Електронний журнал «Ефективна економіка» включено до переліку наукових фахових видань України з питань економіки (Категорія «Б», Наказ Міністерства освіти і науки України № 975 від 11.07.2019). Спеціальності – 051, 071, 072, 073, 075, 076, 292.

Ефективна економіка. 2025. № 1.

DOI: http://doi.org/10.32702/2307-2105.2025.1.29
УДК 332.146

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DECARBONIZING THE NORWEGIAN ECONOMY: MANAGEMENT AND FINANCE ASPECTS

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ДЕКАРБОНІЗАЦІЯ ЕКОНОМІКИ НОРВЕГІЇ: АСПЕКТИ МЕНЕДЖМЕНТУ ТА ФІНАНСІВ

It analyses data published in the Copernicus Monthly Climate Bulletin in November 2024, which indicate that this year will be the warmest year on record and the first year to exceed pre-industrial levels by more than 1.5ºC compared to pre-industrial levels in ERA5 data. This should be a catalyst for stepping up climate action. The International Energy Agency forecasts that, thanks to the growth of solar photovoltaics and wind power, clean energy will become the world's largest source of energy by the mid-2030s. It analyses Norway's efforts to decarbonise. According to the International Energy Agency's data presented in the document "Norway 2022: An Energy Policy Review", Norway has more electric cars per capita than any other country in the world. The vast majority of all new passenger cars sold in 2021 were electric cars powered by renewable energy sources. Norway is also rolling out an extensive charging network. Norway is actively implementing various financial incentives to stimulate the development of electromobility: zero-emission cars benefit from VAT and registration tax exemptions. Hybrid electric cars are eligible for reduced registration tax. The special role of hydropower in meeting the energy needs of Norway is shown, where this industry plays a key role and may remain very significant in the future with investments in the reconstruction of existing stations. It is noted that most European countries do not have significant hydropower resources, so large-scale development of corresponding stations is practically impossible for them. It is emphasized that in some areas of the world where appropriate conditions exist, hydropower may continue to actively develop, but in general this area of energy in the future will only have auxiliary significance. It is indicated that to ensure sustainable development of humanity and decarbonization of the world economy, it is advisable to actively develop wind, especially offshore wind energy, and solar power plants. Taking into account new circumstances and trends, innovative small modular nuclear reactors, which can be a key source of climate-neutral energy, are gaining particular importance for the world energy sector in the near future. The most important factor in the development of the world economy is also electromobility.

Аналізуються дані, опубліковані в Щомісячному кліматичному бюлетені Коперник у листопаді 2024 року, які свідчать, що цей рік стане найтеплішим роком за всю історію спостережень і першим роком, коли температура перевищить доіндустріальні рівні більш ніж на 1,5ºC

порівняно з доіндустріальними рівнями даних ERA5. Це має стати каталізатором для активізації зусиль зі збереження клімату. У прогнозах Міжнародного енергетичного агентства стверджується, що завдяки зростанню сонячної фотоелектричної та вітрової енергії чиста енергія стає найбільшим джерелом енергії у світі в середині 2030-х років. Аналізуються зусилля Норвегії у напрямі декарбонізації. За даними Міжнародного енергетичного агентства, представленими у документі «Норвегія 2022. Огляд енергетичної політики», у Норвегії на душу населення припадає більше електромобілів, ніж у будь-якій іншій країні світу. При цьому переважна більшість усіх нових легкових автомобілів, проданих у 2021 році, були електромобілями, які працюють від поновлюваних джерел енергії. У Норвегії також відбувається розгортання широкої зарядної мережі. Норвегія активно впроваджує різні фінансові пільги для стимулювання розвитку електромобільності: автомобілі з нульовим рівнем викидів користуються пільгами з податку на додану вартість та реєстраційного податку. Для гібридних електричних автомобілів надається знижений реєстраційний податок. Вказується, що для забезпечення сталого розвитку людства та декарбонізації світової економіки доцільним є активний розвиток вітрової, особливо морської вітрової енергетики, сонячних електростанцій, гідроенергетики. З урахуванням нових обставин і тенденцій у найближчій перспективі особливої важливості для світової енергетики набувають інноваційні малі модульні атомні реактори, які можуть бути ключовим джерелом кліматично нейтральної енергії. Найважливішим чинником розвитку світової економіки також є електромобільність.

