

Hydrogen economy as a strategic priority for Ukraine's recovery

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Annotation. This article provides an overview of the state of the hydrogen economy in Ukraine, including the country's resources for hydrogen production, the current state of hydrogen projects, funding sources for the development of the hydrogen economy, and proposals for the future development of the hydrogen industry in Ukraine. Ukraine has significant potential for the development of a hydrogen economy, with abundant resources for the production of hydrogen. However, the development of the hydrogen economy in Ukraine faces several challenges, including the need for investment in research and development, infrastructure development, and technology deployment. To support the development of the hydrogen economy in Ukraine, the government needs to establish a comprehensive plan for the development of a hydrogen infrastructure, increase incentives for the adoption of hydrogen technologies, and foster international partnerships. Overall, the successful development of the hydrogen economy in Ukraine will require a coordinated effort between government, industry, and academia to advance the state of hydrogen technologies and infrastructure, build a skilled workforce, and create incentives for the adoption of hydrogen technologies. The purpose of the article is to identify the status and prospects of the development of the hydrogen economy as a strategic priority for Ukraine's recovery.

Achieving this goal involves solving such tasks as analyzing the state of development and scientific substantiation of strategic directions for further prospects for the formation of the hydrogen economy in Ukraine. The hydrogen economy has become an increasingly important topic in recent years as countries around the world seek to transition to a more sustainable energy system. Ukraine, like many other countries, has recognized the potential of hydrogen as a clean and renewable energy source and made it a strategic priority for its economic recovery. The global hydrogen economy envisions a significant transformation of the current energy system with a focus on sustainability, efficiency, and cooperation to meet the energy needs of the world's population while reducing greenhouse gas emissions and contributing to a more sustainable future. The hydrogen economy in Ukraine is still in the early stages of development, but some efforts have been made recently to promote its growth.

Keywords: hydrogen economy, recovery, infrastructure, technology, financing, investment.

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PROBLEM STATEMENT

The hydrogen economy has become an increasingly important topic in recent years as countries around the world seek to transition to a more sustainable energy system. Ukraine, like many other countries,

has recognised the potential of hydrogen as a clean and renewable energy source and made it a strategic priority for its economic recovery.

The total energy storage potential by region is shown in Figure 1.

