

## EFFICIENCY OF RENEWABLE ENERGY SOURCES IN THE CONTEXT OF THE GREEN ECONOMY

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### Abstract

This article examines the importance of using renewable energy, its theoretical foundations, and the practices of developed countries that have adopted it. It reviews their levels of renewable energy use, a statistical analysis of the share of green energy in total energy, effectively addressing environmental problems through the use of renewable energy, and our country's “Green Economy” in the face of current ecological threats. “Renewable Energy” directions, and initiatives being undertaken in this field, and proposals and reflections that could contribute to the further consistent development of this sector were also presented.

According to data from the International Energy Agency, renewable energy accounted for approximately 30% of global electricity generation in 2023, demonstrating a steady increase over the past decade. Furthermore, reports by the International Renewable Energy Agency indicate that renewable energy capacity worldwide reached over 3,700 GW, with solar and wind energy contributing the largest shares.

The article also analyzes the experiences of developed countries such as Germany, Denmark, and China, which have successfully implemented renewable energy strategies. For instance, Denmark generates more than 50% of its electricity from wind energy, while Germany's “Energiewende” policy has significantly increased the share of renewables in its energy mix to over 45%. China, as the world's largest renewable energy investor, leads in solar panel production and installation capacity.

A statistical analysis of renewable energy's share in total energy consumption reveals its crucial role in reducing dependence on fossil fuels, improving air quality, and enhancing energy security. The use of renewable energy sources has been shown to reduce carbon dioxide emissions significantly, contributing to global efforts aligned with the Paris Agreement targets.

Special attention is given to the environmental and economic benefits of renewable energy in addressing ecological issues such as air pollution, climate change, and natural resource depletion. The study also examines the development of the “Green Economy” in Uzbekistan, highlighting national strategies, including the expansion of solar and wind power plants, and government initiatives aimed at increasing the share of renewable energy to 25% by 2030.

In addition, the article discusses current reforms, investment projects, and international cooperation efforts in the renewable energy sector. It outlines practical recommendations for accelerating the transition to clean energy, such as improving regulatory frameworks, increasing private sector participation, enhancing technological innovation, and raising public awareness.

The findings suggest that consistent and strategic development of renewable energy is essential for achieving long-term environmental sustainability, economic growth, and energy independence. The article concludes with proposals aimed at strengthening policy implementation and ensuring the effective integration of renewable energy into national energy systems.

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## Introduction

In the 21st century, global climate change, the increase in the volume of harmful gases being released into the atmosphere, the limited availability of traditional fuel resources and their volatile prices are forcing countries around the world to accelerate the transition to a new economic model – the green economy. The green economy, based on the principles of sustainable development, entails the wise use of natural resources, ensuring environmental safety, and achieving social well-being alongside economic growth. In this context, renewable energy sources are becoming one of the key drivers of economic development. Globally, renewable energy sources accounted for approximately 32% of global electricity generation in 2024 [1], over 578–585 GW of renewable energy capacity was added, accounting for more than 90% of the global capacity expansion[2]. By 2030, approximately 46% of global electricity generation is expected to come from renewable sources[13]. Renewable energy resources – such as solar, wind, geothermal, bioenergy, and hydropower – help to produce clean energy, reduce the carbon footprint, ensure energy independence, helping to create new jobs and implement innovative technologies in the energy sector. The rapid development of this sector is particularly important for countries rich in natural and climatic resources, such as Uzbekistan. The high potential of solar radiation, strong wind currents, and the availability of opportunities for energy generation from waste create broad opportunities to increase the efficiency of renewable energy sources. In 2025, the share of Uzbekistan's renewable energy sources (solar + wind + hydro) in total electricity generation was approximately 30%, Solar and wind power plants with a total capacity of 5,000 MW and hydroelectric power plants with a capacity of 400 MW were commissioned[4].

The relevance of the topic is that transforming the energy system in line with modern requirements not only boosts production efficiency but also promotes the economical use of resources in the national economy and strengthens energy security. World experience shows that increasing the share of green energy raises economic competitiveness, expands export opportunities, and positively impacts socio-economic stability[5]. From this perspective, studying the economic efficiency of renewable energy sources and developing mechanisms for their application to the national energy system and economic sectors is one of today's most pressing scientific challenges.

