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CRITERIA FOR ASSESSING THE EFFECTIVENESS OF TRANSPORT POWER PLANTS DECARBONISATION IN ACCORDANCE WITH IMPLEMENTATION OF THE SUSTAINABLE DEVELOPMENT CONCEPT

The directions of restoration and further development of the energy sector in Ukraine are considered in accordance with power plants with internal combustion engines, taking into account the widespread implementation of the Sustainable Development concept, which allows solving existing modern social, economic and environmental problems. For Ukraine, taking into account the economic opportunities and selected priorities for the chosen path of development, it is necessary at this time to choose gradual and specific directions to implement the Sustainable Development concept. The most priority areas of practical implementation of the concept are determined and it is indicated that the effectiveness of this implementation is associated with the development of the industry on the basis of the fourth and fifth industrial revolutions (Industry 4.0 and Industry 5.0). One of the main tasks in solving the problems of the concept is to ensure the environmental component. Notwithstanding the noted progress in improving the environmental efficiency of internal combustion engines, further attention needs to be paid to the task of spreading the introduction of "green energy", i.e. decarbonisation – reducing greenhouse gas emissions into the environment (CO_2). The issue of decarbonisation in the future should be given the greatest attention both in the development and in the manufacture and operation of engines. It is shown that the assessment of the impact of CO_2 emitted with the exhaust gases of internal combustion engines into the environment is carried out taking into account the model of operation of engines and the justification of the introduced adjustments. A new criterion is proposed, which is called: "ICE criterion of environmental thermal pollution", which is proposed for use in studies to assess the effectiveness of the implementation of decarbonisation strategies in all modes of transport at implementation of the Sustainable Development concept in global transport power plants. A method for determining the efficiency of physical and chemical processes of mixture formation and combustion in internal combustion engine cylinders is proposed when using hybrid fuel with "green hydrogen" as its component, which allows determining the dependence of hydrogen influence on the level of engines effective performance and formation of harmful emissions in exhaust gases.

Key words: *Sustainable Development in Ukraine; economic, social and ecological components; power plants; internal combustion engines; decarbonization; a criterion of heat pollution of the environment*

Fundamentals of the Sustainable Development concept

In general, the Sustainable Development concept is understood as a set of actions and requirements aimed at protecting the environment, social justice, absence of racial and national discrimination, and ultimately ensuring an increase in the living standard of our planet population. Sustainable Development is a generalized concept of establishing a balance between meeting the humanity current needs and protecting the future generations interests, including their need for a safe and healthy environment [1]. That is, the initiative to introduce and disseminate the Sustainable Development concept should be understood as the activity of the progressive-minded part of humanity to meet the needs of present and future generations on the basis of solving ***existing modern social, economic and environmental problems***

The developers and supporters of the Sustainable Development concept believe that it is through the practical implementation of its ideology that it is possible to ensure the further ***existence and development*** of the future. It can also be argued that by directing the joint efforts of mankind to understand and avoid the impending environmental danger, it becomes possible to resolve social and interstate contradictions, and this, in turn, will contribute to a peaceful existence on our planet and the destruction of immensely accumulated mass destruction weapons.

The scientific substantiation of the Sustainable Development concept is based on the use of modern information technologies and a systematic approach, which, according to its developers, allows, when analyzing the constituent directions of development, to predict with sufficient accuracy the effectiveness of the selected options and choose the most optimal ways, taking into account the economic and social conditions, natural characteristics of each of the countries.

The initiators and first implementers of the Sustainable Development concept are the United States, the countries of the European Union, and Japan. However, taking into account the fact that one of the main tasks related to the implementation of the concept is to solve environmental problems and ensure safe life on the planet, a positive result from the implementation of the actions proposed by the concept can only be achieved through the participation in it on equal terms of all leading countries of the world, both in terms of economic development and population and availability of natural resources.

In Ukraine, the term Sustainable Development is often used to denote only the steady growth of economic

indicators of the country, its regions, cities, villages and individual sectors of economy. Sometimes the implementation of measures to preserve the environment and improve the sanitary living and working conditions of people is added to this list. Such an approach to the problem of Sustainable Development should be considered incomplete or false, since the Sustainable Development concept is based on the five main principles [1]:

1. Humanity can make development sustainable and long-lasting nature, in which case this development will meet the needs of people living today, without losing the opportunity to meet their needs for future generations.

