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MODELLING AND FORECASTING ENERGY EFFICIENCY IMPACT ON THE HUMAN HEALTH

Abstract. *Nowadays, one of the main pollutant factors is the inefficient use and breakdown of energy technologies. Improving access to modern energy, which emits less pollution, both at home and in the community could benefit the health of many people. Besides, it could contribute to the long-term goals of sustainable development. Health is a universal indicator of progress towards sustainable energy. Given the issue's relevance, this article examines the impact of energy on public health. The study's purpose is to substantiate the prospects for achieving sustainable development and human well-being, which depends on the quality of the environment and could be provided by a carbon-free economy. The methodological basis of the work is general scientific research methods, such as empirical and theoretical methods, as well as systemic and functional methods. This study applied VOSviewer tools, Web of Science and Scopus analysis tools, and Google Trends to conduct a bibliometric analysis of the impact of energy factors on public health. Based on Scopus data, the findings confirmed the hypothesis concerning a growing trend of publications examining the impact of energy factors on human health. In the study framework, the VOSviewer 1.6.18 tools allowed the detection of six clusters of research streams: renewable resources, sustainable development, public, energy policy, energy efficiency, and solar energy. The authors noted that different countries research the impact of energy on public health. These issues are most actively studied in China, the USA, and India. A separate dynamics of the publications were studied for 10 countries leading in the publication activity on the subject. The Google Trends tool has identified public interest in the topic. The interest of business and industry is considered separately. The findings showed that in the first case, the interest is more in the health factor. In turn, businesses and industries pay more attention to developing renewable energy sources. Google Trends analysis of the popularity of the search query «renewable energy» identified Korea, Turkey, Nigeria, Bangladesh, and Germany as leaders in the number of queries. However, the keywords healthy leaders are New Zealand, USA, Canada, Poland, and Australia.*

Keywords: renewable energy, healthy environment, sustainable development, energy policy, environment protection.

Introduction. The possibility of sustainable development and human well-being depends on the quality of the environment, which the formation of a carbon-neutral economy could provide. This topic is considered deeply by many scientists worldwide, especially: Gong P., Himri S., Himri Y., Rehman S., Sheng S., Abdel-Khalik A.S., Campbell-Lendrum D., Chen H.H., Costello A., Draoui B., Fahmy F.H. It stands to mention the domestic scientists such as Vasylieva T., Lieonov S. Letunovska N., and Saher L.

The affiliation most contributed to the investigation of energy efficiency are North China Electric Power University, National Renewable Energy Laboratory, Tsinghua University, Politecnico di Milano, Alexandria University, Université Tahri Mohammed Béchar, Université Tahri Mohammed Béchar, Southeast University, Universitat Politècnica de Catalunya, King Fahd University of Petroleum and Minerals, Vellore Institute of Technology, Imperial College London, Beijing Institute of Technology, Chinese Academy of Sciences, and Tianjin University.

In turn, the most significant funding sponsors are the National Natural Science Foundation of China, National Key Research and Development Program of China, Engineering and Physical Sciences Research Council, European Commission, Fundamental Research Funds for the Central Universities, U.S. Department of Energy, UK Research and Innovation, Fundação para a Ciência e a Tecnologia, Ministry of Science and Technology of the People's Republic of China, State Grid Corporation of China, Australian Research Council, Deanship of Scientific Research, King Saud University, European Regional

Development Fund, and Horizon 2020.

Literature Review. Ensuring sustainable development worldwide requires an in-depth investigation of the energy impact on public health. Noteworthy here, the first studies on the issue mentioned above appeared in the 1980s. Herewith the countries have been becoming more interested in this subject since 2007. This issue received the most significant popularity in 2020. The world's population has shown great interest in health and energy issues since 2017, while in business and industry – in 2008.

Thus, Friel S., Marmot M., McMichael A.J., Kjellstrom T., and Vågerö D. (Sharon Friel et al., 2008) studied global justice issues in health and climate stabilization. Friel S., Marmot M., McMichael A.J., Kjellstrom T., and Vågerö D. (Sharon Friel et al., 2011) investigated the issues of sustainable use of renewable resources and their impact on human health. Li G., Zakari A., and Tawiah V. (Abdulrasheed, Li, & Tawiah, 2020) have paid attention to the study of energy improvement and CO2 emissions research.