An important aspect of this research is the revision of existing energy policy during the transition to a green economy, it is necessary to assess the techno-economic advantages of alternative energy sources, improve investment mechanisms, and determine the economic efficiency resulting from an increased share of renewable energy[6].

Based on this, scientific research on this topic is required to increase the level of utilization of renewable energy resources, to develop practical recommendations aimed at increasing the use of renewable energy resources, developing a green energy infrastructure, and ensuring sustainable economic growth.

## Materials and Methods

In preparing this article, research materials, the results of scientific works by national and foreign researchers, as well as materials from Ministries, the National Statistics Committee, and international

information sources were used. The primary materials were collected based on statistical data and analyzed using existing software. The scientific conclusions drawn are based on the results of scientific research. This study is based on a comprehensive analysis of both primary and secondary data sources related to the development and implementation of renewable energy. The research materials include the results of scientific studies conducted by national and international scholars, as well as official data obtained from governmental institutions, including relevant ministries, the National Statistics Committee, and global databases such as the International Energy Agency and the International Renewable Energy Agency.

The primary data were compiled from statistical reports covering energy production, consumption, and the share of renewable energy sources in the total energy balance. These data sets include time-series indicators, allowing for the identification of trends and patterns in the development of renewable energy both globally and within Uzbekistan.

A combination of qualitative and quantitative research methods was employed in this study. The quantitative analysis involved statistical methods such as comparative analysis, dynamic (time-series) analysis, and proportional analysis to assess the growth rates and structural changes in energy consumption. In addition, graphical and tabular methods were used to visualize the data and facilitate interpretation.

For data processing and analysis, modern analytical tools and software packages (including spreadsheet-based and statistical analysis programs) were utilized to ensure accuracy and reliability. The qualitative approach included a review and synthesis of theoretical frameworks, policy documents, and best practices from leading countries in renewable energy adoption.

Furthermore, a comparative method was applied to examine the experiences of developed countries and to identify effective strategies that could be adapted to national conditions. Logical analysis and scientific abstraction were used to formulate conclusions and recommendations.

## Results and Analysis

It is no secret that, as of today, climate change and environmental problems are negatively affecting not just a single country or region but the entire planet[7]. The large-scale release of carbon dioxide into the atmosphere has led to the depletion of the ozone layer, which in turn is causing heat waves, droughts, and various diseases. It is a well-known fact that 60-61 percent of the carbon dioxide released into the atmosphere comes from energy production and transportation. We can also observe that this indicator has been growing steadily year over year (Figure 1).

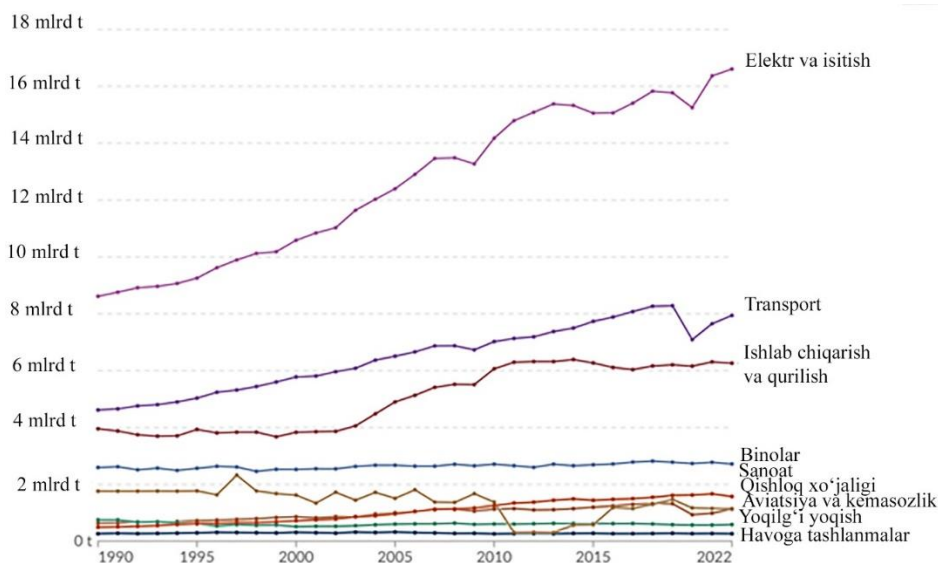


Figure 1. Distribution of carbon dioxide (CO<sub>2</sub>) emissions by source.