2. The restrictions that are being introduced (or are planned to be implemented) in the field of natural resources development are related to the current level of technology and social organization of mankind, as well as to the ability of the biosphere self-regeneration.

3. It is necessary to meet the basic needs of all people and give everyone the opportunity to realize their hopes for a prosperous life. One of the main causes of environmental and other disasters is poverty, which has become a common phenomenon in the world.

4. It is necessary to reconcile the livelihoods of those who use excessive means (monetary and material) with the ecological possibilities of the planet, in particular with regard to the use of energy.

5. The size and rate of population growth must be aligned with the potential of the Earth's changing global ecosystem.

That is, the main principles of the Sustainable Development concept are closely related to the comprehensive solution of the three main components: economic, social and environmental.

The economic component is based on the theory of using the maximum flow of total capital, which can be carried out provided that it is preserved and increased with a global reorientation of material, labour, financial resources in favour of energy-efficient, resource-saving, high-tech, science-intensive and environmentally friendly industries, with the help of which this income is carried out.

At the same time, the optimal use of limited resources and the use of environmentally friendly – nature-saving, energy-saving and material-saving technologies are envisaged, including the extraction and processing of raw materials, creation of environmentally acceptable products, minimization, processing and destruction of waste.

The social component is human-centred and aims to maintain the stability of social and cultural systems, including reducing the number of destructive conflicts between people. An important aspect of this approach is the equitable distribution of benefits. It is also desirable to preserve cultural capital and diversity on a global scale.

The social component should include a more effective decision-making system that considers historical experience and encourages pluralism. Within the framework of the concept, a Human is not an object, but a subject of development, that is, a Human must take an active part in the processes that form the sphere of his life, contribute to the adoption and implementation of decisions, and control their implementation.

The environmental component should ensure the integrity of biological (viability) natural systems. Of particular importance are ecosystems, on which the global stability of the biosphere of the planet depends.

The degradation of natural resources, environmental pollution and the loss of biological diversity reduce the ability of ecological systems to self-regenerate. It is assumed that the focus should be on preserving the ability to self-regenerate and dynamically adapt such systems to change, rather than keeping them in some “ideal” static state.

It should be noted that Sustainable Development is already the basis for the formation of policies of the EU countries and many other countries of the world, including the post-Soviet countries (Belarus, Kyrgyzstan, Uzbekistan, Kazakhstan), where national strategies for sustainable development have been adopted, and mechanisms of the “green” economy are being introduced [2].

Determining the most priority and effective areas of practical implementation of the concept for each country, coordinating the selected areas with other measures with a balanced interaction of mechanisms of all three elements of sustainable development is a task of considerable complexity, since these elements should be considered in a balanced way, taking into account those changes that make it possible to significantly influence production processes.

To some extent, the content of the Sustainable Development concept will be influenced by changes in industry, both during the implementation of the concept and during the implementation of the fourth and fifth industrial revolutions (Industry 4.0 and Industry 5.0).

Industry 4.0, Industry 5.0

The conceptual foundations of the fourth industrial revolution are presented in [3]. According to the concept proposed by the author of this work, Klaus Schwab, the near future of humanity will be determined by the expansion and introduction of the production of intelligent technologies taking into account computing processes (Industry 4.0), that is, the direct positive impact on the economic component of the Sustainable Development concept.

Let's consider the features of this influence.

It is clear that the concepts of the fourth and fifth industrial revolutions directly indicate that they were preceded by other industrial revolutions.

According to the ideology of the concept of Industry 4.0, *the first industrial revolution*, which took place in the late 18th and early 19th centuries, was determined by the transition from manual to machine labour, that is, with the spread of the use in industry of mechanical and thermal energy (mechanical loom and steam engine).

The second industrial revolution (late 19th – early 20th centuries) was defined by the introduction and expansion of machine tool and conveyor production, as well as the creation of stationary and transport internal combustion engines, the construction and commissioning of the first power plants, which in turn contributed to the expansion of the use of means of communication (radio and telephone).

The third industrial revolution, (falls on the end of the 20th and the beginning of the 21st century, is defined by the rapid development of stationary and transport energy, the production volumes of which are sufficient to meet the needs of mankind (in our opinion, even exceed them), associate *with* significant progress and implementation in all areas of human activity, including the technology of production of computer equipment, and technology of human needs (transistors, processors, computers, the Internet, digital cameras), which provides a technological base for the development of the industry.