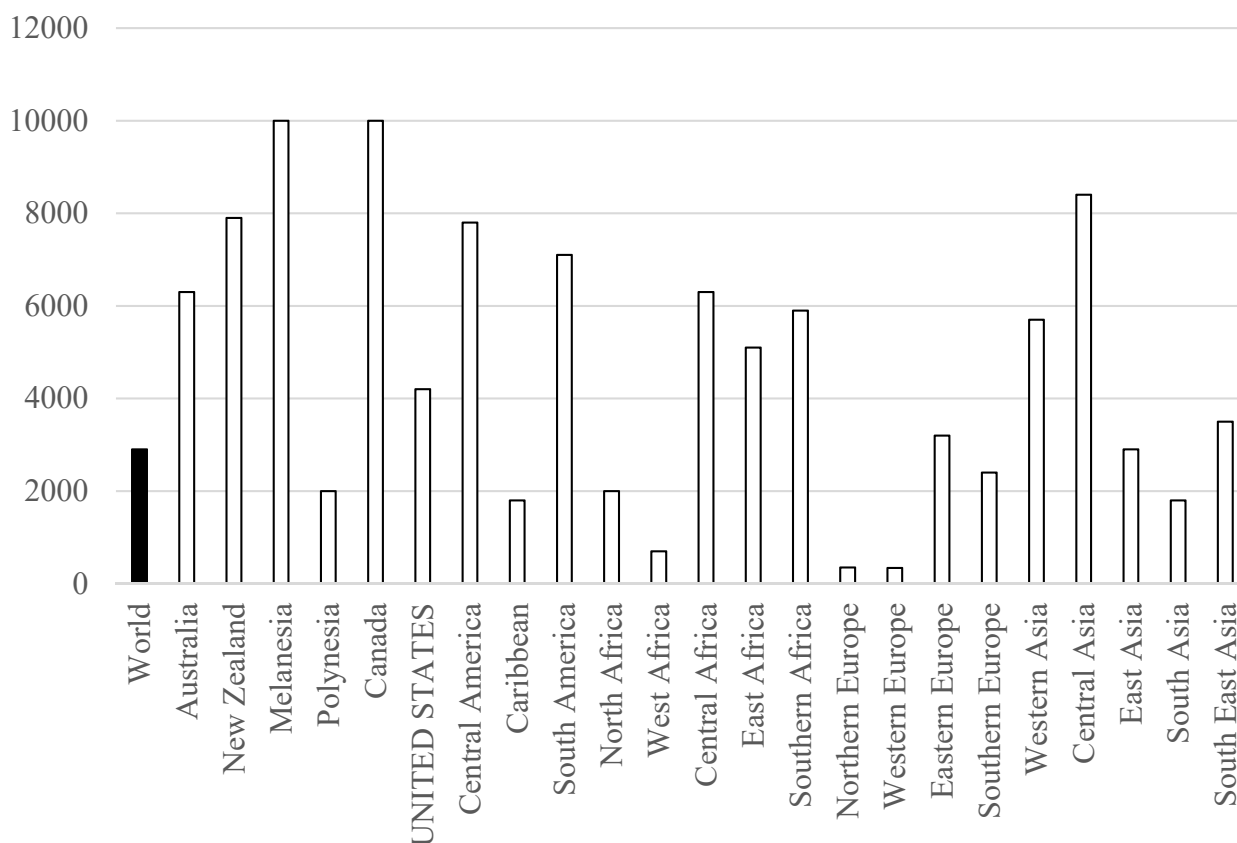


Fig. 1. Energy storage potential by regions of the world, GWh per million people.

Source: [6].

There are several reasons why Ukraine is well suited to develop a hydrogen economy. First, Ukraine has a large and well-developed chemical industry that can be used for hydrogen production. In addition, Ukraine has a significant renewable energy potential, in particular wind and solar, which can be used to produce green hydrogen.

In addition, the development of the hydrogen economy could enable Ukraine to reduce its dependence on imports of fossil fuels, in particular natural gas, which currently accounts for a significant share of energy consumption. By developing a domestic hydrogen production and distribution infrastructure, Ukraine can create a more sustainable and secure energy system.

There are also potential economic benefits associated with the development of a hydrogen economy in Ukraine. The global hydrogen market is expected to grow significantly in the coming years, and Ukraine can position itself as a major player in this market. In addition, the development of the domestic hydrogen industry can create jobs and stimulate economic growth.

However, there are also challenges associated with the development of the hydrogen economy in Ukraine. These include the need for significant investments in infrastructure and technology, as well as the need for a favourable regulatory environment. In addition, there is currently limited domestic demand for hydrogen, which may make it difficult to justify the

investments needed to develop the hydrogen industry.

Overall, despite the challenges associated with the development of the hydrogen economy in Ukraine, the potential benefits are significant. By leveraging its existing industrial capabilities and renewable energy sources, Ukraine can position itself as a leader in the global hydrogen market and create a more resilient and sustainable energy system.

While the development of a hydrogen economy in Ukraine can bring significant benefits, several key issues and challenges need to be addressed to make it a reality. Below are the main challenges related to the development of the hydrogen economy in Ukraine.

1. **Cost.** Hydrogen production is currently more expensive than traditional fossil fuels, making it difficult to compete on price. For hydrogen to become a viable alternative, production costs need to be significantly reduced.

2. **Infrastructure.** The development of a hydrogen economy requires significant investment in infrastructure, including the construction of hydrogen production plants, pipelines and storage facilities. This requires significant capital investment, which may be difficult to secure.

3. **Regulatory environment.** The development of the hydrogen economy requires a favourable regulatory environment that encourages investment and innovation. Clear policies and regulations are needed to support the growth of the industry.

4. **Domestic demand.** Currently, domestic demand for hydrogen in Ukraine is limited, making it difficult to justify the investments needed to develop the hydrogen industry. This may require the creation of policies and incentives that encourage the use of hydrogen as an alternative energy source.

5. **Technology.** The development of a hydrogen economy requires the introduction of advanced technologies, including hydrogen fuel cells and

electrolysers. Additional research and development may be required to improve these technologies and increase their efficiency and cost-effectiveness.

6. **Supply chain.** The development of a hydrogen economy requires a reliable supply chain for hydrogen production and distribution. This requires the establishment of partnerships and cooperation along the entire supply chain, from production to distribution to end users [4-6].