In particular, researchers at Harvard University C-CHANGE (Jonathan Buonokor et al.) created an assessment instrument to calculate the monetized health and climate benefits of wind and solar projects. They elaborated on two strategies to reduce energy consumption (Harvard, 2015; Heger, 2015).

The study by the Harvard T.H. Chan School of Public Health (2020) considered the impact of energy on health in the view of examining how different transportation policies affect health through improved air quality and increased physical activity; energy, economic, environmental, and medical results of the illustrative design of the clean energy standard, which would reach 80% of clean electricity by 2030; the issue of identifying renewable energy sources for greater climate and health benefits in the USA and around the world.

Heger (2015) from the Massachusetts Institute of Technology found that air pollution in the USA accounts for approximately 200 thousand premature deaths annually, while electricity generation causes 52 thousand of these deaths. In turn, health experts have assessed the impact of different renewable energy or energy efficiency plants in different parts of the region. They have developed a model that compares the climate and health benefits of 24 scenarios. They found that the benefits depend on the location and installation and range from $ 5.7 million to $ 210 million per year.

Mark Z. Jacobson, a professor of civil and environmental engineering at Stanford University, has identified one of the main barriers to replacing the current fossil fuel infrastructure. The scholar concluded the reason is of lack of people and political figures aware of the measurable health effects of fossil fuels.

Silva (2021) mention that promoting access to green energy has a strong potential to improve public health.

Besides, it is noteworthy to mention that health is a universal indicator of progress under the Sustainable Energy for All initiative (WHO, 2021).

Pablo-Romero et al. (2015) indicated that reducing renewable energy sources helps reduce fossil fuel use, and associated emissions of pollutants into the atmosphere positively affect human health. Therefore, policymakers should consider these positive externalities of renewables when assessing the possibility of their promotion.

Sustainable energy sources emitting little or no greenhouse gases help reduce global warming, keep the environment clean of dirt and protect the population's health. Considering the multidisciplinary nature of the analyzed topic, it stands to mention the most interested scholars such as Rehman Y., Sheng S., Abdel-Khalik S., Campbell-Lendrum A.S., Chen D., Costello H.H., Draoui A., Fahmy B. (Scopus,2022) Vasylieva et al. (2021); Nechaeva (2004), etc.

Methodology and research methods. The methodological basis of this study is general scientific research methods, such as empirical and theoretical methods, as well as systemic and functional methods. This study applied the fundamental provisions of the general economic theory, the theory of economic efficiency of social production, and the theory of the economics of nature management and environmental

protection. A bibliometric analysis was performed using VOSviewer software, Web of Science and Scopus analysis tools, and Google Trends to study the influence of energy factors on renewable energy.

Results. To study the research directions of scientific publications in the context of the energy efficiency impact on human health, a bibliometric analysis was performed using VOSviewer software tools, Web of Science and Scopus Tools Analysis, and Google Trends instruments. This study covers 2004-2021 since the Google Trends tool restricts the data period.

Based on the use of Scopus software, which contains bibliographic information about scientific publications in peer-reviewed journals, books, and conferences, a selection of publications was obtained by the search words «renewable energy» and «healthy». In total, the initial sample was 528 publications for 2004-2021. Figure 1 presents the dynamics of publications.

Figure 1. **Publication dynamic under the keywords «renewable energy» and «healthy» (2004-2021)**

Sources: developed by the authors based on the Scopus data.

Figure 1 shows the scientific interest in the impact of energy on human health increased in 2008, 2012, and 2021. On the other hand, the decline was in 2009 and 2015. The above dynamics could be explained by changes in financing and investment in renewable energy.