The fourth industrial revolution will be defined by the widespread introduction into production in our time and in the near future of cyber-physical systems to increase the technological efficiency of industry through the increased integration of these systems into the technology of factory processes. It is predicted (but not justified) that these changes will also cover various aspects of life: labour market, living environment, political systems, the technological system, and others.

And it is on this basis, at the next stage of the development of intelligent technologies, that additional opportunities should be provided for the implementation of *the fifth industrial revolution* – Industry 5.0, which will involve the creation of production technologies that include autonomous robots, significant data and analytics, cloud connectivity, cybersecurity, horizontal and vertical integrations of systems, the internet of things, modelling and digital twins.

The implementation of the concepts Industry 4.0 and Industry 5.0 will provide technological capabilities ***of the economic component of the Sustainable Development*** concept, which is directly related to the development of energy.

In line with power plants with modern internal combustion engines, which have a high level of economic and environmental performance, these concepts can additionally provide an increase in the engines ***performance stability***. An example of the implementation of such technologies is the developments carried out in the Odessa National Maritime University, and their implementation in operation [4].

Thus, the industrial revolutions Industry 4.0 and Industry 5.0 can and should be considered as components of the Sustainable Development concept, which directly affect the economic, and, accordingly, the social and environmental components of this concept.

Implementation of the Sustainable Development concept in Ukraine

Over the years of independence, Ukraine has officially supported a number of international decisions on the implementation of the Sustainable Development concept, for example, "An Agenda for the 21st Century" (Rio de Janeiro, 1992), the United Nations Millennium Declaration (2000), the Johannesburg Declaration and the World Summit on Sustainable Development (Johannesburg, 2002), "The Future We Want" (Rio de Janeiro, 2012) [5]. Several attempts were made to create and approve the Sustainable Development concept of the country at the legislative level, but, unfortunately, all these attempts have failed. No legislative initiative on the implementation of the draft strategy for sustainable development of Ukraine has been registered.

The reason for this state of affairs, in our opinion, is related to the lack of justified directions of the national strategy for sustainable development, an action plan and even a concept for its implementation, as well as the lack of an approach in the current legislation to the implementation of the provisions of international documents and agreements in this area by the state. As a result, Ukraine has long been on the sidelines of the global vector of development on the basis of sustainability [2].

However, in September 2015, within the framework of the 70th session of the UN General Assembly, the UN Summit on Sustainable Development was held in New York. The final document of the Summit "Transforming our world: the 2030 Agenda for Sustainable Development" provided for the implementation of the 17 Sustainable Development Goals. In this regard, in 2019 the President of Ukraine by his decree supported the Sustainable Development concept, the achievement of its goals and the results of adaptation, taking into account the specifics of Ukraine's development, set out in the National Report "Sustainable Development Goals: Ukraine".

In December 2020, the Cabinet of Ministers of Ukraine amended the Regulation, which established that

the need to achieve sustainable development goals is taken into account in the process of forming and implementing the state policy of Ukraine.

Thus, at the state level, the Sustainable Development Goals were enshrined as guidelines for the development of program and forecast documents.

Here are the Sustainable Development Goals declared for Ukraine (until 2030):

1. *Overcoming poverty.*
2. *Overcoming hunger, agricultural development.*
3. *Good health and well-being.*
4. *Quality education.*
5. *Gender equality.*
6. *Clean water and sanitation.*
7. ***Affordable and clean energy.***
8. *Decent work and economic growth.*
9. *Industry, innovation and infrastructure*.
10. *Reducing inequality*.
11. *Sustainable development of cities and communities*.
12. *Responsible consumption and production*.
13. *Climate change mitigation*
14. *Conservation of marine resources*.
15. *Protection and restoration of terrestrial ecosystems*.
16. *Peace, justice and strong institutions*.
17. *Partnership for sustainable development*.

That is, taking into account economic opportunities and selected priorities, from which it is necessary to choose gradual and specific directions for their implementation, benchmarks in the form of declared goals of sustainable development currently exist.

In turn, these priorities are directly related to the economic opportunities of the country, ***especially at this time***, and the chosen path of development of sustainable development of Ukraine.

Of the listed Sustainable Development Goals directly related to power plants with internal combustion engines, the following can also be attributed:

– *overcoming hunger;*
– *agricultural development;*
– *affordable and clean energy;*
– *decent work and economic growth;*
– *industry, innovation and infrastructure*;
– *responsible consumption and production*.

