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DECARBONIZATION MANAGEMENT: THE NECESSITY FOR RADICAL SOLUTIONS

МЕНЕДЖМЕНТ ДЕКАРБОНІЗАЦІЇ: НЕОБХІДНІСТЬ РАДИКАЛЬНИХ РІШЕНЬ

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The processes of recent climate changes in Europe and on the planet as a whole are considered. The negative economic consequences of climate change are shown. Such consequences are expressed in an increase in air temperature, droughts, a decrease in crop yields, hurricanes, the destruction of buildings, structures and communications, floods and flooding of large areas of land. The problem of sustainable development of mankind in terms of preserving the planet's climate for present and future generations should provide for the solution of a set of tasks: the production of primary energy in the global sense, using sources that do not cause significant harm to nature, and the transformation of such energy into other types of resources. A set of measures within the framework of the systemic model of decarbonization and the processes of managing the progress of their implementation are considered. In this context, the most important and promising direction is the development of wind energy, the second most important is the use of solar energy. Attention is drawn to the necessity for an integrated approach to the problem of decarbonization management.

Keywords: model, investments, development, globalization, ecology, management, decarbonization, world economy, prospects.

Активне зростання використання людством усіх природних ресурсів в індустріальну та постіндустріальну епоху призвело до вкрай негативного впливу людей на навколишнє середовище. Вказується, що нинішній стан справ із забрудненням атмосфери планети більше не можна ігнорувати. Руйнівні процеси не зупинені, становище у цій сфері з кожним роком стає дедалі складнішим. Раніше вжиті заходи не призвели до зміни ситуації. Зазначається, що необхідні значно радикальніші кроки щодо скорочення викидів шкідливих газів в атмосферу та уповільнення росту середньої температури на планеті. У зв'язку з цим дослідження щодо менеджменту виробництва енергії екологічними способами та її використання становлять значну актуальність.

Мета роботи полягає у тому, щоб сформулювати комплексну модель розвитку декарбонізації економіки із зазначенням важливості пріоритетів та визначення заходів у рамках ефективного управління таким процесом. У роботі використано комплексний підхід, методи аналізу та синтезу. Дослідження ґрунтуються на офіційних відомостях світової економічної статистики, вивченні даних авторитетних інформаційних агенцій. Розглянуто комплекс заходів у рамках системної моделі декарбонізації та процеси управління ходом їх реалізації. У цьому контексті найбільш важливим та перспективним напрямком є розвиток вітроенергетики, другим за значимістю є використання сонячної енергії. Будівництво гігантських за масштабом морських європейських вітропарків є магістральним напрямком розвитку енергетики в рамках декарбонізації та вказує на шлях глобального вирішення енергетичної проблеми людства та збереження клімату планети. Звертається увага на необхідність комплексного підходу до проблеми управління декарбонізацією. З розвитком інновацій відбувається помітне підвищення енергоефективності. Показано значне зниження енергоємності ВВП економіки Німеччини, де реалізується концепція сталого розвитку. Відзначено, що якщо цим шляхом піде безліч країн планети, такий розвиток може суттєво вплинути на процес декарбонізації. Практичне значення роботи полягає у тому, що її результати можна використовувати під час реалізації програми декарбонізації економіки.

Ключові слова: модель, інвестиції, розвиток, глобалізація, екологія, менеджмент, декарбонізація, світова економіка, перспективи.

Formulation of the problem. The world economy in the era of globalization is developing very actively. Economic activity in the post-industrial era has led to a sharp increase in the use of all natural resources. In recent years, the negative impact of mankind on the environment has taken on strong forms. This negative influence can no longer be ignored. Moreover, this negative impact already calls into question the numerous measures taken earlier to overcome the environmental threat. The ineffectiveness of the measures taken and the aggravation of the current situation have become obvious. There was a need for more radical and appropriate action.