Addressing these issues will require significant investment, cooperation and innovation. However, if these challenges can be overcome, the development of a hydrogen economy in Ukraine could bring significant benefits in terms of energy security, economic growth and environmental sustainability.

LITERATURE REVIEW

The scientific articles provide a more in-depth analysis of the potential for the development of the hydrogen economy in Ukraine, as well as the challenges and opportunities associated with it.

Based on the bibliographic analysis of scientific publications, several key conclusions can be drawn about the development of the hydrogen economy in Ukraine:

Ukraine has significant potential for hydrogen production, especially green hydrogen. The country has significant renewable energy resources, including solar and wind, which can be used for hydrogen production through electrolysis;

there are significant challenges to developing a hydrogen economy in Ukraine, including high costs, lack of infrastructure and insufficient domestic demand;

to overcome these challenges, significant investments in research and development, as well as policies and incentives to promote industry growth are needed. Cooperation along the entire supply chain, from production to distribution to end users, is also crucial;

the development of a hydrogen economy in Ukraine can bring significant

benefits, including energy security, economic growth and environmental sustainability. However, it will require significant efforts and investments from both the public and private sectors [1-10].

Scientific publications show that, despite the significant challenges to the development of the hydrogen economy in Ukraine, the country has significant potential and opportunities to become a leader in this field. Addressing these challenges will require significant investment, cooperation and innovation, but the potential benefits are significant.

The issues of development and support of the hydrogen economy in Ukraine and the world are reflected in the works of many researchers, including Kovalenko N., Hutsol T., Kovalenko V., Glowacki S., Kokovikhin S., Dubik V., Mudragel O., Kubon M., Tomaszewska-Górecka W., Kudria S., Ivanchenko I., Tuchynskyi B., Petrenko K., Karmazin O., Riepin O., Manna J., Jha P., Sarkhel R., Banerjee C., Tripathi A., Nouni M. and others [1-10].

OBJECTIVES

The objective of the article is to identify the status and prospects of the development of the hydrogen economy as a strategic priority for Ukraine's recovery.

Achieving this objective involves solving such tasks as analysing the state of development and scientific substantiation of strategic directions for further prospects of the hydrogen economy in Ukraine.

RESULTS

The hydrogen economy is a term used to describe a potential future energy system where hydrogen is the main energy carrier. This involves the production, storage, distribution and use of hydrogen as a fuel for a variety of applications, including transport, heating and electricity generation.

The basic idea behind the hydrogen economy is that hydrogen can be produced using renewable energy sources such as wind and solar power, and then stored and transported in large quantities for use as a clean and efficient fuel source. Hydrogen

can be used in fuel cells to generate electricity or burned in internal combustion engines or gas turbines to produce heat or mechanical energy.

Proponents of the hydrogen economy argue that it can offer several benefits over the current fossil fuel-based energy system, including reduced greenhouse gas emissions, increased energy security, and improved air quality. However, the development of a hydrogen economy is fraught with significant challenges, including the high cost of production and distribution infrastructure, and the need for significant technological innovation to make hydrogen fuel cells and other hydrogen technologies more efficient and affordable.

Key characteristics of the global hydrogen economy:

renewable energy-based hydrogen production: hydrogen will be produced primarily from renewable energy sources such as wind and solar power to reduce greenhouse gas emissions and promote sustainable development;

a wide range of applications: hydrogen will be used for a wide range of applications, including transport, heating and power generation, and will replace traditional fossil fuel-based energy sources;

global distribution network: a global hydrogen distribution network will be established, including the transport of hydrogen across international borders to meet demand;

technological innovation: continuous technological innovation is needed to improve the efficiency and affordability of hydrogen production, distribution and use, as well as to develop new and more efficient hydrogen technologies;

cooperation: the development of a global hydrogen economy will require international cooperation between governments, industry and other stakeholders to develop policies and standards for the production, distribution and use of hydrogen;

investment: Significant investment will be required to develop the infrastructure and technologies needed for the global hydrogen economy, including production facilities, storage, pipelines and hydrogen refuelling stations [7-9].

The global hydrogen economy envisages a significant transformation of the current energy system with a focus on sustainability, efficiency and cooperation to meet the energy needs of the world's population while reducing greenhouse gas emissions and contributing to a more sustainable future.

