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RENEWABLE ENERGY AND HEALTH: BIBLIOMETRIC REVIEW OF NON-MEDICAL RESEARCH

Abstract. Renewable energy has been a top topic for research for decades. Studying this issue is essential based on the need to find effective ways to replace fossil fuels with renewable ones. Climate change is the driver of the transition to renewable energy. And suppose the reason for the need to switch to renewable energy is clear to everyone. The methods provoke significant discussions, which have not stopped for a moment since the beginning of research on this topic. The economic aspect of replacing fossil fuels with renewables is paramount to developing effective business models that allow for the rapid replication of good practices. To this end, various mechanisms of state support and the formation of market incentives for investors were tested. However, the issue of the cost-effectiveness of fossil fuel substitution remains problematic. The issue of energy substitution cannot be considered solely in the economic sphere. The reason for this is the significant number of hidden or indirect effects that are difficult to evaluate. However, this needs to be done to understand renewable energy development's true efficiency and importance. The global impact of large-scale renewable energy technologies is to reduce climate change loss. One of the most important aspects to study and quantify is the impact of energy and public health. It is well known that fossil fuels, being environmentally dirty, harm the human habitat. Declining environmental quality directly affects the number of diseases and life expectancy. Many studies have focused on approaches and quantifying economic losses due to environmental degradation. However, the question of how renewable energy reduces these losses remains poorly studied. Most research on the impact of energy on the environment focuses on reducing emissions. Such studies are extremely valuable but do not allow us to conclude the direct effects of fossil fuel substitution on renewable energy on human life and health and quantify this impact accordingly. This article focuses on the current state of research on the impact of renewable energy on the lives and health of the population and the costs associated with it. Based on available research, the article reviews the scientific developments on this topic in publications, mainly non-medical profiles.

Keywords: health, renewable energy, bibliometric review, lifetime, economic losses.

Introduction. Once again, in human history, humanity has faced political, social, and economic challenges that have long-lasting consequences. Since February 2022, the world has changed. The usual economic structure, formed under the influence of the generally stable economic situation in the world, except for a few crises, was destroyed by the military aggression of the Russian Federation against Ukraine. Russia uses economic levers as a tool in the political struggle and a way to gain an advantage on the battlefield in Ukraine. European countries' dependence on Russian energy resources, including oil and natural gas, has seriously threatened their national security and economic well-being. There is now an urgent need to diversify energy resources to ensure the functioning of the economies of the European Union and to maintain social stability due to rising energy prices and shortages due to Kremlin policies.

The current situation can be both a driver for the development of renewable energy and a deterrent. It all depends on the course of diversification to be chosen by the countries of the European Union.

The most obvious is the course to diversify sources of fossil energy supplies. It is about increasing oil

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and gas production by supplier countries (except the Russian Federation) to replace the amount of energy supplied to the EU from Russia (Person, 2022). In this case, there is no hope for the rapid development of renewable energy over the next few years as an alternative to fossil fuels. However, after resolving the acute crisis of energy substitution, which needs to be resolved quickly, it is advisable to expect to accelerate the development of environmentally friendly renewable energy technologies. Two arguments can substantiate this assumption. The first argument is the lost time in the fight against climate change, which has now receded into the background and has ceased to be a priority in the energy policy of many countries. The second argument is the need to insure against future problems with energy import dependence. Diversification of fossil fuel sources for many countries cannot be considered a credible plan. For countries heavily dependent on energy imports, developing renewable energy in their territory is more reliable in replacing imports. This significantly increases countries' energy independence and contributes to achieving economic security goals.

The first scenario seems more realistic. The first political steps taken by the United States, the European Union, and some other countries confirm that this scenario will be implemented. Negotiations between the United States and Iran, liberalization of sanctions on Venezuela, OPEC talks on increasing oil production, and attempts to normalize relations between the United States and Saudi Arabia show the implementation of a course to replace fossil fuels from Russia with similar energy sources from other suppliers.