Analysis of recent research and publications. The problem of management, innovation management is currently receiving much attention. Many works are devoted to general problems and applied issues in various areas of management. In the latest works of various researchers, the issues of decarbonization, preservation of the planet's climate, development of the world economy and increasing its efficiency in the information age are also considered.

Previously unsolved parts of the overall problem. Despite the many publications of various researchers, the issues of management and innovation management have not yet been studied in depth. This can be explained by the complexity of this problem and the active dynamics of changes in the global economy. In particular, the issues of decarbonization management, taking into account the development of processes in the light of new economic trends, require a deeper study.

Presentation of the main research material. Economic activity in the industrial and post-industrial era led to a gradual and then a sharp increase in the use of all natural resources. In recent years, the negative impact of mankind on the environment has already become so visible that it can no longer be ignored. Moreover, this negative impact calls into question the numerous measures already taken to tame the environmental threat, showing their inefficiency, exacerbating the current situation, but also requiring the need for more decisive and adequate actions.

The year 2022, like many previous years, was marked by high summer temperatures on the planet. According to The Copernicus Climate Change Service [1] and The New York Times [2], the severity of the situation is characterized, in particular, by the fact that: eight of the warmest years on earth have occurred since 2014; 2016 was also the hottest year for the entire observation period; the average temperature on the planet today is 1.2°C warmer than in the second half of the 19th century, a period of strong industrial growth and the beginning of a noticeable use of fossil fuels.

United Nations Environment Programme [3] indicates that active measures are needed to protect the environment: «The Climate Emergency we currently face requires adequate and immediate action. It is one of the most pervasive and threatening crises of our time. We are facing an existential threat and rapid prioritization of attention and action is necessary. If we continue along our current path, scientists say that the consequences will be devastating, having implications on where we live, how we grow food and other services vital to our well-being» [3].

Climate change leads to damage from numerous natural disasters, which in financial terms, according to Deutsche Welle [4], with reference to the largest and reputable

German reinsurance company Munich Re [5], in 2021 alone amounted to $ 280 billion in the world.

Hurricane Ida caused great damage to the United States. He was assigned the category of "exceptional dangerous." The hurricane completely disabled the power supply system in the metropolis of New Orleans in the US state of Louisiana. "Ida" collapsed in August-September 2021 on the coast of the Gulf of Mexico with wind gusts of 240 km/h [6].

The problem of sustainable development of mankind in terms of preserving the planet's climate for present and future generations should provide for the solution of such a set of tasks: the production of primary energy in a large, global sense, using sources that do not cause significant harm to nature, and the transformation of such energy into other types of resources; use in all possible areas, in particular, on all types of transport of ecological energy of various types, the primary sources of which are climate-friendly.

Following the goal of sustainable development, it is possible to propose such a model of decarbonization (Table 1), which covers a variety of areas of activity inherent in the modern global economy. The essence of the tasks of sustainable development and decarbonization is that they need to be addressed in a comprehensive, systematic and consistent manner. The solution of only a part of interrelated tasks will not lead to the achievement of the set goals.

At the same time, it is possible to formulate the most complex, unsolved for a long time, probably the most important scientific and technical problem of mankind: the use of thermonuclear fusion energy in the energy sector. In terms of significance, it surpasses all other tasks taken together, the complexity of achieving a successful result is so great that it is impossible to talk about it with any confidence, one has only to rely on the fact that local scientific achievements, accumulating in multitude, will finally reach the necessary “critical masses” and will lead to the implementation of such a grandiose project.

A very interesting technical solution for increasing the efficiency of wind energy, which is of global importance, was found in Denmark. According to Euronews [9], the country's authorities approved a grandiose plan to build a field of several hundred wind turbines 80 km from the coast. Although the country has a lot of experience in building such structures, this project is called the largest in Danish and probably world history. The cost of the project is about 28 billion euros, and its completion is expected in 2033. According to Dan Jørgensen, Danish Minister of Climate and Energy: “The planned capacity of the island is 10 GW, which is enough to provide 10 million 6 million people, so, naturally, we want to contribute to the development of a green strategy across Europe” [9].

