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INTEGRAL MODEL OF DECARBONIZATION MANAGEMENT IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT CONCEPT

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Methods. Analysis of various factors of influence of the world economy on climate change of the planet in the industrial and modern periods of development, research on issues of management of production and placement of primary electricity sources and their transformation, use of various types of climate-neutral energy in transport. The article implements a comprehensive approach that includes methods of analysis and synthesis. The study is based on official information from the UN, international energy agencies, world economic statistics, leading aviation and automobile concerns.

Results. Based on the analysis of the dynamics of innovation processes, an integral model of decarbonization management is proposed, which includes, in a complex and interrelated manner, such elements that must be developed in priority order, taking into account the coordination of scientific and technical efforts and investment resources of the world's leading countries, international organizations, universities, scientific centers and various organizations, namely: wind power plants, solar energy, electricity storage, traditional nuclear energy, small nuclear reactors, electromobility, use of hydrogen as fuel in transport, energy saving measures.

Novelty. Based on the analysis of the dynamics of innovation processes in the world economy, an integrated model of decarbonization management is proposed in the context of the concept of sustainable development.

Practical value. Analysis of the dynamics of climate change showed a significant increase in average temperatures in most regions of the planet compared to the pre-industrial period of human civilization. In recent years, the number and intensity of various negative climatic events, floods, landslides, hurricanes, droughts, loss of agricultural crops, and forest fires have significantly increased, which, on a global scale, leads to multibillion-dollar economic losses. The most important scientific and technical problem of the modern economy can be considered as the possibility of obtaining primary energy on a scale that satisfies the needs of humanity, in ways that do not harm nature, and the transformation of primary energy into other types of energy for their final use in various spheres of activity, in particular, in transport. The integrated model of decarbonization management facilitates the adoption of management decisions regarding the development of the most significant areas of activity in the context of the concept of sustainable development.

***Keywords*:** management, decarbonization, integral model, management solutions, sustainable development.

Statement of problem. Humanity's influence on the planet's climate is becoming more and more large-scale. This is caused both by the intensity of modern technogenic influence caused by active economic activity, rapid population growth, and the potential for ecological destruction accumulated over many decades of industrial development, which, in joint action, has led to noticeable, perhaps even irreversible climate changes that determine the future existence of civilization. In this

connection, it is expedient to study a set of measures to reduce human impact on nature, determine their priority for further implementation when solving practical tasks.

Analysis of recent papers. Many works by various authors are devoted to the analysis of management issues and management of innovations. However, it should be noted that in the conditions of the dynamic course of global climate changes, which are accompanied by significant financial losses, various directions of neutralization of negative effects on the environment require research which must be considered comprehensively.

Aim of the paper. The purpose of the article is to analyze the dynamics of the planet's climate change, its negative manifestations, innovative processes in the field of energy production and conservation, its use, and, as a result, the development of an integrated model that contributes to the adoption of effective management decisions in the context of sustainable development.

The results of recent studies by various international organizations in the field of global climate change are disturbing. According to the British Broadcasting Corporation (BBC) [1], which refers to the report of the authoritative Copernicus Center under the EU [5], active processes of climate change are taking place on the planet, which, in particular, have the following manifestations:

– in July 2021, in a number of areas of Europe, regions with soils close to water saturation experienced very intense rainfalls, which led to severe floods in several federal states of Germany, Luxembourg, the Netherlands and Belgium;

– in the summer of 2021, very high air temperature was observed in a number of European countries, for example, Italy, Spain, Greece;

– the level of the maximum temperature in Europe was exceeded on the island of Sicily, where 48.8 °C was recorded, which is 0.8 °C higher than the previous maximum;

– a long period of a combination of high temperature and lack of rain contributed to very widespread forest fires in Europe and North Africa, in a number of areas of the Mediterranean Sea, in particular, in Greece, Albania, Portugal, Spain, Italy, Tunisia and Algeria.

According to the Copernicus Center at the EU [2] (Fig. 1), the air temperature in 2021 compared to the average value for 1991–2020. underwent the following changes:

– there was an increase in air temperature over a larger area of the planet;

– a particularly significant increase is observed in such areas as the eastern part of North America, adjacent areas of the Atlantic Ocean, on the island of Greenland and in its coastal waters, in a number of areas of the Arctic Ocean, in the south of South America and adjacent waters of the Atlantic, on a large part of Antarctica, in North and a number of areas of Central Africa;

– a significant increase in air temperature is observed in almost the entire territory of the USA, in the area of the Arabian Peninsula and in many parts of Asia, including in the territory of the eastern regions of China and in the entire territory of Japan, New Zealand, part of Indonesia, and a large part of the surface of the Pacific Ocean;

– a moderate increase in air temperature was noted over large areas of the southern part of the Atlantic, almost the entire area of the Indian Ocean and a large part of the Pacific Ocean.

