Advances in Science and Technology Research Journal

Advances in Science and Technology Research Journal, 2026, 20(3), 60–73
https://doi.org/10.12913/22998624/213341
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Received: 2025.09.22
Accepted: 2025.11.18
Published: 2026.02.01

Analysis of the innovation potential of a company operating in the gypsum-based construction products production sector

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ABSTRACT

This article addressed the problem of assessing the innovation of industrial enterprises in the context of growing demands for sustainable development, digital transformation, and climate neutrality. The aim of the article was to conduct a comprehensive assessment of the innovation of a company in the gypsum-based construction products sector, taking into account eco-innovative aspects and the compliance with European sustainable development priorities. The research problem concerns the lack of tools enabling the simultaneous assessment of technological maturity, innovation potential, and environmental impact in a practical context. The article used a proprietary method for diagnosing the state of innovation, based on TRL and LCA indicators. The method allows for the identification of sources of innovation, an assessment of the company's experience in implementing new solutions, and the identification of areas requiring further development. The collected data enabled the assessment of both the innovation potential and technological readiness of the studied company, while also taking into account the environmental impact of its operations. The obtained results confirm the usefulness of the method as a tool supporting strategic decision-making consistent with the assumptions of the circular economy as well as the green and digital transformation of industry. The presented concept bridged a research gap regarding the practical assessment of innovation in industrial sectors and can serve as a reference point for further comparative studies.

Keywords: innovation, eco-innovation, production company.

INTRODUCTION

Innovation plays a key role in economic development, constituting one of the main drivers of growth and competitiveness of countries. Already at the beginning of the 20th century, an Austrian economist Joseph A. Schumpeter identified innovation as a fundamental factor in economic development. He attributed particular importance to it in the 1940s, when the approach to enterprise management changed enterprises began to be perceived not only as profit-generating institutions, but also as active participants in innovation processes. In this new approach, the key role in company development was assigned to the entrepreneur, who initiated and implemented innovations [1].

Contemporary innovation research is based on the methodology contained in the Oslo Manual 2018, a document jointly developed by the OECD (Organization for Economic Co-operation and Development) and Eurostat (Statistical Office of the European Union). This manual is an international standard for collecting, analyzing, and interpreting innovation data at both the enterprise and sector levels. According to the current definition in the Oslo Manual, an innovation is a new or significantly improved product, process, or combination thereof that significantly differs from the previous solutions used in a given organization and is made available to users (in the case of a product) or implemented for use (in the case of a process) [2]. This definition emphasizes two fundamental elements: the novelty of the solution and its practical implementation.

At the turn of the 1980s and 1990s, in response to growing ecological awareness and the ongoing degradation of the environment, the concept of eco-innovation was developed [3]. It is as complex and multidimensional as the concept of innovation itself. Eco-innovations are defined as new or improved solutions products, processes, or business models that contribute to reducing the negative impact of human activity on the environment. Importantly, this effect can be both intended and unintended. The Oslo Manual considers them a subcategory of innovations that have a beneficial impact on the environment, regardless of their original purpose [2]. Innovation and eco-innovation can be analyzed at both the micro level (individual enterprises) and the macro level – in the context of sectors, regions, and even entire countries. Nevertheless, innovative enterprises are considered the fundamental driving force of the modern economy, as they are where new solutions are created and implemented. Although the literature on the subject contains many general studies covering innovation at the national or regional level (e.g. Eurostat or Central Statistical Office studies) detailed analyses of individual companies are much rarer [4, 5]. The lack of such in-depth analyses makes it difficult to assess the true innovation potential of companies, which in turn limits the ability to effectively support their development and strengthen their competitive position.

The purpose of this article was to present an assessment of innovation of a manufacturing company specializing in the production of gypsum building materials, such as gypsum masses and plasters, gypsum adhesives, gypsum powder, as well as perlite. The study was conducted using a proprietary method for diagnosing the state of enterprise innovation. This approach provides a new perspective on innovation assessment, taking into account not only the level of implemented innovations but also the impact of products and production technologies on the natural environment [6, 7]. This method was developed as a response to the shortcomings of existing tools for assessing the innovation and eco-innovation of enterprises. It offers an alternative perspective on the innovative activities of enterprises and indicates potential directions for their further sustainable development. Given the growing need to implement innovative and pro-ecological solutions, the conducted analysis makes a significant contribution to the implementation of development priorities set by the European Union [8, 9].

ASSESSMENT METHOD

The study employed a detailed innovation assessment method, focused on the analysis of individual companies. This method assumes a two-dimensional approach to innovation, encompassing both technological and intellectual aspects [10]. Technological innovation refers to elements directly related to the product and the manufacturing process – such as the technologies used, machines, devices, and finished products. Intellectual innovation, in turn, concerns intangible aspects of a company's operations, such as creativity, design, research and development, and the generation of new knowledge [10]. A six-point scale for assessing the level of innovation was adopted for each of these functional groups [11]. The study also utilized two complementary methods: LCA (life cycle assessment) and TRL (technology readiness level) [6, 11–13]. The LCA analysis allowed for the quantification of the impact of the company's activities on the environment, while the TRL method allowed for the assessment of the level of technological advancement at which the company has experience in the development of products and technologies. On the basis of the results obtained from LCA, an environmental profile of the company was developed, identifying the sources of impacts – whether they are primarily related to products, technological processes, or other aspects of production activities [10, 14]. The final result of the analysis is a comprehensive characterization of the level of innovation of the analyzed company. This assessment is not limited to the current state, but also allows for the identification of possible, favorable development scenarios aimed at increasing efficiency in both innovation and environmental impact [10, 14]. This approach provides the company with valuable information supporting strategic decision-making and the identification of development directions aimed at increasing competitiveness and innovation capacity. The entire research process was conducted according to the stages presented in Figure 1.

