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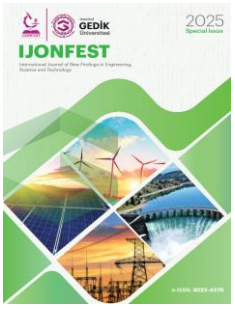

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The Role of Renewable Energy Resources Usage on Sustainability

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Abstract

Using renewable energy sources is researched from many perspectives and is very important for development and reducing environmental damage. Renewable energy is very important not only for protecting the environment and ensuring environmental sustainability, but also for ensuring social and economic development. It is seen that the use of renewable energy sources is of critical importance, especially in achieving the United Nations Development Goals. Renewable energy sources provide environmentally friendly and sustainable energy production that reduces dependency on fossil fuels with inexhaustible energy forms such as solar, wind, hydroelectric, biomass and geothermal energy. These sources provide a number of carbon-free and environmentally damaging solutions during energy production, making a significant contribution to reducing greenhouse gas emissions and effectively combating climate change. The use of renewable energy sources contributes not only to the environment, but also to economic and social development. The creation and increase of employment in the renewable energy sector, ensuring security of energy supply and demand, ensuring ease of access, and reducing costs in the long term support the development of societies. The transition to renewable energy requires not only an environmental or economic transformation, but also a social and cultural transformation. This process enables societies to structure their energy systems in a more equitable, efficient, accessible and reliable way. In this study, which aims to investigate the role of the use of renewable energy resources on sustainability, the content analysis method was used. A scan was conducted with the determined keywords. The data found was analysed with descriptive content analysis, and three themes were determined in the use of renewable energy resources: environmental, economic and social sustainability. As a result, it is seen that there is an increasing research and application on the use of renewable energy resources, and that the use of renewable energy resources has an important role in ensuring environmental, economic and social sustainability.

Keywords: Sustainability; Renewable energy; Global warming; Social sustainability.

1. INTRODUCTION

The increasing global population, industrialization, and rising living standards are driving a rapid rise in energy demand. For centuries, fossil fuels such as coal, oil, and natural gas have been used to meet this growing need. However, greenhouse gas emissions resulting from the combustion of fossil fuels cause serious environmental issues, including climate change, air pollution, and water scar. In recent years, researchers have shown significant interest in renewable energy, sustainable development, and environmental protection. Continuous changes in energy markets aimed at increasing green energy consumption have encouraged research and publication activities on a global scale [1]. Today, the prevailing view is that the development path pursued by human society, particularly since the Industrial Revolution, will likely result in disasters or highly troubling situations for future generations. Consequently, there is a recognized need for "sustainable development," which emphasizes the importance of renewable energy. The United Nations has officially highlighted the necessity of equitable and sustainable development. Following extensive discussions, member states proposed and adopted the Goals and Targets of the 2030 UN Agenda for Sustainable Development in 2015. This agenda includes 17 goals and 169 targets, with the 7th goal specifically focusing on Affordable and Clean Energy. It advocates for a transition to renewable energy, the elimination of fossil fuel-based energy, and increased efficiency in energy use [2]. In this context, the rapidly increasing global energy demand necessitates the development of innovative and environmentally friendly solutions for energy production to ensure a sustainable future. The limited reserves of fossil fuels, their susceptibility to price fluctuations, and their negative environmental impacts have driven the energy sector to explore alternative sources. Renewable energy sources stand out as they not only address environmental issues but also provide a sustainable alternative capable of meeting energy demands continuously. Solar energy generates electricity directly from sunlight, while wind energy converts natural air currents into electricity. Hydroelectric energy generates electricity using the movement of water, and biomass energy generates energy from organic waste and biological

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resources. Geothermal energy contributes to energy production by using heat from the Earth's crust. These resources are important not only for their environmental benefits, but also for their economic and social impacts. In laboratory research solar cell achieving 47.6% efficiency, but in real world condition efficiencies 39.5% [3,4]. Wind energy has also seen efficiency gains, with the Energy Return on Investment (EROI) for wind turbines averaging around 19.8, while specific models, such as the Vestas V150, report an EROI of 31 [5]. The growing adoption of renewable energy has also contributed to improved carbon efficiency, as evidenced by a study analyzing renewable energy consumption across 116 countries from 2005 to 2020 [6]. These developments underscore the continuous progress in renewable energy technologies, driving increased efficiency and sustainability.

