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Negative Impact of Renewable Energy: Critical Analysis

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***Abstract*—The importance of renewable energy has grown enormously in recent years, with the EU's target for renewables to achieve a share of 42.5% of gross energy consumption by 2030. This is related not only to stimulating technological developments in the field and increasing investments, but also to legislative changes to accelerate the modernization of networks, remove regulatory barriers, regulate the activities of prosumers, and encourage consumers and producers to increase consumption. In this study, we aim not only to define the essence of renewable energy sources, but also to prepare a critical analysis of the scientific literature addressing the issues of the negative impact of renewable sources on the environment. In this regard, by applying a bibliometric analysis of the existing literature in Scopus, we highlight the leading specialists in the field and their citation, which is an expression of the significance of the published scientific ideas. Through keywords co-occurrence analysis, we reveal the leading topics around which specialists' research is focused. As a result, we present and summarize the main negative effects of renewable energy sources. In conclusion, and based on the analysis, we confirm our hypothesis that the environmental risks of renewable energy sources are insufficiently analysed and contradict the assumptions of the concept of sustainable development.**

Keywords— bibliometric analysis, negative impact, renewable energies.

I. Introduction

In the scientific and specialized literature, the term "renewable energy" occurs as early as the beginning of the 20th century, when it is used as a contrast to exhaustible energy sources [1] - [3]. Of course, the meaning given at the beginning of the century differs significantly from the meaning that the term acquired during the period of World War II or during the energy debates of the 1970s [3]. In modern times, the concept of renewable energy has become a leading policy around the world and occupies a central role in the fight against climate change. Its defining features, mechanisms for creation and application, as well as its impact on the environment and society in the long term are critical in determining effectiveness and sustainability in the context of the concept of sustainable development.

The relevance of the topic we are considering stems from the EU's goals to expand the share of renewable energy sources (RES) in the overall energy mix. By targeting 42.5% renewable energy consumption by 2030, the EU is pushing Member States to increase investment in this area and increase renewable energy production areas. This will reduce energy dependence on fossil fuels on the one hand, and on the other hand, it will also limit dependence on the main producers and exporters of these fuels. This is directly related not only to the specifics of renewables, but also to the widely accepted statement that they are a better substitute for fossil fuels for several main reasons: (1) limit environmental pollution compared to fossil fuels; (2) limit the extraction of conventional natural resources; (3) have a positive impact on the socio-economic status of people.

Analysing the specialized literature, we reveal the wide range of areas of analysis in the field of renewable energy. The definitive features and sources of renewable energy are discussed and described in detail by [4] - [8]. Several studies [9] - [12] raise the question of the role of renewable energy sources in achieving the goals of the concept of sustainable development. Many studies are also devoted to the policies and practices of introducing renewables at local level [13] - [15], the economic and social effect they cause [16]-[17] or the benefits of their introduction in specific productive sectors [18]. A significant place is also occupied by research focusing on the impact of renewable energy sources [19]-[25].

However, the scope of studies on the negative impact of renewables in the long term remains limited, which for us represents a significant research gap.

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Therefore, in this study, we aim not only to define the essence of renewable energy sources, but also to prepare a critical analysis of the limited scientific literature concerning the negative impact of renewable sources on the environment. Thus, we choose renewable energy as the object of research, and the subject of our study is the negative impact that renewable energy sources have on the environment and society in the long term.

The hypothesis, which we will seek to prove in the course of our work, is that: The negative impact of renewables on the environment and society in the long term is insufficiently analysed.

In the next part of the development, we present some of the definitive features of renewable energy. The empirical part of this work includes conducting a bibliometric and keyword co-occurrence analysis of specialized literature from the Scopus database. As a result, we reveal and summarize the main negative effects of renewables. In conclusion, and based on the analysis, we confirm our hypothesis that the environmental risks of renewable energy sources are insufficiently analysed and contradict the formulations of the concept of sustainable development.

II. Materials and Methods

A. Literature Review

Without examining in depth the definitive features of renewable energy and its sources, we can generally present it as *„… energy obtained from naturally repetitive and persistent flows of energy occurring in the local environment.“* [4, p.3] while *„Non-renewable energy is energy obtained from static stores of energy that remain underground unless released by human interaction“* [4, p.3].

According to [24], renewable energy sources, which are often defined by the scientific community as "clean" energy sources, are powered by naturally renewable energy sources in nature and can be used independently of each other.