Keywords: *Norway, energy, decarbonization, efficiency, climate, electric vehicles, finance, globalization, prospects, wind, solar power plants, small modular reactors, offshore wind farms, benefits, value added tax.*

Ключові слова: *Норвегія, енергетика, декарбонізація, ефективність, клімат, електромобілі, фінанси, глобалізація, перспективи, вітрові, сонячні електростанції, малі модульні реактори, морські вітропарки, льготи, податок на додану вартість.*

Statement of the problem in a general form and its connection with important scientific or practical tasks. The active dynamics of the world economy in recent decades is associated with a significant increase in energy use. Such use has already led to noticeable negative changes in the climate. The solution of environmental problems with unconditional economic growth plays a key role in determining the future of the planet. It is interesting to consider various aspects of decarbonization taking into account the experience of Norway, which has achieved very significant success in this area and can serve as a benchmark for many other countries.

Analysis of the latest research and publications, in which the solution to this problem was initiated and on which the author relies, selection of previously unsolved parts of the general problem, to which the article is devoted. The issues of sustainable economic development, the problem of overcoming the consequences of climate change, the development of progressive energy sources are of interest to experts, scientists and specialists in the production sector. The authors of forecast studies include such prominent experts in this field as: Fatih Birol, Jarmo Tanhua, Essi Lehto, Jari Tanner, Nora Buli, Claudia Kemfert, Rolf Wüstenhagen, Jens Turau, Ravi Kotecha, Darrell Proctor. Researchers are developing issues of global sustainable development and its energy components.

Formulation of the goals of the article (statement of the task). The aim of the article is to formulate a model of decarbonization and development of global energy, highlighting the tasks of the near and distant future in the context of sustainable development.

Results. Analytical data published in the Monthly Climate Bulletin by the international climate research organization Copernicus in November 2024 show the following. Samantha Burgess, Deputy Director of the Copernicus Climate Change Service (C3S): “After 10 months of 2024 it is now virtually certain that 2024 will be the warmest year on record and the first year of more than 1.5ºC above pre-industrial levels according to the ERA5 dataset. This marks a new

milestone in global temperature records and should serve as a catalyst to raise ambition for the upcoming Climate Change Conference, COP29.” [1].

Air temperature anomalies show serious negative dynamics (Fig. 1). Such dynamics have been actively manifested since the 1980s and continue to increase. The levels of temperature anomalies are currently more than three times higher than the anomalies of the 1950s. Negative weather anomalies were observed in all regions of the planet, for example, destructive hurricanes off the coast of the United States, the damage from which is estimated at tens of billions of dollars, droughts that caused significant damage to the 2024 harvest, melting glaciers, the advance of deserts, and the flooding of many territories due to rising sea levels.

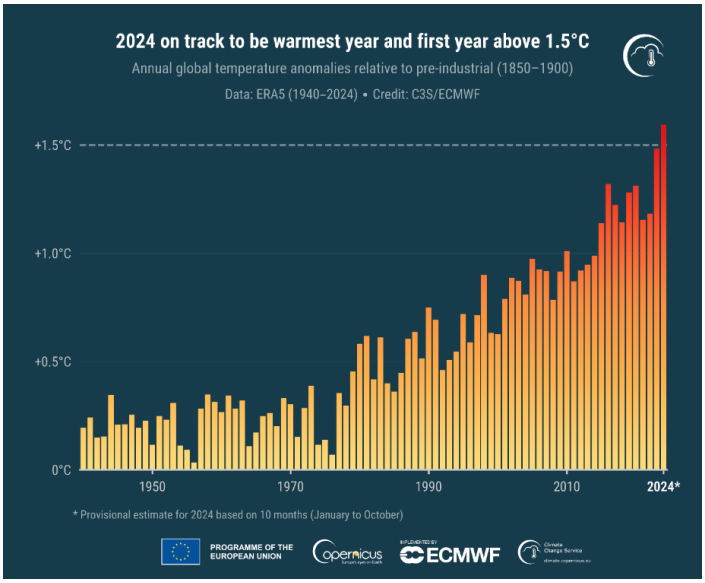

Figure. 1. Annual global surface air temperature anomalies (°C) relative to 1850-1900 from 1940 to 2024.

Source: [1].