Accordingly, the next few years will not be a window of opportunity for renewable energy producers, but shortly, attention to this area of energy will increase again. We can predict that the industry's growth rate will be higher than we have seen in recent years, but not enough to radically address the issue over the next 10-15 years. This means that the relevance of finding ways to use renewable energy technologies will remain the most efficient. Companies in the industry will decide how to invest the most efficiently to get the best possible economic effect in the shortest possible time. At the same time, governments will look for tools to encourage energy companies to choose not the most investment-attractive solutions but the most socially beneficial. That is why it is necessary to consider the indirect effects of implementing renewable energy capacity. Such effects can be a reduction in the cost of minimizing the harmful effects of fossil fuel use in a given region and improving the quality of the environment. In this context, the issue of the impact of energy on the health and livelihoods of the population is particularly relevant. Accordingly, renewable energy projects should be implemented primarily in those places or regions where their positive impact on health will be maximum. This should be one of the critical criteria when evaluating investment projects in renewable energy. Unfortunately, in many cases, such an analysis is not even conducted. That is incredibly wrong, especially for large projects that can significantly affect the health of the population and its longevity, and thus ensure the maximum possible economic effect, taking into account direct and indirect benefits.

Literature Review. Since this article is devoted to a bibliometric review, the literature review is contained in the study's results.

Methodology and research methods. The research was performed using VOSviewer bibliometric analysis tools based on a thematic sample of articles from the Scopus scientific-metric database.

The article analyzes a sample of articles published in journals included in the Scopus database. All the sample items are grouped with common keywords, which suggest that they are more or less exploring renewable energy and health issues.

The sample of publications was formed based on the algorithm in Table 1.

Results. More than 4,000 publications can be identified in the Scopus database based on renewable energy and health keywords. About 1,500 publications were obtained by selecting relevant articles. The distribution of publication activity and citations of publications by year is shown in Figure 1.

According to Figure 1, over the past five years, more than 57% of publications have been published

on the topics covered in this article. The trend of increasing citations is also clear. However, these data do not answer the question of how deeply the issue of the impact of renewable energy on the health and livelihoods of the population, and therefore the costs borne by the state through funding of state and municipal health facilities and private businesses operating in the field Health Care.

Table 1. Stages of the literature search and selection process

Stage	Filters	Result
Stage 1 Data Collection		
Choice of suitable information sources	Scopus Database	
Identification of search field in the database	Title, abstract, keywords	
Identification of search keywords	renewable energy, health	4,362 publications
Stage 2 Data screening		
Identification of publication type	Journal articles	2,181 publications
Choice of the language	English	2,088 publications
Choice of the field of publication	Environmental Science; Social Sciences; Energy; Economics, Econometrics, and Finance; Business, Management, and Accounting; Decision Sciences; Multidisciplinary	1,560 publications
Identification of the publication's time limits	2000-2021 (since the beginning of the growth of the number of publications on the subject)	1,532 publications
Stage 3 Bibliometric analysis		
Tools	VOSviewer 1.6.16, Microsoft Excel	Visualization maps, charts

Sources: developed by the authors.

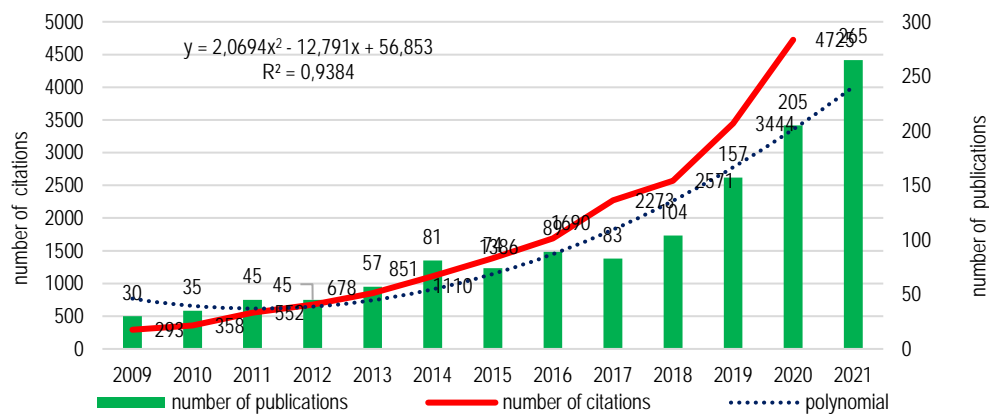


Figure 1. Publication activity and citations of articles on the research topic in the period 2009-2021

Sources: developed by the authors.