According to the same data [2] (Fig. 1), in some areas of the planet there is a moderate, and in some – a rather noticeable decrease in air temperature, for example, in part of Antarctica, in Alaska and in a number of areas of western Canada, places in the southern Pacific ocean, over most of Australia and in some areas of the South Atlantic, as well as in some other places.

In general, according to data [2] (Fig. 2), the past «2021 takes the fifth place in the ranking of the warmest years. The first five months of the year were cooler, and from June to October global average temperatures were among the highest on record. So, last year the average annual air temperature in the world was 0.3 °C higher than the average for 1991–2020, and also 1.1-1.2 °C higher than in the pre-industrial period from 1850 after 1900 In 2021, Europe experienced the hottest summer on record».

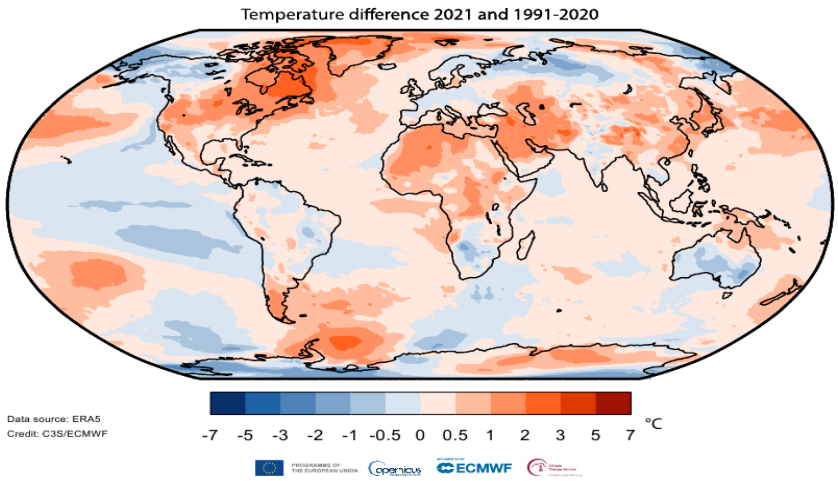

Fig. 1. Air temperature for 2021 compared to the average value for the years 1991–2020
Source: [2]

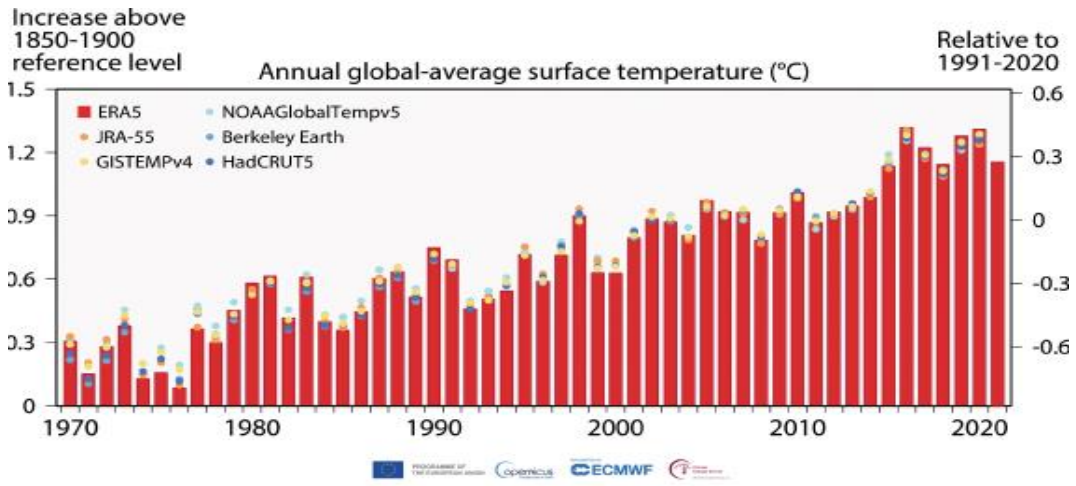

Fig. 2. Average annual values of global air temperature, estimated change from the pre-industrial period (left axis) and in relation to 1991–2020 (right axis) from different datasets
Source: [2]

The planet has also seen a number of extreme weather events, such as heatwaves in the Mediterranean region and severe flooding in Central Europe. It is indicated that the concentration of greenhouse gases in 2021 continued to increase, as evidenced by the preliminary analysis of satellite measurements. New record concentrations of carbon and methane were registered [2].