EMPIRICAL ANALYSIS

Below is a comprehensive assessment of innovation of a manufacturing company specializing in the production of gypsum building materials, such as gypsum fillers and plasters, gypsum adhesives, gypsum powder, and perlite. A wide range of methods, encompassing both theoretical and empirical approaches, was used to obtain data from the enterprise. Theoretical methods included

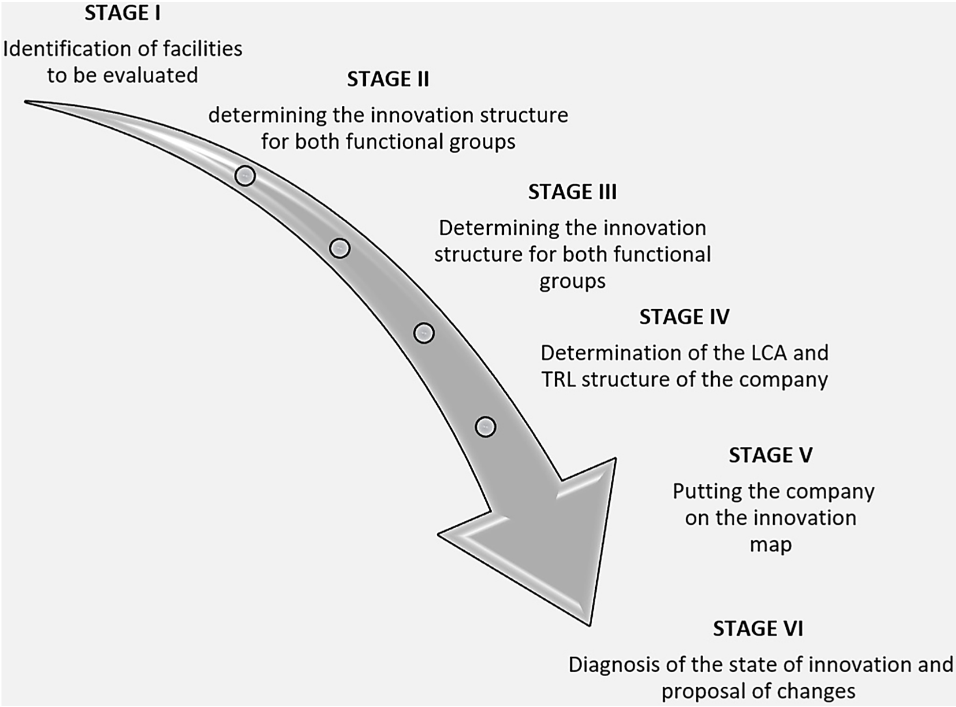

Figure 1. Stages of the innovation level assessment process for companies [6]

analysis and critique of the relevant literature, statistical methods, and logical analysis as well as construction techniques. To obtain empirical data from the enterprises, observation methods, monographic research (a thorough analysis of a selected entity), and document analysis were employed, which included the collection, selection, description, and scientific interpretation of information from the studied enterprise. In the next stage of the analysis, the logical analysis and construction method was used again. Heuristic methods were employed during the diagnosis, aimed at finding solutions by discovering new facts and relationships occurring in the studied reality. The main data collection techniques were observation and direct interviews with management staff, conducted using a specially developed questionnaire. The questionnaire addressed the issues related to technological and intellectual innovation, eco-innovation, and the assessment of the technological readiness of the enterprise.

One of the company's key strengths is its own production of perlite – a key ingredient used in its products. This reduces external transport, resulting in reduced fuel consumption and a positive impact on the environment. The company's goal is to deliver high-quality products while adhering to the principles of sustainable development. The materials produced are completely safe and free from harmful chemicals. The scope of operations covers the entire technological process – from gypsum stone extraction, through its processing, to the production of finished building materials. The plant employs modern technologies and automated production lines, allowing for increased efficiency and process optimization. The company has an extensive quality control system and its own research laboratory, which conducts detailed analyses of both raw materials and finished products. This ensures the consistent, high quality of its products.

Stage 1

In the first stage of the study, presented in Table 1, the objects subject to assessment were identified and then classified into two functional groups. The first group consisted of technological innovations, encompassing elements directly related to products and manufacturing processes. This group included, among others, products, machines and devices, production methods used, as well as personnel involved in production processes [6]. The second category consisted of intellectual innovations, relating to creative activities, such as design, creative thinking, and research and development. These activities typically result in intangible results, e.g., concepts, solutions, or know-how [6, 15].

Table 1. Evaluation of innovative activities in the enterprise

Enterprise			
Functional group	Scope of activity		
	Range	Evaluated factors	Rate
Technological innovation	Manufactured product	Quality requirements for manufactured products met Traditional materials used in production	$\beta_{5=0.1}$ $\beta_{2=0.1}$
	Manufacturing techniques	Automated production lines Meeting ecological requirements	$\beta_{6=0.1}$ $\beta_{5=0.1}$
Intellectual innovation	Research and development work	Using modern production technologies Collaboration with research centres	$\alpha_{6=0.1}$ $\alpha_{5=0.1}$
	Organization and management	Active participation in trade fairs Regular employee training Media promotion	$\alpha_{4=0.1}$ $\alpha_{5=0.1}$ $\alpha_{6=0.1}$

Stage 2

In the analyzed enterprise, the innovation structure coefficients α_i and β_i for both functional groups were calculated according to formulas (1) and (2) [6, 10]. The results illustrating the innovation structure are presented in Table 2 and Figure 2.

$$\alpha_i = \frac{u_i}{\sum_{i=1}^{6} u_i} \cdot 100\% \tag{1}$$

$$\beta_i = \frac{v_i}{\sum_{i=1}^{6} v_i} \cdot 100\% \tag{2}$$

where: μ_i – a numerical indicator defining the number of objects qualified for the innovation zone i (i = 1,...,6) in the field of intellectual innovation area; v_i – a numerical indicator defining the number of objects qualified for the innovation zone i (i = 1,...,6) in the field of technological innovation area.