A partial answer to the question of how well the relationship between renewable energy and health care is studied in the scientific literature can be found in the study of the most cited publications from the

relevant sample. A list of the ten most-cited publications since 2000 is shown in Table 2.

Table 2. Top 10 leading publications in renewable energy and health (based on the Scopus database)

Article title	Total citations	Author	Country affiliation	Journal/Year of publication
Potential importance of hydrogen as a future solution to environmental and transportation problems	829	Balat M.	Turkey	International Journal of Hydrogen Energy, 2008
Sustainable bioenergy production from marginal lands in the US Midwest	494	Gelfand I., Sahajpal R., Zhang X., Izaurralde R. C., Gross K. L., Robertson G. P.	United States	Nature, 2013
100% Renewable energy systems, climate mitigation and economic growth	480	Mathiesen B.V., Lund H., Karlsson K.	Denmark	Applied Energy, 2011
Sustainability of three apple production systems	448	Reganold J.P., Glover J.D., Andrews P.K., Hinman H.R.	United States	Nature, 2001
Social, economical and environmental impacts of renewable energy systems	389	Akella A.K., Saini R.P., Sharma M.P.	India	Renewable Energy, 2009
Feasibility study of small Hydro/PV/Wind hybrid system for off-grid rural electrification in Ethiopia	297	Bekele G., Tadesse G.	Ethiopia	Applied Energy, 2012
Wind turbine condition monitoring by the approach of SCADA data analysis	282	Yang, W., Court, R., Jiang, J.	United Kingdom China	Renewable Energy, 2013
Impacts of a regional drought on the productivity, dieback, and biomass of western Canadian aspen forests	281	Hogg, E.H., Brandt, J.P., Michaelian, M.	Canada	Canadian Journal of Forest Research, 2008
100% clean and renewable wind, water, and sunlight (WWS) all-sector energy roadmaps for the 50 United States	260	Jacobson M.Z., Delucchi M.A., Bazouin G., Bauer Z. A. F., Heavey C.C., Fisher, E., Morris S. B., Piekutowski D. J. Y., Vencill T.A., Yeskoo T.W.	United States	Energy and Environmental Science, 2015
Mitigation of global greenhouse gas emissions from waste: Conclusions and strategies from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report. Working Group III (Mitigation)	260	Bogner, J., Pipatti, R., Hashimoto, S., (...), Sutarnihardja, R.T.M., Gregory R.	United States	Waste Management and Research, 2008

Sources: developed by the authors.

Analyzing the articles from the top 10 citations, we can conclude that they are only partially related to health care but focused on studying renewable energy. The population's life and health are considered through climate changes and living conditions. However, a detailed analysis of the public costs associated with reducing morbidity and mortality and increasing life expectancy due to reduced environmental impact through using renewable energy instead of fossil fuels is virtually non-existent. If such an analysis is carried out, then superficially.

However, the most cited publications also cannot indicate the place of health in renewable energy

research. To determine this, a cluster analysis of all publications selected in the relevant sample should be performed.

Thus, 12509 keywords were included in the preliminary analysis. After checking their relevance and setting the «frequency of occurrence more than the five times» limit, 830 words were selected.

Cluster analysis identified seven clusters of publications (Figure 2). The first (red) cluster contains articles that study the technical and technological aspects of renewable energy development. The second cluster (green) reveals various renewable energy issues. The third cluster (blue) focuses on climate issues. The fourth cluster (yellow) examines the balance between economic development and environmental goals. The fifth cluster (purple) is dedicated to energy resources. The sixth cluster (blue) examines the relationship between climate change and population health change. The seventh cluster (orange) studies the life cycle of renewable energy.