For [15], renewable energy goes beyond the framework of innovative technical alternatives to fossil fuels and symbolises the expansion of societal values through the transformation towards sustainable and nature-friendly energy production and consumption.

Considering the above and the broad interpretation of the definitive features of renewable energy in specialized literature, energy transition strategies, and regulatory documents, for the purposes of our research we perceive renewable energy as *energy generated by naturally occurring processes in nature and assimilated through innovative technological solutions*.

Specific renewable energy sources (see Fig. 1) encompass the technologies and facilities through which natural energy flows are transformed into electricity, such as solar energy, wind energy, hydropower, geothermal energy, and biomass energy [26].

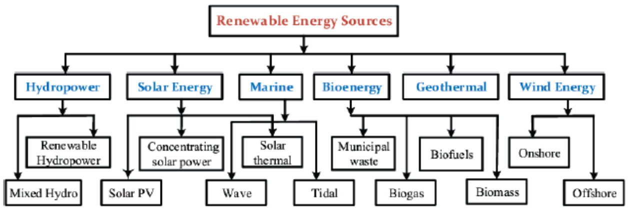

Fig. 1. A summary of the most common renewable energy sources [27].

Renewable technologies (see Fig. 1) are also those whose long-term impact on the environment needs to be analysed to establish their sustainability. Therefore, in the following lines we set ourselves the task of briefly clarifying their essence.

Hydropower is generated using the mechanical energy of flowing water (rivers and streams) and capturing it through pipelines driving generators to create electrical energy [24].

Marine/ocean energy – a type of hydropower, in terms of the natural resource used to create energy, but here it is generated by the tides and by the waves of the marine/ocean. This type of energy is new and still insufficiently developed and used due to the need for large investments for the development of technology [24].

Solar energy can be produced through systems of several types and functions, such as photovoltaic cells which converting direct sunlight into electrical energy, thermal solar systems, or systems heating liquids through sunlight to produce steam to drive a turbine that produces electricity [5], [24].

Bioenergy is produced from several types of residues from biological sources (forestry residues, animal residues, industrial residues, crops, sewage waste, or municipal solid waste) [8]. The production of energy from biological resources, when they are residue or waste, does not compete with other land resources (as is the case with the production of bioenergy from crops plantations that displace other crops and threaten biodiversity) [24].

Geothermal energy is produced by recovering hot water or steam rising to the surface of the earth from the Earth's naturally occurring geothermal processes. Once it reaches the surface, the steam/hot water is used to drive a steam turbine that produces electricity. A key point in the utilization of geothermal energy is that the location where geothermal plants can be opened is severely limited, due to the specific requirements of the natural environment in which geothermal energy is stored [28].

Wind energy is produced by a wind turbine, which converts the kinetic energy of the wind into mechanical energy [5]. Subsequently, mechanical energy is converted again (through a generator) into electrical energy [28]. According to [9], wind energy generation is one of the most economical renewable energy systems.

In this literature review, we have briefly presented the specifics of energy sources, and in the next part we will focus on the overall negative effect they cause. Although in scientific literature the negative side of renewable energy sources remains in the background, the issue has gained greater significance in the last 3-4 years [19] - [25]. The EU's desire to increase the share of renewable energy in the overall energy mix and the legislative changes undertaken stimulate technological development and production of elements, parts, equipment, installations, etc. to produce unconventional energy. This, in turn, has put in the focus of researchers not only the necessary resources for this production, but also the impact it causes on the environment and society.

In the next part of our study, we present the research methodology and through the applied methods of analysis we reveal the critical areas in which the negative effect of renewable energy is manifested.

B. Methodology of the Research

For the purposes of our study, we use a bibliometric analysis of the limited scientific literature addressing the problems of renewable energy. In this way, we will establish the existing development trends in the specific area [29]-[31]. Through the bibliometric approach and keyword co-occurrence analysis, we track the co-occurrence of keywords in the studied population, through which we create networks of knowledge elements [31]. Analysing the citation rate of individual publications, which indicates the number of references to a particular study in other publications [32], we will highlight the leading authors and their research.