It should be noted the growth of scientific publications numbers from 2016 to 2021. Thus, in recent years, from 2015 to 2021, the number of publications has increased annually by 1,159 times. The average

growth rate was determined by the formula of the geometric distribution (chain growth rate) and considering the number of levels of dynamics:

$$T_p = \sqrt[7-1]{1{,}1071 * 1{,}2903 * 1{,}275 * 1{,}1568 * 1{,}2711 * 0{,}9066} = 1{,}159$$

The growth rate shows that publications increased annually by 15.9% from 2015 to 2021 (Tpr = 1.159–1 = 0.159 or 15.9%). Generally, the publication dynamic is characterized by a growing tendency in the analyzed subject. This factor determines the relevance of the research topic.

Figure 2 demonstrates that China, the USA, and India are particularly interested in the research topic. In turn, the USA is one of the first countries to show interest in the impact of energy on human health. Besides, most leading countries have started publication on the analyzed subject since 2007. Herewith the most significant number of works was formed in 2020.
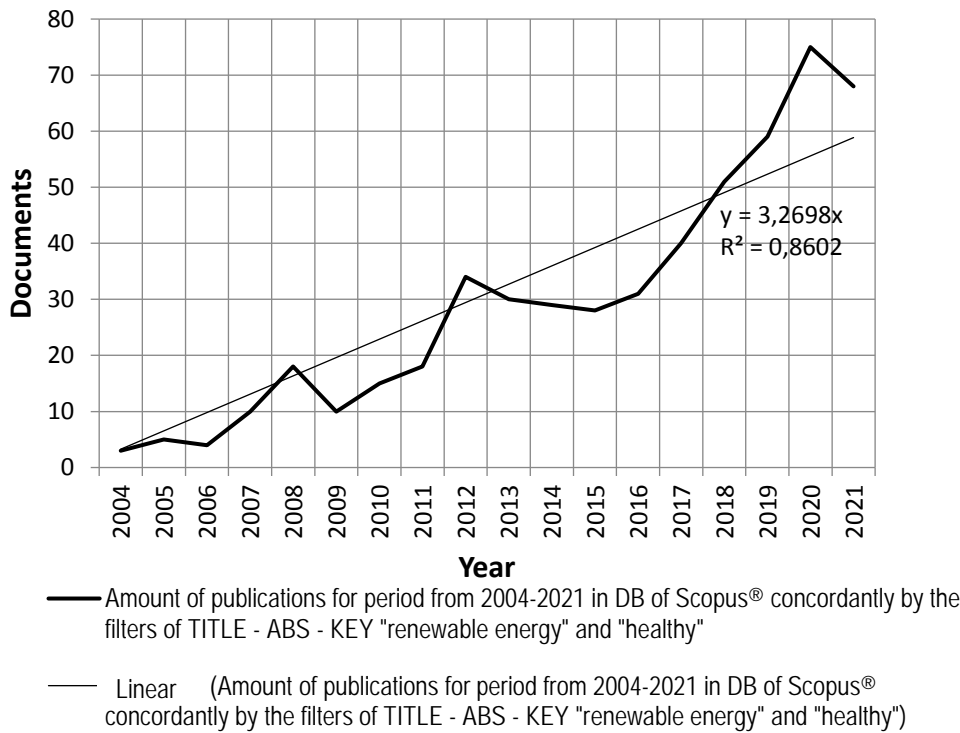

Figure 2. Publication dynamic under the keywords «renewable energy» and «healthy» by countries (2004-2021)

Sources: developed by the authors based on the Scopus data.

To thoroughly analyze the field of scientific interests and identify local issues, the visualization of the conceptual network by the search words «renewable energy» and «healthy» was applied (Fig. 3). The visualization of results was conducted using VOSviewer software 1.6.18.

The bibliometrics findings have identified six clusters of research directions in the context of the impact of energy on human health. The studies devoted to types of renewable energy resources are placed in the red cluster (first cluster). Most of the connections in the first cluster are found in the concept of

«renewable energy resources». In particular, this cluster focuses on the concepts with the most strengthen link.

