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HYDROGEN ENERGY IN THE GLOBAL ENERGY BALANCE POLICY: INCENTIVES FOR ECONOMIC DEVELOPMENT

ВОДНЕВА ЕНЕРГЕТИКА У СВІТОВІЙ ПОЛІТИЦІ ЕНЕРГЕТИЧНОГО БАЛАНСУ: СТИМУЛИ ДЛЯ ЕКОНОМІЧНОГО РОЗВИТКУ

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The article examines the global policy of ensuring energy balance, identifies key trends in global primary energy consumption, focusing on the growing role of renewable sources and hydrogen energy. The dynamics of fossil fuel use is presented and its impact on the economic development of countries is assessed, especially in the context of the contrast between different regions of the world. Particular attention is paid to the prospects for the development of hydrogen energy as a key area in the field of sustainable energy supply. The economic advantages of hydrogen, its role in reducing dependence on traditional energy sources and reducing greenhouse gas emissions are considered. The article forecasts the volume of hydrogen consumption in the world until 2026. The author emphasizes that hydrogen energy is a strategic direction of development of the world energy sector, which contributes to energy security, environmental sustainability and economic growth of countries.

Keywords: *energy balance, hydrogen energy, world politics, economic development, energy sources.*

У статті досліджено світову політику забезпечення енергетичного балансу, яка передбачає узгоджену та прозору систему обліку виробництва, транспортування, зберігання та використання енергоресурсів. Визначено ключові тенденції глобального споживання первинної енергії, акцентуючи увагу на зростанні ролі відновлюваних джерел та водневої енергетики. Представлено динаміку використання викопного палива та оцінено його вплив на економічний розвиток країн, особливо в контексті контрасту між різними регіонами світу. Встановлено, що розвиток відновлюваної енергетики є нерівномірним, із домінуючою роллю Азійсько-Тихоокеанського регіону у впровадженні нових технологій. Окрему увагу приділено перспективам розвитку водневої енергетики як ключового напряму у сфері сталого енергетичного забезпечення. Розглянуто економічні переваги водню, його роль у зменшенні залежності від традиційних джерел енергії та скороченні викидів парникових газів. Визначено основні виклики, пов'язані з виробництвом, транспортуванням і зберіганням водню, а також можливі шляхи їх подолання. Розглянуто технологічні досягнення у сфері водневої енергетики, зокрема розвиток методів виробництва водню, використання електролізу та уловлювання вуглецю. Проаналізовано можливості зниження собівартості виробництва водню, його зберігання та транспортування. Окреслено перспективи інтеграції водню в глобальну енергетичну систему, включаючи його застосування у транспортній, промисловій та енергетичній сферах. Здійснено прогноз обсягу споживання водню у світі до 2026 р. Акцентовано увагу на тому, що воднева енергетика є стратегічним напрямом розвитку світової енергетики, який сприяє енергетичній безпеці, екологічній сталості та економічному зростанню країн. Водночас її масштабне впровадження потребує значних інвестицій, міжнародного співробітництва та технологічних інновацій. Крім того, підкреслено важливість державної підтримки та створення відповідної нормативно-правової бази для стимулювання розвитку водневих технологій та їхньої інтеграції в існуючі енергетичні системи.

Ключові слова: *енергетичний баланс, воднева енергетика, світова політика, економічний розвиток, джерела енергії.*

Statement of the problem. The global energy balance policy is a set of international strategies, measures and agreements aimed at ensuring stable and sustainable energy supply worldwide, as well as reducing the negative impact of the energy sector on the environment. It includes various aspects, such as energy security, energy efficiency, development of renewable energy sources, reduction of greenhouse gas emissions, and cooperation between countries in the energy sector.

The global policy of maintaining the energy balance is an important element in achieving sustainable development, reducing energy risks and mitigating the effects of climate change. It requires coordination of efforts at the international, national and regional levels, as well as active participation of governments, businesses and civil society.