We use Scopus as a source of data for our analysis, as the database contains a large volume of publications on renewable energy issues (as of 25.03.2026, the database contains 387,946 documents whose titles, keywords or abstract contain the term "renewable energy"). Our choice is dictated by the fact that Scopus is recognized as the largest database with summaries and citations of peer-reviewed publications on a wide range of topics that may not be available in Web of Science [33]. The advantages of Scopus are also confirmed by [34]-[36], which also conduct bibliometric analysis in the field of unconventional energy sources of publications available in Scopus.

Applying statistical techniques, we extract information about leading researchers and their publications, their citations, as well as the source of this publication activity. We visualize the results through VOSviewer [37], as it allows us to create network maps to establish the existing links between the analysed keywords and development trends [37].

To identify the Scopus publications in which authors address the negative impact of renewable sources, we carried out the following:

- Search strategies – We applied a search for a set of keywords in TITLE-ABS-KEY ("renewable energies" OR "renewable energy" AND "negative environmental impact" OR "negative impact").
- Inclusion and Exclusion Criteria – the inclusion and exclusion criteria introduced by us are in terms of: time range – from 2000 to 2026, therefore earlier publications are excluded; language – we only include publications in English, the rest are excluded; Relevance of content – we only include publications addressing the negative effects of renewable energy, the rest are excluded. There are no exceptions in terms of territory, country or author.

III. Results

A. Bibliometric Performance analysis

By applying the search strategy and the inclusion and exclusion criteria, we generated a sample of 376 posts. We limited the posts to 371 by removing 5 posts that are not in English. We then reviewed the content of each of the publications, excluding another 294 publications that did not address the negative impact of renewable energy sources. The final sample includes 74 publications focusing on the negative impact of renewable energy on the environment and the socio-economic situation of society.

Data on the distribution of publications by year of publication is presented in Figure 2. The presented data allow us to assert that in recent years there has been a relative increase in interest in the issues of the negative impact of renewable resources.

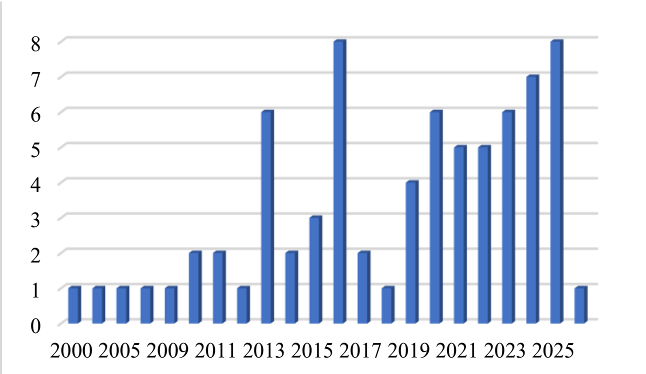

Fig. 2. Number of publications in the period 2000-2026 in Scopus [own calculation, based on Scopus].

The analysis of the publications allows us to establish the number of citations of each author, as well as the publications with the highest citation, which is indicative of the significance and dissemination of these publications among the scientific community (see Table 1).

The information in Table 1 also testifies to the directions of analysis of the authors, and here we can categorically point out that the researchers' interest is focused on the individual sources of renewable energy (photovoltaic systems, wind energy, renewable tidal energy, etc.) and their impact on the environment. It should also be noted here that the citation of the publications is directly dependent on the time factor that is necessary for the dissemination of the author's ideas. This makes the publications of recent years still not report wide distribution among the scientific community.

Analysing the countries from which the selected publications originate, we find that the largest number of documents originate in the United States (8 documents; 717

citations), followed by India (7; 53), Germany (5; 338) and China (5; 131).

The analysis allowed us to argue that research on the negative effect caused by renewable energy sources is partial, fragmented, and insufficient to establish the long-term impact of this type of energy and its sources on the environment. For us, this represents a significant research gap that needs to be filled by broadening and deepening the scope of research in the field.

B. Keywords co-occurrence analysis

To identify the fundamental areas where researchers look for the negative effect of renewable energy, we conducted keywords co-occurrence analysis of the selected studies. To visualize a network map of the relationships between keywords (see Fig. 3), we used VOSviewer, with the analysis in the extracted dataset including "all keywords" in a full count. The total number of generated keywords appearing more than five times reached thirty-three. For each of these words, VOSviewer calculates the strength of the links to the other keywords, and we present the top ten of them in Table 2.

