



LOW-CARBON TECHNOLOGIES AS A FACTOR OF ECONOMIC DEVELOPMENT UNDER CLIMATE CHANGE

Tatiana Artomova¹

¹ State Institution – Institute of Economics and Forecasting of NAS of Ukraine
Department of Economic Theory

Abstract: A good climate is a public good, an indicator of well-being, and the highest level of social welfare. Climate has a positive effect on migration labor flows; it determines the positive synergistic effects of economic development. In the 1970s, scientific approaches to the problem of improving the ecological component of the surrounding combined with the concept of socio-economic development contributed at the end of the XX century to the development of the concept of sustainable development in the world. Today, one of the pressing environmental problems is the risk of climate change – global warming, which can lead to irreversible changes in the ecosystem of the planet. The Paris Agreement adopted in December 2015 sets the goal of recording a global increase in average global temperatures in order to avoid a climate catastrophe. The Low Carbon Development Initiative (LCDI) manifests a new quality and lifestyle for all economic entities. On the one hand, this economic development presupposes a transition to a new level of individual and national competitiveness. On the other hand, without proper material, social, and financial assistance this economic development can result in the further stratification of society, an increase in poverty, and economic stagnation. In order to develop a National Strategy for Climate Change and Low Carbon Development and fight climate change within the paradigm of sustainable socio-ecological-economic development, it is necessary to rely on a solid theoretical platform. Therefore, the analysis of theoretical approaches to substantiating the prerequisites for sustainable development, taking into consideration the introduction of low-carbon technologies and the clarification of the key ideas for effective management of climate change processes, is an urgent agenda for economic entities of various levels.

Keywords: climate as a public good, the threat of global warming, sustainable economic development, the Paris Agreement, low-carbon technologies, efficient management of common resources

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Introduction

The role of climate as a factor determining the direction of labor migration and, thereby, the dynamics of economic development of various regions of the planet, has been studied in the scientific literature since the end of the 19th century and is most active since the mid-1950s. In the context of these studies, a good climate has gained the status of a “normal” public good, the demand for which is going up as the level of public welfare increases due to increased incomes and average life expectancy of the population. This regularity was noted by the American scientist Edward Ullman,

¹ Tatiana Artomova, Doctor of Economics, Chief Researcher, blagosostojanie1986@gmail.com, ORCID: 0000-0001-8511-3141

who drew attention to the fact that due to the economic growth in the United States, a good climate increasingly determines the internal migration flows of people who are striving to ensure a decent quality of life and living comfort (Ullman 1954, pp. 119-132; Ullman 1957). In several subsequent works by other authors, the influence of a good climate as the “attraction” for migration flows has received statistical confirmation (Greenwood 1969, pp. 189-194; Svart 1976, pp. 314-130).

On the other hand, it was found that a good climate alone is not necessarily the cause of labor migration. The equilibrium in the labor and housing prices determined by the free market, among other things, takes into account the climatic preferences of people moving to a more favorable region. Consequently, this process does not promise the individual to receive additional benefits (Graves 1980, pp. 227-237; Cragg, Kahn 1999, pp. 519-539). The advantage resulting from a better climate is offset by higher rental rates, lower wage rates, and other expenditures.

In general, a good climate promotes the concentration of skilled personnel in a certain geographical location, attracting opportunities for higher incomes due to the agglomeration effect. The last factor (not the climate itself) determines the intensity of migration flows. So, according to J. Roback’s research (Roback 1988, pp. 1257-1278), population density is estimated and “paid” by people by analogy with a good climate – as a component of the quality of living.

Today, in scientific and civic circles, one of the pressing environmental problems is *the risk of global warming*. At the same time, in the light of recent authoritative studies (a special report of the Intergovernmental Panel on Climate Change (IPCC)), the problem of global climate change can no longer be ignored, because irreversible negative changes in the planet's ecosystem can already appear by 2030. The Paris Agreement of 2015 gave a signal to the whole world about the inevitability of a “low-carbon future”; all economic agents received a promise about the need to adapt to this future in order to ensure the conditions for the transition to a higher level of competitiveness.

The purpose of this article is an analysis of theoretical approaches to substantiating the prerequisites for sustainable development of national economies and business entities, considering the introduction of low-carbon technologies, as well as the clarification of key ideas for effective management of climate change processes. The following research methods and tools were used in the article: a critical analysis of scientific literature, program documents, and special reports of international organizations from the perspective of a systematic approach.

The problem of creating a comfortable climate environment as a conceptual component of sustainable development of the world community

In the 1970s, scientific approaches to the problem of improving the ecological component of the environment, combined with the concept of socio-economic development, contributed to the development of the concept of sustainable development as a response of the world community to the challenges associated with the

formation of the technosphere and technogenic civilization. International non-governmental organizations for the study of globalization processes were established: The International Federation of Institutes for Advanced Study (IFIAS), the Club of Rome (published the report “The Limits to Growth”), the International Institute for Applied Systems Analysis (IIASA), etc.

