

INDICATORS OF SUSTAINABLE PRODUCTION IN CHEMICAL ENTERPRISES

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Abstract

The growing pressure of the public on the sustainable behavior of companies is causing changes in the product portfolio as well as changes in production processes in all industries. The ongoing digitization of business processes facilitates production, helps monitor production processes, and ensures high quality and competitiveness. Chemical production companies are also adapting to the transformation of the industry and, even concerning the rising prices of resources, they are trying to produce sustainably. The sustainability of production and products needs to be monitored through appropriate indicators. Their use and utilization were mapped by qualitative research in a selected chemical company. The dimensions of sustainability were identified according to the triple-bottom-line concept and the key indicators of production sustainability evaluation were verified in them.

Introduction

In connection with legislative and social pressure in the field of sustainable development, manufacturing companies are increasingly faced with the necessity of implementing sustainable production procedures. As a result of globalization and technological progress, the size of the consumer and industrial markets is growing, but for industrial sectors, this fact also means a sharp increase in competition¹. Companies are thus forced, both legislatively and for economic and social reasons, to adapt their production to current trends - especially in sustainability. To differentiate their product from the competition and meet all legislative requirements, manufacturers are switching to more sustainable production processes that allow them to increase the added value of products and services, which makes them more attractive to customers, but at the same time, they can reduce the consumption of resources entering the production process (materials, water, energy, etc.)². This approach positively affects the economic efficiency of the company, social satisfaction, and environmental responsibility of the company³.

The idea of sustainable production first appeared in the literature at the end of the 20th century, the term sustainable production and consumption was officially introduced at the 1992 environmental conference in Rio de Janeiro⁴. The document that resulted from this conference became Agenda 21, which, in connection with sustainable production, states that the main global cause of continued environmental degradation is unsustainable patterns of production and consumption, especially in industrialized countries⁵. For that reason, two main areas have been identified in this document, firstly: focusing on unsustainable patterns of production and consumption; and second, the development of national policies and strategies to support changes in unsustainable consumption patterns.

Sustainable production can currently be understood as the creation of goods and services using processes and systems that do not pollute the environment, save energy and other environmental resources, are economically viable, and at the same time safe for workers and consumers⁶. According to the current trend towards an economically, environmentally, and socially sustainable industry, most industrial enterprises have the ambition to save resources (material, energy, time, labor), become carbon neutral in processes and supply networks, and at the same time produce new, carbon neutral and circular products that are necessary to mitigate climate change⁷. The requirements of systematic optimization at all levels from production to value networks in the process of industrial transformation and autonomous production are mentioned by Uygun and Ilie⁸. Characteristic modern approaches, methods, and tools to achieve autonomous sustainable production currently include e.g. circular economy, cleaner production, pollution prevention, best available techniques (BAT), process optimization, recycling, reuse, repair, higher use of renewable resources, integrated supply chain, life cycle assessment, environmental accounting, promoting social responsibility and more⁹. There is general agreement that the concept of sustainable production must be anchored in three dimensions of sustainability: economic development, environmental protection, and social development¹⁰.

The economic sustainability of production is conditioned by added value creation based on cost and revenue components¹¹, which also include the costs of implementing environmentally and socially friendly technologies, but also possible revenues from the successful implementation of these innovations¹². The fundamental

condition for the creation of added value is represented by innovations that constantly improve economic, energy, but also environmental performance in various areas of production and ensure the acquisition of a competitive advantage on the market¹³.

The environmental dimension of sustainable production is defined according to the long-term environmental problems of humanity: Global warming and climate change; Stratospheric ozone depletion; Human health, Human toxicity, Ecotoxicity, Acidification, Eutrophication, Formation of photo oxidants, Depletion of raw materials, and Use of landscape¹⁴.

The social dimension of sustainable production is usually based on the identification and definition of relevant social aspects that concern individual stakeholders¹⁵.