The hydrogen economy in Ukraine is still in its early stages of development, but there have been some recent efforts to promote its growth. Here are some of the key developments in the hydrogen economy in Ukraine:

hydrogen production potential: Ukraine has significant potential for hydrogen production, especially from renewable energy sources. The country has abundant solar and wind resources that can be used to produce hydrogen through electrolysis;

government initiatives: The Ukrainian government has started to promote the development of the hydrogen economy through various initiatives, including the adoption of the National Hydrogen Strategy in 2020. The strategy outlines a roadmap for the development of the hydrogen economy in Ukraine with a focus on green hydrogen production and the creation of a domestic hydrogen market;

involvement of the private sector: Private sector involvement in the development of the hydrogen economy in Ukraine is growing, with several companies and organisations exploring the potential for hydrogen production and use;

research and development: There is some research and development in the field of hydrogen technologies in Ukraine, including the development of new materials and technologies for hydrogen production and storage [14].

The capacity potential of renewable energy sources in Ukraine in the pre-war period is shown in Figure 2.

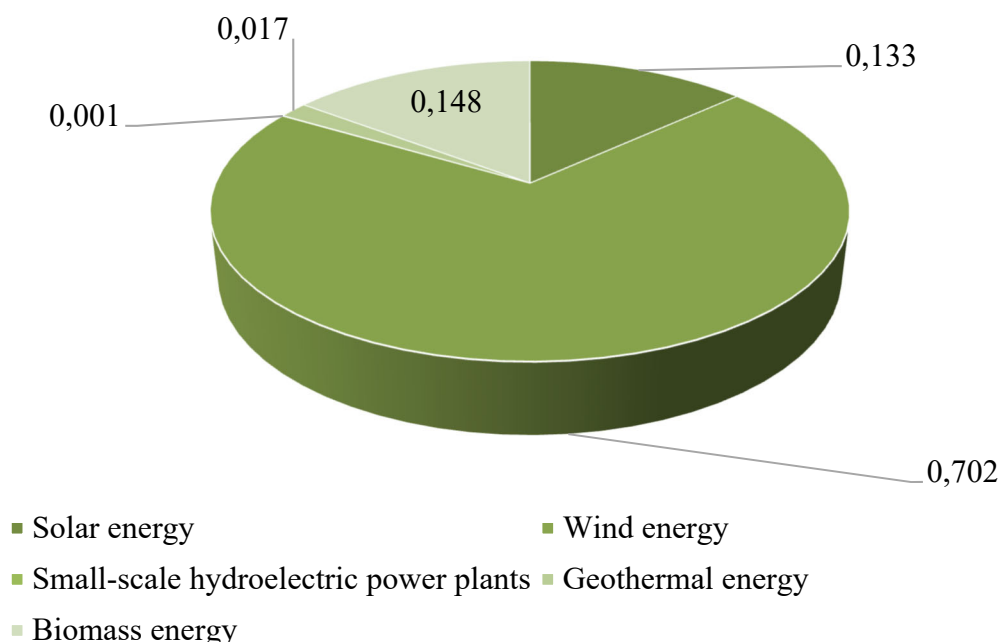


Fig. 2. Structure of renewable energy sources capacity potential by type, p.p.

Source: [15, c. 17].

However, there are still several challenges that need to be addressed to further develop the hydrogen economy in

Ukraine. These include the lack of infrastructure for hydrogen production, storage and distribution, as well as

insufficient domestic demand for hydrogen. In addition, the high costs associated with hydrogen production and infrastructure development are a significant problem [2-6].

Existing economic schools of thought have different views on the development of the hydrogen economy as an emerging industry aimed at replacing fossil fuels with hydrogen as an environmentally friendly and sustainable energy source. Let us consider them in more detail.

The neoclassical school of economics

This school of thought emphasises the importance of markets and prices for the efficient allocation of resources. Proponents of neoclassical economics may see the hydrogen economy as a potential solution to environmental problems caused by the use of fossil fuels and believe that market forces will stimulate innovation and investment in this sector [2, 6].

Keynesian economic school

Representatives of this economic school emphasise the role of government intervention in economic management, especially during recessions. Proponents of Keynesian economics may see the development of the hydrogen economy as a way to create new jobs stimulate economic growth, and may support public investment in the sector [6].