In 1972, the United Nations Conference on the Human Environment (also known as the Stockholm Conference) and United Nations Environment Programme (UNEP) marked the processes of institutionalizing the efforts of the international community to solve environmental problems that began to restrain socio-economic development. The principles of environmental policy and diplomacy, the system of environmental law, ministries, and departments of the environment were formed. Individual scientists, in order to overcome environmental and food crises, pushed for working out measures to stabilize the planet's population.

In the 1980s, the United Nations Environment Program (UNEP) focused on the need for a transition to economic development without environmental destruction. The World Summit on Sustainable Development in 2002 confirmed the commitment of the world community to the ideas of sustainable development in the unity of its three components – environmental, social, and economic. This triune formula was presented in the report “Our Common Future” of the World Commission on Environment and Development (WCED). The concept of sustainable development in many respects echoes the concept of V. Vernadsky's noosphere. However, according to experts, the global financial and economic crisis and the subsequent syndrome of new normality indicate that the world's model of sustainable development model has not yet been developed.

The economic approach to the concept of sustainable development is based on the theoretical model of Hicks-Lindahl, which combined the scientific ideas of Sir J. Hicks (Hicks 1940; 1946) and E. Lindahl (Lindahl 1919), expressed by them at different times. In accordance with the provisions of this concept, the maximum amount of total income can be produced provided that the total capital with which this income is produced is preserved. Such a condition implies the optimal use of limited resources based on environmentally acceptable (nature, energy, and material saving) technologies. At the same time, during the discussion of the features and priorities of preserving physical, natural, and human capital, as well as the problems of assets valuation, ideas about two types of sustainability were formed:

- weak, which is strategically focused on the conservation of both natural and produced capital;
- strong, which is based on the preservation of natural capital (in this regard part of the income from the use of non-renewable resources is used to increase the value of renewable natural capital).

When adapting the concept of sustainable development to business, the harmonization of its economic, environmental, and social components is achieved through the development of key development indices in the relevant sectors of the economy, as well as mechanisms for integrating these indicators into the planning and assessment system at the level of the geographical region.

The concept of sustainable development contradicts the provisions of traditional economic theory, which focuses on continuous economic growth. In this regard, the representatives of the environmental economy have formed the idea of restraining economic growth associated with negative social consequences. A Center for the Advancement of the Steady State Economy was created to distribute these ideas. In the works of Hermann Daly (Daly 1999), the concept of “sustainable economy” is introduced, its physical components are limited and do not change over time. The Canadian economist Peter Victor (Victor 2019) proposed an interactive model to explore the potential for achieving a stable but not growing economy. Sustainability is defined as “sustainable development in the long-term, intergenerational plan”.

In the last decades of the twentieth century, the concept of sustainable development was enriched by the spread of a new approach to “Human Development” with the assistance of such an influential international organization as the United Nations Development Programme (UNDP). A significant contribution to the development and practical adaptation of the concept of Human Potential Movement was made by M. Desai, 1998 Nobel laureate A. Sen, Mahbub ul-Haq, 2015 Nobel laureate E. Deaton, 2019 Nobel laureates M. Kremer, A. Banerji, E. Duflo, etc. A fundamentally new approach that underlies the concept of human development is that the achieved level of social welfare should be assessed not just by statistical indicators of average income per capita but by taking into account the possibilities of providing a decent life for each person, such as broadening the opportunities for education, and a long, healthy and happy life.

The main points of the concept of human development were presented in 1990 in the first UNDP “Human Development Report”. They were subsequently rethought, and in 2002 they were embodied in the Declaration of the 55th session of the UN General Assembly “The Millennium Development Goals”, and in 2015 at the UN Summit in the Declaration of “Sustainable Development Goals” for the period of 2016-2030 for mankind. On the one hand, in a post-industrial society, humanitarian capital, innovative technologies, and information are becoming the main resources of socio-economic development. On the other hand, new requirements are being formed for workforce quality and structure. In this regard, the problem of transforming human potential into human capital is of particular importance, because the stock of abilities and motivations accumulated by a person effectively affects the increase in production and income. In modern conditions, human capital in the middle world makes up two-thirds of the country's national wealth; whereas the remaining components – natural wealth and reproducible capital – make up one-third.

Thus, the initial problem of creating a comfortable climatic environment for public human life was completed in the framework by two concepts – sustainable development and human development.

