Research on green energy engineering and management in the context of sustainable development

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The automotive industry is going through a period of profound transformation, driven by the objectives of climate neutrality, electrification of transport and reduction of energy consumption. In this sense, the integration of renewable energy sources in industrial processes is not only an environmental obligation, but also an opportunity to increase economic competitiveness. This paper presents examples from Romania regarding the development of industrial facilities based on renewable energy, highlighting the positive impact on emission reduction and regional development.

The European context of the energy transition is presented, highlighting the objectives assumed by the European Union policies regarding increasing the share of renewable energy and reducing carbon emissions. The current difficulties of the European energy system are discussed, such as dependence on energy imports, price volatility and the need to strengthen energy security. In this context, Romania is presented as a country with a high potential for the development of hydro, wind and solar energy, capable of contributing significantly to the European decarbonization objectives.

The general objective is to develop a method for analyzing and evaluating green energy management by designing an intelligent decision support model based on fuzzy logic. To achieve this objective, seven specific objectives are formulated that aim to conceptually substantiate the research, analyze the energy context, identify the limitations of renewable energy development in Romania, conduct empirical research on public perception, analyze existing energy management models, develop the fuzzy model and validate it in industrial contexts.

The specific objectives of the doctoral thesis are listed below:

1. **OS1**. Description and discussion of the fundamental concepts of green energy, energy management and sustainable development.
2. **SO2**. Analyzing the current state of renewable energy development and understanding the factors affecting the energy transition.
3. **SO3**. Identification and assessment of the main technical, economic, social and legal constraints on the development of renewable energy in Romania.
4. **SO4**. Assessing the public's attitude towards green energy by conducting a questionnaire and analyzing the data obtained by applying statistical methods in the PSPP software.
5. **SO5**. Research of 15 models from the specialized literature on energy management.
6. **SO6**. Design and testing a fuzzy logic model to evaluate factors affecting the implementation and management of green energy systems in the context of sustainable development.
7. **SO7**. Testing the proposed framework within the two selected industries.

Chapter 1, entitled **Introduction. Motivation and importance of the research topic,** establishes the general framework of the research and argues the need to approach green energy management in the context of sustainable development. It starts from the premise that the economic and technological transformations of recent decades, together with the effects of climate change and the need to reduce greenhouse gas emissions, have determined the emergence of new challenges for

energy systems and industry. In this context, renewable energy sources are becoming an essential component of economic development and environmental protection strategies.

The motivation for the research is based both on professional training in the fields of engineering and management, and on the experience gained in the automotive industry. These experiences have highlighted the need to develop production systems capable of using energy from renewable sources and reducing dependence on fossil fuels. At the same time, the research of the specialized literature showed that, although Romania has significant potential for the development of green energy, there are still numerous technical, economic and institutional barriers that limit its exploitation.

The final part of the chapter presents the structure of the thesis and the relationship between the chapters and the research objectives. It is explained that each chapter contributes to achieving a specific objective, and together they form an integrated methodological framework. The chapter concludes by emphasizing that the development and implementation of green energy represents one of the most important directions for the sustainable development of industry and the economy, and modern analysis and decision-making support tools can contribute to accelerating this process.

Chapter 2, entitled **Defining the conceptual framework of the doctoral thesis**, has the role of building the theoretical foundation of the research and defining the concepts used in the development of the proposed model. The chapter begins by presenting the fundamental notions regarding green energy and sustainable development, highlighting the fact that the energy transition represents one of the most important challenges of contemporary society. The increase in energy consumption, the depletion of fossil resources and the effects of climate change require the development of energy systems based on renewable sources and the efficient use of available resources.

Green energy is defined as energy produced from renewable sources such as solar, wind, hydropower, biomass and geothermal energy. These sources are characterized by high availability, low environmental impact and the ability to contribute to reducing carbon dioxide emissions. Unlike fossil fuels, renewable resources allow the development of a sustainable energy system and reduce the dependence of states on energy imports. The chapter highlights the direct link between the development of renewable energy and the achievement of global objectives regarding environmental protection and combating climate change. Another concept analyzed is sustainable development, presented as a balance between the economic, social and environmental dimensions. The author emphasizes that economic development must be achieved without compromising the natural resources necessary for future generations. In this context, green energy becomes a central element of sustainability strategies, simultaneously contributing to reducing pollution, increasing energy security and economic development. The effects of climate change on the environment, biodiversity and health of the population are also analyzed, arguing the need to accelerate the transition to renewable energy sources.