The proposed draft concept [5] indicates the need to develop a National Strategy for Sustainable Development of Ukraine, the main component of which should be the preservation of natural resource potential, environment and individual ecosystems in the process of economic activity, as well as the development of relevant programs at the industry-specific, regional and state levels. However, the shortcomings of this draft Concept of transition to sustainable development include a too general approach, lack of scientific justification for the chosen path of reform and the means of assessing its effectiveness developed at least in the first approximation.

The main issues that need to be addressed in the development of the concept are related to the definition of the goal and priorities of sustainable development of Ukraine at both the state and regional levels, which should ensure the independence and national security of Ukraine.

Next, we'll consider the impact and areas of conservation of natural resource potential, the environment and individual ecosystems in the process of economic activity related to energy production, as one of the main components of the implementation of the Sustainable Development concept.

Importance of energy production for implementation of Sustainable Development concept

If we analyze the main principles of the Sustainable Development concept, we can determine that they are all closely related to the production and consumption of energy. Energy provides opportunities for the development of the state itself, but, accordingly, is largely associated with the availability and efficient use of natural resources, which at the same time can significantly affect the deterioration of the global ecosystem of our planet.

It follows from this *that the implementation of the economic component of the concept* is ensured subject to spread of the use of energy-efficient, resource-saving, high-tech, science-intensive and environmentally friendly industries with optimal consumption of limited natural resources.

The social component, which is focused directly on the person and is aimed at maintaining the stability of the social and cultural systems of the country, including reducing the number of destructive conflicts between people, provides for the equal use and distribution of all benefits, the overall level of which, in turn, largely depends on the amount and efficiency of energy use.

The environmental component, which ensures the integrity, stability and viability of the planet biosphere, is directly and largely related to the amount and efficiency of energy use, the processes of the full cycle of use of energy sources, including manufacturing technologies, operating conditions, rational use, opportunities for increasing efficiency and disposal of power plants.

It should be noted that the effective implementation of the concept economic component of a generalized approach requires the identification of the most priority and effective areas separately for each country.

Thus, when considering the goals of sustainable development for Ukraine at this time, it is additionally

necessary to take into account the fact that they are achieved by ensuring the implementation of directions for overcoming the consequences of the war, restoring destruction, and, accordingly, restoring agriculture and industry, ensuring consumption and production, while simultaneously solving planetary problems related to climate mitigation, conservation of marine resources, protection and restoration of terrestrial ecosystems.

Therefore, among the declared goals of sustainable development for Ukraine, it is necessary to choose gradual specific directions for their implementation, which are directly related to the economic opportunities of the country and the chosen path of development of sustainable development of Ukraine, as well as taking into account economic opportunities, reasonable and chosen priorities. *The implementation and development of these areas are directly related to the spread of the use and increase in the efficiency of the use of power plants*.

However, it should be emphasized that the primary requirement for the reconstruction and development of the country is the development and implementation of the Sustainable Development concept of Ukraine. Expressing confidence that such a concept will be developed, we will determine its compliance with the use of energy sources and specifically – power plants with internal combustion engines.

Importance of power plants with internal combustion engines in the implementation of the Sustainable Development concept in Ukraine

High mobility and efficiency, reliability and resource, ease of operation have given internal combustion engines (ICE) leadership in the production of mechanical energy. ICE has been widely used in road, rail, sea and air transport, agricultural machinery. ICE is the basis of stationary power plants and construction machines [6]. Today, all military vehicles of high mobility are created and used with ICE power plants and most often with diesel engines. Mobility, reliability, high starting readiness are attributed to the characteristic properties of these engines [7].

The evolution of modern diesel engines, which are developed, introduced into production and used in operation, is ensured by improving the design, manufacturing technology, organization of the workflow, fuel and air supply systems, purification of exhaust gases from harmful emissions into the environment. In terms of their fuel and environmental performance, modern engines differ significantly from their predecessors.

The assessment using the fuel and environmental criterion [8] shows that this indicator, for example for automobile diesel engines, has increased 4.17 times over the past 30 years, mainly due to a decrease in emissions of harmful substances into the environment with exhaust gases. At the same time, the level of standardized harmful emissions with exhaust gases of engines (environmental indicators) is approaching its minimum. At the same time, fuel economy indicators were improved, but with less intensity compared to environmental indicators. And this fact is explained by the previously achieved high level of proof of the work process, and, accordingly, the effective and indicator values of modern engines.