This study will examine the importance of renewable energy resources, their contributions to environmental sustainability, and their impacts on sustainability. In addition, the environmental, economic, and social benefits of these resources are discussed. The purpose of the study is to discuss the role of renewable energy in terms of sustainability and to reveal the general trend of academic studies in the fields of renewable energy and sustainability. Renewable energy is an important study discipline in the academic field as well as in public and private sector institutions and is considered very important in terms of environmental sustainability and circular economy. In this sense, renewable energy sources are considered as one of the important tools of sustainability.

2. IMPORTANCE OF RENEWABLE ENERGY SOURCES

Energy is an important element in meeting people's basic needs and carrying out economic activities, as well as in the formation of countries' social and economic development levels [7]. The increasing population growth in the world greatly increases the need for energy for various reasons. Due to factors such as increasing demand, high external dependency on energy, the problem of supply security arising from political instabilities in places where strategic resources are located, and climate change causing negativities on a global scale, the idea that fossil fuel supply will not be sufficient in the future has increased the importance of energy.

Fossil resources used to meet the increasing energy demand cause the accumulation of CO_2 gas in the atmosphere and climate change. This situation leads to the melting of glaciers, the decrease of fertile soils, and the extinction of some living species. One of the most important conditions for preventing climate change is to focus on the use of renewable resources instead of the use of fossil resources. Our reliance on fossil fuels to meet our increasing energy needs is causing an alarming spike in emissions that are a major contributor to climate change [8]. This has the potential to result in the daily melting of glaciers, the depletion and development of fertile soils vital to agriculture, and the extinction of certain species [9]. The fact that these effects are linked highlights the urgency of addressing our reliance on fossil fuels.

Therefore, an important strategy to minimize the existence of climate temperatures, a change resistant: the growth of flexible and sustainable energy, the use of brightness instead of the continuous relationship with fossil fuels. This transformation is not only a scandal, but also a necessary and important step towards working within the guarantee of a sustainable life for both human societies and the natural world.

It is possible to classify energy resources as non-renewable and renewable. This classification is defined as energy resources that can remain unchanged in a normal cycle process, do not decrease despite being consumed, and are renewed; Energy sources that do not renew themselves when consumed, decrease and run out are defined as non-renewable energy sources. Non-renewable energy sources are divided into two as fossil and nuclear sources. Oil, coal and natural gas are fossil sources, nuclear energy is core sources and hydro, solar, wind, geothermal and biomass energies are renewable energy sources [10].

Producing energy using renewable energy sources is more costly than producing energy from fossil fuels. However, incentives are provided in various countries to reduce these costs. On the other hand, a decrease in these costs has been observed due to technological developments from the past to the present. In addition to the cost, there are also some economic and natural obstacles to countries with renewable energy sources meeting their energy needs. For example, there are limited wind-efficient regions in the world that can generate electricity with wind energy. Solar energy is not suitable for generating sufficient and efficient energy in every region. Again, due to the effect of global climate change, hydroelectric energy production can be done with less efficiency during dry periods. Increasing population and growth also mean more production and more energy need. Meeting this increasing energy demand from renewable energy sources instead of fossil fuels is an important step in leaving a livable world for future generations. On the other hand, increasing the share of renewable energy sources in energy production means an important step towards sustainable development. For this reason, turning to renewable energy sources and developing technologies to use these sources are considered as efforts that must be endured in order to ensure long-term development. [11] For these reasons, the place where renewable energy sources are used is of great importance in terms of energy production.

3. RENEWABLE ENERGY SOURCES

Solar energy is a significantly powerful energy that results from the fusion reaction that turns hydrogen gas in the sun's core into helium. Solar collectors, solar power plants, and solar cells have all been designed to take advantage of the energy provided by sun rays. These devices allow solar energy to be used directly as heat energy or indirectly as electrical energy [12]. Solar energy can be considered one of the most abundant energy sources. Solar energy spreads to the Earth's surface at a relatively

constant rate, 365 days a year, through radiation. The intensity of solar radiation is considered to be 1367 W/m^2 when penetrating the atmosphere, but it decreases to 1000 W/m^2 on the ground surface. The intensity of solar radiation reaching the Earth's surface varies with geographical location, weather conditions, environmental pollutants, and building density [13]. Solar energy, as a renewable energy source, attracts great attention because it is carbon dioxide neutral and can be used for both space and water heating [14].