Ecological economics school

This school of thought focuses on the relationship between the economy and the environment and seeks to find ways to balance economic growth with environmental sustainability. Proponents of ecological economics may view the hydrogen economy as a promising way to reduce greenhouse gas emissions and mitigate climate change and may support policies that encourage the adoption of hydrogen technologies [12].

The development of a hydrogen economy is likely to require a combination of market innovation and government intervention to overcome potential market failures and externalities such as environmental pollution. Thus, different

schools of thought may have different views on the most effective ways to promote the growth of the hydrogen economy.

It should be noted that although the hydrogen economy in Ukraine is still in its early stages of development, several positive developments and initiatives indicate that the country has the potential to become a significant player in this field in the future.

Several hydrogen economy projects have been launched in Ukraine in recent years. Here are some examples:

the Green Hydrogen Hub is a joint project of the Ukrainian government and the European Bank for Reconstruction and Development (EBRD) aimed at promoting the development of green hydrogen production and use in Ukraine. The project envisages the construction of a pilot hydrogen production plant in the city of Dnipro, which will use renewable energy sources to produce hydrogen;

Hydrogen Mobility Europe (H2ME): Ukraine is a partner country in the H2ME project, which aims to promote the development of hydrogen refuelling infrastructure and the deployment of fuel cell vehicles in Europe. Within the framework of the project, several hydrogen filling stations are planned to be deployed in Ukraine.

HY4Heat: HY4Heat is a project funded by the European Union to promote the use of hydrogen for heating buildings. Ukraine is one of the partner countries of the project, which includes a feasibility study for the installation of hydrogen boilers in residential buildings.

Renewable Hydrogen Coalition: The Renewable Hydrogen Coalition is a Ukrainian industry association that aims to promote the development of the hydrogen economy in Ukraine. The association includes several Ukrainian companies and organisations involved in the production, storage and distribution of hydrogen.

Solar Hydrogen Energy Corporation (SHEC): SHEC is a Ukrainian company specialising in the development of solar

hydrogen production technologies. The company has developed a solar hydrogen production system that can produce hydrogen using only water and sunlight [4-8].

These projects and initiatives demonstrate the growing interest and investment in the development of the hydrogen economy in Ukraine, with a focus on green hydrogen production and a wide range of potential applications, including transport, heating and electricity generation.

Ukraine is actively developing the hydrogen economy as part of its strategic decarbonisation programmes.

National Hydrogen Energy Development Plan. In May 2021, the Government of Ukraine approved the National Hydrogen Energy Development Plan, which outlines the country's strategy for the development of the hydrogen economy. The plan sets targets for hydrogen production and consumption, and deployment of hydrogen infrastructure, and identifies key policy measures to support the development of the sector [13].

Pilot projects. Ukraine has launched several pilot projects to demonstrate the feasibility of hydrogen technologies. For example, in 2020, the Ukrainian Hydrogen Industry Association launched a project to create a hydrogen filling station in Kyiv, and a project to convert a diesel locomotive to run on hydrogen fuel is currently underway [13].

International partnerships. Ukraine has formed partnerships with other countries and organisations to promote the development of the hydrogen economy. In September 2021, Ukraine and Japan signed a memorandum of cooperation in the field of hydrogen, which provides for cooperation in research and development, as well as the promotion of hydrogen technologies in Ukraine [13].

Political incentives. Ukraine has introduced policy incentives to support the development of the hydrogen sector. For example, the country offers tax incentives

for hydrogen production, as well as subsidies for the purchase of hydrogen-powered vehicles [13].

Ukraine is making significant efforts to include the hydrogen economy in its strategic decarbonisation programmes. The National Hydrogen Energy Development Plan, pilot projects, international partnerships, and policy incentives are aimed at promoting the development of a sustainable and low-carbon hydrogen economy in Ukraine [13].

Ukraine has significant potential resources for the development of a hydrogen economy. Here are some of the main resources that can be used for hydrogen production in Ukraine:

renewable energy sources: Ukraine has large wind, solar and biomass resources that can be used to produce renewable hydrogen through electrolysis or other methods. The country has one of the highest levels of solar radiation in Europe, making it well-suited for solar energy production;

natural gas: Ukraine has significant reserves of natural gas, which could be used as a feedstock for hydrogen production through steam methane reforming (SMR) or other methods. However, this approach will lead to greenhouse gas emissions unless carbon capture and storage (CCS) technologies are implemented;

coal: Ukraine has significant coal reserves, which could also be used as a feedstock for hydrogen production through gasification. However, this approach will also lead to greenhouse gas emissions unless carbon capture and storage (CCS) technologies are implemented;

water: Water is a key resource for hydrogen production through electrolysis, which can produce green hydrogen using renewable energy sources.