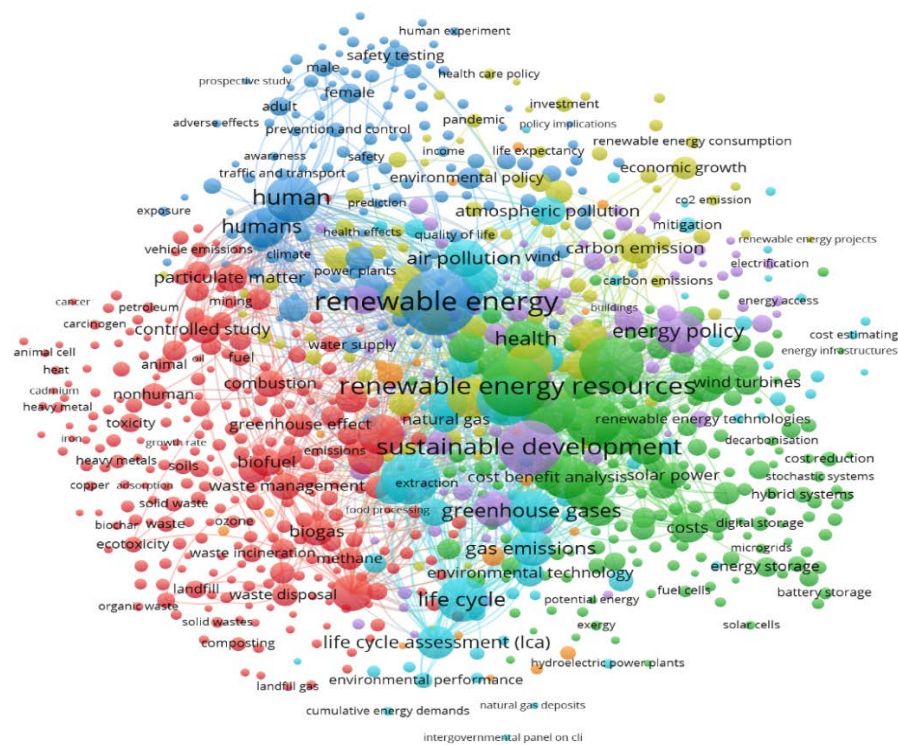


Figure 2. Cluster analysis of publications in the field of renewable energy and health care
Sources: developed by the authors.

Consider in more detail each of the identified clusters. Cluster 1 (red, 258 keywords) reveals the technical aspects of implementing environmentally friendly technologies and includes more than just energy technologies (Figure 3). This cluster contains a wide range of issues related to various environmental pollutants. This cluster is the most heterogeneous because its publications cover many topics. Energy in this cluster's publications is mainly considered through the prism of biofuels. Medical issues in the cluster are related to diseases caused by environmental pollutants, among which a significant share is given to cancerous tumors.

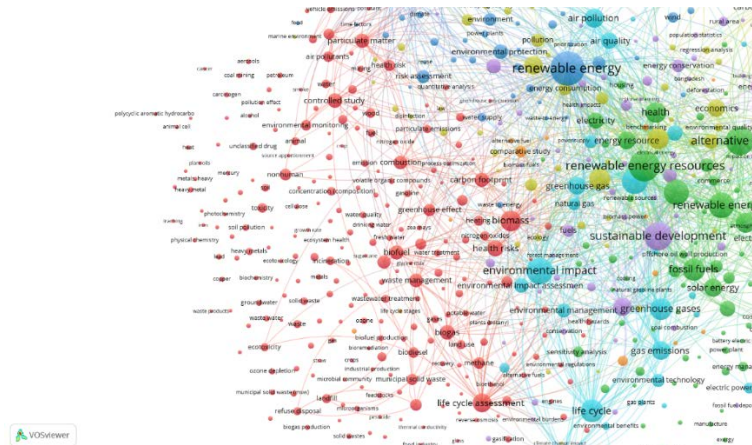


Figure 3. Fragment of cluster analysis of publications in the field of renewable energy and health care (cluster 1)

Sources: developed by the authors.