Indicators of sustainable production

Evaluation of the economic performance of the company (or production) is one of the priorities and traditional requirements of investors and company owners. In the development of sustainable production systems, the ability to assess the creation of added value is a crucial step¹⁶. In addition to the evaluation of the creation of added value, methods of financial analysis, and market performance of the company (market share, sales volume, etc.) are also applied, as well as methods including non-financial aspects of evaluation, such as the Balanced Scorecard (BSC) or Economic Added Value (EVA). Economic evaluation methods also include metrics such as Customer Lifetime Value and Customer Potential Value.

The assessment of environmental performance is usually based on legislative norms and standards governing obligations that the company should respect and consider when identifying environmental aspects. The most common include air emissions; leakage of substances into the water; leakage of substances into the soil; use of raw materials and natural resources; energy use; energy release (eg. heat, radiation, vibration/noise, light); generation of waste and/or by-products; use of space, etc.¹⁷. Based on the defined environmental aspects, a set of indicators are subsequently defined, with the help of which it is possible to evaluate the level of sustainable production.

The manufacturing industry must ensure a balance not only between economic and environmental, but also social aspects to maintain the existence of the market, however, social aspects are often difficult to quantify¹¹. In today's perception, the traditional concept of social aspects connected with safety for workers and consumers extends to some other stakeholders (Local communities, Other supply chain actors, Children, and Society). For the formulation of indicators for social aspects shared with these stakeholders, it is appropriate to use the Social Life Cycle Assessment (S-LCA) methodology, however, compared to the economic and environmental dimensions, it is more difficult to find objective quantitative indicators¹⁸.

The evaluation of economic sustainability is objectively essential for the survival of the company, however, for effective decision-making, the performance of the economic, environmental, and social dimensions must be assessed in a balanced and mutual way. One of the pilot attempts to evaluate sustainable production was presented by Veleva and Ellenbecker¹⁹ already in 2001 with a set of 21 indicators based on the then view on the sustainability of production using the Lowell Center Indicator Framework model, a three-dimensional evaluation model was proposed in 2003 by Krajnc²⁰, which, however, was not balanced – he proposed ten indicators for the social dimension, compared to 16 economic and 63 environmental ones. In 2005, Hauschild, Jeswiet, and Alting mentioned the need to consider the product in its entire life cycle in sustainable production models²¹. The necessity of implementing environmental management systems and evaluating environmental aspects during production is mentioned by Hillary²². Paju connected the traditional Value Stream Mapping (VMS) method with the Life Cycle Assessment (LCA) method and formulated the Sustainable Manufacturing Mapping method²³. The importance of the environmental dimension and environmentally conceived product in the entire value network is demonstrated by Giri and Bardhan²⁴, to which Lee adds that green solutions even smaller producers are leaning towards gaining a competitive advantage in global markets²⁵. Faulkner and Badurdeen proposed a methodology that extends the usual Value Stream Mapping technique for lean manufacturing with added metrics to measure the sustainability of environmental and social impacts, known as Sus-VSM²⁶. A model connecting the requirements of lean production with the Cleaner Production environmental approach was proposed by Ramos²⁷. The concept was further extended by Jamil et al. (2020, p. 342) when they defined a summary of indicators that can be used to evaluate the performance of manufacturing companies in all three pillars of sustainability.

Mengistu and Panizzolo identified a total of 1013 indicators across different scientific and business publications for the three basic dimensions of production sustainability assessment, which they say implies a lack of consensus

for their application to measure industrial sustainability²⁸. There is still a need to establish a concise set of basic indicators that will be universal, uniform, or can be specified according to the needs of a given type of industry.

Research Methodology

Academic research and studies from the relevant fields of research, sustainable production and consumption, lean management, and environmental and social assessment are used to address the validity of theoretical assumptions regarding the formulation and implementation of sustainable production indicators in business practice.

A form of qualitative research with representatives of a large chemical production company was chosen for the research itself. The intention was to address representatives of a multinational corporation with demonstrable experience with environmental, social, and sustainability assessment. The pre-selection was made based on press releases and awards received in the field of sustainability approach, on the assumption that a large multinational company has sufficient resources for sustainability assessment, development, implementation, and maintenance of indicators.