In the Stated Policies Scenario (STEPS), clean energy deployment accelerates as the pace of overall energy demand growth slows, leading to a peak in all three fossil fuels before 2030 ((Fig. 2). Increasing reductions in coal demand means it is overtaken by natural gas in the global energy mix by 2030. Clean energy grows more than total energy demand between 2023 and 2035. Led by surging solar photovoltaic (PV) and wind power, clean energy becomes the largest source of energy in the mid-2030s. Although the STEPS sees a threefold increase in renewables that brings fossil fuel use down from 80% of total energy demand in

2023 to 58% in 2050, this falls far short of the step change that occurs in the Announced Pledges Scenario (APS) and the Net Zero Emissions by 2050 (NZE) Scenario, especially the latter. In both these scenarios, renewables begin to rapidly eat into the fossil fuel market share. By 2035, clean energy meets 40% of global energy demand in the APS, and this rises to nearly three-quarters by 2050. In the NZE Scenario, clean energy meets 90% of global energy demand in 2050 [2].

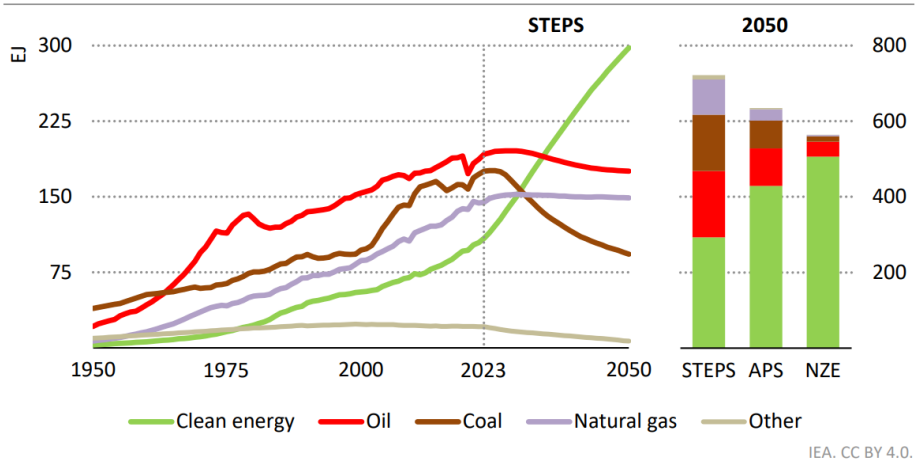

Figure 2. Global energy mix by scenario to 2050. Notes: EJ = exajoules; STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario.
Source: [2].

The International Energy Agency (IEA) prepared the document «Norway 2022. Energy Policy Review» [3]. Dr. Fatih Birol, Executive Director International Energy Agency, commends Norway for its efforts to decarbonise its economy, noting in particular the following: «Since the last IEA in-depth review in 2017, Norway has remained a global pillar of energy security, providing the world with stable supplies of oil and gas produced in an environmentally responsible manner. Thanks to its ample reserves of oil and natural gas, Norway remains a significant international supplier, with close to 90 % of its energy production exported… Norway has an opportunity, therefore, to show the world how to undertake complex emissions reductions, as all countries will eventually face this issue. Norway's existing expertise can help it achieve a successful energy and climate transition… If the right policies and incentives are put in place, Norway is well

placed to lead the world in decarbonising a wide range of sectors through technologies such as electric vehicles, carbon capture, utilisation and storage, and hydrogen» [3].

According to data International Energy Agency, presented in the document «Norway 2022. Energy Policy Review» [3]: «Norway has more electric cars per capita than any country in the world. Around 86% of all new passenger cars sold in 2021 were EVs (with 64.5% being fully battery electric), drawing from a renewables-based electricity grid. In comparison, less than 14% of new passenger cars sold in 2021 were regular internal combustion cars. Norway is a relatively small car market with about 2.9 million passenger cars. By the beginning of November 2021, 436 807 cars (15.1%) were fully electric…».

The limited number of charging stations for electric vehicles in Europe and globally is holding back the development of electromobility. In this regard, it is important to highlight the attention that Norway is paying to the deployment of a wide network of such charging stations. In the document International Energy Agency It is indicated that:«In 2021, 18 086 public electric chargers were available in the country, of which 5 225 were fast chargers. In addition, Tesla had 1 182 electric chargers for Tesla cars in 2021. The country has 0.35 public charging points for every 10 EVs» [3].