Climate change leads to damage from numerous natural disasters (Fig. 3), which in financial terms, according to Deutsche Welle [3], with reference to the largest and most authoritative German reinsurance company Munich Re [4], in 2021 alone amounted to 280 billion dollars in the world. The largest economy of the planet, the economy of the USA, suffered losses of about 145 billion dollars from natural disasters. Hurricane Ida, which was assigned the category of «extremely dangerous», completely disabled the power supply system in the metropolis of New Orleans in the American state of Louisiana. «Ida» hit the coast of the Gulf of Mexico with wind gusts of 240 km per hour [5].

The problem of sustainable development of humanity in terms of preserving the planet's climate for current and future generations should involve solving the following set of tasks:

– production of primary energy globally in a large amount using sources that do not cause significant damage to nature, and transformation of such energy into other types of resources;

– in all possible areas, in particular, on all types of transport, the use of ecological energy of various types, the primary sources of which are climatically safe.

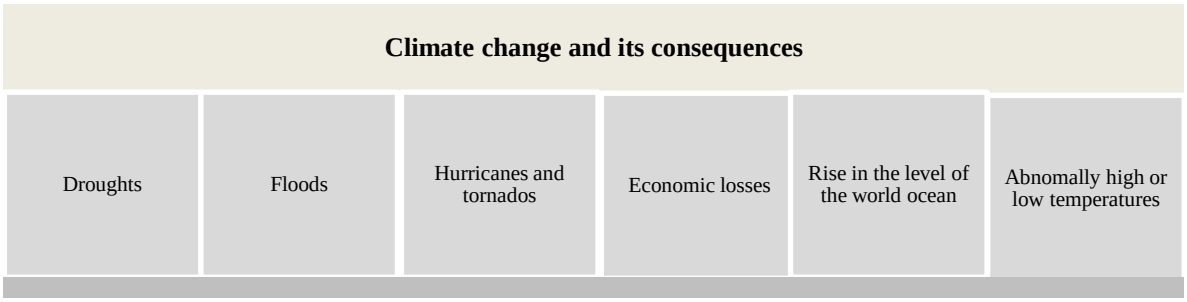

Fig. 3. Effects of climate change

Following the goals of sustainable development, it is possible to propose the following model of decarbonization (Table 1), which covers very different fields of activity typical of the modern global economy. The essence of the tasks of sustainable development and decarbonization is that they must be solved comprehensively, systematically and consistently. Solving only a part of the interdependent tasks will not lead to the achievement of the set goal.

Table 1

An integral model of decarbonization management

№	The direction of integral development	State of the problem	Perspectives and possible solutions
1	Development of wind power plants	In the near term, wind power is seen as a leading source of energy. In recent years, the share of wind stations in the production of electricity in Germany was at the level of 25–27%, in Denmark it was about 55–56%, because of the constant increase in the efficiency of such stations. The problem of wind energy is the unevenness of its operation and the need to accumulate the produced energy. In addition, due to the relatively low energy production of one station, a large number of installations is required.	To solve the problem of uneven operation of wind power plants, to increase their power and efficiency, it is promising to place wind power plants in shallow areas of the World Ocean. Such an idea is based on the fact that, with rare exceptions, winds sufficient for the operation of installations are almost always present in marine areas. At the same time, the majority of such power plants can be located in coastal areas, especially where there is a demand for electricity. At the same time, in a more distant perspective, one of the ways to develop wind energy is the placement of power plants in various, even very remote areas of the World Ocean with the production of hydrogen in such places and its subsequent transportation to areas of consumption.
2	Development of solar energy	Solar power plants already occupy an important place in the production of electricity in the world today. In Germany, they account for approximately 8% of annual electricity production. They require fairly large areas for electric panels, which is quite difficult in densely populated areas, for example, in Europe. Nevertheless, it is an important promising source of energy. Dynamically developing.	Prospects for the development of solar power plants can be largely connected with the placement of gigantic power plants in terms of area and significant power in desert areas of the planet, where agricultural activity is impossible. Because of the large number of sunny days in a year, such plants are able to produce energy in a volume comparable to large thermal or nuclear plants. Transmission of electricity from production areas to consumption areas is possible with the help of power lines, as well as underwater cables. As one of the options, the production of hydrogen in the places of electricity production and its transportation to the areas of consumption can be considered.