At one time, Ukraine occupied one of the leading places in the development and manufacture of ICE. The centre of diesel construction was Kharkiv. Created by an outstanding scientist, engineer and organizer Professor V.T. Tsvetkov in the twenties of the last century at the Kharkiv Polytechnic Institute, the scientific school of engine building contributed to the significant development of this important energy component of solving the social and economic components of development for the country.

Engines for road, rail, ship transport, aircraft engines, engines for military equipment and stationary installations were produced in Ukraine. In addition to Kharkiv, there were enterprises and scientific institutions for the development of engine building in Zaporizhzhia, Melitopol, Pershotravnevyi and Tokmak. In addition, a significant number of enterprises producing units, assemblies and components for engines were involved in the production. Unfortunately, over the past 30 years, the engine industry has been practically destroyed. Nevertheless, it is one of the important areas that can ensure energy independence and implementation of the Sustainable Development concept in Ukraine.

Naturally, now we cannot talk about returning the engine industry to the level that existed in the past, we can certainly hope for the help of other leading countries, but thanks to the experience that remains to create highly efficient internal combustion engines, it is necessary to focus on the main areas, which, we believe, should include the creation of engines for armoured vehicles, agricultural vehicles and aircraft. And this has already been a significant contribution to the practical implementation of the Sustainable Development concept in Ukraine.

One of the main problems in solving the problems of the concept in this case is the provision of the environmental component.

Despite the noted progress in improving the environmental efficiency of ICE, further solution requires the task of reducing greenhouse gas emissions into the environment (CO_2). Regardless of the impact of internal combustion engines in the thermal pollution of the planet does not exceed 6% [9], it is the issue of green energy development (decarbonisation) in the future that

should be given the greatest attention both in the development and manufacture and operation of engines.

To assess the impact of CO_2 emitted with the exhaust gases of diesel engines on humans and the environment, the average value of its emissions is determined by the operating model and the introduction of corrections is justified. First of all, this is a correction that takes into account the effect of carbon dioxide on various recipients other than humans – δ_{CO2}, as well as a correction that takes into account the possibility of accumulation of the substance in environmental components and food chains, as well as its ingestion into the human body by non-inhalation – α_{CO2} [10].

The justification and introduction of such corrections, of course, is an objective scientific approach that takes into account all the components of the negative impact of carbon dioxide (CO_2) on humans and the environment – the greenhouse effect of climate change and the biosphere as a whole, both under direct impact and in the long term, as well as taking into account the formation and level of its emissions during the operation of diesel engines in the overall natural and anthropogenic balance.

Therefore, in studies of decarbonisation processes, assessment of the effectiveness of measures taken by scientists and manufacturers to reduce emissions of CO_2 by transport power plants, in a comparative analysis of different brands and types of ICE in terms of their negative impact on the thermal state of the environment, a system of criteria is necessary that unambiguously allows obtaining an objective assessment. Previously, a fuel and environmental criterion was proposed, which today has wide practical use [11].

This study proposes a new criterion, which was named by the authors: "ICE criterion of environmental thermal pollution", the basis of the criterion is the results of scientific work [12].

$$K = k_1 \cdot k_2$$

This criterion characterizes the perfection of the internal combustion engine according to the main parameters of its working process ($k_2 = \eta_e/\eta_{max}$), and also allows to obtain for a comparative assessment indicators that will provide the researcher with objective information on the effectiveness of decarbonisation processes ($k_1 = 1 - C_{CO_2}$).

In this case, the general criterion K will have a value from zero to one, ($0 < K < 1$). Then the thermal pollution criterion will be defined as

$$K = k_1 \cdot k_2 = (1 - C_{co2}) \cdot \eta_e/\eta_{max},$$

where C_{CO_2} is the share of carbon in the ICE fossil fuel (currently this indicator, for example, for traditional diesel fuel is approximately 0.85); η_e is the effective efficiency of the ICE; η_{max} is the maximum efficiency, which is defined as $\eta_{max} = E_Q/Q_x$ (for modern ICE of land transport $\eta_{max} = 0.75 - 0.85$, which is equal to the maximum possible efficiency of the power plant in its ideal cycle without internal and external dissipation of the exergy of this ideal cycle), here E_Q = the exergy of the heat supplied to the working body in the ICE cylinder during combustion; Q_x is the total amount of heat supplied to the working body in the ICE cylinder during combustion.