Based on a theoretical basis qualitative research was carried out as structured one-to-one interviews with three managers of a chemical company producing basic construction materials. Respondents represented individual dimensions of corporate sustainability – Business Excellence Manager, Environmental Manager, and HR manager. The research was carried out in the period January 2023 - April 2023. Information obtained was processed using content analysis. The first set of questions investigated the company's general approach to sustainability and its impact on competitiveness. The second set of questions investigated the assessment of economic sustainability. The third set of questions was focused on the evaluation of environmental sustainability, and finally, the fourth set of questions investigated the evaluation of the social sustainability of production, or products.

Research findings

The first set of questions first confirmed that the issue of sustainable development is one of the main priorities for the company. The strategic decision-making of the company is mainly driven by global trends, which are very closely connected with sustainability - currently, it is mainly the issue of climate change, lack of natural resources, or digitization and lifestyle. The entire corporation, therefore, focuses on the continuous improvement of its industrial processes to optimize its performance while protecting the environment and participating in general social development. This interest is thus fundamentally reflected in the company's behavior concerning any decisions in the field of development, supplier selection, product design proposals, production process planning, and the implementation of new technologies. Therefore, all these areas always include the criterion of sustainability as an essential element in decision-making, i.e. the requirement that any implemented change must support the achievement of set corporate goals in the field of sustainability.

The basic goal in the area of economic sustainability of production (second set of questions) is the efficient allocation of funds for the company and its owners, while the company's approach is primarily focused on the implementation of an investment policy that takes advantage of growth opportunities in key markets. The basic indicators by which the company evaluates the economic side of the sustainability of the production process and the success of the stated priority goal are the indicators related to the measurement of market performance. For this purpose, the company most often uses traditional financial indicators, which are then also part of the company's financial statements. These are mainly the volume of sales of individual products, cost of production, variances analysis, operating margin, profitability, productivity, Overall Equipment Efficiency (OEE) measurement, market share, Return on Investment (ROI), return on shares, increase in sales, and others.

In the area of the environmental impact of the production process, the company focuses its attention both on the inputs coming into production and on the output flows and emissions. In this context, a significant challenge for the company is the systematic support of circularity, the deviation from linear patterns of the production cycle, and the effort to accelerate the transition to a circular economy. With specific indicators, it monitors water consumption, which is further divided into potable, underground, and recirculated water. Energy consumption is monitored - electricity, compressed air, gas, and steam. In the area of material consumption, the ratio of recycled inputs at the expense of primary raw materials is monitored. For all the mentioned groups of inputs, the company also evaluates the production of related outputs, whether wanted or unwanted. It regularly and systematically evaluates the amount of product on the amount of supplied inputs, the sale of forced by-products of production, or the proportion of waste intended for recycling and the proportion of waste returned to

production. In the case of emissions, the company pays particular attention to the creation of CO2 emissions, and special indicators are assessed as preventive measures in connection with environmental protection.

The evaluation of corporate production in the field of social sustainability is based on the identification of the requirements and needs of individual groups of stakeholders, which are divided into six groups in total: "Employees", "Market", "Civil society", "Local community", "Regulatory authorities", and "Investors". The social area of the sustainability of the production process in the company is focused most intensively on employees (Employees) and customers (Markets), for whom it conducts regular targeted surveys, which aim to systematically reassess and verify the fulfillment of the set quantitative goals associated with social policy. For the other categories, it formulates a general and qualitative assessment based on the general principles of corporate culture - respect for others, safety and health protection, respect for rights and freedoms, integrity, loyalty, and solidarity.

Table 1 shows an overview of sustainable production indicators for each dimension.

Table I
Overview of sustainable production indicators

Economic indicators	Environmental indicators	Social indicators
Sales	Material consumption	Health and safety risks
Cost of production	Energy consumption	Injuries and accidents
Variances	Water Consumption	Remuneration and benefits
Operating margin, Value Added	Environmental risks	Noise emissions
OEE	Product output	Diversity
Productivity	Waste	Human Rights and Freedoms
Profitability, (ROI)	Emissions, CO ₂	Employees' loyalty
Market share	LCA	Customers' satisfaction
Return on shares	Biodiversity	Philanthropy and solidarity

While the company uses objective quantitative indicators for the economic and environmental dimensions, in the social dimension it much more often uses the methods of qualitative indicators, often benchmarking or descriptive evaluations.