Another energy widely used today is hydroelectric energy. The most common use of this energy is to build dams on rivers to accumulate water in reservoirs and to generate electrical energy in turbines by utilizing the potential energy of the accumulated water. Hydroelectric power plants (HES) are used for this purpose [12]. Hydroelectricity is a concept that corresponds to the process of generating electrical energy by utilizing the gravitational force of water at a certain level. Hydroelectric power plants, on the other hand, refer to facilities in the process of generating electrical energy. The basic working principle of hydroelectric power plants is that they generate electricity by rotating turbines by causing water to fall from a certain level. The main advantage of hydroelectric power plants is that no chemical waste is generated during the operating process and greenhouse gas emissions are at lower values compared to fossil fuel power plants [15].

Geothermal energy is the earth's natural heat, defined as the thermal energy contained in hot fluids (water vapor, gas) and hot dry rocks under pressure that have accumulated deep inside the earth's crust. The countries that benefit the most from geothermal energy in the world are the USA, the Philippines, Indonesia, Mexico, Italy and New Zealand, respectively, and it is seen that Turkey's geothermal energy installed capacity has increased rapidly in recent years [12]. Geothermal energy is a sustainable energy source that stands out due to its many advantages. First and foremost, being a renewable and inexhaustible resource, it plays an important role in environmentally friendly energy production. Compared to fossil fuels, its carbon emissions are quite low, making geothermal energy a strong option in the fight against climate change. Additionally, it has the capacity to provide uninterrupted energy regardless of weather conditions, such as sunlight or wind, which is a significant advantage for energy supply security. Since it relies on local resources, it reduces dependence on energy imports and supports economic development. Beyond electricity generation, its use in various areas, such as residential and greenhouse heating, thermal tourism, and industrial applications, makes it a versatile energy source.

Biomass energy is derived from plant and animal-based sources rich in carbohydrate molecules. Currently, biomass energy sources are used to produce fuels such as bioethanol, biodiesel, and biogas. Bioethanol and biodiesel are fuels made from various plant or animal lipids. The fermentation of organic substances (plant and animal waste, urban and industrial waste) in an oxygen-free environment produces biogas, which is mostly composed of methane and carbon dioxide [12].

Wind energy is a type of energy that occurs as a result of the sun's rays heating the earth's surface differently. Different heating on the surface of the earth causes air temperature, humidity and pressure factors to change, thus causing air movement, creating wind [16]. Wind energy is a completely natural source that does not cause pollution and is unlikely to run out. Wind energy is an important source that does not cause atmospheric heating, acid rain or CO2 emissions, and does not negatively affect natural vegetation or human life. It also saves fossil fuels, has no radioactive effects and has rapid technological development. This renewable energy source can be easily and quickly converted into electrical energy [17]. For example, it can be observed that energy demand has increased due to Turkey's increasing production and economic growth. When the increase in energy production over the years is examined in Graph 2, the share of renewable energy in total energy production followed a fluctuating course until 2014. However, renewable energy production started to increase from 2014 onwards and this increased production contributed to the total energy output. While the share of renewable energy reached 43.5% in 2019, hydroelectric and wind energy emerged as the largest renewable energy sources. The share of solar energy among renewable energy sources continues to increase steadily [18]. These results will ensure that the use of renewable energy becomes more important with each passing year.

4. METHODOLOGY

In this study, content analysis method was used to examine the effects of renewable energy sources on sustainability.

Content analysis, though often described as the systematic, objective, and quantitative study of message features, also acknowledges the crucial role of qualitative methods in understanding the intricate meanings embedded within communication. The line between these approaches is often less distinct than it appears, hinging on whether the phenomena under investigation are fundamentally numerical or interpretive, and whether the resulting data consists of quantifiable measurements or more nuanced, descriptive interpretations [19]. Content analysis is also expressed with three different methods as meta-analysis, meta-synthesis (thematic content analysis) and descriptive content analysis [20]. This study used a descriptive content analysis approach. We searched the Google Scholar database for academic resources published between 2012 and 2024, using keywords like "Renewable Energy," "Sustainability," "Global Warming," and "Social Sustainability." We focused on peer-reviewed journal articles and conference proceedings written in English. Because there's been a big increase in research on renewable energy since 2012, we felt this timeframe was appropriate for our analysis. Our content analysis was descriptive, meaning we looked for broad themes rather than getting into highly specific sub-topics. We identified three main themes related to sustainability: environmental, economic, and social. Our analysis of the publications from 2012 to 2024 showed that the research connected to our keywords generally fell within these three areas.