Stage 3

At this stage, the values of structural indicators describing intellectual (α_0) (3) and technological (β_0) innovativeness are determined in accordance with formulas (3) and (4). On the basis of these indicators, the levels of intellectual W_{IK} and technological innovation W_{IT} innovativeness are determined in accordance with formulas (5) and (6) [6, 15].

$$\alpha_0 = \frac{\sum_{i=1}^{6} i \cdot (i \cdot \alpha_i)}{\sum_{i=1}^{6} (i \cdot \alpha_i)} \tag{3}$$

$$\beta_0 = \frac{\sum_{i=1}^{6} i \cdot (i \cdot \beta_i)}{\sum_{i=1}^{6} (i \cdot \beta_i)} \tag{4}$$

$$W_{IK} = W_{I,\ \text{dla}}\ \mu_0 = \alpha_0 \tag{5}$$

$$W_{IT} = W_{I\ \text{dla}}\ \mu_0 = \beta_0 \tag{6}$$

$$W_I = 0.10 \cdot \mu_0 - 0.10 \text{ dla } 1 \le \mu_0 < 2$$
$$W_I = 0.15 \cdot \mu_0 - 0.20 \text{ dla } 2 \le \mu_0 < 3$$
$$W_I = 0.50 \cdot \mu_0 - 1.25 \text{ dla } 3 \le \mu_0 \le 4$$
$$W_I = 0.15 \cdot \mu_0 + 0.15 \text{ dla } 4 < \mu_0 \le 5$$
$$W_I = 0.10 \cdot \mu_0 + 0.40 \text{ dla } 5 < \mu_0 \le 6$$

The calculated indicator values for the enterprise include:
$W_{IT} = 0.85$ $W_{IK} = 0.84$

Stage 4

LCA structure

The aim of the study was to assess the environmental impact of a manufacturing company

Table 2. Structure of enterprise innovation

Parameter	Innovation zone	Structure coefficients α of intellectual innovation		Structure coefficients β technological innovation	
Conservative (non-innovative)	Definitely	α_1	0.0	β_1	0.0
	Average	α_2	0.27	β_2	0.23
	Moderately	α_3	0.13	β_3	0.08
Innovative	Definitely	α_4	0.13	β_4	0.15
	Average	α_5	0.20	β_5	0.38
	Moderately	α_6	0.27	β_6	0.15

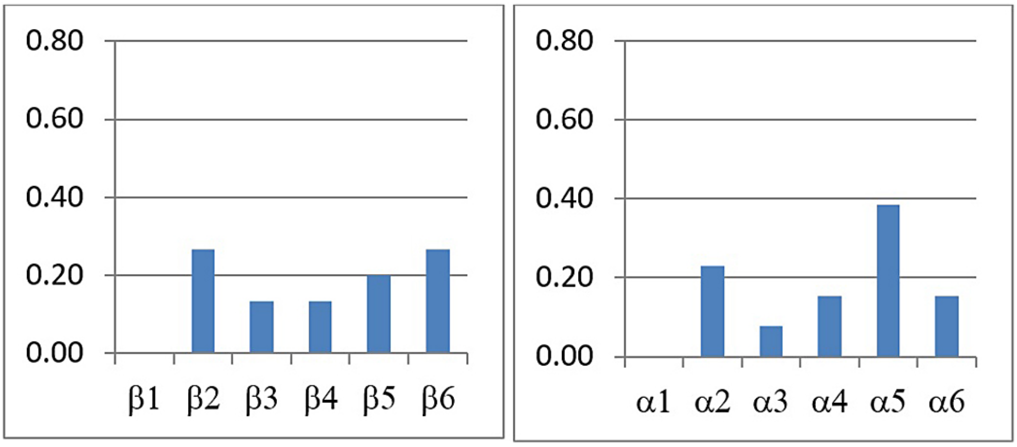

Figure 2. The company's innovation structure across both functional groups

specializing in the production of gypsum building materials. The scope of the LCA analysis covered identified products and their associated production processes. In the case of the analyzed entity, two main production lines were considered: a gypsum binder production line and a perlite production line. The study used a functional unit of 1 Mg (1 ton) of final product as a reference point for the inventory of input and output data. System boundaries were then defined and a full environmental inventory was conducted, taking into account all inputs and outputs related to the analyzed production processes. As a result, an environmental balance sheet for the company was obtained, including the consumption of materials, energy, and water, as well as the emissions of pollutants into air, soil, and water, as well as the amount of final waste. The scope of the LCA analysis, along with the identified individual production processes, is presented in Figure 3, 4.

The life cycle impact assessment (LCIA) was conducted using SimaPro 8.1 software and the ReCiPe Midpoint (H) method. In this analysis, individual products were assigned weighting factors reflecting their relative contribution to the company's total production volume. This allowed for the development of a comprehensive and detailed environmental profile. The results were compiled in the form of a MAT_{LCA} matrix table, which provided a structured representation of the company's overall environmental impact [16].

$$M_{TRL} = \begin{bmatrix} 0.00001 & 0.00000 & 0.00001 & 0.00006 & 0.00001 & 0.00003 & 0.00000 & 0.00002 & 0.00000 & 0.00006 & 0.00007 & 0.00000 & 0.00000 & 0.00000 & 0.00006 & 0.00000 & 0.00000 & 0.00001 \\ 0.00000 & 0.00000 & 0.00000 & 0.00000 & 0.00000 & 0.00000 & 0.00000 & 0.00000 & 0.00000 & 0.00000 & 0.00000 & 0.00000 & 0.00000 & 0.00000 & 0.00000 & 0.00000 & 0.00000 & 0.00000 \end{bmatrix}$$

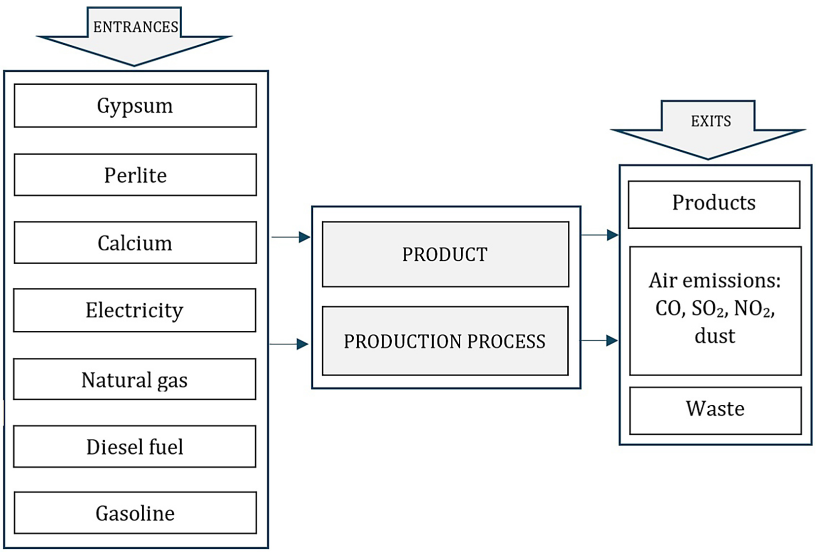

Figure 3. General framework of the inventory analysis concerning the product and its production process [16]