Continuation of table 1

3	Development of electricity storage devices	The problem of saving electricity produced by wind and solar power plants is largely related to the uneven operation of such stations, but is also exacerbated by the unevenness of electricity consumption. Hydro-accumulating stations served as energy accumulators in significant quantities for a long time. Along with important advantages, they require significant costs for construction and operation and have efficiency problems.	Currently and in the future, the Tesla Megapack, large-sized lithium-ion batteries manufactured and installed by Tesla Inc. can act as energy storage devices. Each Megapack can store up to 3 MWh of electricity. More than 100 such accumulators can be quickly mounted on large accumulator stations. The Megapack can be used to store energy generated by intermittent renewable energy sources such as solar and wind. Stored energy is used as needed, for example, during periods of peak demand.
4	The development of traditional nuclear energy industry	Currently, according to the International Atomic Energy Agency (IAEA), more than 400 nuclear reactors in 30 countries provide about 11% of global electricity production [6]. Traditional large nuclear power plants occupy an important place in many developed countries, for example, France. According to [7], France ranks first in the world today in terms of the specific weight of atomic energy in the electric power industry (about 70%). As of July 2020, France has 56 industrial nuclear reactors in operation with a total capacity of 61.4 GW. France is the largest exporter of electricity in the world [7].	The European Union recognizes nuclear energy as environmentally acceptable, at least from some perspective. This is with the aim of ensuring climate neutrality by 2050, which is in line with international obligations. Research by the International Atomic Energy Agency shows that in conditions of high prices for natural gas, the best opportunities for hydrogen production, which will then be used in transport and other areas, are related to nuclear energy [8]. In the future, thermonuclear energy can appear on a global scale as an extremely important source of energy, surpassing all others in importance. The realization of this does not belong to the near future of humanity, but significant efforts of world science are being made in this direction
5	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 900 to 1450 MW.	Small modular reactors (SRMs), according to the International Atomic Energy Agency (IAEA) [9], are «modern nuclear reactors that can produce a large amount of low-carbon electricity. Many SMRs are under construction or licensing in Argentina, Canada, China, Russia, the United States of America, and South Korea. There are more than 70 commercial SMP projects under development worldwide, designed for different performance and different application fields, such as electric power, hybrid energy systems, heating, water desalination and steam generation for industrial applications. SMPs have lower capital costs per unit of production» [9].

Continuation of table 1

6	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, electric vehicles will probably dominate the production of new cars. The implementation of electric mobility is restrained by the higher cost of electric cars, caused mainly by the price of batteries, their small capacity, longer charging times and insufficient number of charging stations	There is a very intense development of scientific research in the field of significantly reducing the cost of batteries, increasing the energy density and capacity of batteries, which brings significant results. Accumulator batteries that are currently used provide an electric car with a range of about 400-600 km, which can already be compared with conventional cars. Prospective models of a number of companies, in particular, Mercedes-Benz and Tesla show mileage on one charge at the level of 1000-1200 km with the use of high-density batteries. There is an significant decrease in the price of batteries. Innovations related to the improvement of batteries and their recycling, the development of a network of charging stations are supported by multibillion-dollar subsidies from the governments of the world's leading countries. With great probability, we can assume that such efforts will make it possible to obtain competitive electric cars and ensure their charging capabilities in the near future.
7	Using hydrogen as a fuel on 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 the price of such resources, the use of hydrogen becomes more and more justified.	Hydrogen as energy can be used in various types of transport, for example, in railway transport, in sea and ocean transport, in long-distance passenger buses. The use of hydrogen as aviation fuel is particularly interesting. Research in this direction is conducted, in particular, by the European aircraft manufacturer Airbus, which presented three aircraft concepts (Fig. 5) capable of flying with zero CO2 emissions [10].
8	Energy saving in 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. 6) [11] 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.	Saving energy in all areas of activity is possible when using the experience of advanced countries and implementing projects in the field of energy production and use, in heating systems, in transport, in everyday life, when improving technological processes in industry, construction, and other industries.

At the same time, it is possible to formulate the most difficult and probably the most important scientific and technical task of mankind, the one that has not been solved for a long time: the use of thermonuclear fusion energy in electricity generation. In terms of significance, it surpasses all other tasks, taken together, the difficulty of achieving a successful result is so great that it is impossible to speak about it with any confidence, one should only count on the fact that local scientific achievements, accumulating in abundance, will finally reach the necessary “critical masses” and will lead to the implementation of such a grandiose project.

The development of electric mobility can be the most important mechanism of global decarbonization. The most acute problem here is the improvement of batteries. A joint study published by the European Patent Office (EPO) and the International Energy Agency (IEA) [12, 13] indicates, in particular, the following (Fig. 4):

– enterprises of South Korea and Japan, which include Samsung, Panasonic, LG, Toyota and Hyundai, clearly occupy leading positions in the world in the field of battery technologies;

– as a result of the development of innovations, as well as the influence of the mass production factor, there was a sharp decrease (by approximately 90% compared to 2010) of prices for lithium-ion batteries for electric vehicles.