A number of wind farms already operating in the world have high capacity, although they are many times inferior to the planned project in Denmark. For example, [10], the well-known British offshore wind farm London Array, located at the mouth of the River Thames, about 20 km from the coast, on which 175 turbines are installed, was the world's largest offshore wind farm during commissioning and had a capacity of 630 MW. London Array is very indicative, it can be compared in terms of power with an average thermal power plant.

According to Deutsche Welle [11], in September 2022, the energy ministers of the European Union members Belgium, Denmark, Germany, Ireland, Luxembourg, the Netherlands, France and Sweden, as well as Norway, agreed on an extremely large-scale investment plan that involves the joint construction and further use of wind farms. He assumes that already in 2030, their capacity in the North Sea (table 2) will increase 4 times - to 76 GW, by 2040 it will be 138 GW, and by 2050, when the European Union wants to achieve climate neutrality, it should reach 260 GW.

As further reported by Deutsche Welle [11], even earlier, at the end of August 2022, in Copenhagen, high representatives of the coastal countries of the Baltic Sea, namely: Germany, Denmark, Latvia, Lithuania, Poland, Finland, Sweden and Estonia, reached an agreement by 2030 to increase available capacities of offshore wind farms by 7 times and bring them up to (table 2) 20 GW. By 2050, this indicator should increase to 93 GW.

An analysis of the plans for the development of offshore wind farms for the period up to 2050 in the North and Baltic Seas shows that their total capacity of 353 GW is significantly higher than the installed capacity of generating sources of electricity in Germany in 2021, which amounted to approximately 232 GW [12]. It is also necessary to take into account the already existing wind power plants and the development of wind energy on the European mainland, the development of solar energy. It is also necessary to take into account the constant decrease in the energy intensity of the GDP of European countries, especially Germany. All this suggests

Table 1

Integrated model of environmental development management

№	Development direction	State of the issue and prospects	Geography of development
1	Development of wind power plants	Wind power industry appears in a fairly close perspective as a leading source of energy. In recent years, the share of wind farms in the production of electricity in Germany was at the level of 25–27%, in Denmark about 55–56% with a constant increase in the efficiency of such stations. The problem of wind energy is the unevenness of their work and the need to accumulate the energy they produce. In addition, due to the relatively low energy output of one station, a large number of installations are required. Very promising.	In different regions of the world
2	Development of solar energy	Solar power plants already occupy an important place in the production of electricity in the world today. In Germany, their share accounts for approximately 8% of annual electricity production. They require fairly large areas for electrical panels. However, it is an important promising source of energy. Dynamically developing.	The most powerful, gigantic power plants can be located in desert areas with energy transmission to places of consumption. Other electrical installations are everywhere
3	Development of traditional nuclear energy	Currently, according to the International Atomic Energy Agency (IAEA), more than 400 nuclear reactors in 30 countries provide about 11% of global electricity production [7].	At a distance from cities
4	Development of small nuclear reactors	Currently, small and medium power reactors or modular reactors are not widely used in the world energy industry, but recently many companies in a number of countries around the world have been busy studying the possibility of their application and developing practical samples of such reactors. Such reactors can have a power of about 50-70 to 300 MW, which is much less than conventional reactors of nuclear power plants. For example, the nuclear reactors used in France today have a capacity of between 900 MW and 1450 MW.	Almost everywhere, including in cities
5	Development of electric mobility	The direction of the transition to the use of electric cars instead of cars with internal combustion engines is supported by the leading automotive concerns of the planet and the governments of many countries. At the turn after 2030, it is likely that electric vehicles will dominate the production of new cars.	In different regions of the world
6	Use of hydrogen as fuel in transport	Currently, hydrogen as a fuel is used in an extremely limited way. The problem of using hydrogen is largely economic. As the cost of oil and gas on the world market increases, and recently there has been a multiple increase in prices for such resources, the use of hydrogen is becoming more and more justified.	
7	Savings in the use of energy in all spheres of activity	Currently, in economically developed countries, on the basis of a complex of factors, structural changes in the economy, there is a noticeable decrease in the energy intensity of GDP. For example, in Germany (Fig. 1) [8] from 1990 to 2019, this indicator decreased by 41%. In a number of countries, the efficiency of energy use is at a very low level and there are no noticeable changes in this direction.	

that in the future, wind and solar energy will provide most of the energy needs, and possibly even fully meet the energy needs of Northern Europe.