Norway is actively implementing various incentives to stimulate the development of electric mobility: “ZEVs benefit from VAT (25 %) and registration tax (around EUR 10 000 on average) exemptions. PHEVs benefit from a reduced registration tax, though this reduction is subject to stricter conditions since January 2022. Moreover, the government introduced a rule that ZEVs should pay no more than half of what conventional vehicles pay for parking, boarding ferries and driving on toll roads. The rate up to the 50% level is decided by local authorities. Estimated at almost NOK 18.7 billion in 2021 (EUR 1.9 billion), the benefits come with substantial costs” [3].

Analysis of the International Energy Agency review presented in the document «Norway 2022. Energy Policy Review» [3], allowed us to establish the following:

- the Scandinavian countries have formed a joint electricity market, it is also connected with other Northern European countries, for example, with Germany, the Netherlands, Poland, Lithuania, Latvia, Estonia;

- in recent years, Norway has been a net exporter of electricity to other countries, providing 20.5 TWh of net exports in 2020, which made it one of the largest energy exporters in Europe;

- in the review of the International Energy Agency, solar stations will show a very strong increase in capacity (table 1), so in 2025 it is expected to reach a capacity of 699 MW, and by 2030 up to 1796 MW, that is, 6 times compared to 2021.

- the country's wind power, as suggested by the authors of the document "Norway 2022. Energy Policy Review", will grow very slowly until 2025 (up to a capacity of 5041 MW) based on those licenses that have been issued for a long time, but the Norwegian Water Resources and Energy Directorate predicts that "offshore wind will only start to contribute after 2030 and will generate 7 TWh of energy in 2040" [3];

- the most important for the country's energy are hydroelectric power plants, they make up 88% of the country's generating capacity from 1690 hydroelectric power plants (Energy Facts Norway, 2021) [3];

- The Norwegian government has targets for increasing offshore wind capacity, in 2020 Norway opened two offshore wind zones with a total capacity of up to 4.5 GW, with 3 GW of capacity set at Sørlige Nordsjø II, where the turbines will be located fixed to the seabed in an average water depth of 60 meters, while another zone, Utsira Nord, has a maximum floating wind capacity of 1.5 GW. The government's goal is to promote offshore wind development through a large-scale national strategy [3].

Table 1. Electricity generation capacity growth projections in Norway (MW), 2021-2030.

View	2021	2025	2030
Hydro	33269	34092	34701
Wind	4929	5041	5019
Solar PV	300	699	1796
Thermal	315	315	315

Source: [3].

The Scandinavian countries have different attitudes towards the use of nuclear energy to generate electricity. Sweden currently, according to the International Atomic Energy Agency [4], (as of November 2024) operates 6 nuclear reactors, the total capacity of these reactors is 7008 MW(e), and another 7 reactors (total capacity 4054 MW(e)) are permanently shut down. In 2023, Sweden's nuclear power plants produced 46679 GWh of energy, which is 28.6% of the country's total electricity. The share of nuclear energy in Sweden's energy balance has changed significantly over the years. Thus, in 2005 it was 45%, then it decreased, for example, in 2010 - to 38%, in 2015 - to 34%, in 2020 - to 29% [4]. At this level, the indicator has stabilized in recent years.

Finland is significantly inferior to Sweden in terms of the total capacity of nuclear power units. According to the International Atomic Energy Agency [5], Finland has 5 nuclear reactors with a total capacity of 4,369 MW(e). Since 2005 (33%), the share of nuclear energy has increased significantly (42% in 2023). This is largely due to the commissioning of the largest nuclear reactor in Europe and one of the largest in the world, Olkiluoto 3, which has an electrical capacity of 1,600 MWe [5]. Scandinavian countries such as Norway and Denmark currently do not have nuclear power plants.

Norway is an important example country for other countries in the world in the development of electric mobility, as evidenced by the review "Norway 2022. Energy Policy Review" [3] (Fig. 3).