5. RESULTS AND DISCUSSIONS

The relationship between sustainability and renewable energy sources can be understood by recognizing the trend and its environmental reasons. Sustainable energy is abundant energy that we can use for a long time. On the other hand, sustainable energy helps us reduce greenhouse gas emissions and prevent environmental damage [21]. Therefore, since it is possible to access energy sources such as sunlight and wind most of the time, the movement towards sustainable energy should be continued and sustainable energy approaches should be encouraged [22]. Especially in the field of energy and sustainability, it shows the important role played by renewable energy in reducing CO_2 emissions and achieving sustainable development. In addition to their impact on affordable and clean energy production (SDG 7), renewable energy systems can also affect a number of other SDGs such as eradicating poverty in the social category (SDG 1), eliminating hunger (SDG 2), good health and well-being (SDG 3) and sustainable cities and communities (SDG 11) [23].

For gas, oil, and coal, the current climate impact is a greater concern than their ultimate depletion. There is no doubt that "global warming" exists. The ice cover in the Arctic has shrunk dramatically, and glaciers are retreating practically everywhere on the planet. While some early studies found ice increase, longer-term data reveal that overall Antarctic ice is also decreasing. Carbon dioxide levels in the atmosphere are also rising, with much of this due to human activity. A clear association between the carbon dioxide content in the atmosphere and global temperature has also been proven and recognized through observation [2]. Therefore, it is believed that using non-renewable energy is a major threat to both humanity and the environment. Consequently, the ecosystem's sustainability is at risk. Sustainability benefits from the growing usage of renewable energy sources, and social sustainability has also been observed to benefit from this trend.

Economic growth is defined as the increase in production capacity and the amount of goods and services produced in a country in a certain period of time. According to another definition, growth occurs with the increase in GDP per capita [24]. There is a theoretical mutual causality relationship between energy and economic growth. While the increasing national income as a result of growth increases consumption and investment expenditures, increases energy demand, energy encourages technical development and causes more production. In this context, renewable energy supports economic growth by contributing to the development of both capital-intensive and labour-intensive production technologies [25]. In Turkey, it is estimated that there will be a 1.8% increase in gross domestic product in the event of a 10% increase in the share of renewable energy use in total energy consumption in the long term [18]. It also reduces health costs. The reason for this is that the damage caused by non-renewable energy types to the environment and human health is minimized in renewable energy. The investment cost of renewable energy may be high at the beginning, but in the long term, the returns obtained from these sources can cover their costs. Energy independence, low operating costs and environmental gains show that such projects are an important economic driver for sustainable development. In order for countries to meet their energy demands without interruption, they need to use renewable energy sources. Sustainable development is meeting the needs of the current generation without eliminating the ability of future generations to meet their demands. In this context, the existence of renewable energy sources is important for sustainable development. Therefore, a two-way relationship can be mentioned between energy consumption and economic development. Energy consumption is high in an economically developed country. In this context, the existence of energy resources is important. On the other hand, a country with high energy consumption is developing economically. However, long-term development depends on the sustainability of energy resources. Therefore, countries need to use renewable energy sources to ensure sustainable economic development.

The social dimension of renewable energy use covers a wide area of impact, from social awareness to employment creation, from energy equality to health and quality of life. This transformation encourages individuals and communities to participate more actively in energy production and consumption while supporting economic development by creating employment opportunities at the local level. At the same time, it contributes to public health by reducing air and water pollution and provides a more equitable system by reducing energy inequalities. While local energy production ensures that communities are resilient to crises and natural disasters, initiatives such as energy cooperatives increase the participation of individuals in decision-making processes. Positive effects are also seen in cultural and psychological terms as the society adopts environmental responsibility and sustainability values. However, the success of these projects is directly related to social perception and acceptance; therefore, the needs and expectations of local communities should be taken into consideration.

New problems are being added to the increasing problems in the world we live in. One of the most important of these is the increasing energy consumption due to the increasing population. Despite the population growth, the capacities of existing energy production systems cannot meet the need. The need to meet this need offers people three options: increasing the capacity of their production systems, establishing nuclear power plants, and generating energy with renewable energy sources. When these options are compared, it is seen that utilizing renewable energy sources offers a longer-term future than other alternatives [26].

The study's examination of peer-reviewed journal articles and conference proceedings revealed that, between 2012 and 2024, publications were identified that addressed the three primary themes of social, economic, and environmental sustainability. In this sense, renewable energy sources are linked to environmental, economic, and social sustainability. These main themes are seen in Table 1.