Since the ICE criterion of environmental thermal pollution (K) is proposed to be used to assess the effectiveness of decarbonisation processes for different types of internal combustion engines, the authors propose to take the maximum value – η_{max}=0.85 to determine this criterion.

Then, for example, the involvement of the share of green hydrogen in the hybrid fuel of the ICE will ensure a decrease in the value of C_{CO_2}, and the value of $k_1=(1 - C_{CO_2})$ will increase, which is a positive indicator for the implementation of the decarbonisation strategy. Comprehensive measures aimed at increasing the efficiency of the internal combustion engine (η_e) provide a reduction in fuel consumption for the production of specific work, which in fact is a direct indicator of reducing thermal pollution of the environment. Such results will provide an increase in the range of $0 < X_j < 1$ coefficients k_1 and k_2, and, of course, the value of the total coefficient K.

Thus, when implementing the Sustainable Development concept, an assessment of the effectiveness of the implementation of decarbonisation strategies in transport power plants is proposed using the thermal pollution criterion K.

Green hydrogen as part of a decarbonisation strategy

One of the main directions of decarbonisation is the spread of the use of hydrogen as a fuel or its component in the energy sector. The practical implementation of this direction in the internal combustion engine allows to simultaneously solving the problem of environmental pollution and the consumption of limited resources of petroleum fuel.

Ukraine has significant opportunities for the development of hydrogen energy, production of alternative fuels, use of renewable energy sources. Solving the problem of providing energy with mobile installations with low environmental pollution and fuel consumption of petroleum origin is associated with the introduction of an integrated approach, including the spread of the use of hydrogen, along with other alternative fuels and renewable energy sources.

To assess the efficiency of physicochemical processes of mixture formation and combustion in the ICE cylinders of hybrid fuel with green hydrogen in its com-

position, it is necessary, together with the choice of alternative fuel and justification of the proportion of hydrogen additives, to determine the dependencies of the influence of hydrogen on the formation of harmful emissions with exhaust gases and emissions of CO_2 and the level of effective performance of engines.

At the same time, it is also necessary to systematically summarize the known technologies, ways and means of effective use of various types of alternative fuels for ICE. It is the restoration of engine building in the implementation of a set of studies aimed at decarbonisation of engines that makes it possible to make a significant contribution to the implementation of the Sustainable Development concept in Ukraine.

It should also be emphasized that the scientific and technical problems of sustainable development of domestic transport are constantly investigated by scientists of the National Technical University Kharkiv Polytechnic Institute. For example, strategies and tasks for solving sustainable development problems, the results of scientific research in the field of the sustainable development concept were repeatedly reported at international, national and regional scientific conferences [XXVIII International Congress of Engine Builders, XXXII International Scientific and Practical Conference "Information Technologies: Science, Technology, Education, Health" (MicroCAD-2024), the Fifth All-Ukrainian Scientific and Practical Conference "EUROPEAN INTEGRATION OF ENVIRONMENTAL POLICY OF UKRAINE", Odessa 2023, were implemented in dissertations for the degree of Candidate of Technical Sciences in the specialty 05.05.03 – Engines and Power Plants [13, 14], dissertations for the degree of Doctor of Philosophy in the specialty 142 – Energy Engineering [15, 16], publication of a PhD candidate [17].

All this allows us to argue about the potentially high possibilities of scientific and technical support for the restoration of domestic engine building. Definitely, including the implementation of a set of studies aimed at decarbonising both existing ICE currently used in transport and new internal combustion engines of the transport type, without which today the plans for the implementation of sustainable development tasks are absolutely illusory. In addition, the conditions are being implemented not only for the effective implementation of the Sustainable Development concept in Ukraine, but also creates the opportunity to win Ukraine a worthy place among the leading countries of the world as an integral innovative component of our civilization in the implementation of the UN Sustainable Development concept.

Conclusion

The implementation of the Sustainable Development concept is aimed at developing and ensuring the continued existence of the future through the resolution of social and interstate contradictions should contribute to a peaceful existence on our planet and avoid the impending environmental danger.

The scientific substantiation of the Sustainable Development concept is based on the use of modern information technologies and a systematic approach, which, according to its developers, allows, when analyzing the constituent directions of development, to predict with sufficient accuracy the effectiveness of the selected options and choose the most optimal ways, taking into account the economic and social conditions, natural characteristics of each of the countries. The main principles of the concept are closely related to the integrated solution of three main components: economic, social and environmental.