The Green Cluster (174 keywords) consists entirely of publications on energy. The vast majority of publications in this cluster are related to renewable energy. A significant proportion of publications related to energy storage technologies are necessary for developing renewable energy, creating micro-networks, and integrating them into higher-level energy networks. Another aspect of the cluster publications is computerized systems and information and communication technologies, which promote renewable energy networks to generate energy and are a necessary component of smart grids. Accordingly, considerable attention in these publications is paid to optimizing the power grid.

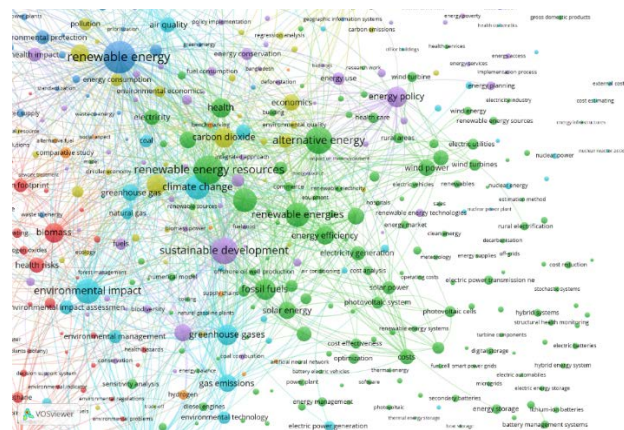


Figure 4. Fragment of cluster analysis of publications in the field of renewable energy and health (cluster 2)

Sources: developed by the authors.

Articles of economic orientation are widely represented in this cluster. Forming a profitable business model, which can be easily disseminated among energy market participants, is a key issue, the effectiveness of which depends on the pace of renewable energy development. That is why the issue of

investment attractiveness of renewable energy projects occupies a prominent place in this cluster. The relationship between renewable energy and public health is not considered in the publications of this cluster.

The third cluster (blue, 136 keywords) is related to climate policy and environmental protection measures, including regulating renewable energy and the creation of conditions for its further development. An important aspect considered in some articles of this cluster is the formation of rules to create conditions for improving the population's health.

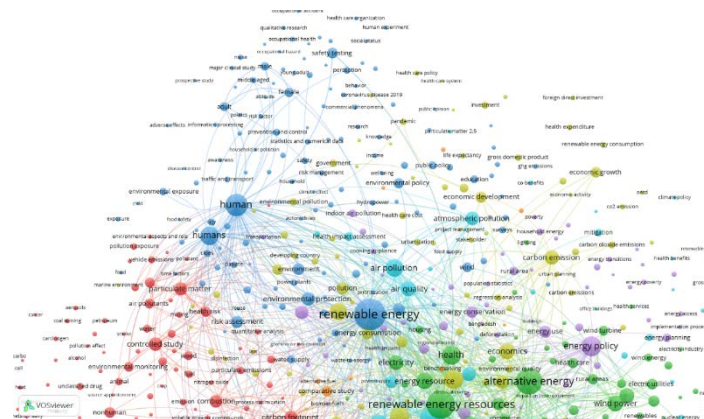


Figure 5. Fragment of cluster analysis of publications in the field of renewable energy and health (cluster 3)

Sources: developed by the authors.

Yellow cluster articles (90 keywords) address the issue of maintaining a balance between economic development and the need for large-scale implementation of renewable energy technologies to reduce emissions of harmful substances into the atmosphere. Thus, this area of research focuses on sustainable development.



Figure 6. Fragment of cluster analysis of publications in the field of renewable energy and health (cluster 4)

Sources: developed by the authors.

Purple cluster publications (87 keywords) focus on resource provision for renewable energy development, as it also leads to some losses. However, they differ significantly from those caused by fossil fuel extraction, processing, and consumption. Such costs include, in particular, the withdrawal of land

resources allocated for establishing or maintaining renewable energy facilities. The articles in this cluster also explore how such use of natural resources affects the population's functioning and, consequently, its health.