Table 1. Main themes on the role of renewable energy sources use on sustainability.

Environmental Sustainability	Economic Sustainability	Social Sustainability
Environmental sustainability, which is determined as one of the main themes that renewable energy sources are most closely related to, has been associated with the United Nations Sustainability Goals in many studies. There are many studies that show that renewable energy sources, which play an important role in reducing greenhouse gases and environmental damage, make a significant contribution to environmental sustainability. It is also emphasized that it is a process that serves the SDG7- Affordable and Clean Energy goal.	There are studies indicating that renewable energy sources provide economic advantages in the long term despite their high initial costs and will increase GNP. There is a theoretical causal relationship between energy and economic growth. However, as a result of economic growth, the increase in production and consumption increases the need for investment, which in turn increases energy demand. It is also stated that energy studies contribute to increasing production by developing technology. This situation reveals that renewable energy sources have an important role in sustainable economic development. Again, it is evaluated in relation to SDG8- Decent Work and Economic Growth.	It is seen that renewable energy sources and production also affect social development, contribute to awareness, expansion of employment areas, equal energy and healthy life. At the same time, it contributes to public health by reducing air and water pollution and provides a more equitable systemby reducing energy inequalities. However, it is seen that the need for energy sources increases day by day due to the increase in the world's population. Renewable energy sources are an alternative to meet the needs of the increasing population, while also contributing to the balancing of social life and ensuring sustainability. It contributes to the goals of SDG1-No Poverty, SDG2-Zero Hunger, SDG3-Good Health and Well-being.

The findings emphasize the pivotal role of renewable energy sources in achieving sustainable development. By significantly reducing greenhouse gas emissions and minimizing environmental harm, renewables offer an effective solution to climate change and global warming. Furthermore, its implementation improves energy security, stimulates economic growth, and assures equal energy access, especially in rural areas. The move to renewable energy necessitates not just scientific advancements, but also a comprehensive approach that includes public awareness, cultural adaptability, and strong political commitment. Overall, renewable energy is a vital component of a sustainable future, preserving the environment and encouraging a healthier, more equitable world for future generations.

The results of the research conducted on the Google Scholar Database between 2012-2024 are given in Table 2, which was created according to the keywords specified below. As a result of the search conducted in the Google Scholar database with the above-mentioned keywords in the last 12 years, it is concluded that the most publications were made in the field of sustainability, second in social sustainability, third in renewable energy and finally in global warming. The result graph of the publications containing the keywords "Renewable Energy," "Sustainability," "Global Warming," and "Social Sustainability" made between 2012-2024 is given below in Figure 1.

Table 2. The results of the research.

Years	Renewable Energy	Sustainability	Global Warming	Social Sustainability
2012	286.000	1.240.000	139.000	442.000
2013	341.000	1.300.000	148.000	554.000
2014	411.000	1.280.000	145.000	555.000
2015	458.000	1.280.000	152.000	624.000
2016	495.000	1.240.000	157.000	644.000
2017	583.000	1.210.000	161.000	727.000
2018	655.000	1.200.000	171.000	826.000
2019	651.000	1.140.000	183.000	872.000
2020	729.000	1.060.000	185.000	898.000
2021	612.000	865.000	182.000	721.000
2022	510.000	675.000	156.000	520.000
2023	256.000	449.000	123.000	365.000
2024	171.000	243.000	75.600	191.000
Total	6.158.000	13.182.000	1.977.600	7.939.000

According to the graph above, it is seen that the sustainability keyword, which has the most publications, has a decreasing trend from 2012 to 2019, but has remained at the same rate in quantity, but has decreased dramatically since 2020. The publications made according to the Global Warming keyword, which has the fewest publications, have decreased dramatically in 2021. In the publications made according to the words Renewable Energy and Social Sustainability, there has been a steady increase between 2012 and 2020, but their numbers have decreased dramatically in 2020. In particular, the EU's initiation of the

Green Deal Process in 2020 and the inclusion of member and candidate countries in this process may cause the number of publications created with these keywords to shift to a different area. Especially after the Covid 19 Pandemic, the applicability of the issues included in the Green Deal Action Plan such as sustainability, renewable energy, carbon footprint reduction, circular economy, sustainable agriculture, sustainable financing within the framework of the law has come into question [27, 28].