The chapter continues with the presentation of Romania's energy system and the main sources of electricity production. The advantages and limitations of hydropower, wind power, solar power and biomass are analyzed, highlighting Romania's high potential for their development. The challenges generated by the intermittent nature of renewable sources are also discussed, highlighting the importance of developing storage technologies and intelligent energy management systems. In this context, the concepts of microgrids, smart grids and autonomous energy production and distribution systems are presented.

Particular attention is paid to the relationship between renewable energy and the construction sector. The concept of green building is analyzed and it is highlighted how the integration of photovoltaic panels, storage systems and energy efficient technologies contributes to reducing consumption and achieving the objectives of nearly zero-energy buildings. The advantages of using modern building energy management systems (BEMS), BIM technologies and blockchain solutions for optimizing consumption and managing energy exchanges are presented.

The chapter also deals with the issue of life cycle assessment (LCA), a method used to analyze the environmental impact of renewable energy technologies over their entire life cycle. It is argued that the

use of this method allows the identification of stages with high environmental impact and contributes to the optimization of investments in energy infrastructure. At the same time, the most important directions of technological development in the field of energy efficiency are presented, such as intelligent lighting systems, automated building management and the integration of digital technologies in energy resource management. Overall, the chapter builds the conceptual framework necessary for the entire research and demonstrates that sustainable development depends on the integration of innovative technologies, public policies and efficient energy management. All the concepts presented constitute the theoretical basis for the analysis of renewable energy limitations and for the development of the fuzzy decision support model proposed in the following chapters.

Chapter 3, entitled **Defining the contextual framework of research,** aims to present the context in which the research is carried out and to analyze the current state of renewable energy development both internationally and in Romania. While the previous chapter defined the fundamental concepts underlying the research, this chapter follows how they are put into practice and influence the development of various economic sectors. The emphasis is on analyzing the energy context, public policies and management strategies adopted to accelerate the transition to a sustainable energy system.

It is highlighted that the development of renewable energy is determined by a series of economic, technological and legislative factors. The increase in global energy consumption, the decrease in fossil fuel reserves and international objectives regarding the reduction of greenhouse gas emissions have led states to invest in renewable sources and in innovative technologies for energy production and management. In this context, the European Union promotes policies that aim to increase energy efficiency, develop smart infrastructure and reduce energy dependence, and Romania must adapt its national strategies to meet these requirements.

The evolution of the Romanian energy sector is further analyzed, highlighting the main transformations produced in recent years. It is shown that Romania benefits from a significant potential for the development of renewable energy due to the available natural resources, especially in the field of hydroelectric, wind and solar energy. However, the exploitation of this potential is influenced by a series of technical and economic constraints, such as the insufficiently developed energy infrastructure, the high costs of investments and the lack of efficient mechanisms for storing energy produced from renewable sources. An important aspect analyzed in this chapter is the role of technological innovation in the development of modern energy systems. It is emphasized that the digitalization and automation of industrial processes allow for the permanent monitoring of energy consumption and the optimization of resource use. Concepts such as the Internet of Things (IoT), artificial intelligence and digital energy management platforms are presented, which contribute to increasing operational efficiency and reducing energy consumption. The implementation of these technologies facilitates the development of smart energy systems, capable of responding quickly to changes in demand and efficiently integrating production from renewable sources.

The chapter pays special attention to energy management in the construction sector. The main measures adopted to reduce the energy consumption of buildings are analyzed, including the use of materials with high thermal insulation performance, the installation of photovoltaic systems, the use of heat pumps and the implementation of intelligent consumption control systems. It is highlighted that the development of buildings with nearly zero energy consumption (Nearly Zero Energy Buildings – NZEB) represents one of the priority directions of European policies on energy efficiency and carbon emissions reduction. Another important component of the chapter is dedicated to the automotive industry, a sector considered strategic for the Romanian economy and one of the largest industrial consumers of energy. It presents the transformations that this industry is going through in the context of the electrification of transport and the implementation of sustainability strategies. The measures adopted by companies to reduce energy consumption, the use of renewable sources in production processes and the implementation of energy management systems in accordance with international standards are analyzed. At the same time, the role of energy audits in identifying energy losses and in substantiating investments to increase energy efficiency is highlighted.