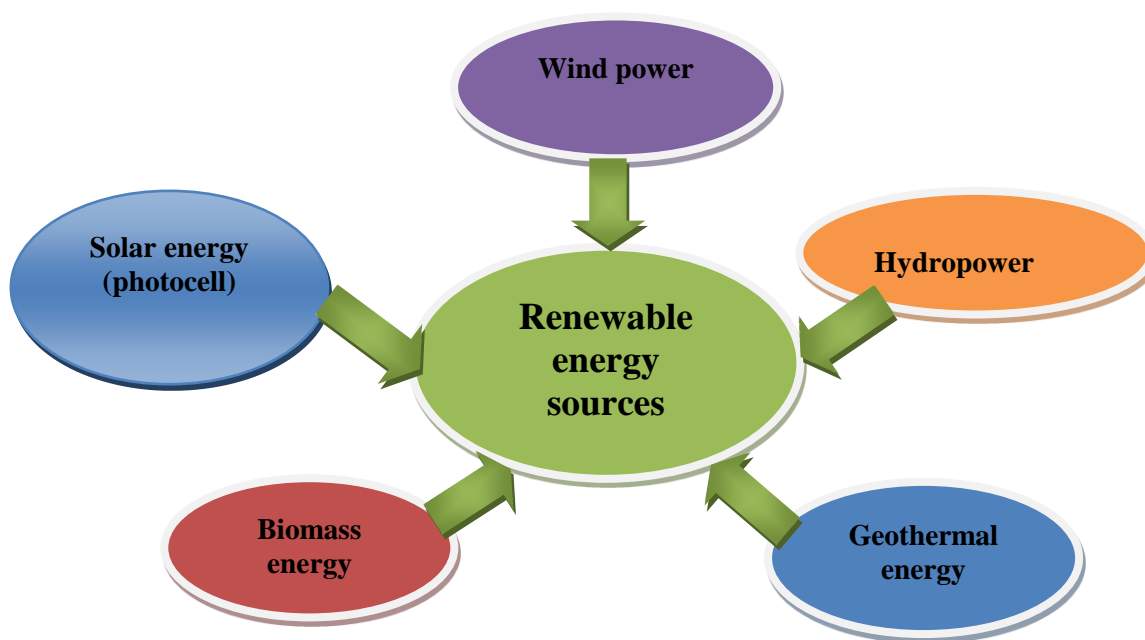
Moreover, drilling for oil and gas to produce energy and fuel for transportation, and opening coal mines, not only harms the atmosphere but also has a negative impact on the Earth[8]. As a result of this process, the Earth's natural layers are disrupted, voids form in geological structures, and sometimes land subsidence occurs. Open-pit coal mining strips large areas of their vegetation, resulting in erosion and desertification[9].

In oil and gas extraction, petroleum products, drilling fluids, and waste seep into the soil and groundwater, chemically contaminating them. This, in turn, has a long-term negative impact on soil fertility.

To address the problems mentioned above, “renewable energy” can be presented as a practical and effective solution[10].

Renewable energy is a collection of energy sources that are continuously generated through natural processes, are not depleted by human activity, and cause minimal harm to the environment.

The main types of renewable energy have been systematized (Figure 2).



**Figure 2. Renewable energy sources**

Solar energy (photocell) is the production of heat or electricity using sunlight.

Wind energy is the production of electricity using wind generators.

Hydropower is the production of energy through the movement of rivers or water currents[11].

Biomass energy is energy obtained from the combustion or decomposition of plant residues, wood, and organic waste.

Geothermal energy is the production of energy using heat sources within the Earth's crust.

Similar to the above, the use of renewable energy sources is incomparable in its contribution to conveying nature to future generations in its original form, which is also confirmed in the theories of scientists[12].

In 1989, British economists David Pearce, Anil Markandya, and Edward Barbier developed the Blueprint for a Green Economy. Its main ideas are that economic growth should be in harmony with nature, rather than at the expense of environmental growth, and that renewable energy sources are the most important element of a green economy. This approach was subsequently adopted by the United Nations Environment Programme (UNEP) as an official concept in 2008[13].