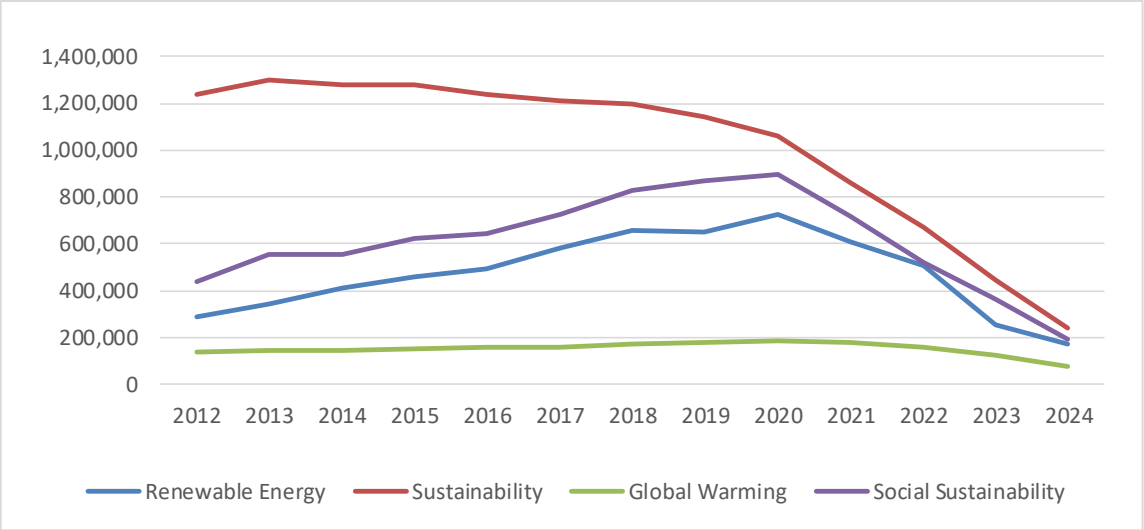

Figure 1. The result graph of the publications containing the keywords.

6. CONCLUSION

Renewable energy sources are essential for sustainable development, mitigating environmental damage, and fostering economic growth. The depletion of fossil fuels, coupled with rising energy demand and environmental concerns, necessitates a transition to renewable alternatives. Solar, wind, hydroelectric, biomass, and geothermal energy play a crucial role in reducing greenhouse gas emissions while enhancing energy security and promoting national and regional energy independence. By serving as viable alternatives to fossil fuels, these sources drive economic progress and ensure equitable energy access. Renewable energy projects, particularly in rural areas, contribute to social and economic development by creating jobs and improving local energy availability. This not only enhances the quality of life but also provides communities with reliable and sustainable energy solutions. However, transitioning to renewable energy extends beyond technological advancements; it requires public awareness, social acceptance, and strong political commitment. The widespread adoption of renewable energy is vital for environmental sustainability and ecosystem preservation. Unlike fossil fuels, renewables significantly reduce carbon footprints and conserve natural resources, fostering a healthier planet for future generations. According to the results of the content analysis conducted in this study, it is concluded that renewable energy resources have an important role in sustainability. The results obtained in this context can be listed as follows:

- It was concluded that the most academic work in the last 12 years was in the field of sustainability,
- The least number of publications in the last 12 years was on global warming,
- Studies in the fields of renewable energy and social sustainability continued to increase until 2020,
- There was a dramatic decrease in all publications in the fields of "Renewable Energy," "Sustainability," "Global Warming," and "Social Sustainability" since 2020.

However, within the scope of the key words examined, the publications can be associated with the EU Green Deal process requiring implementation rather than academic studies after 2020. In addition, the following issues are noteworthy in this study:

- Renewable energy reduces greenhouse gas emissions and enhances energy security.
- Solar, wind, hydro, biomass, and geothermal energy provide sustainable alternatives to fossil fuels.
- Renewable energy projects stimulate job creation and improve local energy access, especially in rural areas.
- Successful energy transition requires public awareness, cultural acceptance, and strong political commitment.
- Widespread adoption of renewable energy promotes environmental sustainability and resource conservation.
- Transitioning to renewables is essential for long-term economic and ecological stability.

In conclusion, renewable energy offers the most effective and environmentally responsible path toward sustainable development, climate change mitigation, and energy security. Embracing these sources is a crucial step in the global energy transition and a fundamental component of a long-term, eco-conscious development strategy.

Authors' Contributions

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1- Study design 2- Data collection 3- Data analysis and interpretation 4- Manuscript writing			

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