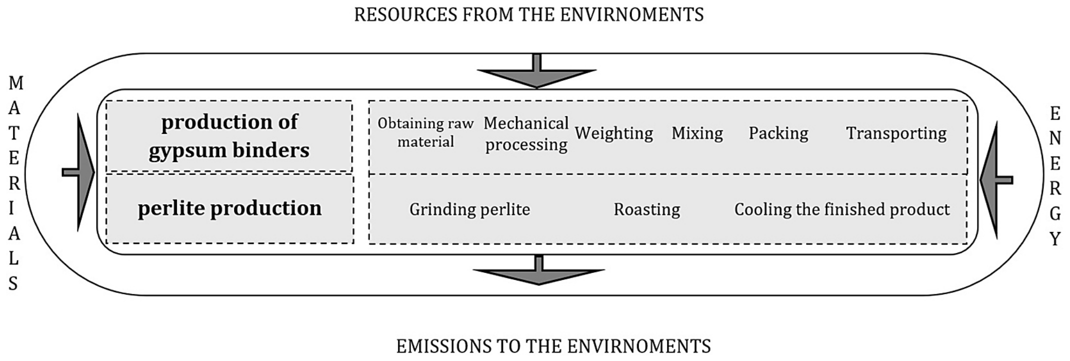

Figure 4. Scope of life cycle analysis (LCA) and its core unit processes

The study applies the ReCiPe Midpoint (H) method, in which each column represents a specific environmental impact category. These categories include: climate change, ozone depletion, terrestrial acidification, freshwater eutrophication, marine eutrophication, human toxicity, photochemical smog formation, dust formation, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, ionizing radiation, agricultural land take, urban land take, conversion of natural land, water use, mineral use, fuel use [15]. Table 3 and Figure 5 illustrate the structure of the life cycle assessment.

The results of the company's LCA analysis indicate that the most significant negative environmental impacts are concentrated in the categories of marine ecotoxicity, freshwater ecotoxicity, freshwater eutrophication and natural land transformation (Figure 5). These environmental burdens are primarily associated with the production of gypsum binders (Figure 6).

The analysis of the environmental impact profile for the adopted functional unit of 1 Mg of the analyzed products, namely gypsum binders and perlite, indicates that the most significant negative impacts occur in the categories of natural land transformation, marine ecotoxicity, freshwater ecotoxicity, and freshwater eutrophication (Figure 7). These impacts are primarily associated with the production of gypsum binders (Figure 8).

The LCA analysis shows that electricity and natural gas used in production processes are the main sources of pollution in all key environmental impact categories. This applies to both gypsum binder production and perlite production. For example, in the gypsum binder production process, electricity accounts for 71% of the total human toxicity impacts (Figure 9), while natural gas generates 48% of the climate change impacts (Figure 10). In the case of perlite production, the energy used in the technological process accounts for 62.6% of the marine ecotoxicity impacts (Figure 11).

Studies have shown that the material used in the production process is also a significant source of pollution. In the analyzed company, an impact category was identified in which the raw material constitutes the dominant source of environmental impacts. An example is perlite production, where perlite ore accounts for 84.3% of all impacts in the category of "natural land transformation" (Figure 12).

TRL structure

Four technologies were identified within the company and assessed according to their technology readiness levels (TRLs). These technologies correspond to the subsequent rows of the matrix $M_{\_TRL}$ and are presented in detail in Table 4 [6, 17, 18].

$$M_{TRL} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \end{bmatrix}$$

Technology 1 – gypsum stone extraction using drilling and blasting. Gypsum stone is extracted from the company's own open-pit mine. After blasting the exploitation wall, the material is transported to an impact crusher for preliminary crushing. The appropriately sized material is then transferred via belt conveyors, a bucket conveyor, and a distribution feeder to the storage silos of the calcining plant. The current activities in this technology correspond to levels 7–9 on the TRL scale. Level 7 – the technology used was transferred from laboratory conditions to operational conditions, i.e., the process of extracting gypsum stone using the drilling and

Table 3. Enterprise profile indicators by impact category in the ReCiPe midpoint (H) method

Parameter	Production of gypsum binders	Perlite production	Structure factors $\alpha_i = \sum_{i=1}^{j} \alpha_{n1}$
Climate change	0.00001	0.00000	0.00001
Ozone depletion	0.00000	0.00000	0.00000
Terrestrial acidification	0.00001	0.00000	0.00001
Freshwater eutrophication	0.00006	0.00000	0.00006
Marine eutrophication	0.00001	0.00000	0.00001
Human toxicity	0.00003	0.00000	0.00003
Photochemical oxidant formation	0.00000	0.00000	0.00000
Particulate matter formation	0.00002	0.00000	0.00002
Terrestrial ecotoxicity	0.00000	0.00000	0.00000
Freshwater ecotoxicity	0.00006	0.00000	0.00006
Marine ecotoxicity	0.00007	0.00000	0.00007
Ionising radiation	0.00000	0.00000	0.00000
Agricultural land occupation	0.00000	0.00000	0.00000
Urban land occupation	0.00000	0.00000	0.00000
Natural land transformation	0.00006	0.00000	0.00006
Water depletion	0.00000	0.00000	0.00000
Metal depletion	0.00000	0.00000	0.00000
Fosil depletion	0.00001	0.00000	0.00001

