labour.

Tab. 6. Actions in the field of final disposal

Superior category	Major category	Frequency of occurrence	Subcategory	Frequency of occurrence
Actions in the field of final disposal	We implement solutions to facilitate disassembly and recycling	20	Ensuring collection of used products and recycling/recovery	5
			Ensuring the possibility of post-assembly waste return and recycling /recovery	2
			Ensuring that dismantling can be carried out using common hand tools and unskilled labour	7
			Providing dismantling service	1
			Use of homogeneous, recyclable materials	4
			Elimination of coatings that are difficult in the final processing stage	1
	We take additional organisational measures	4	Collection of used equipment (on its own)	4

Tab. 7. Stages for which advanced actions are implemented

Industry	Number of employees	stages
Manufacture of other outerwear	Below 10	Product use
	Up 250	Product use
Manufacture of other furniture	50–250	Production
	50–250	Production
Manufacture of electric lighting equipment	10–49	Distribution
Manufacture of household appliances	Up 250	Product use Final disposal
	Up 250	Product use
	50–250	Product use
Manufacture of building ceramics	Up 250	Production
Production of insulating materials	Up 250	Product use Final disposal

4. Discussion of the results

It seems indisputable that companies should consider the life cycle perspective in pro-environmental activities. It involves identifying and prioritising environmental aspects in a product life cycle, determining the most critical, and implementing basic measures to address them. Critical points (hot spots) in the life cycle of various products are described in the literature (e.g., Joachimiak-Lechman et al., 2017; Joachimiak-Lechman et al., 2019). However, the range of actions companies from different industries apply to reduce the impact of product life cycle has not been studied in depth. The degree to which companies consider the life cycle perspective, i.e., a degree understood as the variety of measures taken and their complexity, depends on a number of internal factors. In this area, product specificity plays an important role.

All surveyed companies undertake activities to reduce the environmental impacts occurring at least at two stages in the life cycle of their products. Twelve companies include all life cycle stages in their product design and development practices. Seven companies exclude only one stage. The activities vary in scope. The final disposal stage is the most difficult issue for the surveyed companies. A survey of 300 manufacturing companies in Spain concluded that the most frequent practice in product design was the design for recycling (Triguero et al., 2023). The study presented in this paper shows that the surveyed companies pay the most attention to the product performance parameters.

Table 7 indicates companies with advanced actions and their implementation stages. Ten companies undertook actions that could be considered advanced. Six of these companies use advanced activities to address the product's use phase, meaning that manufacturers reduce the used product's environmental impact by considering and implementing complex solutions. Two companies undertake such activities at more than one life cycle stage (use and final disposal). Based on other studies (Siwiec et al., 2023), paying attention to product performance parameters involves competing on quality.

Table 7 shows the size of companies undertaking advanced activities. The company size is an important factor influencing involvement in pro-environmental activities, which was also concluded by Dostatni et al. (2024). As mentioned, six large business entities participated in the interviews presented in this paper. Their activities focusing on the life cycle perspective varied in scope, and not all entities showed particular commitment. Two out of the three surveyed household appliance manufacturers were large entities. In their statements, many examples illustrated efforts to reduce the environmental impact of product use. However, one-third of household appliance manufacturers belonging to the SME sector were equally active in improving the environmental aspects of this stage. A similar situation was observed in the apparel industry: a micro-company showed a far-reaching commitment to product development in terms of life cycle aspects, which was not far behind the large company's. Consequently, while it is easier for large entities to undertake such activities, the key element is environmental awareness. The following statement was made by a representative of a micro-enterprise in the apparel industry: "Every company should focus on minimising the negative impact on the environment. We operate in terms of eco-design all the time, and regardless of the financial situation, that's just the way it is".

This study is unique as it analysed different manufacturing sectors. Due to the diverse characteristics of the surveyed products, a comparison of the selected industries is difficult. Nonetheless, a few general points are worth mentioning. Manufacturers of household appliances and other energy-powered products show a relatively high level of interest in environmental aspects of the life cycle. This is probably because their products are characterised by many parameters that can be improved. Also, eco-design requirements are significant; thus, manufacturers have to change their thinking about the products they offer. All surveyed manufacturers of energy-powered products are taking steps to reduce the intensity of used energy. The apparel and furniture industries are not bound by eco-design requirements at the moment. Therefore, the improvements focusing on the product life cycle are driven by the need to adapt to potential trends. In the case of the apparel industry, two of the three surveyed companies showed a noteworthy interest in improving the environmental aspects of the life cycle of the products (especially in the field of durability/reliability). Less interest in the life cycle perspective was demonstrated by manufacturers of the products used in the construction industry. Companies in this industry reported a relatively narrow range of performance improvement opportunities.

Conclusions

The interview focused on the actions surveyed companies took in product policy on life cycle thinking. The questions were asked in the context of product design or development, but respondents often spoke about pro-environmental activities in a broader context. Some surveyed companies were unaware of the measures they took for pro-environmental product development. Based on the responses, many surveyed entities did not link their product-related environmental actions directly with eco-design. The study provided evidence that companies mainly implemented pro-environmental practices for pragmatic reasons.

The evaluation of product-focused pro-environmental activities should consider whether the crucial stage that requires appropriate measures is given priority in these activities. Only one of the interviewed companies (an apparel industry representative) did not pay attention to environmental aspects critical to the product life cycle. In its case, the idea of life cycle thinking was not present. Other companies participating in the study considered the life cycle perspective when designing or further developing the existing products by considering environmental aspects that are the hot spots in the product life cycle. However, the activities varied in scope. Ten entities implemented complex activities targeting various aspects (not only the most relevant) of the product life cycle.

All the surveyed entities implement pro-environmental activities in production processes, and most concern several aspects (e.g., material and energy consumption). In the statements, respondents clearly emphasised that pursuing optimal resource consumption was associated with rising production costs. In addition to production process-oriented activities, each surveyed company undertakes activities related to other life cycle stages (at least one). This indicates a new corporate approach that goes beyond the operational boundaries of the organisation. Based on the results, it can be concluded that the surveyed companies take the greatest number of actions to reduce the environmental impact of the use stage of products, mostly aiming to increase their durability/reliability. Respondents emphasised that it ensured quality and guaranteed customer satisfaction. Respondents showed relatively little interest in using recycled or natural raw materials. Some surveyed entities thought it would negatively affect the product quality. None of the surveyed companies asserted that environmental criteria of supply were a primary issue for them (more important than price).

The paper proves that eco-design requirements are an unquestionable driver for activities from a life cycle perspective. Eco-design requirements for energy-powered products impose many obligations on manufacturers regarding environmental aspects. Even though the interview did not explicitly intend to assess compliance with legal requirements, many respondent statements indicated that they were indeed complying and, in certain instances, going beyond what was required. All surveyed manufacturers of energy-powered products took measures to reduce energy intensity when the product is active and/or in standby mode. They were less active, e.g., in ensuring product durability/reliability (except for home appliance manufacturers, which take numerous measures in this area) and in facilitating disassembly and recycling. Importantly, these issues will likely be included in the expanded eco-design regulation, so the surveyed companies were expected to pay more attention to them.

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