TABLE 1 THE 10 MOST CITED ARTICLES FOR THE PERIOD 2000-2026 IN SCOPUS

Position	Article title	Authors	Total Citations
1	Environmental impacts of solar photovoltaic system: A critical review of recent progress and future outlook	[38]	561
2	Marine Renewable Energy: Potential benefits to biodiversity? An urgent call for research	[39]	380
3	High-level penetration of renewable energy sources into grid utility: Challenges and solutions	[40]	364
4	An integrated DEMATEL-ANP approach for renewable energy sources selection in Turkey	[41]	342
5	Wind farm siting using a spatial analytic hierarchy process approach: A case study of the Städteregion Aachen	[42]	281
6	Near-optimal pi controllers of STATCOM for efficient hybrid renewable power system	[43]	102
7	Fluxes of the greenhouse gases (CO2, CH4 and N2O) above a short-rotation poplar plantation after conversion from agricultural land	[44]	96
8	Assessing the effects of wind farms on soil organic carbon	[45]	73
9	Geographical and environmental perspectives for sustainable development of renewable energy in urbanizing China	[46]	73
10	Comparing life cycle implications of building retrofit and replacement options	[47]	72

Considering the information from Table 2, we establish the strongest link between the keywords in terms of the impact of renewable energy on the environment in the context of sustainable development, which is not surprising, since this is the main topic of the analysed publications.

TABLE 2 KEYWORDS CO-OCCURRENCES (2000-2026)

Keyword	Occurrences	Total link strength
environmental impacts	49	221
renewable energy	35	175
sustainable development	25	132
renewable resource	17	86
greenhouse gas	13	86
renewable energy sources	13	42
life cycle	12	68
climate change	11	76
fossil fuel	11	68
life cycle assessment (lca)	11	60

From the network maps (see Fig. 3) we obtain information about the grouping of the highlighted words and the period during which a keyword appeared in the analysed studies.

Visible from the network map of the keywords (see Fig. 3, left), they are grouped into three clusters. *The first red cluster*, which includes "environmental impact" and "environmental protection," also covers terms related to electrical equipment and efficiency, energy sources, and their life cycle assessment, as well as renewable energy sources such as solar and wind energy, wind farm. *The second green cluster* examines the policies in the field of renewable sources, the economic and social effect they cause, the assessment of their impact on the environment, the relationship with sustainable development and in particular biodiversity and the various aspects of the impact caused by biomass. *The third blue cluster* includes terms relating to biogases and carbon footprint, greenhouse gases, and climate change. The question of land use and fossil fuels is also raised.