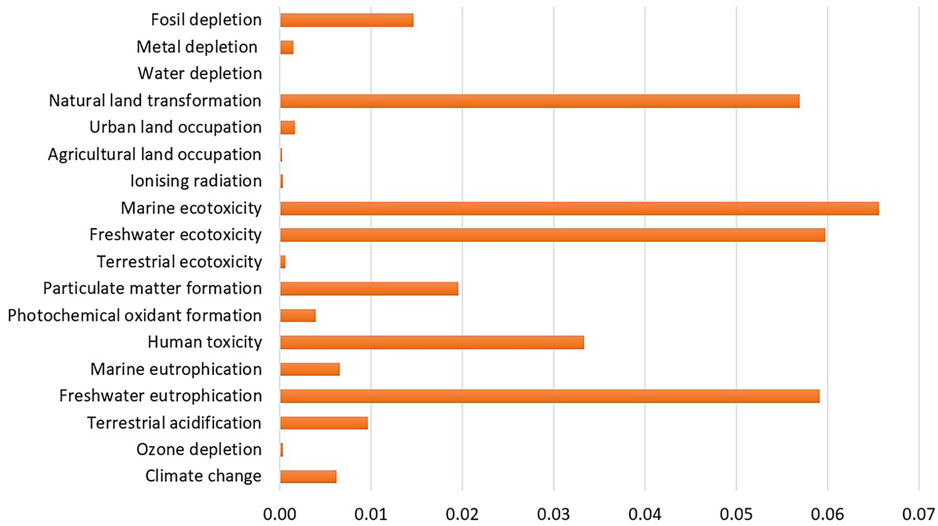

Figure 5. The LCA structure of enterprise

blasting method was carried out. The properties of the gypsum stone obtained under these conditions were examined. Level 8 – the stone was extracted using the drilling and blasting method – suggested comments regarding the obtained product were taken into account. Level 9 – the technology was tested under operational conditions, obtaining a positive result. The company continues to use the drilling and blasting method for extracting gypsum stone.

Technology 2 – automated gypsum stone processing using steam-heated calciners. The technology involves an automated process of drying and grinding gypsum stone to the required granulation in a vertical bowl-roller mill with hot air flowing through it. The dried and crushed raw material is then transported by belt conveyor to steam-heated calciners – a solution considered innovative on a global scale. The use of steam as a heating medium significantly reduces the consumption of natural

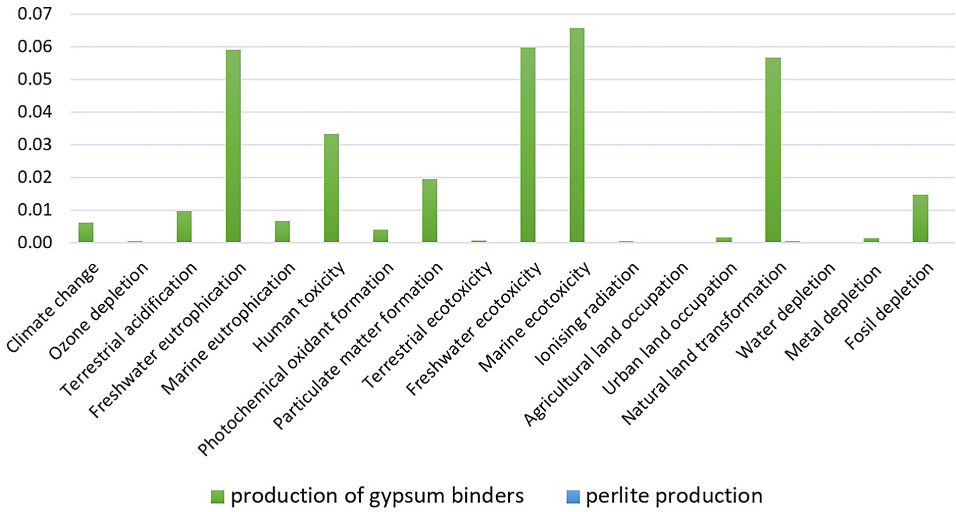

Figure 6. The LCA structure of enterprise: production of gypsum binders and perlite production

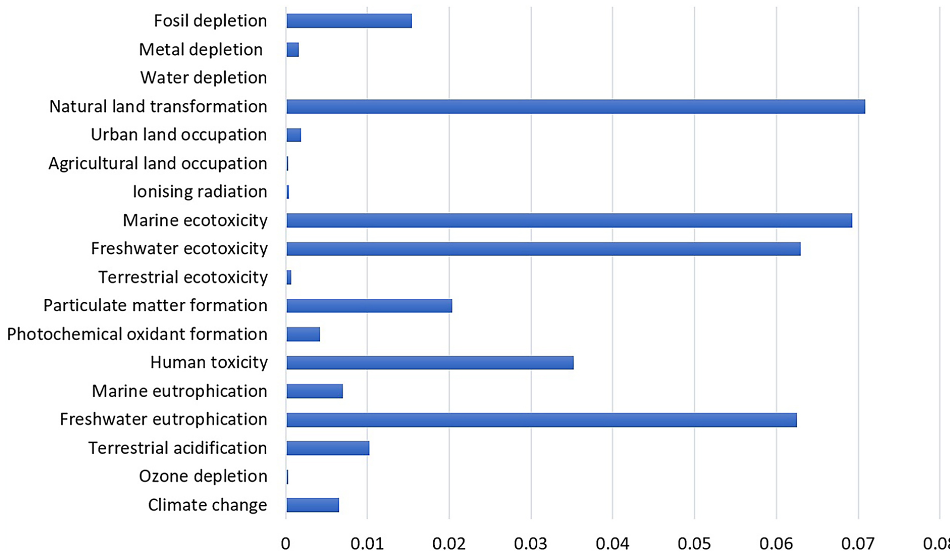

Figure 7. Ecological profile of 1 Mg of manufactured products in the enterprise

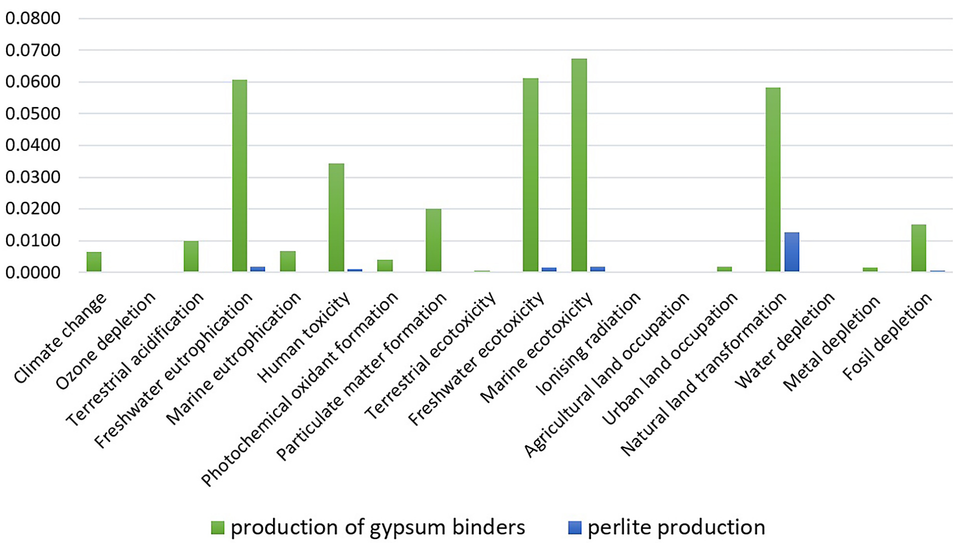

Figure 8. Ecological profile of 1 Mg of production of gypsum binders and perlite production