The United Nations, specifically in the report "Our Common Future," led by Gro Harlem Brundtland, states that Sustainable Development is

"a model of development that meets the needs of the current generation without limiting the opportunities of future generations" [14]. Renewable energy is a practical embodiment of this theory, combining economic growth and ecological balance. The most famous works on the effect of renewable energy and their authors are given (Table 1).

**Table 1. Content of works supporting renewable energy efficiency**

<b>№</b>	<b>Muallif</b>	<b>Asar nomi</b>	<b>Asarning o'zbekcha mazmuni va asosiy g'oyasi</b>
1.	Amory B. Lovins	Reinventing Fire	This work shows how to restructure the energy system of the future, move away from fossil fuels, and create a fully renewable energy economy by 2050. The author justifies the possibility of achieving economic success through technology, market, and energy efficiency.
2.	Ron Pernick & Clint Wilder	Clean Tech Nation: How the U.S. Can Lead in the New Global Economy	The work analyzes opportunities for renewable sources, energy efficiency, job creation, and economic growth to enhance the green economic competitiveness of the United States. The authors emphasize that "clean technologies" will become a new economic wave.
3.	Tom Rand	Kick the Fossil Fuel Habit	The author justifies the need to abandon fossil fuels for energy security and environmental sustainability. The work highlights the prospects of alternative sources such as wind, solar, biomass, and geothermal energy.
4.	Jeremy Rifkin	The Third Industrial Revolution	Rifkin points to the combination of digital technologies and renewable energy as the foundation of the third industrial revolution. Ideas will be put forward to reduce centralization in energy production and consumption, as well as the introduction of smart energy systems.
5.	Cédric Philibert (IEA)	Solar Energy Perspectives	This work, prepared by the International Energy Agency, provides a scientific analysis of the global potential, economic efficiency, price dynamics, and technological developments of solar energy. Solar energy will prove to be the leading source in the future.
6.	Hermann Scheer	Energy Autonomy: The Economic, Social and Technological Case for Renewable Energy	The work analyzes the impact of renewable energy on economic independence, social stability, and environmental security. The author scientifically proves that energy independence is the main pillar of national development.
7.	Godfrey Boyle	Renewable Energy: Power for a Sustainable Future	This work contains scientific and technological information on all renewable sources, such as wind, solar, hydro, and bioenergy. Methods for increasing energy efficiency, environmental impact, and economic benefits are highlighted.

8.	David J. C. MacKay	Sustainable Energy – Without the Hot Air	This work contains scientific and technological information on all renewable sources, such as wind, solar, hydro, and bioenergy. Methods for increasing energy efficiency, environmental impact, and economic benefits are highlighted.
9.	Alma Cota, Majid Ghassemi & Robert Foster	Solar Energy: Renewable Energy and the Environment	The work scientifically examines the physical foundations, ecological advantages, environmental impact, and economic profitability of solar energy. A systematic analysis will be conducted to improve energy quality through the use of high technologies.
10.	Ali Keyhani	Design of Smart Power Grid Renewable Energy Systems	The work examines the mechanisms for integrating renewable energy into the power grid through smart grids. The efficiency and technological advantages of digital networks powered by green energy are demonstrated.

Practical work in the field of renewable energy sources is also significant.

Over the last decade, many developed nations have elevated renewable energy policies to the level of a national strategy to ensure energy security and combat climate change. In particular, the European Union, the USA, China, and Japan hold leading positions in this field.

The European Union aims to achieve carbon neutrality by 2050 through the Green Deal program.[15] In countries such as Germany, Denmark, and the Netherlands, renewable energy generation accounts for 50-70% of the total electricity balance.

For example, Germany has been implementing the "Energieunde" ("Energy Shift") policy since 2000, gradually replacing coal and nuclear energy.

by reducing and expanding solar and wind sources[16]. As a result, energy exports have increased. In 2023, the country received 54% of its electricity from renewable sources.

The development of green energy in the USA is based on market mechanisms. Companies such as Tesla, Next Era Energy, and General Electric hold leading positions in the development of energy technologies. In 2022, 21% of electricity generated in the U.S. came from renewable sources. This figure is planned to be increased to 44% by 2050[17].

The U.S. government allocated \$370 billion in subsidies to promote green technologies under the Inflation Reduction Act (2022), making it the largest environmental investment in history[18].