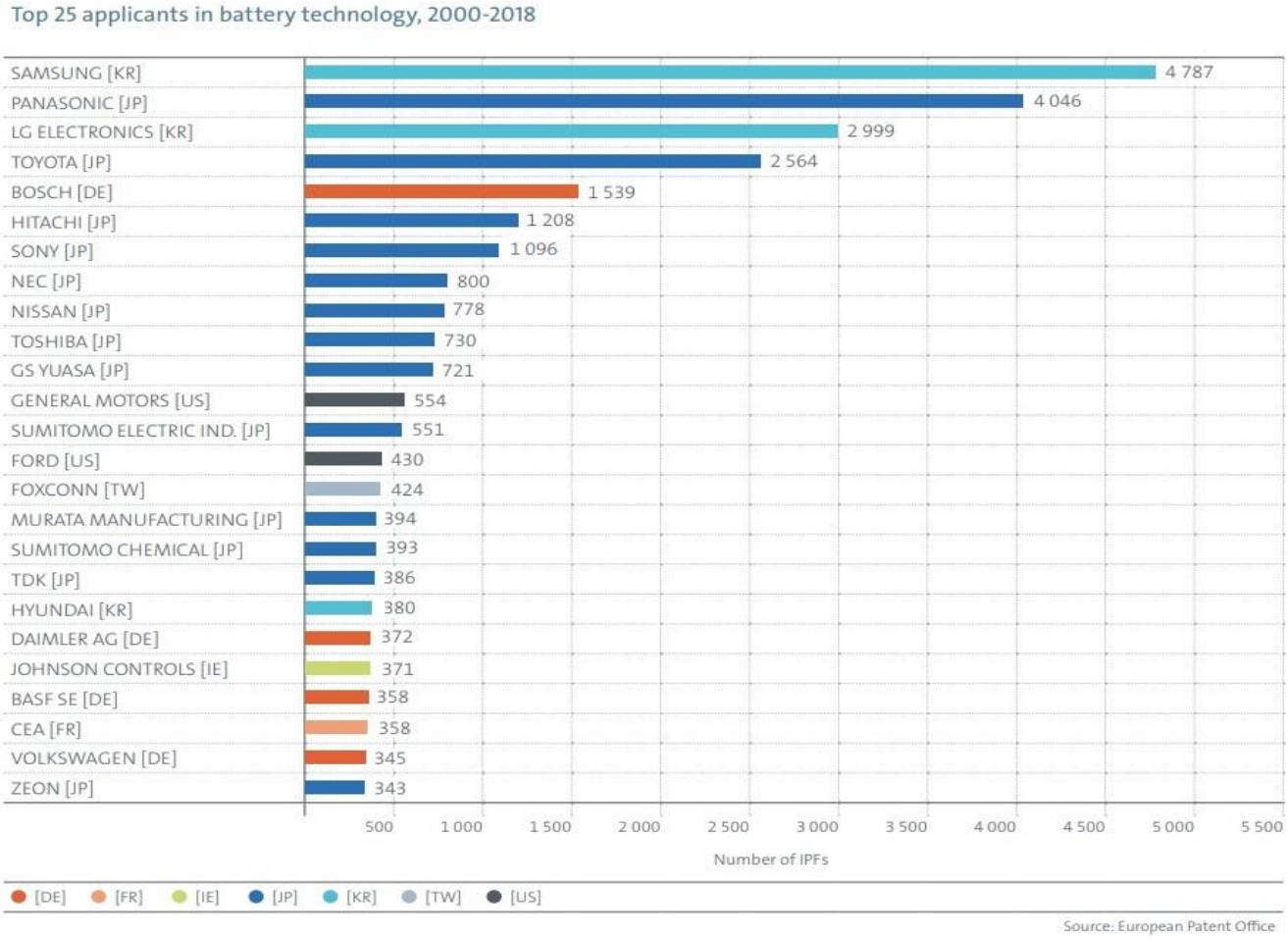

Fig. 4. Leaders in the field of battery technologies, 2000–2018.
Source: [13]

Europe is making active efforts to improve batteries. According to Deutsche Welle [14], the European Union allowed the governments of 12 countries to allocate 2.9 billion euros for state support to 42 companies that are developing innovative technologies for the production and disposal of batteries for electric vehicles. These subsidies are expected to bring in another 9 billion euros of private investment. The European Commission indicates that these companies plan to implement about 300 projects by 2028, which will involve more than 150 partners from all over Europe - universities, research centers, small and medium-sized enterprises.