For the scientific substantiation of measures for the implementation of strategies and tasks for decarbonisation on transport, the authors proposed a new criterion, called the "ICE criterion of environmental thermal pollution".

Technological opportunities to increase the efficiency of the economic component of the Sustainable Development concept, including those that ensure the development of energy related to the implementation of the Industry 4.0, and later – Industry 5.0 concept. In accordance with power plants with modern internal combustion engines, which have a high level of economic and environmental performance, the introduction of technologies of the Industry concepts will further increase the stability of engine performance in operation.

The priority of the National Strategy for Sustainable Development of Ukraine should be the preservation of natural resource potential, the environment and individual ecosystems in the process of economic activities related to energy production and, accordingly, the development of engine building, focusing primarily on the creation of engines for agricultural machinery, aircraft and armoured vehicles.

One of the main problems for solving the problems of the Sustainable Development concept in this case is the provision of the environmental component. Regardless the noted progress in improving the ICE environmental efficiency, the solution requires the task of reducing greenhouse gas emissions into the environment (CO_2), that is, the issue of green energy development should be given the greatest attention both in the development and manufacture and operation of engines. It is the practical implementation of this direction that will

simultaneously solve the problem of environmental pollution and the consumption of limited resources of petroleum fuel.

To solve the problem of providing energy with mobile installations with a low level of environmental pollution and fuel consumption of petroleum origin, it is necessary to implement an integrated approach, including the spread of the hydrogen use.

Determination of the efficiency of physicochemical processes of mixture formation and combustion in the ICE cylinders of hybrid fuel with green hydrogen in its composition is associated with the choice of alternative fuel and substantiation of the share of hydrogen additives, determination of the dependence of the influence of hydrogen on the formation of harmful emissions with exhaust gases and CO_2 emissions and the level of effective engines performance.

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КРИТЕРІЇ ОЦІНЮВАННЯ ЕФЕКТИВНОСТІ ДЕКАРБОНІЗАЦІЇ СИЛОВИХ УСТАНОВОК ТРАНСПОРТУ

А.П. Марченко, І.В. Парсаданов

Напрямки відновлення та подальшого розвитку енергетики в Україні розглянуто відповідно до енергетичних установок з двигунами внутрішнього згоряння із врахуванням поширеного впровадження концепції «Сталий розвиток», що дозволяє вирішувати існуючі сучасні соціальні, економічні і екологічні проблеми. Для України з урахуванням економічних можливостей і обраних пріоритетів щодо обраного шляху розвитку в цей час необхідно обирати поступові і конкретні напрямки реалізації концепції сталого розвитку. Визначені найбільш пріоритетні напрямки практичної реалізації концепції та вказано, що ефективність цієї реалізації пов'язана із розвитком індустрії на основі четвертої та п'ятої промислових революцій (Індустрія 4,0 і Індустрія 5.0). Одною із головних задач при вирішені проблем концепції стає забезпечення екологічної складової. Не зважуючи на відмічений прогрес у підвищенні екологічної ефективності двигунів внутрішнього згоряння, подальшої уваги потребує виконання завдання щодо поширення впровадження «зеленої енергетики», тобто декарбонізації – зменшення викидів в навколишнє середовище парникового газу (CO_2). Питанню декарбонізації в перспективі необхідно приділяти найбільшу увагу як при розробці, так і при виготовлені та експлуатації двигунів. Показано, що оцінку впливу CO_2, що викидається з відпрацьованими газами двигунів внутрішнього згоряння в навколишнє середовище, проводять з урахуванням моделі експлуатації двигунів та обґрунтуванням введених поправок. Запропоновано новий критерій, який отримав назву: «Критерій ДВЗ теплового забруднення навколишнього середовища», який пропонується для використання у дослідженнях щодо оцінки ефективності впровадження стратегій декарбонізації на усіх видах транспорту при реалізації концепція «Сталий розвиток» в транспортних силових установках світу. Запропоновано метод визначення ефективності фізико-хімічних процесів сумішоутворення і згоряння в циліндрах ДВЗ при використанні гібридного палива із «зеленим воднем» як його складової, що дозволяє визначити залежності впливу водню на рівень ефективних показників двигунів та утворення шкідливих викидів у відпрацьованих газах.

Ключові слова: Сталий розвиток в Україні; економічна, соціальна та екологічна складові; електростанції; двигуни внутрішнього згоряння; декарбонізація; критерій теплового забруднення навколишнього середовища.