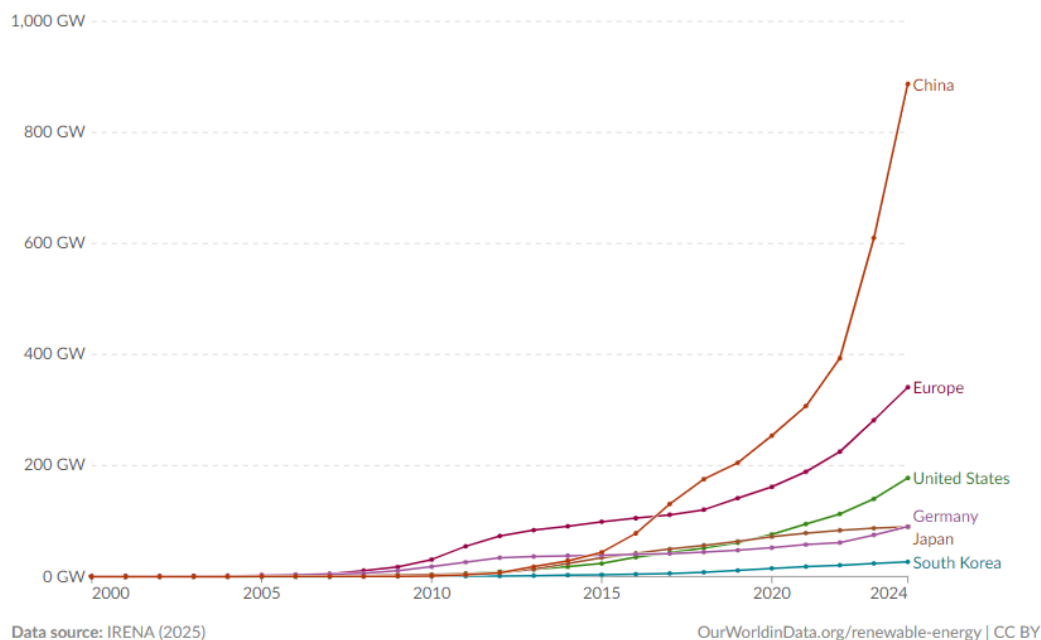
China is the world's largest producer of renewable energy and ranks first in terms of wind and solar power capacity. As of 2024, more than 1,200 gigawatts of renewable capacity have been installed in the country—equivalent to all European energy production. However, due to very high energy consumption in China, the share of coal is still high (about 60%) [19]. Nevertheless, the government aims to "achieve a carbon emission peak" by 2030 and become "carbon neutral" by 2060.

Japan has dramatically increased investment in solar and geothermal energy in an effort to reduce dependence on nuclear energy following the 2011 Fukushima nuclear disaster. In 2024, 28% of the country's electricity generation came from renewable sources.

South Korea has allocated \$56.5 billion through the Green New Deal program, of which about \$42 billion is planned to be spent on investment and the creation of new jobs in the green economy. From the figure below, we can also observe the relative amount of renewable energy capacity in the aforementioned countries by year (Figure 3).

## Installed solar energy capacity

Cumulative installed solar capacity, measured in gigawatts (GW).