As the authoritative German radio station [14] further emphasizes: «About three years ago, the battery industry in the EU was practically non-existent. Today, Europe is the global center of the battery industry», said Maros Šefčovych, Vice President of the European Commission (EC), the main executive body of the EU, giving the «green light» to the European Battery Innovation project. It is recognized as a «project of pan-European interest» (IPCEI). «Thanks to the focus on next-generation batteries, this

powerful pan-European project will help revolutionize the battery market», says Marosh Šefčovych. According to him, by 2025, batteries created in the EU will annually drive at least 6 million new electric cars [14].

As reported by Deutsche Welle, back in September 2020, the American entrepreneur Elon Musk stated the following during the Tesla Battery Day online presentation: «We don't have an affordable car, but we will have one. However, for this we have to reduce the cost of batteries». He expressed his readiness after about three years to organize the production of significantly more capacious batteries of the new generation, while their price will be half as low. And then, Elon Musk noted, «we will be able to produce a very convincing electric car at a price of $25,000» [15]. In January 2022, according to CarAndDrive [16], the Tesla Model S electric car covered 1,200 km on a single charge thanks to the use of a battery created by engineers at Michigan-based startup Our Next Energy. So, at least in terms of battery capacity, Elon Musk's predictions are likely to be confirmed.

A very interesting technical solution to increase the efficiency of wind energy, which is of global importance, was found in Denmark. According to Euronews [17], the country's authorities have approved a grandiose plan to build a field of several hundred wind turbines 80 km from the coast. Although the country has extensive experience in the construction of similar objects, this project is called the largest in the history of Danmark, and probably world history. The expected cost of the project is about 28 billion euros, and its completion is expected in 2033. As noted by Dan Jorgensen, Minister of Climate and Energy of Denmark: «The planned capacity of the island is 10 GW, which is enough to provide for 10 million families. Only about 6 million people live in Denmark, so, naturally, we want to contribute to the development of a «green» strategy on a Europe-wide scale» [17].

A number of wind power plants, which are already operating in the world, have a high capacity, although they are many times inferior to the planned project in Denmark. For example, [18], the well-known British offshore wind farm London Array, located in the mouth of the River Thames, approximately 20 km from the coast, on which 175 turbines are installed, was the largest offshore wind farm in the world at the time of commissioning and had a capacity of 630 MW The London Array is very representative, in terms of power, it can be compared with an average thermal power plant.

The world's largest solar park on one site with a planned total capacity of 5 GW by 2030 will be the Mohammed bin Rashid Al Maktoum Solar Park – a network of solar power plants in the desert in the UAE [19].

Recently, according to the British Broadcasting Corporation [20], a European team of scientists from the JET physics laboratory, located near Oxford, for the first time demonstrated 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. «The conducted JET experiment brings us one step closer to fusion power», Dr. Joe Milnes, head of the technical part of the experiment and responsible for the operation of the reactor, told reporters. 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 [20].

According to the International Atomic Energy Agency (IAEA): «There is growing interest worldwide in small and medium-sized reactors or modular reactors because of 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. They also have improved safety performance…, lower initial capital costs. 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» [21].

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.

One of the world leaders in aircraft construction, the Airbus concern, declares that it

considers hydrogen to be an extremely promising aviation fuel of the future and the key to achieving the goals of reducing the impact of aviation on climate change. Airbus presented three concepts of the world's first commercial passenger aircraft with zero carbon dioxide emissions (Fig. 5), which can be put into operation in 2035 [10]. All of them should run on hydrogen fuel. Airbus CEO Guillaume Faury said: «These concepts will help us explore and refine the design and layout of the world's first zero-emissions commercial aircraft… The transition to hydrogen as the primary energy source for these concept aircraft will require decisive action from the entire aviation ecosystem. Together with the support of government and industrial partners, we can solve this challenge of expanding the use of renewable energy sources and hydrogen to ensure a sustainable future for the aviation industry» [10]. Underscoring the importance of the global aviation transition to hydrogen fuel, Guillaume Faury said: «This is a historic moment for the commercial aviation sector as a whole and we intend to play a leading role in the most important transition the industry has ever seen. I firmly believe that the use of hydrogen - both in synthetic fuel and as the main source of energy for commercial aircraft - can significantly reduce the impact of aviation on the climate» [10].

Fig. 5. Concepts of hydrogen-fueled aircraft of the Airbus concern
Source: [10]

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 serve as an example for other countries (Fig. 6). The concept of sustainable development is practically implemented here. The active growth of the economy based on innovative development, the increase in the standard of living of the population in the German social market economy is accompanied by a significant decrease in the specific consumption of energy resources. If many countries of the planet follow this path, it can significantly positively affect the decarbonization process.