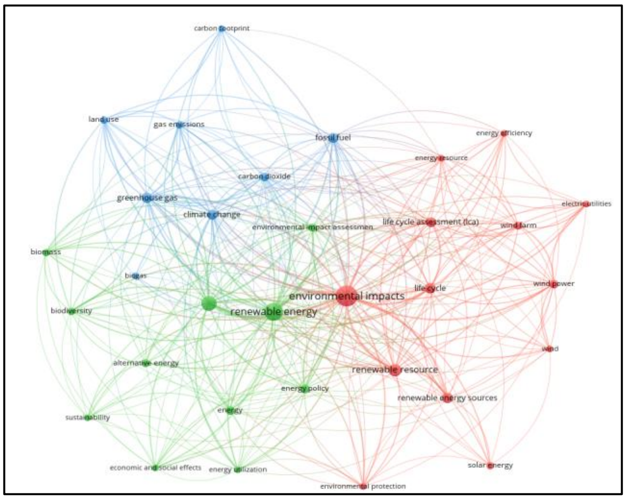

Fig. 3. Keyword Network Visualisation, VOSviewer

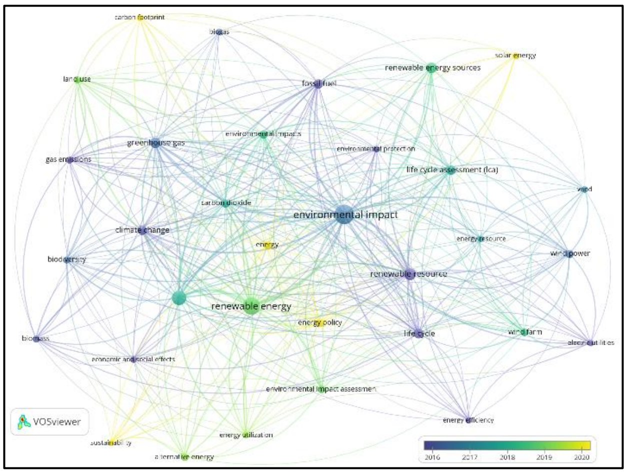

Fig. 4. Keyword Overlay Visualisation, VOSviewer

The right visual map (see Fig. 4) presents us with the same keywords and relationships between them, but we focus on the period of their appearance in the analysed studies, which allows us to highlight the development and trends among researchers. Among the first topics that came to the attention of the authors in the period 2016-2018 are fossil fuels and greenhouse gases causing climate change, energy sources and their efficiency, environmental protection and renewable energy sources such as biomass, biogases, and wind energy. In the period after 2018 to 2020, the focus shifts to assessing the impact of renewables on the environment, land use, sustainability, energy storage options, solar energy, and carbon footprint.

These areas of study reveal a small fraction of the sectors where in-depth analysis is needed to identify the negative impact of renewable energy in the long term and to reveal ways to overcome its negative impacts.

C. Critical Review

The limited number of publications in Scopus that we analysed gave us the starting points for which to deepen our research, including all publications available in online databases (Google Scholar, Science Direct, Web of Science, Scopus), and the analysis will focus on the negative impact of renewable energy in the following areas: production, use, energy storage, waste, socio-economic consequences.

Production – the production of renewable energy technologies requires the use of scarce raw materials (tellurium and indium – needed for photovoltaics) and rare earth elements (for wind turbines) [48] - [50], the limited global distribution of which raises the question of the relevance and economic appropriateness of extracting such terrestrial resources and how their life cycle can be extended, so that they can be used repeatedly, provided that they are also used in other sectors. More researchers [50] are also paying due attention to environmental pollution caused by the extraction of these rare earth raw materials, as well as to toxic substances released in nature during their use in production [51].

Use – the positioning and use of renewable sources on large land/water areas also causes a negative effect, which is multiplied by considering the various sources of energy. Starting with biomass, whose efficiency and return on energy invested remains low compared to that invested in securing the supply chain [3], here we have the widest recognition among researchers for the adverse effects of its use (loss of biodiversity; groundwater pollution and soil degradation; emits significant carbon emissions when burned; competes with food production and leads to price increases) and at the same time, biomass is actively involved in a number of strategies for the development and expansion of the share of renewable energy [3], [52]. The observed negatives of hydropower are related to impacts on fish populations [39], greenhouse gas emissions from biomass decay under reservoirs, and socio-economic consequences for the population. In the case of solar and wind energy, due to the variability of energy flows, it is necessary to occupy large areas with facilities (photovoltaics and wind turbines) for energy production, which causes deforestation, soil and water pollution, loss of biodiversity, and creates the need to extract ever larger quantities of scarce and rare earth elements [38], [45], [51].

Energy storage – the issue of the capacity and efficiency of renewable energy storage systems, the possibilities for their expansion and reduction of the negative effects arising from their production is also gaining more attention. The expansion of renewable energy sources necessitates an increase in storage capacity and an increase in the production of batteries that require critical minerals. The production process itself has severe consequences for the environment, caused by the transformation of land for mining basins, the outflow of heavy metals, the increase in the amount of industrial waste and wastewater, the depletion of freshwater and salt water, climate change [53].

Waste – the expansion of the application of renewable energy inevitably leads to the generation of large volumes of harmful and hazardous waste, which turn into non-recyclable parts of renewable energy systems. Current research and innovative technologies offer innovative solutions to achieve the recyclability of solar panels, wind turbine blades, and energy storage batteries [54] - [57], but now the economic efficiency of these processes is below the profitability threshold, therefore it is unattractive for widespread application.

Socio-economic impact – the main socio-economic consequences are related to the extraction of rare earths, which has a negative effect on local communities, due to the depletion of water resources, the destruction of biodiversity, the transformation of agricultural land into renewable energy fields, which affects the most vulnerable groups. In the "Lithium triangle" (Chile, Argentina, Bolivia), the area of extractive basins overlaps with the territories of indigenous peoples, which necessitated his forced eviction. There is also an increased morbidity among the population living in the mining areas.

IV. Discussion and Conclusion

In this study, we do not dispute the importance of renewable energy in modern times as a tool to limit the harmful effects of fossil fuels on the environment. The diversity of renewable energy sources (see Fig. 1) depicts people's abilities to transform natural energy streams into electricity through innovative technologies and facilities. This is also the main direction in the author's research, taking into account the positive effects of renewable technologies [13] – [25] for achieving sustainable development [9] – [12].