Global energy policy also has a significant impact on the global economy, as it defines strategies for the transition to sustainable energy sources, regulates energy prices, and promotes technological innovation. Efforts to decarbonize, deploy renewable energy sources, and improve energy efficiency stimulate investment in green technologies, create new jobs, and increase energy security. At the same time, fluctuations in the fossil fuel market, geopolitical conflicts, and regulatory restrictions can cause instability in global trade, inflationary pressures, and a redistribution of economic influence between energy exporting and importing countries.

Technological innovations are now forming a key element of the global energy balance policy – hydrogen energy, which contributes to energy security and economic development. Many countries consider hydrogen as a strategic fuel for industry, transportation and the energy sector, reducing dependence on fossil resources. However, the successful integration of hydrogen into the global economy depends on infrastructure development, international regulation, and lower production costs, making hydrogen energy particularly relevant for future sustainable development.

Analysis of recent research and publications. The study of the energy balance and renewable energy sources was carried out by such scientists as O. Akimenko, I. Kostiuchenko, D. Semenova, V. Syniehubov, E. Fryer, I. Lishchynskyi, M. Lizun, I. Prykhodko, V. Ihnatyshyn, M. Roser [3], C. Rigollet, A. Prinzhofer [5], D. Bobro [7], and others. Problematic issues and prospects for the development of hydrogen energy are constantly studied by think tanks and scientific institutions such as the National Institute for Strategic Studies, Razumkov Center, Institute for Renewable Energy of the National Academy of Sciences of Ukraine, etc. At the international level, the International Energy Agency [6; 8], the International Renewable Energy Agency, the Energy Research Analysis Group, the European Environment Agency, the Energy Institute [1; 4], and others collect statistical data in the energy sector, analyze and forecast its development trends.

Given the dynamic development of the energy sector and the active implementation of innovative projects in it, there is a need to constantly monitor the specifics of energy consumption by regions of the world, identify current trends in the use of renewable energy sources, their role in global energy balance policy and incentives for economic development.

Setting the task. The purpose of the article is to determine the peculiarities of energy consumption, the role of hydrogen energy in the global energy balance policy, and its potential for economic development of countries.

Summary of the main results of the study. The global policy of ensuring energy balance should be aimed at a mutually agreed and transparent system of accounting for the production (extraction), receipt, transportation, storage, distribution and consumption (use) of energy resources to meet the needs of economies in fuel and energy resources.

Analyzing the current consumption of resources for electricity generation is a key task in the context of shaping the global policy of maintaining the energy balance. An important aspect is the comparison of traditional energy sources, such as coal, gas, and nuclear power, with renewable alternatives, including solar, wind, and hydrogen energy. Awareness of current trends and efficiency of resource consumption allows us to identify incentives for further sustainable economic development.

Global primary energy consumption reached a new record for the second year in a row, with non-OECD countries dominating both the share and annual growth rates. Fossil fuels continue to support their development, accounting for 82% of global energy production in 2024 [1].

The contrast between the northern and southern hemispheres is quite stark. Primary energy consumption in the Global South exceeded that of the Global North for the first time in 2014. In 2023, it accounted for 56% of total energy consumption and grew twice as fast as the global average rate of 2%. The Asia-Pacific region was responsible for 85% of the Global South's demand (and 47% of global demand), dominated by the economies of China, India, Indonesia, Japan, and South Korea. Although growth rates in South and Central America and Asia Pacific were above the global average, total demand in Africa fell by 0.4% in 2023, and electricity consumption remained unchanged. Electricity demand in North America and Europe fell by 1% and 2%, respectively. In these regions, demand for electricity is increasingly influenced by energy efficiency regulations, energy-saving lighting, and changing consumer habits (Fig. 1) [2].

In 2023, global electricity production increased by 2.5% to reach a record level of 29,925 TWh. This trend shows that the global energy system is becoming increasingly electrified [2].