Green (second cluster) is associated with the impact of economic factors on human health. The cluster includes public health, environmental protection, economic development, etc.
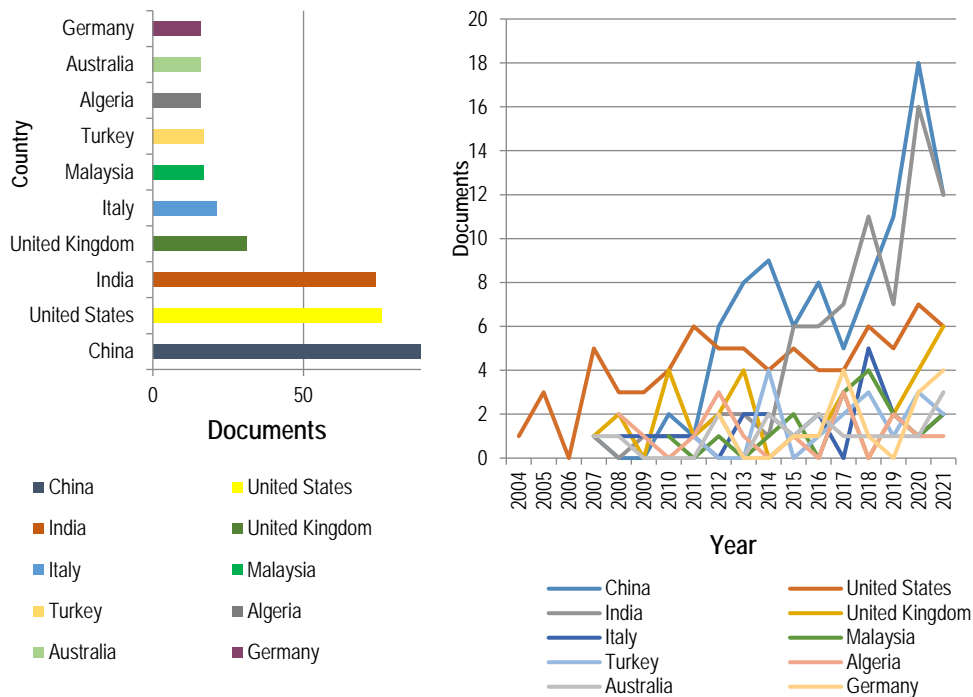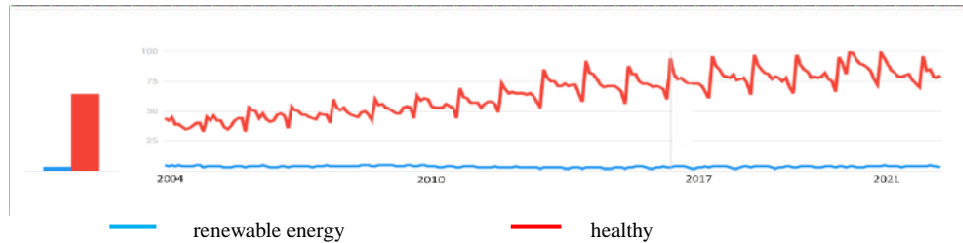

Figure 3. Keywords cooccurrence network of publications under the keywords «renewable energy» and «healthy» by countries (2004-2021)

Sources: developed by the authors based on the Scopus data.

The third cluster (blue) includes issues on energy management, green energy, design of greenhouses, energy conservation, energy utilization, non-renewable energy, recycling, and energy conservation. Most of the links were found with «renewable energy efficiency».

The fourth cluster (yellow) operates with sustainable development issues. The cluster focuses on key concepts such as environmental management, a carbon-neutral economy, energy security, a healthy environment, and global warming.

The fifth cluster (purple) covers the studies examining investment activities, energy market, economic and social effects, electricity generation, electricity industry, and development of innovative grid technologies. Most of the links in this cluster are found in the concept of «energy policy».

The sixth cluster (blue) demonstrates various types of energy investigated by the authors. Particular attention is paid to solar energy.

Besides, the obtained results showed the public interest in the impact of energy on human health. The frequency of queries in search engines was determined using the Google Trends tool. Given the data limitations in Google Trend, the study period covers 2004-2021. Figure 3 demonstrates the dynamics of the search frequency of the terms «renewable energy» and «healthy» worldwide.