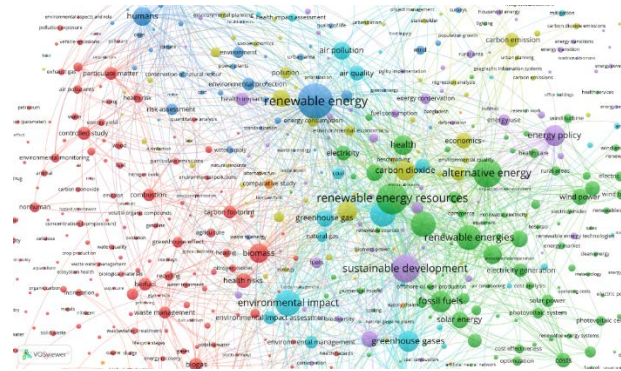


Figure 7. Fragment of cluster analysis of publications in the field of renewable energy and health (cluster 5)

Sources: developed by the authors.

The Blue Cluster (64 keywords) is the most studied relationship between climate change due to the activities of entities in the energy sector and changes in public health. The clear environmental direction of publications in this cluster allows us to draw conclusions based on empirical data on the amount of emissions of harmful substances into the atmosphere and changes in climatic conditions that occur as a result. Separate articles in this cluster also examine the effects of climate change on the population and the burden on the health care system. However, this cluster is among the least numerous in terms of the total number of publications. At the same time, the insignificant number of keywords compared to other clusters indicates the focus of authors whose articles will be assigned to this cluster on a narrow topic. This may mean a deeper study of the problem.

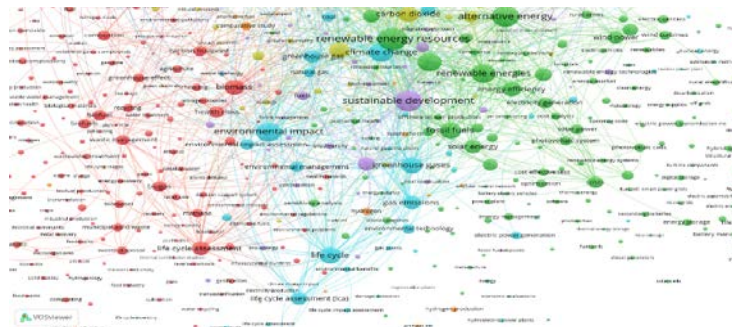


Figure 8. Fragment of cluster analysis of publications in the field of renewable energy and health (cluster 6)

Sources: developed by the authors.

The smallest cluster identified as a result of bibliometric analysis (orange, 21 keywords) collected publications on socio-economic and organizational aspects of the functioning of renewable energy and its life cycle. A retrospective contextual analysis of publications shows a lack of significant attention to the subject of this article in publications after 2018 (Figure 9). Instead, much attention has recently been paid to finding solutions to still problematic technical and technological issues of renewable energy development, such as finding energy storage technologies (batteries) that will make a breakthrough in renewable energy and accelerate its growth in energy production and consumption.