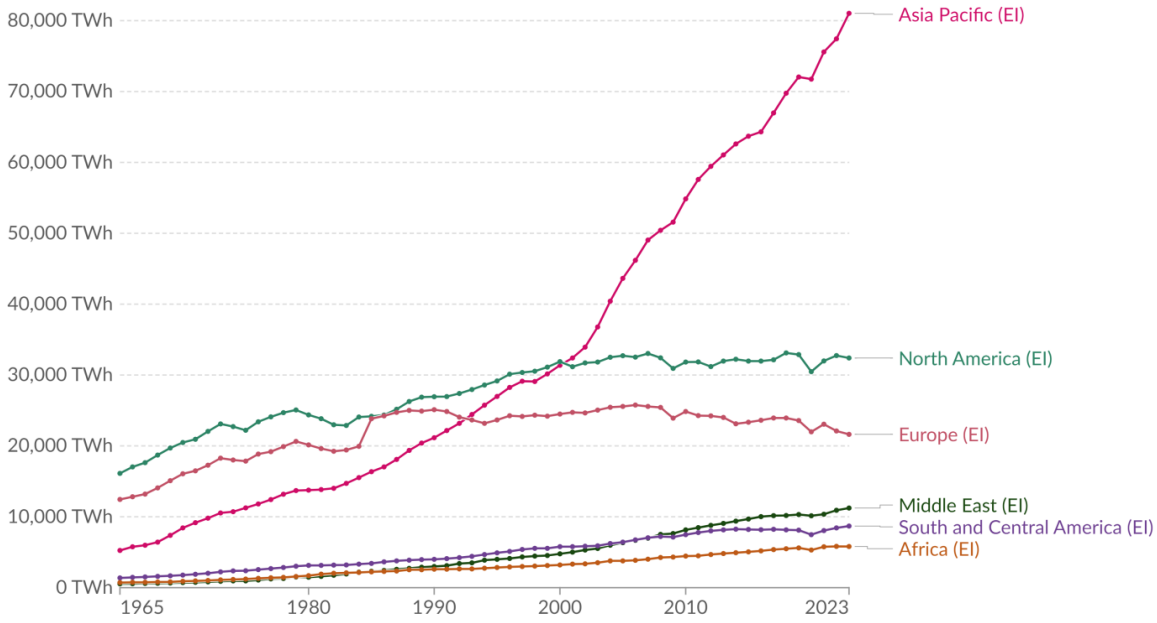

Figure 1. Primary energy consumption by world region

Source: [2]

Coal has retained its position as the dominant fuel for electricity generation, with fossil fuels accounting for 60% of global electricity generation overall (Fig. 2). The share of renewable energy in total electricity generation increased from 29% to 30% [3].

Regionally, South and Central America recorded the highest contribution of renewables at 72%. The share of nuclear power plants remained unchanged at around 9% due to new construction in China and the return to service of plants in France and Japan, offset by the closure of the remaining plants in Germany. In 2023, the capacity of the battery electric storage system (BESS) amounted to 56 GW, almost 50% of which was installed in China [4].

Electricity production from renewable sources, excluding hydropower, increased by 13% to a record level of 4748 TWh. This growth was almost entirely driven by wind and solar, accounting for 74% of all net additional electricity generated. As a share of primary energy consumption, renewables (excluding hydropower) accounted for 8%, or 15% including hydropower. China added 55% of all renewable energy generation in 2023, more than the rest of the world combined [4].

Scientific and technological progress (STP) has a significant impact on the global energy balance,