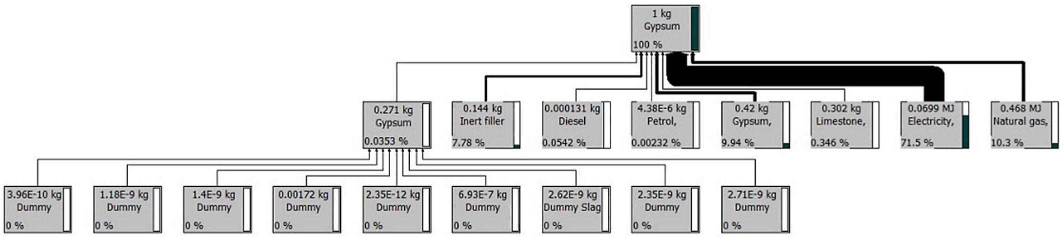

Figure 9. Gypsum binder production process tree in the category of impact of toxicity to humans

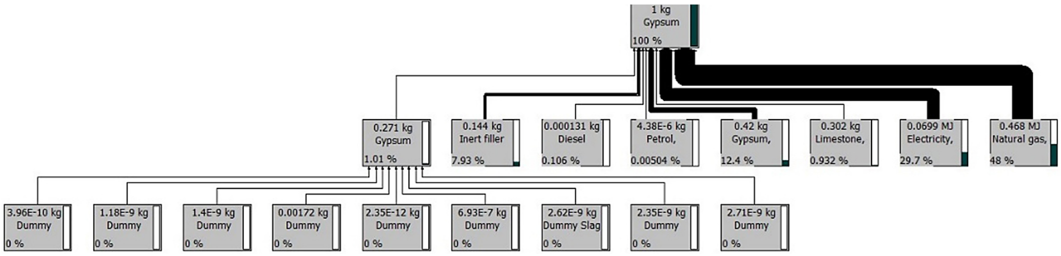

Figure 10. Gypsum binder production process tree in the climate change impact category

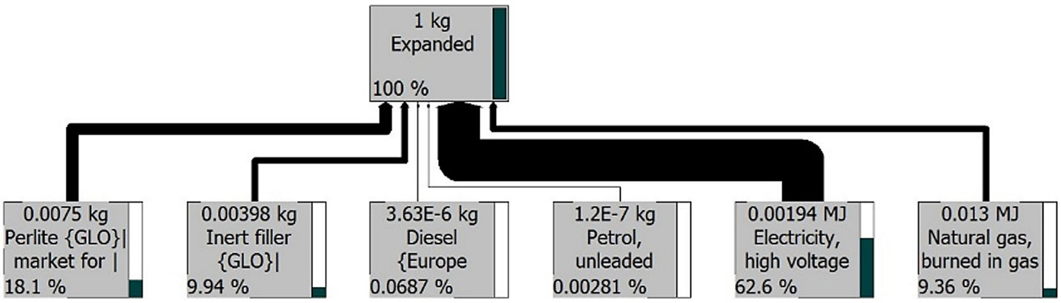

Figure 11. Perlite production process tree in the marine ecotoxicity impact category

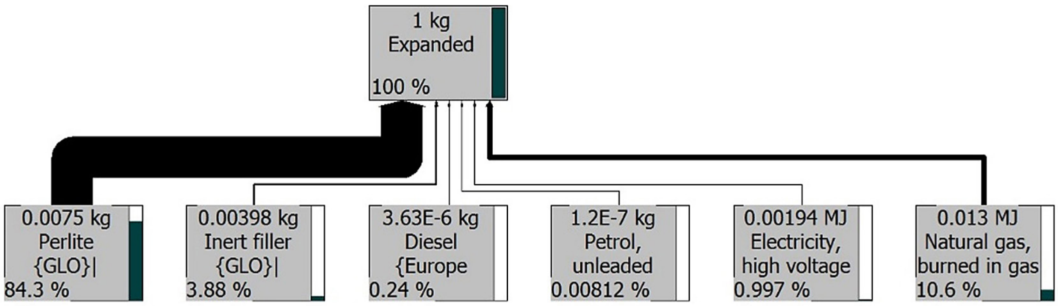

Figure 12. Perlite production process tree in the category of transformation of natural areas

resources and eliminates the emission of harmful compounds (CO_2, NO_x, SO_x) as well as the dust generated by fuel combustion. Additionally, raw material delivery is automated using a covered conveyor belt, reducing transport emissions and further resource consumption. The technological process first involves dehydration of the gypsum stone, followed by calcination, which produces calcium sulfate hemihydrate – the gypsum binder. The resulting product is cooled and transported to storage silos using bucket and screw conveyors. The company's activities related to this technology fall within the full range of the TRL scale (levels 1–9). Level 1 – the basic principles of the gypsum stone processing process using steam-heated calciners were observed and characterized.

Table 4. The state of technological development in the enterprise based on the TRL assessment

Technology	TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
1	0	0	0	0	0	0	1	1	1
2	1	1	1	1	1	1	1	1	1
3	0	0	0	0	0	0	1	1	1
4	0	0	0	0	0	0	1	1	1

Level 2 – the technology concept and possible applications of the gypsum stone processing process using steam-heated calciners were defined. TRL 3 – the assumptions regarding the new production technology were confirmed analytically and experimentally. Level 4 – laboratory tests of the potential of the gypsum stone processing process using steam-heated calciners were conducted. Level 5 – a trial run of the gypsum stone processing process using steam-heated calciners was conducted. Level 6 – The operation of the technology prototype under conditions close to real-world conditions was demonstrated. A prototype of the gypsum stone processing process was conducted using steam-heated calciners, with appropriate parameters selected. Level 7 – the technology used was transferred from laboratory to operational conditions, i.e., the gypsum stone processing process was carried out. The properties of the gypsum stone produced under these conditions were examined. Level 8 – the gypsum stone processing process was carried out using steam-heated calciners. The suggested comments were taken into account. Level 9 – the technology was tested in operational conditions, obtaining a positive result. The company continues to use the discussed technology to this day.