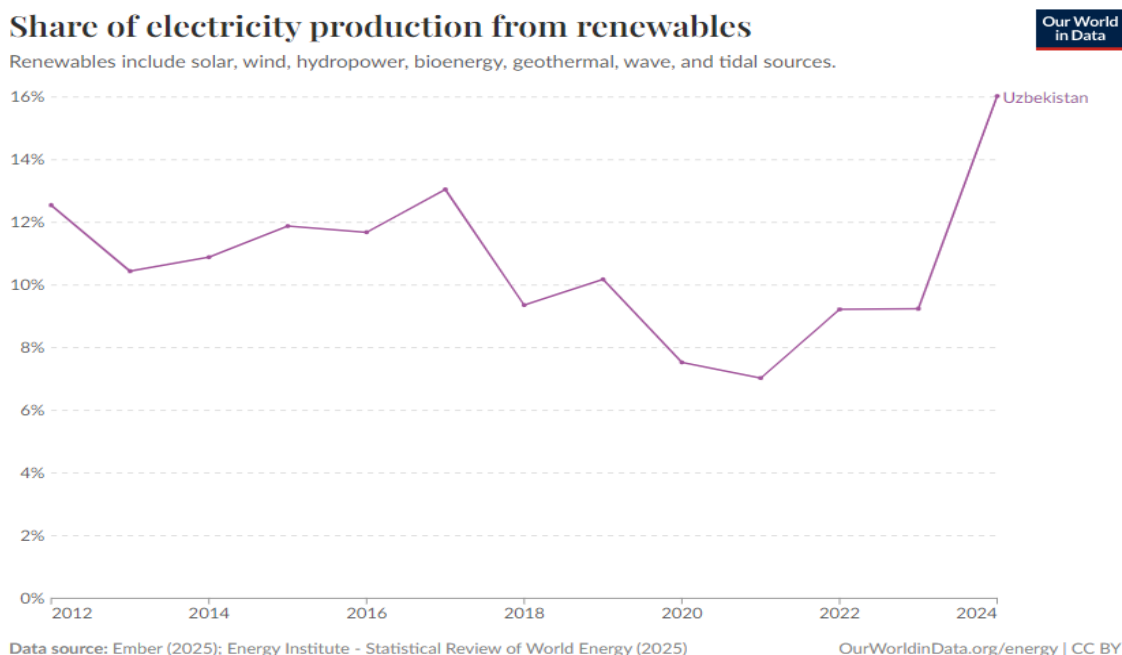


**Figure 3. Change in renewable energy capacity (MW/GW) by country**

Large-scale reforms are being implemented in our country to eliminate environmental problems by increasing the share of renewable energy sources. In particular, on May 21, 2019, the Oliy Majlis adopted the Law "On the Use of Renewable Energy Sources." This law defined the renewable energy sector as an independent sphere. Subsequently, on October 4-5 of the same year, President Shavkat Mirziyoyev adopted the "Strategy for the Transition to a Green Economy for 2019-2030"[20]. The purpose of the resolution was to:

- transition of the national economy to the path of "green" development;
- Improving energy efficiency, reducing energy intensity, and expanding renewable sources;
- reducing carbon intensity, economically and sustainably managing natural resources;
- creation of green investments, "green" financial mechanisms and a state institutional system.

During the years specified in the strategy, indicators such as doubling energy efficiency, significantly reducing gross carbon intensity, and increasing the share of renewable energy sources were also identified. In 2021, the share of renewable energy was 7.1%, and by 2025, this amount will reach 23% [21] (Figure 4).



**Figure 4. Share of renewable energy in our country (%)**

Of course, such high growth in such a short period is the result of the laws mentioned above. However, it should be noted that these figures still indicate a high share of electricity generated in our country through the emission of carbon dioxide into the atmosphere. Therefore, given that about 3/4 of our country's year is sunny, it is advisable to pay more attention to solar energy compared to other types of energy. There are also some shortcomings in the storage of electricity from renewable energy sources. In particular, despite the presence of production capacities, there is a shortage of raw materials for lithium-ion systems, modern batteries, and limited technological experience. Another aspect of the issue is that the state remains the leader in the production of renewable energy, and the share of the private sector is low.

In order to eliminate this issue, it is advisable to apply the following processes in practice:

- exemption from income tax for 5-10 years for investors building renewable energy plants;
- introduction of a zero customs rate for renewable energy technologies, since currently at least 85% of these technologies are imported;
- provision of special low-interest "green" loans by state banks;
- development of local production: solar panels, inverters, batteries, as well as increasing the potential of personnel in this field.

It can be said that the use of the presented methods to overcome the mentioned problems will not only improve the scale of renewable energy production and the environmental level but also prevent the industry from becoming a monopoly.

**Conclusion.** In order to eliminate this issue, it is advisable to apply the following processes in practice:

Exemption from income tax for 5-10 years for investors building renewable energy plants.

Introduce a zero customs rate for renewable energy technologies, as no less than 85% of these technologies are currently imported.

Provision of special low-interest "green" loans by state banks.

Development of local production: solar panels, inverters, batteries, as well as increasing the potential of personnel in this field.

It can be said that the use of the presented methods to overcome the mentioned problems will not only improve the scale of renewable energy production and the environmental level but also prevent the industry from becoming a monopoly.

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