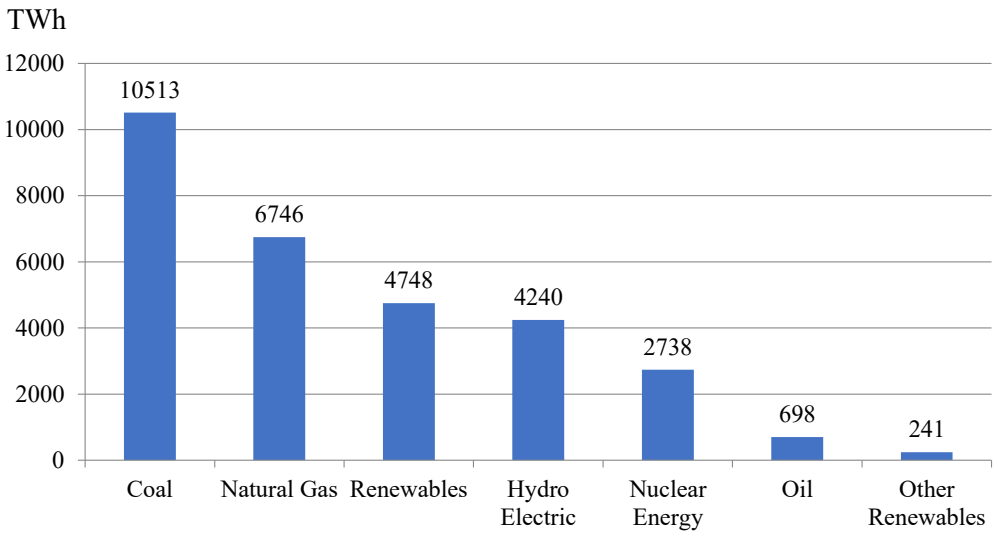

Figure 2. Types of resources for global electricity production in 2023

Source: compiled by the author according to [4]

changing the structure and sources of energy, increasing energy efficiency, and developing new energy technologies. Hydrogen technologies are one of the areas of STP in the energy sector.

Hydrogen is the most common element in nature, odorless and non-toxic. However, it is not found in its elemental form on Earth and is generated from other hydrogen-containing sources. Approximately 96% of all hydrogen produced in the world is produced using fossil fuels, with natural gas being the most common raw material [5].

The production of hydrogen requires electricity regardless of the method, so the price of hydrogen produced increases with the price of electricity.

The dynamics of hydrogen use by region according to the International Energy Agency is shown in Fig. 3.

Based on the data of the International Energy Agency, we will forecast the level of global hydrogen consumption by 2026 (Fig. 4). According to the forecast, the polynomial function characterizes the regression with an approximation reliability index of 0.95, which indicates a high level of reliability of the forecast. According to Fig. 4, the volume of hydrogen consumption in the world in 2026, according to current trends, will reach 70 Mt, which is a significant increase.

Natural hydrogen (sometimes also called "white", "golden" or "naturally occurring") is a resource that is constantly renewed. Its exploitation requires little energy, fresh water and does not emit CO_2. The cost of production is estimated at less than USD 1/kg. USD/kg and decreases in the business model of co-production (geothermal energy, helium, valuable salt solutions) [6].

Thus, natural hydrogen could be an ideal complement to electrolysis-derived hydrogen in the future for carbon-free energy. Its lower cost compared to other renewable and carbon-free energy sources makes it more competitive. However, methods for its large-scale exploration and production do not yet exist.

The cost of hydrogen produced as a result of thermochemical/biochemical treatment of biomass or pyrolysis/anaerobic digestion of municipal waste using CO_2 capture and storage technology varies from 1.31 to 2.06 USD/kg. USD/kg. Hydrogen produced from electricity with zero CO_2 emissions,

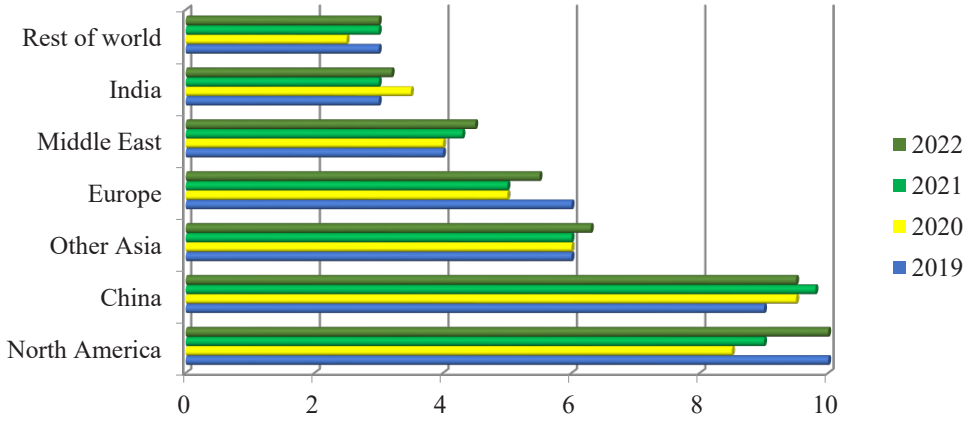

Figure 3. Hydrogen use in the regions of the world in 2019–2022

Source: compiled by the author according to [6]