Discussion and result analysis

In terms of the level of sustainability assessment of the production process, the company covers almost all relevant aspects of sustainable production. Despite this fact, due to the growing global interest in this issue, areas were identified where the strategy of measuring the sustainability of production could be expanded.

Based on the interviews conducted and the analysis of the corporate report on sustainability, it can be stated that a lot of attention is paid to the transition to energy sources that aim to fulfill the corporate goals in the area of carbon neutrality, specifically electricity. For this reason, the company has very well mapped any emissions coming from production, even from its parts. However, increased attention should be focused on the specific origin of the consumed electricity and monitoring of energy ratios from individual sources (e.g. nuclear, thermal, wind energy, etc.). At the same time, this would enable the company to do a deeper analysis of indirect CO2 emissions, i.e. emissions that do not occur in the company, but because of its activities.

On the side of unwanted production outputs, the company primarily focuses on the carbon footprint, thereby evaluating its level of contribution to global warming. In the area of emissions, however, due to the nature of the production process, which largely produces thermal energy, it would be appropriate to focus attention also on the release of thermal emissions, for example, the temperature of the water leaving the environment. However, also in the case of other energy emissions, it would be appropriate to monitor other quantitative indicators - e.g. light, noise, or odor emissions or specific business metrics for evaluating the impact of production on the natural ecosystem and efficiency in the use of the landscape area. The company does not use the evaluation of emissions with an impact on e.g. acidification, eutrophication, tropospheric ozone, and other forms of environmental aspects.

In the social dimension, the vast majority of methods used are generally qualitative, based on interviews, feedback, consultations, and benchmarking, often of an informal nature, but the formalization and quantification of the information obtained and the promotion of more objective evaluation indicators, for example, the satisfaction index, could be beneficial for the company. The number of complaints/lawsuits, etc. This would lead to overall support for the evaluation of the social area of sustainable production across industrial enterprises,

and the comparison with competing enterprises would thus become significantly more efficient in this area. In the social areas: Human rights and freedoms, Employees' loyalty, Customers' satisfaction, Philanthropy and solidarity, quantitative indicators are not used, and the evaluation is only qualitative and descriptive.

Conclusion

Industrial enterprises are currently motivated to implement sustainable production mainly by strict legislation in resource consumption and waste production and emissions, but also by social pressure to develop sustainable products and sustainable production processes. Effective management of sustainable production cannot be achieved without control in the form of measuring factors that affect the sustainable side of production. Setting indicators of sustainable production for a fair evaluation of whether the production or the product itself is viable in the long term, environmentally friendly, and socially responsible is essential for the future positive perception of the company.

During the qualitative research, it was found that the level of evaluation of the sustainability of the production process in the selected company is very high. The company takes a responsible approach to measuring economic sustainability, using for this purpose both conservative assessment methods that only monitor the financial perspective of production efficiency and methods that also include non-financial elements – benchmarking and economic added value. The company constantly strives to reduce the consumption of resources, both by preventing waste, and by using recycled material and incorporating solutions that support circularity into the product design. Increased emphasis is placed on the issue of controlling the reduction of CO₂ emissions, in all areas related to the production process. In the social area of sustainability of the production process, the company constantly adapts its efforts to current social trends and changing lifestyles, community standards, and civil society.

In conclusion, it can be stated that the research confirmed a proactive approach in the evaluation of the economic and environmental dimensions of sustainable production, as well as partial shortcomings in the form of a low representation of some quantitative indicators, which would increase the effectiveness of the evaluation process, especially in the social dimension. However, the company achieved a very advanced form of assessment in the assessment of the sustainability of production and the product itself, which proves that it is aware of the importance of individual sustainability domains for the future competitiveness of its products on the market.

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