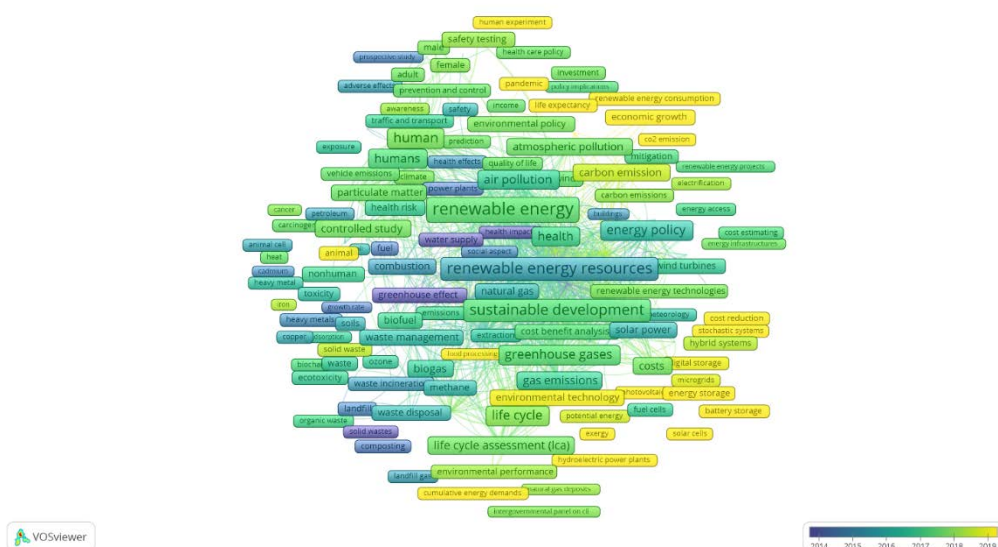


Figure 9. Retrospective analysis of renewable energy and health publications
Sources: developed by the authors.

Conclusions. Renewable energy projects are assessed based on economic feasibility and environmental impact but rarely on the effects on public health and the costs involved. This is unjustified for the formation of a comprehensive view of the value of a particular renewable energy project. A Massachusetts Institute of Technology study (News, 2013) found that air pollution in the United States causes approximately 200,000 premature deaths per year, with electricity generation causing 52,000 of these deaths (Heger, 2021). Thus, the study of renewable energy in this context is essential.

The bibliometric analysis showed that the attention of scientists to this problem is insufficient. There is no tendency to update research in this area, although, at the COP26 climate change conference in Glasgow, Scotland, this topic resonated at COP26 more than it has at previous United Nations climate summits (Joselow, 2021, The Glasgow Climate Pact, 2022).

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Відновлювані джерела енергії та охорона здоров'я: бібліометричний огляд немедичних досліджень

Відновлювана енергетика впродовж кількох десятиліть є топовою темою для наукових досліджень. Важливість вивчення даного питання ґрунтується на потребі пошуку ефективних способів заміщення викопного палива відновлюваним. Кліматичні зміни є драйвером переходу на відновлювані джерела енергії. І якщо причина необхідності переходу на відновлювану енергетику зрозуміла кожному, то способи викликають значні дискусії, які не припинялися ні на мить з початку наукових досліджень на дану тематику.

Економічний аспект заміщення викопних енергоресурсів відновлюваними є превалюючим для розроблення дієвих бізнес-моделей, які дозволять швидко тиражувати успішні практики. З цією метою було апробовано різні механізми державної підтримки та формування ринкових стимулів для інвесторів. Однак незважаючи на це, питання економічної ефективності заміщення викопних видів палива залишається проблемним.

Питання енергозаміщення не можна розглядати виключно в економічній площині. Причиною цьому є значна кількість прихованих або непрямих ефектів, які важко врахувати. Однак це необхідно робити для розуміння справжньої ефективності та значимості розвитку відновлюваної енергетики. Глобальним ефектом від масштабного впровадження технологій відновлюваної енергетики є скорочення втрат, пов'язаних зі зміною клімату.

Одним з найбільш важливих аспектів для вивчення та кількісної оцінки є вплив енергетики та здоров'я населення. Загально відомо, що викопне паливо, будучи екологічно брудним, негативно впливає середовище проживання людей. Зниження якості життєвого середовища безпосередньо позначається на кількості захворювань та тривалості життя населення. Низка досліджень присвячена підходам та кількісній оцінці економічних втрат внаслідок погіршення життєвого середовища. Однак слабо дослідженим залишається питання яким чином відновлювана енергетика впливає на скорочення цих втрат. Більшість досліджень щодо впливу енергетики на довкілля фокусується на питаннях скорочення викидів шкідливих речовин. Такі дослідження є надзвичайно цінними, однак не дозволяють зробити висновок щодо безпосереднього впливу заміщення викопного палива відновлюваними енергоресурсами на життя та здоров'я людей, а відповідно дати кількісну оцінку цьому впливу.

Дана стаття сфокусована на вивченні поточного стану досліджень впливу відновлюваної енергетики на життя та здоров'я населення та витрати, пов'язані з цим. Стаття, спираючись на наявні дослідження, оглядає наукові напрацювання на дану тематику у виданнях переважно немедичного профілю.

Ключові слова: здоров'я, відновна енергія, бібліометричний аналіз, життєвий цикл, економічні втрати.