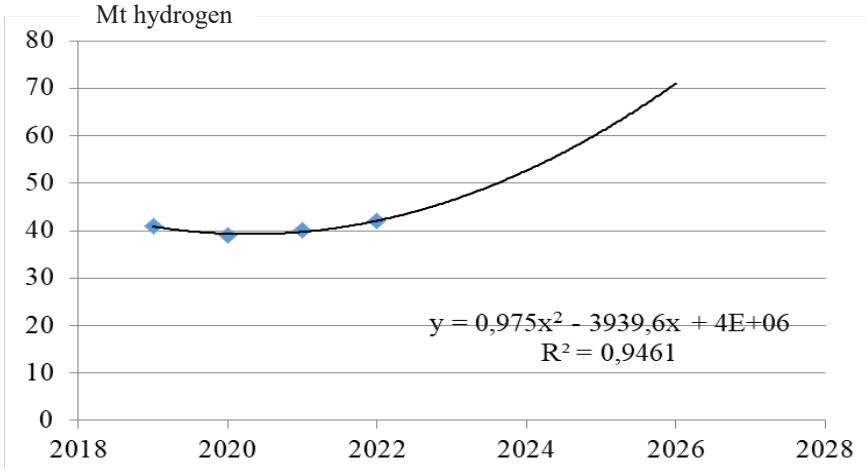

Figure 4. Forecast of hydrogen consumption in the world until 2026

such as nuclear power, is 2.5-4 times more expensive than hydrogen from fossil fuel sources [7].

There is no publicly available information on the amount of investment in specific methods of hydrogen production, as there are no industrial plants of this kind yet, and the cost of hydrogen production at experimental research facilities may be several times/dozens of times higher than the actual cost.

The prospects for investment in the creation of a global hydrogen energy infrastructure are very high. In recent years, China has the highest level of investment in renewable energy sources [8].

Hydrogen energy is considered one of the most attractive areas of energy development in the coming years. This is because hydrogen is a clean source of energy that does not emit harmful substances into the atmosphere. In addition, hydrogen can be used to generate electricity using fuel cells, which makes it very efficient, as the efficiency of such installations can theoretically exceed 80-85%, and is economically viable [8].

Thus, hydrogen energy opens up great opportunities for the economic development of countries around the world, providing innovative incentives and strategic advantages in various fields.

First, it is the investment attractiveness of this energy sector. Investors are interested in the development of hydrogen energy because of the growing energy demand around the world. Hydrogen can be used to generate electricity in countries that do not have access to traditional energy sources. The use of hydrogen will increase the efficiency of generating capacities in the electricity sector of countries, in particular, solve the problem of locked-in capacities, increase efficiency and reduce the cost of energy supply to remote and isolated areas.

Hydrogen can be used as an alternative to oil and gas as an energy source. This will reduce countries' dependence on energy imports and reduce emissions of harmful substances into the atmosphere.

The development of hydrogen energy will also create an additional source of flexibility in the electricity sector (by integrating hydrogen energy storage into the grid) and thus contribute to the tightening of the electricity consumption schedule, smoothing out daily and seasonal consumption irregularities, which will preserve the global energy balance and create conditions for economic growth.

Hydrogen can be used in the electricity, transportation, metallurgy and chemical industries, expanding opportunities for economic diversification and modernization of the energy sector and increasing the competitiveness of national economies.

Conclusions. Hydrogen energy plays a key role in the global energy balance policy, providing countries with opportunities for economic development, energy independence and environmental sustainability. The use of hydrogen as an alternative energy source helps to reduce dependence on fossil fuels, cut greenhouse gas emissions and create new jobs in innovative sectors of the economy. Countries that actively implement hydrogen technologies gain strategic advantages by expanding their role in the global energy market and attracting significant investments in sustainable economic development.

