The development of ecological accounting as an informational foundation for environmental management and auditing in the implementation of green technologies

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Abstract. The article is dedicated to the analysis of approaches to the establishment and implementation of ecological accounting, providing necessary information for environmental management and auditing during the adoption of green technologies. Contemporary environmental issues shape the trend of green economy development, for which ecological accounting data serves as the information source. Based on the analysis of perspectives from various Russian and international researchers, the definition of ecological accounting is refined and approaches to its establishment and maintenance are scrutinized. The examined approaches, including production-based, regional, strategic, and life cycle analysis-based, delineate strengths and weaknesses, necessitating the formation of an integrated methodology of ecological accounting that consolidates financial and non-financial information regarding environmental activities. The proposed methodology of ecological accounting involves six stages, each involving the compilation and synthesis of necessary data on environmental activities for environmental management, facilitating the development of measures to enhance environmental responsibility and fortify environmental sustainability of companies, industries, and regions. The formulated methodology should possess adaptability to changing environmental conditions to ensure timely response and reflection of environmental threats.

1 Introduction

Contemporary ecological issues, encompassing climate change, including global warming, air pollution, loss of biodiversity, extinction of certain species, water resource pollution, soil depletion, and others, demand a comprehensive approach to their resolution. Accordingly, the development of ecological accounting plays a crucial role in shaping the green economy, as it provides an informational basis for making ecological decisions and monitoring the implementation of environmental activities. This accounting yields representative data, synthesizing information on the impact of conducted activities on the environment, aiding in the formulation of effective plans for reducing adverse effects.
noted by Prof. T. G. Sheshukova, “the development of the ecological accounting system, as well as the establishment of environmentally-oriented production, whose key tasks include establishing correlations between economic, environmental, and social indicators, leads to increased control over the environmental friendliness of production activities, and the utilization in practice of a set of indicators of economic efficiency corresponding to the basic principles of ecologization” (Sheshukova, T.G.).

At present, one of the trends is the assumption of environmental responsibility by economic entities, enhancing the business reputation of the firm and reducing environmental risks. Given the relevance of the issues under consideration, certain approaches to organizing ecological accounting have emerged both in Russian and global science. Global experiences in ecological accounting, which serve as a factor in society’s sustainable development, are synthesized in the works of M.D. Hussain, T. Eugénio, and M. Yakhou. Among Russian researchers actively engaged in the issues of establishing and implementing ecological accounting are K.S. Saenko, T.N. Gogoleva, I.N. Sannikova, and other s. Dissertations defended on the specified issue are of scientific interest, particularly those of B.A. Morgunov, N.N. Rubanova, and V.F. Savchuk. Moreover, contemporary demands for enhancing the efficiency of environmental management and auditing in the implementation of green technologies require ecological accounting to increase the representativeness of data. Consequently, the present study aims to examine approaches to establishing ecological accounting and formulate directions for improving its methodology.

2 Materials and methods

The study was conducted utilizing both traditional and specialized methods of scientific inquiry. Among the traditional methods employed were literature review and analysis of Russian and international sources dedicated to the establishment and implementation of ecological accounting. Specialized methods were utilized in dissecting approaches and methodologies for ecological accounting, particularly in identifying strengths and weaknesses of various approaches, modeling the organization and implementation of ecological accounting as an informational foundation for environmental management and auditing in the adoption of green technologies. The research was based on open literary sources, including scholarly articles, dissertations, conference materials, as well as on the analysis of environmental reporting by Russian companies, notably the Lukoil Group, companies from Kazakhstan, such as KAZ Minerals, and companies from Kyrgyzstan, particularly Kumtor Gold Company.

3 Results and Discussion

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environmental data of entities necessary for management and determining the environmental potential of the company, as well as for ensuring its environmental safety" (Kozhukhova, O.S.). This definition emphasizes the objects of ecological accounting and the potential utility of information but sets the goal as ensuring environmental safety, a point open to criticism as safety implies initial protection against threats rather than developmental directions.

Foreign researcher Deegan C. offers a more concise definition, stating that "environmental accounting is the area that identifies resource use, measures and summarizes data on costs associated with a company's or national economy's impact on the environment" (Deegan, C.). Accordingly, this definition is considered both at the macro-level, in relation to ensuring sustainable societal development, and at the level of specific enterprises, summarizing data on a company's environmental activities.

In this study, we will employ the following definition, interpreting ecological accounting as a subsystem of management that generates representative information about an organization's environmental activities to ensure its effectiveness, make strategic environmental decisions, and ensure sustainable development.

During the research, approaches to the establishment and implementation of ecological accounting were examined, their advantages and disadvantages were elucidated, and these are presented in Table 1.