The chapter also analyzes the economic factors influencing the implementation of green energy. The initial investment costs, the investment recovery period, the financing mechanisms and the economic incentives offered through European and national programs are discussed. It is shown that the success of the energy transition depends not only on technological progress, but also on the existence of stable public policies, capable of encouraging private investment and the development of energy infrastructure.

The contextual research part presents statistical analyses on the evolution of the automotive sector and energy consumption, using economic and performance indicators. The relationships between investments in renewable energy, the competitiveness of enterprises and their economic performance are analyzed. The results highlight the fact that organizations that invest in green technologies benefit not only from reducing operational costs, but also from improving the organizational image and increasing competitiveness on the market.

The importance of the human factor in the energy transition process is also highlighted. The implementation of modern technologies requires the development of professional skills and the adaptation of organizational culture to new sustainability requirements. In this sense, continuous professional training and management involvement in promoting energy efficiency are considered essential elements for the successful implementation of green energy strategies.

The chapter concludes by summarizing the main trends and challenges identified in the contextual analysis. The researcher concludes that the development of renewable energy is a complex process, simultaneously influenced by technological, economic, social and institutional factors. Understanding these relationships is essential for the substantiation of the decision support model proposed in the following chapters. At the same time, the conclusions drawn demonstrate the need to develop intelligent tools capable of simultaneously integrating numerous variables and providing decision-makers with objective solutions for optimizing green energy management.

Chapter 4, entitled **Assessing Romania's Capacity for Renewable Energy**, aims to critically assess Romania's capacity to develop and integrate renewable energy sources into the national energy system. Unlike the previous chapters, which were predominantly theoretical and contextual in nature, this chapter aims to identify the real limitations that influence the energy transition process. The analysis is carried out from a multidisciplinary perspective, taking into account technical, economic, social, institutional and environmental aspects. The researcher emphasizes that although Romania has important natural resources and benefits from the support of European policies, the development of renewable energy is influenced by numerous structural constraints that require integrated solutions and coherent policies.

The first part of the chapter presents the contextual framework of applied research. The researcher highlights that Romania must align its energy system with the objectives assumed by the European Green Deal and the "Fit for 55" legislative package, which provide for the reduction of greenhouse gas emissions, the increase in the share of renewable energy and the improvement of energy efficiency. Although the country has a high potential for the development of hydroelectric, wind and photovoltaic energy, the existing energy infrastructure is characterized by a high degree of centralization and a limited capacity to integrate new technologies. These characteristics reduce the flexibility of the system and make it difficult to adapt to the requirements of a modern energy mix. The researcher then analyzes one of the most important technical challenges of renewable energy, namely the intermittent nature of wind and solar energy production. The production of these sources depends on meteorological conditions and cannot be controlled to the same extent as production based on conventional fuels. In the absence of efficient storage systems and a sufficiently flexible electricity grid, variations between production and consumption can lead to imbalances in the functioning of the energy system. The chapter shows that Romania's current energy infrastructure is not yet ready to integrate a very large volume of renewable energy without substantial investments in digitalization, grid modernization and the development of storage technologies.

A detailed analysis is dedicated to Romania's dependence on hydroelectric energy. Although this represents the main renewable energy source and contributes significantly to energy security, the researcher highlights the fact that climate change has reduced the predictability of hydropower production. Prolonged droughts and changes in precipitation patterns cause river flows to decrease and, implicitly, reduce electricity production precisely during periods of high demand. In addition, the development of new hydropower plants is limited by both economic considerations and the impact on ecosystems and biodiversity. For this reason, the research concludes that hydroelectric energy must be integrated into a diversified portfolio of renewable sources and complemented by modern water resources storage and management systems. The chapter continues with the analysis of economic and financial barriers. The researcher shows that, despite the reduction in the costs of renewable technologies at an international level, the initial investments required for their implementation remain high for many investors. Limited access to financing, the instability of the legislative framework and frequent changes in support mechanisms reduce the attractiveness of investments and slow down the pace of development of energy projects. In addition, the recovery of investments depends on the evolution of the energy market and the stability of public policies, which generates a high level of uncertainty for investors.