Development dynamics of offshore wind farms in Northern Europe

Period	Pressure, GW	
	North Sea	Baltic Sea
2030	76	20
2040	138	no data
2050	260	93

Source: based on [11]

The construction of giant-scale marine European wind farms is the most important, major direction of energy development within the framework of decarbonization and indicates the path to a global solution to humanity's energy problem and preservation of the planet's climate.

Significant achievements and prospects of global solar energy. For example, the world's largest solar park on one site with a planned total capacity of 5,000 MW by 2030 will be the Mohammed bin Rashid Al Maktoum Solar Park – a network of solar power plants in the desert in the United Arab Emirates [13]. This can be compared to the largest power plants on the planet.

Recently, according to the British Broadcasting Corporation [14], a European team of scientists from the JET physics laboratory located near Oxford demonstrated for the first time in practice the possibility of creating thermonuclear power plants. In the course of the JET experiment, which lasted about five seconds, physicists managed to obtain the amount of useful energy, which is more than twice the previous world record set during the conduct of similar experiments in 1997, Dr. Joe Milnes, head of the technical part, told journalists of the experiment and responsible for the operation of the reactor. Construction of the International Thermonuclear Experimental Reactor (ITER), the first operational thermonuclear reactor, began in 2020 at the Cadarache research center in southern France, 65 km from Marseille. ITER should become the first industrial reactor where the thermonuclear fusion reaction can be scaled [14].

According to the International Atomic Energy Agency (IAEA): "There is growing interest worldwide in small and medium-sized reactors or modular reactors due to their ability to meet the need for flexible power generation for different users and applications and to replace aging power plants. operating on organic fuel. In addition, they are options suitable for remote regions with less developed infrastructure and open the possibility of creating synergistic hybrid energy systems combining nuclear and alternative energy sources, including renewable sources" [15]. It can be assumed that the coming decades will be a period of massive use of modular reactors, and this use will be of a global nature.

As innovations develop, there is a noticeable decrease in the energy intensity of GDP in a number of developed countries. The most important economy in Europe, Germany, can be an example of other states (Fig. 1, [8]). The concept of sustainable development is practically implemented here. If many countries of the planet follow this path, it can significantly positively affect the decarbonization process.

As reported by the Voice of America [16], in December 2022 in the USA, the greatest scientific success was officially announced: for the first time, more energy was produced during the thermonuclear fusion reaction than was spent on its implementation. The US Department of Energy reported that scientists from the Livermore National Laboratory in California achieved success. This theoretically enables fundamental breakthroughs in the field of national defense and "clean" energy, US Energy Secretary Jennifer Granholm said. She added that this is one of the outstanding scientific achievements of the 21st century, which will remain in the history books. Kim Badil, director of the Livermore Laboratory, stated that this success could lead to the technology gaining practical application in a few decades, rather than in 50–60 years, as previously believed [16].

As part of the management of the decarbonization of the economy for the near and more distant perspective, it is expedient to implement such measures.

1. Radical, multiple expansion of wind energy capacity worldwide, especially in shallow areas of the world ocean, as is planned, for example, in northern Europe, as well as in unused areas of land.

2. Increasing the capacity of solar power plants. Large and giant solar stations can be located in deserts, as is already done in a number of projects.

3. Development of means of energy transmission and accumulation. Much of the energy, it seems, will be produced in remote areas of the planet and transmitted to places of consumption in various ways.