At the same time, the development of hydrogen energy requires significant investments, international cooperation, and technological breakthroughs, particularly in the areas of hydrogen production, transportation, and storage. The creation of appropriate infrastructure and support of government policies will play a crucial role in the large-scale implementation of hydrogen technologies.

REFERENCES:

1. Energy Institute Statistical Review (2024) *Rekordy ta trendy v energetyci v 2024.* [Records and trends in energy in 2024]. KPMG. Available at: https://surl.li/kepqxi (accessed February 3, 2025).

2. Our World in Data (2023). *Primary energy consumption by world region.* Available at: https://ourworldindata.org/grapher/primary-energy-consumption-by-region?facet=none/ (accessed February 5, 2025).

3. Roser M. (2020) Why did renewables become so cheap so fast? *Our Worldin Data*. Available at: https://ourworldindata.org/cheap-renewables-growth#article-citation (accessed February 6, 2025).

4. Energy Institute (2024) *Statistical Review of World Energy.* Available at: https://www.energyinst.org/statistical-review/home (accessed February 7, 2025).

5. Rigollet C., Prinzhofer A. (2022) Natural Hydrogen: A New Source of Carbon-Free and Renewable Energy That Can Compete With Hydrocarbons. *First Break*, vol. 40, is. 10, p. 78–84. DOI: https://doi.org/10.3997/1365-2397.fb2022087

6. International Energy Agency (2023) *Global Hydrogen Review 2023*. Available at: https://iea.blob.core.windows.net/assets/cb9d5903-0df2-4c6c-afa1-4012f9ed45d2/GlobalHydrogenReview2023.pdf (accessed February 6, 2025).

7. Bobro D. G. (2021) Problemni pytannja ta perspektyvy rozvytku vodnevoji energhetyky v Ukrajini [Problematic issues and prospects for the development of hydrogen energy in Ukraine]. *Nacionaljnyj instytut strateghichnykh doslidzhenj* [National Institute of Strategic Studies]. Available at: https://niss.gov.ua/sites/default/files/2021-03/voden.pdf (accessed February 3, 2025).

8. International Energy Agency (2024) *World Energy Investment 2024*. Available at: https://www.iea.org/reports/world-energy-investment-2024 (accessed February 6, 2025).

БІБЛІОГРАФІЧНИЙ СПИСОК:

1. Рекорди та тренди в енергетиці в 2024. Статистичний огляд Energy Institute 2024. *KPMG*. URL: https://surl.li/kepqxi (дата звернення: 03.02.2025).

2. Primary energy consumption by world region. *Our World in Data*. 2023. URL: https://ourworldindata.org/grapher/primary-energy-consumption-by-region?facet=none/ (дата звернення: 05.02.2025).

3. MaxRoser.Whydidrenewablesbecomesocheapsofast?*OurWorldinData.*2020.URL:https://ourworldindata.org/cheap-renewables-growth#article-citation (дата звернення: 06.02.2025).

4. Statistical Review of World Energy. *Energy Institute*. 2024. URL: https://www.energyinst.org/statistical-review/home (дата звернення: 07.02.2025).

5. Christophe Rigollet, Alain Prinzhofer. Natural Hydrogen: A New Source of Carbon-Free and Renewable Energy That Can Compete With Hydrocarbons. *First Break.* 2022. Volume 40, Issue 10. P. 78-84. DOI: https://doi.org/10.3997/1365-2397.fb2022087

6. Global Hydrogen Review 2023. *International Energy Agency*. URL: https://iea.blob.core.windows.net/assets/cb9d5903-0df2-4c6c-afa1-4012f9ed45d2/GlobalHydrogenReview2023.pdf (дата звернення: 06.02.2025).

7. Бобро Д.Г. Проблемні питання та перспективи розвитку водневої енергетики в Україні. *Національний інститут стратегічних досліджень*. 2021. URL: https://niss.gov.ua/sites/default/files/2021-03/voden.pdf (дата звернення: 03.02.2025).

8. World Energy Investment 2024. *International Energy Agency*. URL: https://www.iea.org/reports/world-energy-investment-2024 (дата звернення: 06.02.2025).