In addition to economic aspects, the researcher pays special attention to the social impact of renewable energy development. The perceptions of local communities on wind and photovoltaic projects are analyzed, highlighting the fact that public opposition is determined not only by the effects on the landscape or on the use of agricultural land, but also by the lack of involvement of the population in the decision-making process. In many situations, communities perceive the distribution of economic benefits as unfair, and the lack of transparent communication leads to a decrease in the level of social acceptance. The researcher emphasizes that the success of the energy transition depends largely on the active involvement of citizens and the development of effective public consultation mechanisms. The last part of the chapter is dedicated to the comparative analysis of fifteen energy management models identified in the specialized literature. These models are evaluated from the perspective of the structure, the criteria used and their applicability in different fields. The analysis highlights the fact that most existing models treat technical, economic or social factors separately and fail to integrate into a single framework the complexity of the decision-making process associated with renewable energy management. Starting from these limitations, the researcher selects the relevant variables that will constitute the basis for the development of the fuzzy inference model presented in the next chapter. This stage moves from critical analysis of the literature and empirical data to the design of a decision-making tool capable of managing uncertainty and interdependencies between factors that influence the performance of green energy systems.

Chapter 5, entitled **Fuzzy System Methodology,** represents the core of the doctoral research and highlights the main original contribution of the researcher by developing an intelligent decision support model based on fuzzy logic for the evaluation of green energy management. If in the previous chapters the conceptual framework, the current context of renewable energy development and the limitations of existing systems were analyzed, this chapter proposes a solution capable of responding to the complexity of the decision-making process in the energy field.

The researcher starts from the idea that decisions regarding the implementation and management of renewable energy are simultaneously influenced by numerous technological, economic, social and institutional factors. In practice, these factors cannot always be described by exact values or strictly mathematical relationships, since much of the information used comes from subjective assessments, expert estimates or data characterized by uncertainty. For this reason, classical statistical analysis methods and deterministic models are insufficient to capture the real complexity of the decision-making process. In this context, fuzzy logic is chosen as the main modeling method due to its ability to integrate uncertain information and reproduce the way experts formulate decisions in complex situations.

The first part of the chapter presents the theoretical foundation of fuzzy logic. The researcher explains the differences between classical logic and fuzzy logic, highlighting the fact that, unlike binary systems, in which an element belongs or does not belong to a category, fuzzy logic allows for the

existence of degrees of membership with values between 0 and 1. This feature offers the possibility of modeling real phenomena, where the boundaries between categories are rarely clear and where decisions are influenced by perceptions and interpretations. By using membership functions and inference rules, the fuzzy system can transform qualitative information into quantitative results useful for the decision-making process.

The researcher justifies the choice of fuzzy logic by comparing it with other multi-criteria methods identified in the specialized literature. The analysis carried out in the previous chapter showed that most existing models treat the different dimensions of energy management separately and do not allow the simultaneous integration of all relevant factors. The proposed model aims to overcome these limitations by building a system capable of analyzing the relationships between technological, economic, social and managerial indicators in a unified and flexible manner.

The model development process begins with the identification of input variables. These are selected based on the analysis of the specialized literature and the results of empirical research. The variables reflect the main dimensions of green energy management, including energy efficiency, the degree of use of renewable sources, the level of investment, economic sustainability, environmental impact, social acceptance and managerial performance. The choice of these indicators aims to build a model that is as close as possible to the organizational reality and capable of capturing the interdependencies between the different components of the energy system.

After defining the variables, the researcher develops the membership functions used in the fuzzy system. For each variable, linguistic levels such as "low", "medium" and "high" are established, each being represented by specific mathematical functions. These functions allow the transformation of numerical values into information compatible with the fuzzy inference mechanism. The researcher explains that the choice of the type of functions and the membership intervals directly influences the sensitivity of the model and the quality of the results obtained.