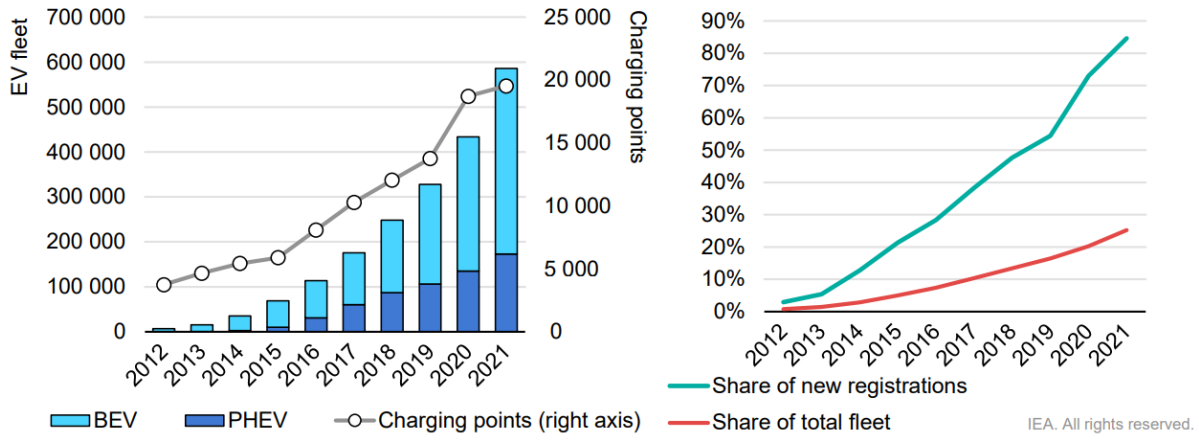

Figure 3. Registered electric vehicles and public charging stations in Norway, 2012-2021.

Source: [3].

In 2012, there were very few electric vehicles in Norway, in a short period of time, by 2016, the total number of battery electric vehicles (BEV); plug-in hybrid electric vehicles (PHEV) exceeded 100 thousand, in 2018 the number of electric vehicles already exceeded 200 thousand. It is noteworthy that the trend that manifested itself from the very beginning of the emergence of electric vehicles and has persisted all the time is a pronounced dominance of BEVs in the composition of electric vehicles and about three times less PHEVs. The growth in the number of electric vehicles in Norway was so rapid that it can be clearly characterized by the following figure: the number of electric vehicles from 2015 to 2021 increased almost 10 times, which is unique.

According to the International Atomic Energy Agency (IAEA) [6], there were 415 nuclear reactors in the world (as of November 20, 2024). It is important to emphasize that the overwhelming majority of reactors were built a long time ago, to illustrate this, it can be noted that there are 290 reactors that are 30 years old or older, and 38 reactors are more than 50 years old. It is obvious that even to maintain the capacity of nuclear energy at the current level, it is necessary to put into operation new units of nuclear power plants to replace those that are being retired or to find other solutions to energy problems. At the same time, it is also necessary to take into account the circumstance, which can be predicted with all

certainty, that modern global civilization will need significantly more energy and its production will need to be ensured.

Global Energy Outlook Model.

Given the forecasts for the development of the world economy, which provide for a significant increase in the need for energy, especially electrical energy, it is necessary to develop a program for the development of global energy, which assumes a significant increase in the production of electricity and, most importantly, the dominant production of primary electricity using climate-neutral sources, in the name of preserving the planet's climate. The volumes of energy production with zero emissions must be as significant as never before. Let us consider the following energy sources in this context.

A). Wind energy. It is expected to be the most important energy source on a global scale in the future. Wind energy has not had a high capacity factor for a long time. In the last few decades, as a result of innovative efforts, this parameter has been increased many times over, and the capacity of individual wind turbines has increased significantly. Relatively recently, such capacity did not exceed 2-3 MW, but now there are individual installations with a capacity of 20 MW. An innovative solution is to place wind turbines offshore, in coastal areas in shallow waters, where wind parks of several hundred installations can be created. The total capacity of such power plants can be comparable, for example, to a high-capacity unit of a nuclear power plant. The construction of wind power plants offshore is difficult, but in marine conditions there is almost always quite intense wind and the capacity factor of offshore wind power plants can reach 50%. Today, a very significant amount of electricity, more than half of the total volume, is already generated in Denmark. There are plans among the Nordic countries to jointly build offshore wind farms in the North and Baltic Seas. It can be assumed that wind energy will be the main source of energy for humanity in the future.