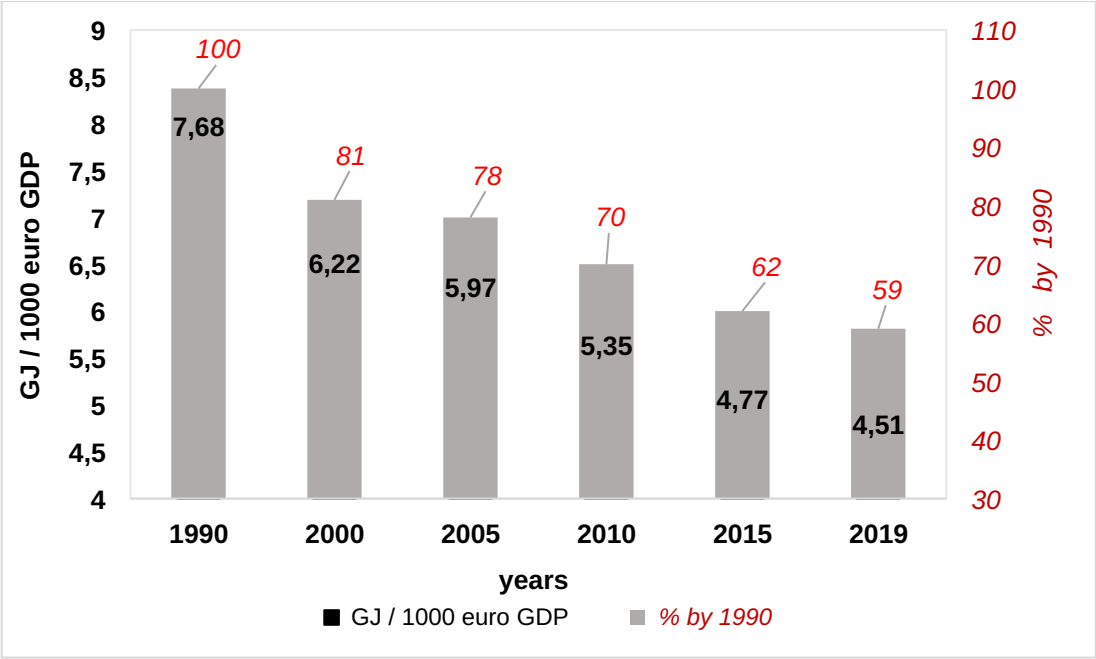

Figure 1. Energy intensity of Germany's GDP

Source: based on [8]

4. Development of small modular nuclear reactors, usually directly in places where energy is needed.

5. Radical strengthening of attention to solving the problem of peaceful use of thermonuclear energy. Here, despite the extreme complexity of the problem, the maximum scientific and technical efforts and investments of the world's leading countries should be concentrated in view of the colossal effect in case of its successful solution.

6. Increasing energy efficiency in all spheres of life. In the economically developed countries of the world, there are many successful examples of solving this problem, which should be followed in the future.

An important specific feature of decarbonization management is the need to inform the population of various countries, the general public about the correct decarbonization measures. The right decarbonization measures may not be clear to everyone. Such measures may be unaccustomed to the population. Such measures may be associated with temporary difficulties for the population, an increase in energy costs for the population. Therefore, such decarbonization measures are likely not to be supported by the entire population. But without the support of the population, the success of reforms in the modern world is impossible. Without the support of the population, the success of complex energy reforms and decarbonization is impossible. Therefore, in the management of decarbonization, measures to constantly inform the population about the right measures to decarbonize the economy are of key importance.

Conclusion. Thus, the analysis of the processes currently taking place in the field of climate change and energy showed the following. The economic activity of mankind has led to noticeable negative processes in the surrounding natural environment, the damage from which continues to increase. This difficult problem can no longer be ignored. For the prospects of the global economy of the planet through decarbonization, it is advisable to focus efforts on the development of wind and solar energy, as well as to combine them with maximum economy in the use of all resources.

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