Technology 3 – automated gypsum product production process. The production process of gypsum mixtures, as well as their packaging and palletizing, is automated using industrial computer control systems, under constant operator supervision. The technology involves precise dosing of ingredients according to a specific recipe, their thorough mixing, and packaging of the finished product. Raw materials and additives are transported from storage silos to dosing scales using screw feeders. They are then transferred by gravity to the mixer, where the ingredients are combined. The resulting mixture is then directed to the mixing tank and then to the tank above the rotary bagger. The bagger automatically fills the bags supplied by the feeder, simultaneously weighing each product portion. The bags are then moved onto a conveyor belt, where they are cleaned and blown clean with compressed air. The finished product is then placed on pallets, which are subsequently sent to the finished goods warehouse. The company's work using this technology is at an advanced stage of implementation and falls within the TRL range of 7–9, meaning the technology has been proven and is being effectively used under operational conditions. Level 7 – the gypsum product production technology was transferred from laboratory to operational conditions. Level 8 – several gypsum products were manufactured, taking into account customer feedback. Level 9 – the gypsum product production technology was tested under operational conditions, with a positive result.

Technology 4 – perlite expansion process. The perlite expansion process involves roasting ground perlite ore in a furnace at temperatures ranging from 850 to 1150 °C. The high temperature rapidly evaporates the water contained within the ore grains, causing them to swell and expand many times their volume. This process creates a lightweight, porous material – expanded perlite. After roasting, the perlite is cooled and transported to a special tank, from where it is then used to produce dry gypsum mixtures. The company's activities in this technology are at an advanced stage of implementation and cover TRL levels 7–9, meaning that the technology has been successfully tested and applied under operational conditions. Level 7 – the perlite expansion technology used was transferred from laboratory to operational conditions. The properties of the perlite produced under these conditions were tested. Level 8 – perlite expansion was performed, and the suggested comments were taken into account. Level 9 – the perlite expansion technology was tested under operational conditions, obtaining a positive result.

TRL structure factor computed as per the formula (7) [6]:

$$\vartheta_i = \frac{\sum_{k=1}^{n} a_{ik}}{\sum_{i=1}^{9}\sum_{k=1}^{n} a_{ik}} \quad for\ i = 1 \ldots 9 \tag{7}$$

The value of the TRL index was obtained using the formula below (8) [6]:

$$W_{TRL} = \frac{\sum_{i=1}^{9} i \cdot \vartheta_i}{\sum_{i=1}^{9} \vartheta_i} \quad (8)$$

Figure 13 presents the TRL structure of the enterprise.

Stage 5

The innovation map provides a graphical representation of the W_{IK} and W_{IT} indicators calculated for both functional groups [18,19]. In the analyzed enterprise, these indicators are: W_{IT} = 0.85 and W_{IT} = 0.84, which is illustrated in Figure 14.

Stage 6

The diagnosis of the innovativeness status of the surveyed enterprise is presented in detail in Table 5. The position of an enterprise on the innovation map provides insight into its current level of innovation, outlines recommended directions for development, highlights areas where targeted improvements are needed, and identifies the company's key strengths [6]. The company is characterized by a high level of both technological and intellectual innovation, with a noticeable slight advantage in technological innovation. The company's position on the innovation map places it in the zone of sustainable development, which indicates effective utilization of synergies resulting from simultaneous activity in both functional groups. By effectively utilizing its own resources, the company is able to maintain a high level of innovation without the need for intensive external support. From the perspective of innovation strategy, the primary goal should be to maintain its current market position, with only minor adjustments possible in development directions. The recommended direction for improving the company's operations is to strengthen its intellectual innovation. This can be achieved primarily through developing collaboration with research centers, which will enable access to current knowledge, modern technologies, as well as participation in research and development projects. Investments in employee competency development are also a key element of this strategy, allowing for better utilization of staff potential and increasing the company's ability to generate and implement its own technological solutions. At the same time, efforts should be made to modernize and intensify the activities conducted in the existing research laboratory, which conducts qualitative analyses of raw materials and finished products. Strengthening this area will enable more effective support for innovation processes and contribute to increasing the company's technological independence. These activities will not only allow for maintaining the current level of innovation, but will also increase the company's potential to create and implement its own unique technologies, which may translate into increased competitiveness in the long term. The conducted environmental assessment (LCA) indicates that the primary source of pollutant emissions in key environmental impact categories is energy consumption in the production of gypsum binders and perlite. In particular, the gypsum binder production process, due to its scale and energy-intensive nature, generates significantly greater environmental impacts than