B). Solar energy. Second in importance after wind energy in terms of meeting the needs of mankind. In many desert areas of the planet it can be the main source of energy and even surpass all other sources. In other areas, for example in

Europe, it can be an auxiliary source of energy. Throughout the world, in Norway, in particular, there is an intensive increase in electricity generation using solar power plants. This process will probably increase in the future.

C). Hydropower. In Norway it plays a key role and can remain very significant in the future with investments in the reconstruction of existing stations. Most European countries do not have significant hydropower resources, so any large-scale development of corresponding stations for them is practically impossible. In some areas of the world, hydropower can develop, but in general this area of energy will be of only auxiliary importance.

D). Nuclear energy. The construction of traditional large nuclear reactors, which have been providing nuclear power for a long time now, is a complex problem. Such reactors are very expensive. There have been at least two recent examples of nuclear power plant construction in Europe being bequeathed with multiple increases in project deadlines and costs. According to the Associated Press, the 1,600 MW Olkiluoto 3 nuclear reactor in Finland was commissioned in 2022. Its construction was delayed by 14 years. Construction of the Olkiluoto 3 reactor began in 2005 and was scheduled to be completed in 4 years. Experts estimated the final cost of Olkiluoto 3 at approximately €11 billion (US$12 billion), almost three times the original cost [7, 8]. Another case took place in France. According to Deutsche Welle, the 1,630 MW Flamanville-3 reactor was built by mid-2024. Its construction took 17 years, and the cost reached €12.7 billion, four times the original estimate [9]. It can be argued that traditional large nuclear reactors have a very high risk of multiple increases in construction time and cost. These are very important factors that will restrain the development of such reactors.

E) As we see it, in the near future the very wide use of small modular nuclear reactors (with the capacity of one unit usually around 70-80 MW) and nuclear microreactors (with the capacity of 10 MW) can be extremely significant. This is due to many important advantages of SMRs, namely: modular design, relative simplicity, increased safety of the design, much shorter construction times

and costs compared to traditional large nuclear reactors, the possibility of serial production of modules at factories and their installation at the construction site, small capacity of one unit and the possibility of relatively quickly installing additional units as needed, wider placement options, high capacity factor. With all the positive qualities of wind and solar power plants, they have a significantly lower capacity factor, depend on the weather, wind energy, sunlight. To build a sufficiently powerful wind power plant, especially an offshore one, many wind turbines are needed, sometimes hundreds, which is difficult and time-consuming. Offshore conditions cause additional difficulties for the installation of installations and transmission of energy to the points of consumption. In order to decommission the most climate-damaging coal power plants, which are currently widespread in the world, in the short term, it is most expedient to use SMRs, since all other energy sources will not be able to cope with this task so quickly. It can therefore be stated that, in our opinion, SMRs are a new, innovative and key factor in decarbonization in the near future. This does not mean that in the long term, humanity will not be able to almost completely abandon the use of nuclear power plants. Such a situation is possible and expedient, with a high degree of probability, when wind energy as a clearly dominant and solar energy, hydropower and bioenergy will mainly meet the global needs of humanity. The use of nuclear energy in such a situation will be extremely limited, in some special cases.

F) The comprehensive use of all components is an important condition for the success of the decarbonization of the economy: we are talking about the development of advanced types of energy, taking into account their benefits for specific circumstances - SMRs, wind and solar energy, traditional nuclear energy, hydropower, bioenergy. Electric energy obtained in a climate-neutral way should be effectively used in the economy, in transport, where the key is the complete transition to electric vehicles on a global scale, the use of electricity and hydrogen fuel on railways and in maritime transport, in other areas.

Conclusions. The study established the following. Analysis of comprehensive and detailed information from the most authoritative international

organizations studying meteorological processes, global climate change is becoming increasingly intense and negative in its content. Norway occupies a unique position in the world in the development of climate-neutral energy production, in particular, hydropower, the rate of increase in the number of electric vehicles and public charging stations. To ensure sustainable development of mankind and decarbonization of the world economy, it is advisable to actively develop wind, especially offshore wind energy, solar power plants, and hydropower. Taking into account the new circumstances and trends in the near future, innovative small modular nuclear reactors, which can act as a key source of climate-neutral energy, are of particular importance for the global energy sector, as we see it. The most important factor in the development of the world economy is electric mobility and a complete rejection of engines using gasoline and diesel fuel.

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Стаття надійшла до редакції 09.01.2025 р.