Thus, Ukraine has significant potential resources for the development of a hydrogen economy, with a particular focus on renewable energy sources for the production of green hydrogen. However, there are also challenges related to hydrogen production and distribution,

including the need for infrastructure development and investment in new technologies.

The development of a hydrogen economy in Ukraine will require significant investments in research and development, infrastructure and technology deployment. Here are some of the main sources of funding that could be used to support the development of a hydrogen economy in Ukraine.

1. Public funding: The Ukrainian government has already taken several initiatives to promote the development of the hydrogen economy, including the adoption of the National Hydrogen Strategy and the establishment of a hydrogen working group. The government can provide funding for research and development, infrastructure development and technology deployment.

2. European Union funding: Ukraine is a partner country in several hydrogen economy projects funded by the European Union, including the Green Hydrogen Hub project and the Hydrogen Mobility Europe project. These projects can provide significant funding for the development of hydrogen infrastructure and technology deployment in Ukraine.

3. Private sector investment: Private sector interest in the development of a hydrogen economy in Ukraine is growing, with several companies and organisations exploring the potential for hydrogen production and use. Private sector investment could be used to support the development of new technologies and infrastructure for the hydrogen economy.

4. International financial institutions: International financial institutions, such as the European Bank for Reconstruction and Development (EBRD) and the World Bank, could provide financing for the development of a hydrogen economy in Ukraine, including infrastructure development and technology deployment.

In general, the development of the hydrogen economy in Ukraine will require significant investments from various

sources, including public funding, private sector investments, and international financial institutions [3-7].

Proposals for the development of the hydrogen economy in Ukraine:

create a hydrogen infrastructure plan: Ukraine needs a comprehensive plan for the development of hydrogen infrastructure, including the deployment of hydrogen refuelling stations, the development of hydrogen production capacity, and the development of transport and storage infrastructure;

support for research and development: Ukraine needs to invest in research and development to improve the state of hydrogen technology, including the development of new hydrogen production technologies and improvements to existing technologies such as electrolysis and methane steam reforming;

increase renewable energy production: To support the development of green hydrogen, Ukraine needs to increase the production of renewable energy, in particular solar and wind energy, which can be used to power the electrolysis for green hydrogen production;

provide incentives for the introduction of hydrogen: To encourage the adoption of hydrogen technologies, the Ukrainian government could create incentives for the purchase of fuel cell vehicles, hydrogen boilers and other hydrogen technologies;

promote international partnerships: Ukraine should seek to establish partnerships with other countries and international organisations working on hydrogen technologies and projects, such as the European Union and the International Partnership for Hydrogen and Fuel Cells in the Economy;

develop training and education programmes: To support the growth of the hydrogen industry in Ukraine, the country needs to develop training and education programmes to prepare a skilled workforce capable of designing, building and maintaining hydrogen infrastructure and technologies.

CONCLUSIONS

In summary, Ukraine has significant potential for the development of a hydrogen economy, having abundant resources for hydrogen production, including renewable energy sources, natural gas, coal and water. However, many challenges need to be overcome, including the need for investment in research and development, infrastructure development and technology deployment.

To support the development of a hydrogen economy in Ukraine, the government needs to develop a comprehensive plan for the development of hydrogen infrastructure, including the deployment of hydrogen refuelling stations, the development of hydrogen production capacity, and the development of

transportation and storage infrastructure. In addition, the government needs to increase incentives for the adoption of hydrogen technologies and promote international partnerships to accelerate the growth of the hydrogen industry in Ukraine.

Overall, the successful development of the hydrogen economy in Ukraine will require coordinated efforts between government, industry and academia to improve the state of hydrogen technology and infrastructure, train a skilled workforce, and create incentives for the adoption of hydrogen technologies. With the right investment and support, Ukraine has the potential to become a leader in the hydrogen economy and contribute to global efforts to reduce carbon emissions and transition to a low-carbon economy.

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