The development of decarbonization processes and an important component of this multifaceted phenomenon - electromobility should be facilitated by a number of constituent elements that may be present in different states to a certain degree or be absent. The specified elements can manifest themselves strongly or only emerge. Such components should include the following:

– economic capabilities of the state to carry out decarbonization;

– political opportunities determined by various components, such as the attitude to the problem of decarbonization of the executive power, the ratio of views of the coalition forces in the countries where they form the executive power;

– attitude to decarbonization in the parliaments of the countries on the part of the

parties represented there, taking into account the political traditions of the specific country;

– technological conditions of the countries' economic, scientific and technical capabilities determined by their level of development;

– the presence of restraining factors, such as, for example, a traditionally developed coal industry and a large number of people working in this industry, who are voters and whose opinion cannot be ignored by political forces.

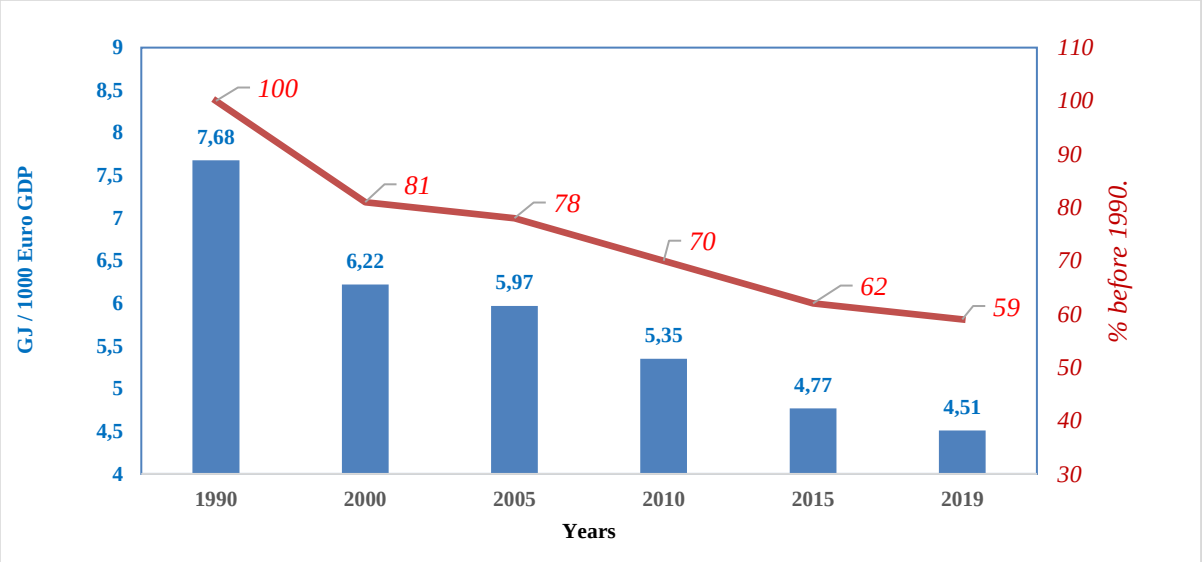

Fig. 6. Dynamics of the energy intensity of GDP of the Federal Republic of Germany
Source: [11]

The combination of influencing factors looks very interesting in such an important country as Germany, in which, according to the results of the elections held in the fall of 2021, a new coalition was formed. The features that create the attitude of the government, business circles, citizens, scientific, technical and financial capabilities of the country are as follows:

– commitment of the government coalition to decarbonization and electromobility;

– positive attitude to this process of other parties that are not part of the coalition;

– support for decarbonization in society, among broad social groups, which has been taking place for quite a long time;

– support of representatives of German business of both the largest and medium and small companies;

– the most powerful network of universities, scientific institutions, the ancient history of the country as one of the most important centers of world science and technology;

– a highly developed production base, the presence of multi-branch mechanical engineering, electrical engineering, electronics, machine tool construction, chemical industry, etc.

Conclusions. So, the analysis of the problem of climate change and the development of decarbonization processes showed the following. As a result of active innovation efforts, the most important element that determines the efficiency of the development of electric mobility – batteries have significantly decreased in cost. New generation batteries, the development of which is being conducted by the world's leading concerns with the assistance of universities, research centers and multibillion-dollar subsidies from the European Union, as it appears, will have even greater energy density, capacity and will provide a significant increase in the efficiency and competitiveness of electric cars.