An essential step in the development of the model is the construction of the fuzzy rule base. The rules are formulated in the form of "If...then..." relationships, which describe how different combinations of input variables influence the final result. These rules are developed based on conclusions drawn from the specialized literature, practical experience and empirical research results. By using a large number of rules, the model can reproduce the reasoning process of an expert and can simultaneously evaluate the effects of several factors on the performance of energy management.

After defining the rules, the researcher describes the fuzzy inference mechanism used for information processing. The system analyzes the values entered for each variable, identifies the applicable rules and brings together the results obtained in a single fuzzy value. To transform it into an easy-to-interpret result, the defuzzification procedure is applied, through which a final numerical value is obtained that expresses the performance level of green energy management. This result can later be used by managers and decision-makers to assess the existing situation and identify improvement measures.

The model implementation is carried out in MATLAB, using tools dedicated to the development of fuzzy systems. The researcher presents the model architecture, the implementation stages and the interface used for data entry and interpretation of results. The choice of the MATLAB platform is justified by the flexibility offered in the design of fuzzy systems, the possibility of simulating different scenarios and the existence of powerful tools for sensitivity analysis and model validation.

An important element of the methodology is the integration of empirical research results into the model building process. The data obtained by applying the questionnaire and statistically analyzed in PSPP are used to validate the variables and adjust the membership functions. In this way, the model is not built exclusively on the basis of theoretical hypotheses, but also reflects the real perceptions of respondents regarding green energy management, which gives it a high degree of practical applicability.

The researcher highlights that the main advantage of the proposed model lies in the ability to simultaneously integrate quantitative and qualitative information, reducing the effects of uncertainty that characterize decision-making processes in the energy field. Unlike classical models, the fuzzy system allows the evaluation of situations in which information is incomplete or difficult to quantify and provides flexible results, adaptable to different organizational contexts. In addition, the model can be updated by introducing new variables or inference rules, which gives it a dynamic character and the possibility of use in future research.

The chapter concludes by emphasizing that the developed fuzzy model represents an original contribution to the field of green energy management. By integrating technological, economic, social and managerial factors into a single analysis framework, it provides a support tool for substantiating strategic decisions regarding the development of renewable energies. At the same time, the researcher highlights that the performance and reliability of the model must be demonstrated through a rigorous testing and validation process, a stage that is the subject of the next chapter.

Chapter 6, entitled **Testing, Validation and Final Form of the Proposed Fuzzy Framework,** is dedicated to the process of testing, validating and optimizing the fuzzy model developed in the research. After developing the system architecture and implementing it in MATLAB, the researcher aims to verify the model's performance in different scenarios and evaluate its capacity to support the decision-making process regarding green energy management. This chapter plays an essential role in demonstrating the practical applicability of the model and in confirming that the proposed solution can represent an effective tool for organizations implementing sustainable development strategies.

The validation process begins by verifying the functioning of each component of the fuzzy system. The researcher analyzes the membership functions, the rule base and the inference mechanism, observing whether they respond correctly to different combinations of input variables. Numerous simulations are performed to observe the behavior of the system in various situations and to identify any inconsistencies or overlaps between the inference rules. This stage allows the model parameters to be adjusted and any errors to be eliminated before applying it to real data analysis.

An important stage of validation consists of testing the model through representative scenarios for green energy management. The researcher builds several combinations of input variables, corresponding to situations encountered in practice, such as different levels of energy efficiency, renewable energy investments, managerial performance and the degree of social acceptance. For each scenario, the fuzzy system generates a result that expresses the estimated level of energy management performance. The analysis of these results allows observing how the modification of a single variable or a group of variables influences the final evaluation. The researcher pays special attention to the sensitivity analysis of the model. The purpose of this stage is to determine how sensitive the system is to variations in input values and whether the changes produced are reflected in a logical and coherent way in the final results. The analysis demonstrates that the model reacts gradually to changes in parameters and avoids the occurrence of sudden or disproportionate variations, an essential characteristic for a tool intended to support the decision-making process. This property confirms that fuzzy logic allows the modeling of complex relationships without generating instability in the evaluation.