Figure 3. Frequency dynamics of «renewable energy» and «healthy» search queries worldwide
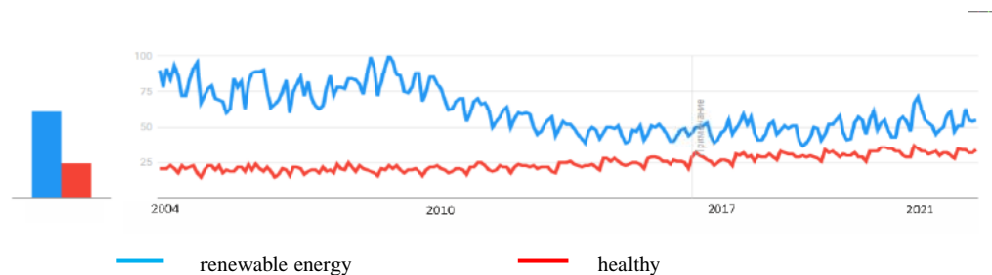Sources: developed by the authors based on Google Trends data.

Figure 4. Frequency dynamics of «renewable energy» and «healthy» search queries worldwide among businesses and industries (2004-2021)
Sources: developed by the authors based on Google Trends data.

Figure 4 shows that the public search query «healthy» frequency is higher than the corresponding «renewable energy» indicator. The above search queries were most popular from 2017 to 2021. Besides, the search query «healthy» frequency was higher than the corresponding «renewable energy» among businesses and industries.

The Google Trends tool allows comparing search terms and seeing a map of the world, which shows the shades of their popularity. The color intensity of a region corresponds to the percentage of searches for a more popular term in it. The popularity of a search term is related to the total number of Google searches over sometime in a given region.

It stands to mention that the search query «renewable energy» was most popular in Korea, Turkey, Nigeria, Bangladesh, and Germany.

Table 1 confirms the bigger popularity of the search query «healthy» among the population's requests. At the same time, businesses and industries are more interested in developing renewable energy sources.

On the other hand, New Zealand, the United States, Canada, Poland, and Australia are in the top five by the number of the search request «healthy».

Table 1. Comparison of «renewable energy» and «healthy» search queries by regions

Country	Renewable energy	Healthy
Korea	19%	81%
Turkey	16%	84%
Nigeria	14%	86%
Bangladesh	14%	86%
Germany	14%	86%

Sources: developed by the authors based on Google Trends data.

In addition to the scientific and public interest concerning the impact of the energy factor on human health, studies published in Nature Climate Change have shown that renewable electricity projects and energy efficiency measures could benefit health by millions of dollars a year (Harvard T.H., 2015). For example, premature death, heart attacks, asthma exacerbations, and hospitalizations for cardiovascular or respiratory problems could be decreased by generating electricity from low-carbon energy sources, using clean energy sources (such as wind and solar), reducing fossil fuel electricity production and emissions of harmful gases such as nitrogen oxides and carbon dioxide, etc.

Conclusions. Renewable energy could benefit public health and the climate by displacing emissions from fossil fuel generators (Buonocore et al., 2021). The study findings showed an essential advantage of developing renewable energy sources (Magill et al., 2015). Using environmentally friendly energy could undoubtedly reduce the number of pollutants and create a generally healthy atmosphere. All these issues are highly relevant today and require detailed study. For example, wind and solar energy are the most studied renewable energy sources, while others are largely understudied. Therefore, there is a need to consider the health benefits of using different types of renewable energy sources.