The statement of Elon Musk, a person whose name is inextricably linked with the technical progress of mankind, about a significant reduction in the cost of electric cars that are produced, will most likely be successfully implemented, and the number of

such cars and concerns that will be able to produce them will increase rapidly increase.

A significant increase in global oil and natural gas prices makes electric vehicles even more competitive. At the same time, it accelerates the transition to such ecological sources of energy as wind or solar.

The use of wind power plants located in coastal waters, on natural or artificial islands, shallow waters of the World Ocean, where significantly higher wind intensity and stability are observed, will allow to radically increase the production of electricity at such stations on a global scale. In the history of mankind, it is the unprecedented large-scale use of wind energy, which is produced in the vast expanses of the oceans and its transmission in various ways, even by transformation into other types, will allow in the near future to almost completely solve the energy problem of civilization, waiting for the time when it will be fully resolved during the implementation of projects for the use of thermonuclear reactors.

One of the important ways of reducing the human impact on nature can be a consistent reduction of the energy intensity of GDP, energy demand through the improvement of technologies in the broadest spheres of activity, which has already been quite noticeable in the leading countries of the world during the last few decades.

The largest solar power plants occupying gigantic areas will be created in the desert regions of the planet, their power will be comparable to large thermal or nuclear plants.

In many cases, the transmission of electricity from large, remote locations of its production will probably be possible using submarine cables, in other cases, hydrogen production and its subsequent transportation to consumption locations may be established to conserve energy.

Small modular nuclear reactors are likely to be a supplement or even a replacement for traditional large nuclear reactors, with their help it will be possible to produce large volumes of hydrogen, which will act as a fuel in aviation, on sea and river vessels and in a number of other areas.

Efforts in the field of using fusion energy will continue. In this direction, taking into account the colossal global importance of this problem, it is necessary to multiply the intensity of work and their funding within the framework of international projects with the participation of the leading countries and scientific centers of the planet.

Further research should be extended to the study of logistical aspects of decarbonization.

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ІНТЕГРАЛЬНА МОДЕЛЬ МЕНЕДЖМЕНТУ ДЕКАРБОНІЗАЦІЇ У КОНТЕКСТІ КОНЦЕПЦІЇ СТАЛОГО РОЗВИТКУ

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Методологія дослідження. Аналіз різних факторів впливу світової економіки на зміну клімату планети в індустріальний та сучасний періоди розвитку, дослідження питань управління виробництвом та розміщенням джерел отримання первинної електроенергії та їх трансформації, використання різних видів кліматично-нейтральної енергії на транспорті. У статті реалізовано комплексний підхід, що включає методи аналізу та синтезу. Дослідження ґрунтується на офіційних відомостях ООН, міжнародних енергетичних агентств, світової економічної статистики, провідних авіаційних та автомобільних концернів.

Результати. На основі аналізу динаміки інноваційних процесів запропоновано інтегральну модель менеджменту декарбонізації, яка включає у комплексі та взаємозв'язку такі елементи, які необхідно розвивати у пріоритетному порядку, з урахуванням координації науково-технічних зусиль та інвестиційних ресурсів провідних країн світу, міжнародних організацій, університетів, наукових центрів та різних організацій, а саме: вітрові електростанції, сонячну енергетику, накопичувачі електроенергії, традиційну атомну енергетику, малі атомні реактори, електромобільність, використання водню як палива на транспорті, заходи економії енергії.

Новизна. На основі аналізу динаміки інноваційних процесів у світовій економіці запропоновано інтегральну модель менеджменту декарбонізації у контексті концепції сталого розвитку.

Практична значущість. Аналіз динаміки кліматичних змін показав помітне збільшення середніх температур у більшості регіонів планети порівняно з доіндустріальним періодом розвитку людської цивілізації. В останні роки значно зросли кількість та інтенсивність різних негативних кліматичних проявів, повеней, зсувів, ураганів, посухи, втрати врожаю сільськогосподарських культур, лісових пожеж, що, в масштабах планети, призводить до багатомільярдних економічних збитків. Найважливішою науково-технічною проблемою сучасної економіки можна вважати можливість отримання первинної енергії в масштабах, що задовольняють потреби людства, способами, що не завдають шкоди природі, та трансформацію первинної енергії в інші види енергії для їх кінцевого використання в різних сферах діяльності, зокрема, на транспорті. Інтегральна модель менеджменту декарбонізації сприяє прийняттю управлінських рішень щодо розвитку найбільш значущих напрямів діяльності у контексті концепції сталого розвитку.

Ключові слова: менеджмент, декарбонізація, інтегральна модель, управлінські рішення, сталий розвиток.

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