Next, the model is validated by relating the results generated by the system to the information obtained in the empirical research presented in the previous chapter. The researcher compares the behavior of the model with the perceptions and responses of the 120 participants in the questionnaire, monitoring the degree of concordance between the automatically generated evaluations and the trends identified in the statistical analysis. The results show that the model reproduces to a high extent the relationships observed in the empirical data and provides evaluations compatible with the opinions expressed by the respondents. This concordance contributes to the external validation of the system and demonstrates that the formulated fuzzy rules adequately reflect the reality analyzed. Another important element of the chapter is the evaluation of the robustness of the model. The researcher tests the functioning of the system under conditions characterized by incomplete or uncertain information, simulating situations in which some variables present intermediate values or are difficult to interpret.

The results demonstrate that the model maintains its stability and provides coherent evaluations even when the available data are not accurate or complete. This characteristic represents one of the main advantages of fuzzy logic and justifies the choice of this method for green energy management, a field in which the decision-making process is frequently influenced by uncertainty and the existence of criteria that are difficult to quantify.

The chapter also includes a comparative analysis between the proposed model and classical methods for assessing energy performance. The researcher highlights the fact that traditional approaches generally use rigid indicators and deterministic mathematical relationships, which limits their ability to simultaneously integrate quantitative and qualitative information. In contrast, the fuzzy model allows the inclusion of variables such as user perception, level of social acceptance, managerial experience or organizational maturity, factors that significantly influence the success of renewable energy project implementation, but which are difficult to express through conventional methods.

The test results confirm that the system develops consistent and stable assessments for all analyzed scenarios. The researcher demonstrates that the model can be used both to assess the current situation of an organization and to simulate the effects of strategic decisions regarding investments in renewable technologies, improving energy efficiency or developing organizational policies oriented towards sustainability. In this way, the system is not limited to a simple evaluation function, but becomes a planning and support tool for strategic management.

Based on the results obtained from testing and validation, the researcher performs model optimization and establishes the final form of the proposed fuzzy framework. Certain membership functions are adjusted and some inference rules are revised to improve the accuracy of the assessments and to reduce possible overlaps between the different linguistic categories. The final form of the model is presented as a flexible and adaptable system, which can be used in organizations from different fields and which can be extended by introducing new indicators or rules, depending on the evolution of technologies and energy policies. In conclusion, the researcher demonstrates that the fuzzy model developed in the thesis represents an efficient tool for evaluating green energy management. Validation carried out through simulations, sensitivity analyses and comparison with empirical research results confirms the reliability and robustness of the system. At the same time, the research highlights the fact that the use of fuzzy logic allows the simultaneous integration of technical, economic, social and managerial factors, providing decision-makers with a complex picture of energy performance and facilitating the adoption of well-founded decisions under conditions of uncertainty.

Chapter 7, entitled **Conclusions. Personal Contributions. Research Perspectives,** summarizes the main results obtained during the research and highlights the original contributions made in the field of green energy management. The researcher returns to the objectives formulated in the first chapter and demonstrates that they were met by combining an in-depth theoretical analysis with empirical research and by developing an intelligent decision support model based on fuzzy logic. In this way, the research offers both a scientific and a practical contribution, addressed to organizations and decision-makers involved in the energy transition process.

The first important conclusion formulated is that the development of renewable energy does not depend exclusively on the existence of natural resources or technological progress. The successful implementation of green energy strategies is influenced by a complex set of economic, social, institutional and managerial factors, which constantly interact. Consequently, the decision-making process cannot be based solely on technical or economic indicators, but must simultaneously integrate information from different fields, sometimes characterized by uncertainty or difficulties in quantification.

The analysis carried out during the thesis demonstrates that Romania has a significant potential for the development of renewable energy, due to its natural resources and favorable geographical position. However, the exploitation of this potential is limited by the existence of important obstacles. These include the insufficiently modernized energy infrastructure, the reduced energy storage capacity, the volatility of the legislative framework, financing difficulties and the lack of effective coordination between

the institutions involved in the implementation of energy policies. The researcher also highlights the fact that social acceptance and the level of information of the population significantly influence the success of renewable energy projects, which requires the development of public policies oriented towards communication and the involvement of local communities.