At the same time, we firmly defend the position that not every source of energy and not every technology that is used to absorb renewable energy is safe and environmentally friendly. On the contrary, through the analysis of the limited scientific literature, we found that this research area is at the beginning of its development and the long-term effect of renewable energy sources is not sufficiently analyzed. This is confirmed by the Hypothesis derived in this study.

As can be seen from the keywords occurrence analysis (see Table 2), it is 'environmental impact' that is the most common keyword in the analysed set of publications. "Environmental impact" and "environmental protection" are also the keywords around which part of the author's research is focused. Other areas of research are related to the analysis of the life cycle of renewable energy sources and the economic and social effect they cause. In the future, it is necessary to deepen the analysis of the possibilities for reducing the negative impact that the use of renewable technologies generates in the long term, since the cumulative effect leads to a multiplication of the identified and described negatives. Proof in support of our views is the data on the production of photovoltaic (PV) modules, panels and elements (see Fig. 5).

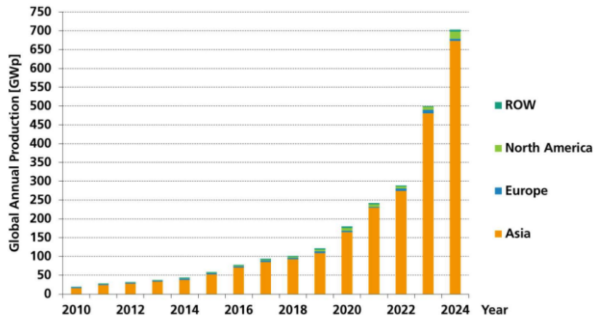

Fig. 5. PV Module Production by Region [58, p.12]

As we find out from Fig. 5, in 2024, nearly 700 GWp of photovoltaic energy is obtained from Asian (in particular Chinese) photovoltaic panels. At the same time, the existing debate about the production of these panels and their parts in plants powered by coal-fired power plants raises the question of how "clean" the electricity produced is. Of course, technological advancements and bringing this issue to the forefront are stimulating Chinese enterprises to switch to using clean energy to produce solar modules, panels, and parts.

In the context of this example, the role of the current study is also manifested – it does not aim to deny the positive side and advantages of renewable energy, but to direct the focus of researchers to the possibilities of increasing the efficiency of renewable energy sources to avoid the already established negative effects.

All the above so far allows us to say that we have fulfilled the purpose of the study by outlining the main thematic areas in which scientific literature investigating the negative effect of renewable energy on the environment is developing. We have listed the publications with the highest citation in Scopus for the period of the study and their authors, who laid the foundation for a research field that should find significant development in the coming years.

According to the prepared critical analysis of the negative effect of renewable energy sources, we offer guidelines in which the efficiency of the use of renewable energy can be improved, including:

- Preparation of a comprehensive analysis of the impact of renewables on the environment and affected groups in the long term.
- Using innovative digital technologies to achieve sustainability [59] and AI-based technologies [60] to increase efficiency in the use of renewable energy, as well as to uncover guidelines to address existing problems.
- Investing in innovative solutions to replace rare earths with more widespread substitutes with the same properties.
- Limiting planned obsolescence and establishing mechanisms to model the innovative obsolescence of renewable energy technologies [61], as well as

investing in innovative recycling practices [54] - [57].

More attention needs to be paid to achieving a balance and harmony between nature and innovative renewable energy solutions, following the example of the "blue economy" [62], rather than pursuing cost-effective but unclear long-term solutions. Taking these criticisms into account can significantly improve the efficiency and appropriateness of expanding the share of renewable energy in the overall energy mix and contribute to stimulating innovative development and competitiveness of industry and SMEs [63] - [64].

The contribution of this research is to outline the problem areas of the development, use and disposal of renewable energy sources, which can serve as a starting point for researchers for further in-depth research and to uncover the possibilities for limiting them. Issues critical for the development of renewable energy are addressed, the solution of which will contribute to achieving a sustainable and balanced development of the energy sector.

Beyond the scope of the current research and subject to future analyses, is the possibility of revealing the negative effects on the environment by individual types of renewable energy sources and highlighting specific guidelines and areas for achieving clean energy, which will contribute to the energy transition and achieving carbon neutrality.

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