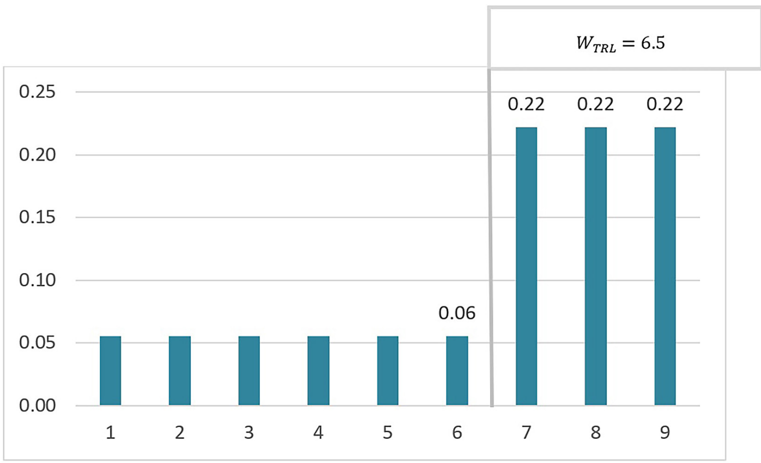

Figure 13. The technology readiness level (TRL) structure of the enterprise

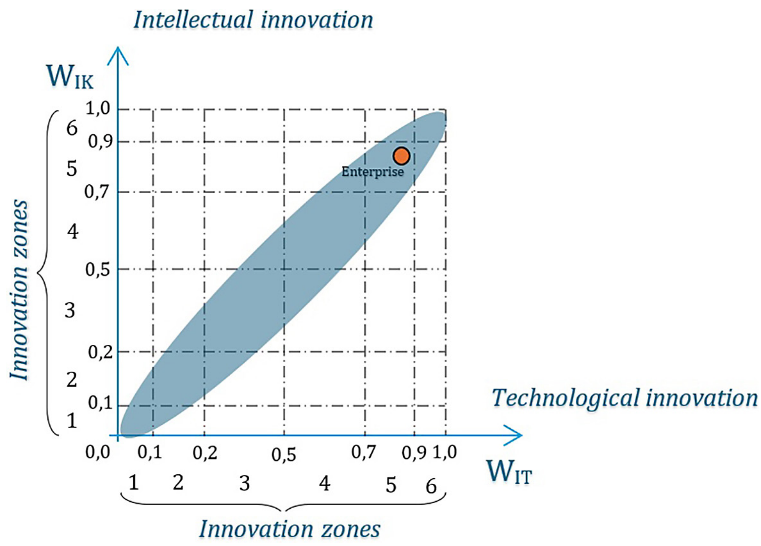

Figure 14. The company presented on the innovation map

Table 5. Diagnosis on the state of innovation

Innovation structure		LCA structure	TRL structure
Technological innovation	Technological innovation		
W_{IT} = 0.85	W_{IK} = 0.84	1. Electricity and natural gas used in production processes are the main sources of pollution in all key environmental impact categories. 2. The most significant negative environmental impacts are concentrated in the categories of marine ecotoxicity, freshwater ecotoxicity, freshwater eutrophication and natural land transformation. 3. Environmental burdens are primarily associated with the production of gypsum binders.	W_{TRL} = 6.5

perlite production. To mitigate its negative impact on the natural environment, the company should focus on implementing measures aimed at increasing energy efficiency and reducing pollutant emissions. One key area is improving the energy efficiency of production processes, which can be achieved by modernizing technological equipment, optimizing machine operating parameters, as well as implementing advanced systems for real-time energy consumption monitoring and management. An additional solution worth considering is the implementation of waste heat recovery systems, which can contribute to significant energy savings. Simultaneously, it is crucial to implement the solutions that reduce energy consumption and greenhouse gas emissions. In this regard, a gradual transition towards low-emission energy sources is recommended, for example, by using electricity from renewable energy sources (RES). Another important element of this strategy is the use of low-emission or zero-emission technologies directly in production processes, as well as the automation and digitization of processes, enabling better adjustment of energy consumption to actual operational needs. Furthermore, reducing energy losses in transmission systems and auxiliary installations is an additional factor in overall improvement of the energy efficiency of the plant. Taking the actions described will not only reduce the company's carbon footprint and improve its image among stakeholders, but will also enable long-term reductions in operating costs, increase market competitiveness, and better adapt to growing regulatory requirements for environmental protection. Analysis of the company's TRL (Technology Readiness Level) structure indicates that the company's activities are primarily focused on higher TRL levels, which translates to a predominance of implementation work based on external technologies. This structure is relatively balanced, however, the W_{TRL} = 6.5 index, which falls in the upper range (W_{TRL} > 4.5), indicates limited research activity within the company. Therefore, it is recommended that the company not limit itself to the commercialization and adaptation of ready-made technological solutions. To increase the company's ability to create and implement its own innovative solutions, it is necessary to strengthen its research and development potential. A key element of this process is the development of intellectual capital, understood as the systematic improvement of employee qualifications and competencies, fostering creative attitudes, and stimulating a culture of innovation within the organization. Equally important is strengthening collaboration with academic institutions, such as technical universities, research institutes, and technology development centers, which provides access to specialized knowledge, modern research methods, and increases opportunities for participation in innovative projects. Active participation in research and development projects, both domestic and international, is also essential, as they can be a source of new experiences, technological inspiration, and potential strategic partnerships. This approach will allow the company not only to become independent from external technology sources, but also to gradually build a leading position in innovation within its industry.

CONCLUSIONS

This article analyzed the level of innovation of a manufacturing company specializing in the production of gypsum building materials, such as plasters and fillers, gypsum adhesives, gypsum powder and perlite. The study utilized a proprietary method for diagnosing the state of enterprise innovation, enabling a comprehensive assessment of the company's level of innovation and eco-innovation, as well as the technological advancement of identified solutions. The method allows for a comprehensive assessment of an organization's performance – it takes into account innovation, development opportunities, environmental impact and the ability to implement technologies at various levels of advancement. The LCA method allowed for the determination of environmental impacts resulting from the company's operations and the identification of their sources – both at the product and production process levels. Additionally, the TRL method enabled the assessment of the level of development of identified technologies, providing information on the sources of development and use of new technological solutions within the company. This method also allowed for the assessment of the company's experience in product and technology development. The collected data demonstrates the company's potential in conducting research and development activities, providing an important basis for determining the direction of its further development. In this article, the TRL framework, innovation map, and LCA analysis served not only as tools for assessing technological maturity, innovation, and environmental impact, but also as support in the process of making strategic decisions regarding the future directions of a company's technological and investment development. As a result, the proposed methodology can effectively support companies in making informed strategic decisions and planning development activities consistent with the long-term vision of a sustainable and competitive European economy. The study was conducted according to the stages described in the empirical chapter. The study results present a comprehensive analysis of the company, which not only allows for an assessment of the company's current state of innovation but also identifies the areas requiring further development in the context of European climate, digital, and technological goals. As a result, it can support companies in making strategic decisions and planning development activities consistent with the long-term vision of a sustainable and competitive European economy. The results of the analysis refer to a specific company operating in a specific sector, so their direct generalization to other companies or industries is not discussed in detail. However, previous research conducted by the author in the metal, construction, and automotive sectors confirmed the universal nature of the proposed method as well as its effectiveness in various industry contexts. Considering the need to implement innovative products and technologies that reduce negative environmental impact, the conducted analysis of the company's innovation performance can be considered an important element in responding to the challenges related to the development directions set by the European Union.

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