An important result of the research is the comparative analysis of existing energy management models. The study of the specialized literature highlights the fact that most of the available models are oriented towards the evaluation of specific dimensions, such as energy efficiency or economic performance, without simultaneously integrating technological, social and managerial factors. Starting from this limitation, the researcher justifies the need to develop a new model, capable of providing an integrated approach adapted to the complexity of the decision-making process in the field of green energy.

The main original contribution of the thesis consists in the design and development of an intelligent decision-support system based on fuzzy logic. The proposed model allows the evaluation of green energy management by integrating multiple variables, representing the technological, economic, social and managerial dimensions of the energy transition process. The use of fuzzy logic offers the possibility of modeling the relationships between these variables even in conditions where the available information is incomplete or characterized by uncertainty. Thus, the system reproduces the decision-making process in a manner close to human reasoning and generates results that are easy to interpret and use in practice.

The researcher emphasizes that one of the strengths of the model is its flexibility. The structure of the system allows the introduction of new indicators or modification of inference rules depending on the particularities of the field of application. Consequently, the model can be adapted not only for the automotive sector and the construction industry, analyzed in the research, but also for other economic areas in which energy management plays a strategic role. This feature gives the model a high potential for expansion and development in future research.

Another important result of the thesis is the practical validation of the model. Tests performed in MATLAB and comparison with the results of empirical research demonstrate that the fuzzy system produces coherent and stable assessments, being able to reflect the influence of different categories of factors on the performance of energy management. Sensitivity analysis confirms the robustness of the model and its ability to function in conditions characterized by incomplete or variable information. These results demonstrate the practical applicability of the model and the possibility of its use as a support tool for managers and decision-makers.

The researcher also highlights the practical implications of the research. The model can contribute to the substantiation of organizational strategies regarding the use of renewable energy sources, the optimization of energy consumption and the planning of investments in green technologies. The system can also support public authorities in the evaluation of energy projects and in the development of policies aimed at accelerating the transition to a low-carbon economy. By integrating information from different sources, the model facilitates the identification of optimal solutions and reduces the risk of adopting decisions based exclusively on economic or technical criteria.

Regarding personal contributions, the researcher highlights several elements that differentiate this research from existing studies. These include the implementation of a complex analysis of the conceptual and contextual framework of green energy, the critical assessment of the limitations of the energy system in Romania, the development and implementation of an original fuzzy model, the implementation of an empirical research based on a questionnaire and the integration of its results into the architecture of the decision support model. All these components contribute to the development of an innovative tool, with applicability both in research and in practice.

The researcher also acknowledges the existence of some research limitations. The sample size used in the empirical research, the focus on certain economic sectors and the use of a limited number of variables are aspects that may influence the degree of generalization of the results. Also, the rapid

evolution of renewable energy technologies requires the periodic updating of the model and its adaptation to new economic and legislative conditions.

Based on these limitations, several future research directions are proposed. The researcher recommends expanding the model by integrating modern artificial intelligence and machine learning techniques, which could improve the system's ability to learn from data and automatically adapt inference rules. At the same time, it is suggested to apply the model to other economic sectors, such as agriculture, transport or public administration, as well as to carry out comparative studies between Romania and other European countries to evaluate the differences in green energy management.

In conclusion, the thesis demonstrates that the sustainable development of the energy sector requires the use of modern analysis and decision support tools, capable of managing the complexity and uncertainty characteristic of this field. The proposed fuzzy model represents an original and valuable contribution, offering an integrated approach to green energy management and constituting a useful tool for both academia and organizations involved in the energy transition process.

The doctoral thesis achieves an interdisciplinary approach to green energy management, integrating perspectives from the fields of engineering, management, sustainable development and artificial intelligence. The research starts from the analysis of fundamental concepts and the European and national energy context, continues with the identification of existing limitations in the development of renewable energy and with the performance of an empirical research on the perception of green energy, and finally proposes and validates an intelligent decision support model based on fuzzy logic.

The originality of the thesis lies in the development of a methodological framework that allows the simultaneous integration of technological, economic, social and managerial factors in the evaluation of green energy management performance. The results demonstrate that fuzzy logic represents an efficient method for substantiating decisions under conditions of uncertainty and complexity, offering a modern alternative to traditional evaluation methods.