References

Buonocore, J. J., Luckow, P., Norris, G., Spengler, J. D., Biewald, B., Fisher, J., & Levy, J. I. (2016). Health and climate benefits of different energy-efficiency and renewable energy choices. *Nature Climate Change, 6*(1), 100-105. [Google Scholar]

Buonocore, J. J., Luckow, P., Norris, G., Spengler, J. D., Biewald, B., Fisher, J., & Levy, J. I. (2016). Health and climate benefits of different energy-efficiency and renewable energy choices. *Nature Climate Change, 6*(1), 100-105. [Google Scholar]

Friel, S., Butler, C., & McMichael, A. (2011). Climate change and health: risks and inequities. *Global health and global health ethics*, 198-209. [Google Scholar]

Friel, S., Marmot, M., McMichael, A. J., Kjellstrom, T., & Vågerö, D. (2008). Global health equity and climate stabilisation: a common agenda. *The lancet, 372*(9650), 1677-1683. [Google Scholar]

Ghosh, K. (2020) How Renewable Energy Can Help Improve Health. Renewable energy. . Retrieved from [Link]

Harvard T.H. (2015). Chan Health Benefits of Renewable Energy. Retrieved from [Link]

Harvard T.H. (2020). Renewable electricity projects and energy efficiency measures can improve health and reduce air pollution. Retrieved from [Link]

Heger, M. (2015). Renewable Energy is Good for Your Health Regions could save $5.7 million-$210 million per year by replacing coal-fired power with renewable energy or energy efficiency measures. IEEE Spectrum. Retrieved from [Link]

Letunovska, N., Saher, L., Vasylieva, T., & Lieonov, S. (2021). Dependence of public health on energy consumption: A cross-regional analysis. In *E3S Web of Conferences*. [Google Scholar]

Li, G., Zakari, A., & Tawiah, V. (2020). Energy resource melioration and CO2 emissions in China and Nigeria: Efficiency and trade perspectives. *Resources Policy, 68*, 101769. [Google Scholar]

Magill, B. (2015). Better Health a Key Benefit of Renewables, Study Says. . Retrieved from [Link]

Mahmut, U. S. (2021). The relationship between renewable energy use and health expenditures in EU countries. Retrieved from [Link]

Pablo-Romero, M. D. P., Román, R., Sánchez-Braza, A., & Yñiguez, R. (2016). Renewable energy, emissions, and health. *Renewable Energy: Utilisation and System Integration, 173*. [Google Scholar]

Silva, S., Laranjeira, E., & Soares, I. (2021). Health Benefits from Renewable Electricity Sources: A Review. *Energies, 14*(20), 6678. [Google Scholar] [CrossRef]

WHO. (2012). Health Indicators of sustainable energy in the Context of the Rio+20 UN Conference on Sustainable Development. . Retrieved from [Link]

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Моделювання та прогнозування впливу фактору енергетичної ефективності на здоров'я людини

В сучасних умовах одним з основних факторів забруднення є неефективне використання та розподілення енергетичних технологій. Удосконалення доступу до сучасної енергії, яка виділяє менше забруднення, як у домі, так і в громаді, може принести користь здоров'ю мільйонам людей та сприяти досягненню довгострокових цілей стійкого розвитку. У свою чергу

здоров'я є універсальним індикатором прогресу в досягненні сталої енергії. Ураховуючи актуальність проблематики у статті досліджується вплив енергетичного фактору на громадське здоров'я.

В статті під час дослідження впливу енергетичного фактору на громадське здоров'я виконано бібліометричний аналіз з використанням таких програмних засобів як VOSviewer, Web of Science, Scopus Tools Analysis та Google Trends. Метою дослідження є обґрунтування перспектив досягнення сталого розвитку і добробуту людини, що залежить від якості довкілля та може бути забезпечено за умови формування вуглицево-нейтральної економіки.

Результати аналізу з використанням інструментів бази даних Scopus® підтвердили гіпотезу про зростаючу тенденцію публікацій, що вивчають питання впливу енергетичного фактору на здоров'я людини. Так, з 2015 по 2021 рік кількість публікацій щорічно збільшувалася в 1,159 разів.

За допомогою VOSviewer (версія 1.6.18), було виокремлено шість кластерів: «поновлювальні види ресурсів», «сталий розвиток», «громадськість», «енергетична політика», «енергетична ефективність», «сонячна енергія». В кластері «поновлювальні енергетичні ресурси» зосереджені поняття з найпотужнішою силою зв'язку.

Ключові слова: відновна енергія, здорове навколишнє середовище, сталий розвиток, енергетична політика, захист навколишнього середовища.