<table>
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<tr>
<th>Approach</th>
<th>Approach Essence</th>
<th>Advantages Zones</th>
<th>Disadvantages Zones</th>
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<td>Product Approach</td>
<td>The main objective is to measure and assess the negative impact of business processes on the environment, taking into account costs and resource consumption, as well as evaluating production emissions and waste</td>
<td>Accurate and detailed tracking of the adverse effects on the environment; Focus on problematic aspects of resource consumption, emissions, and waste; Resulting in the development of measures to enhance energy efficiency</td>
<td>Focus on internal factors, while ignoring external ones; Fixation of negative impacts rather than their prevention; Incomplete consideration of the product life cycle.</td>
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<td>Life Cycle Assessment</td>
<td>The approach involves evaluating the environmental footprint of activities at all stages of the product life cycle, from raw material extraction and resource procurement to disposal (burial) of waste</td>
<td>Capability to assess each stage of the life cycle and the overall impact on the environment; Potential for conducting integrated analysis of environmental impacts; Flexibility in adopting ecological innovations in line with objectives</td>
<td>High costs associated with obtaining reliable data for each stage of the life cycle; Variability in interpreting assessment results; Necessity of engaging specialists or increased costs for their training.</td>
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<td>Regional Approach</td>
<td>The regional approach entails assessing the environmental activities of an economic entity at the level of a specific region, encompassing its impact on the regional ecosystem and the performance indicators of the region.</td>
<td>Accounting for the specificity of the ecology and economy of a particular region; Emphasis on local regional issues, enabling the improvement of the situation within the region; Contribution to the sustainable development of the region through the</td>
<td>Inability to extrapolate to the national and international levels; Potential contradiction between the strategic goals of the company and the regional program; Heterogeneity of regional legislation,</td>
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The strategic approach entails integrating environmental initiatives into the company's development strategy, including the formulation of specific plans to enhance environmental responsibility over the long term.

Integration of business and environmental goals; Development of a long-term strategy aimed at reducing negative impacts on the environment; Enhancement of competitiveness and reinforcement of the image of an environmentally responsible company.

High implementation costs and complexity; Long payback periods; Potential decrease in efficiency in the initial stages; Potential divergence of interests among investors, shareholders, management, and employees.

In our view, the highest effectiveness of ecological accounting is achieved through a comprehensive approach to its organization, namely by integrating the production, regional, and strategic approaches. This encompasses both current accounting and the recording of expenses and losses resulting from negative environmental impacts, as well as the evaluation of the ecological effectiveness of strategic initiatives considering regional specifics.

According to several researchers, the methodology of ecological accounting comprises:

- Financial accounting of ecological entities, including the accounting of current expenditures on environmental management and activities, accounting for environmental assets, environmental liabilities (both actual and estimated), as well as the consumption of energy and other resources;

In our opinion, ecological accounting should not be confined to the subsystems of financial and managerial accounting, as it encompasses a range of non-financial indicators, including employee and public satisfaction with environmental initiatives, the company's involvement in enhancing the environmental responsibility of human capital, the preservation of ecosystem biodiversity in the region, and others. For example, the environmental reporting of "Kumtor Gold Company" not only refers to the cost assessment of environmental activities but also describes the application of bioremediation methods to address soil contamination issues with petroleum products, as well as experimental and demonstration tests of tailing pond supernatant.

The methodology of ecological accounting as the informational basis for environmental management and auditing should encompass the stages depicted in Figure 1. The strengths of the proposed methodology include a focus on key indicators and timely provision of information for managing environmental risks, enabling the development of effective environmental management measures. Areas for growth may include the continual updating of the methodology with the introduction of new indicators and their interpretation in accordance with the technological characteristics of environmental impact and its response to implemented measures.
4 Conclusion

Fig. 1. \textit{Justification of the fundamental objectives of environmental accounting, which may include, for instance, reducing emissions, increasing the proportion of waste recycling, and decreasing the ecological footprint of products. Additionally, the scope of application is delineated, encompassing specific production processes, products or services, regional considerations, and other pertinent parameters.}

- Identification of key non-financial indicators related to environmental impact (energy consumption, emission volumes, water resource usage metrics, etc.).
- Development of a system of key indicators for assessment and analysis (energy consumption volume, emission volume, waste utilization rate, proportion of renewable energy sources, etc.).
- Development of a data collection system, encompassing tools and methods for measuring key indicators.
- Formalization of the data collection process.
- Analysis of acquired data, comparison with baseline/planned values, identification of developmental trends, determination of key influencing factors.
- Interpretation of analysis results and formulation of directions for the advancement of green technologies.
- Compilation of non-financial performance reports, incorporating analysis data and conclusions.
- Establishment of a feedback mechanism for further elaboration of a set of measures aimed at improving performance indicators.
- Establishment of a monitoring system to track changes in key indicators.
- Development of environmental management and audit mechanisms in the implementation of green technologies.
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