Today, in scientific and public circles, one of the pressing environmental problems is the risk of global warming. At the same time, in light of recent authoritative studies (special report of the Intergovernmental Panel on Climate Change), the problem of global climate change can no longer be ignored, because irreversible negative changes in the planet's ecosystem can already appear by 2030. The Paris Agreement,

adopted in 2015 and signed by 195 countries, sets the goal of fixing the global increase in average temperatures by 1.5°C compared with the pre-industrial level of development. And this is the only way to avoid a climate catastrophe. However, today the global community is confidently moving towards the 3°C mark; and to stay within the declared framework, large-scale and costly changes are required in all spheres of life.

It is necessary not only to reduce the volume of greenhouse gas emissions but to completely level it, in other words, “reduce to net zero” no later than the middle of the XXI century. What is more, it implies a complete rejection of coal, oil, and gas combustion, in other words, the transfer of economic activity to fundamentally new sources of energy. All economic entities will need to radically revise the principles of land use, agriculture, urban planning, the organization of industry and transport, and the system of individual consumption.

The Paris Agreement came into force in 2020 and was the result of lengthy attempts to resolve the sustainable development of the global economy at a new stage. The key principle of the previous Kyoto Protocol was the differentiated responsibility for reducing emissions, which was charged, first of all, to developed countries and countries with economies in transition; new large global economic players (India, China) did not carry significant obligations. But at the beginning of the XXI century, cardinal changes have taken place in the system of world social production.

The task of developing a new universal agreement, taking into account the changing realities, was set in the mid-2000s, but for a long time, it seemed impossible, which required the extension of the Kyoto Protocol. The signing of the Paris Agreement was largely made possible thanks to its “hybrid” form. Such an agreement is legally binding, but countries independently formulate goals (“Nationally Determined Contributions”) to reduce emissions, based on plans for the development of energy and other “carbon-intensive” industries. The most important result of the Paris Agreement is the orientation of the world community towards a low-carbon economic development, which marks the irreversible trend of its sustainable development. The process of “greening” the world’s leading economies began before the signing of the Paris Agreement. In the USA, it was associated with the Shale Revolution; in Europe, since the 2000s the development of renewable energy is declared as one of the key tasks.

Thus, the Paris Agreement was made possible because it corresponded to the existing development plans of the leading states. Nationally determined contributions recorded by these countries are necessary guidelines for a low-carbon development strategy, which are implemented here without the appropriate global agreement. These strategies in most cases are only partly related to combating climate change; to a greater extent, they are determined by the need to reduce energy dependence, local pollution, and are aimed at creating new jobs and other factors.

At the same time, the Paris Agreement gave a signal to the whole world about the inevitability of a “low-carbon future”; all economic agents received a promise about the need to adapt to such a future to provide the prerequisites for a new level of competitiveness. The ways of adaptation vary for different economic agents.

So, many large companies introduce a “carbon price”. In other words, when implementing investment projects, they consider emissions as if they were taxed at a certain rate. This allows to “eliminate” the most carbon projects. The dirtiest projects experience problems with financing: there has been a tendency to withdraw capital investments from assets in “dirty” industries. By the beginning of 2017, 700 organizations, 5.4 thousand individuals from 76 world countries with a total asset of 5 trillion USD officially announced support for the “low-carbon development” initiative. Most of the assets are in pension funds and insurance companies (90%), universities, regional and municipal governments, etc. (Makarov, Stepanov 2018, p. 83). States are increasingly using “carbon pricing” as a tool to regulate greenhouse emissions and modify relevant sectors of the economy.

Thus, the low-carbon development of the economy since the signing of the Paris Agreement marks a new quality and lifestyle for all economic entities – individuals, households, businesses, national economies (states), and global society. On the one hand, low-carbon development involves the formation of new forms and the transition to a new level of competitiveness. At the new stage of competition, economic entities, by improving the energy balance structure, reducing greenhouse emissions, improving the climate component of the environment, should be able to provide a new quality of economic growth, renewing the employment structure, overcoming poverty, increasing the human development index and, together, achieving Sustainable Development Goals. On the other hand, the indicated trend without adequate material, social, and financial assistance may result in the further stratification of society at the local (within individual countries) and global levels, increased poverty, the emergence of new depressed regions, insurmountable obstacles to boost economic growth, and increased competitiveness of national economic entities of various levels.

Conceptual approaches to developing a low-carbon economic development strategy

In order to develop a national strategy for low-carbon development and combat climate change within the paradigm of sustainable socio-ecological-economic development, it is necessary to rely on a solid theoretical platform. Its components may include the following approaches:

- Studies that reveal the foundations of a stable polycentric climate regime presented in the writings of E. Ostrom (Ostrom 2010, pp. 550-557), R. Keohane, D. Victor (Keohane, Victor 2011, pp. 7-23).
- Concepts for the development of renewable energy sources (Mitchell, Mitchell 2016; *World Energy Outlook 2016*; *Annual Energy Outlook 2017*).
- The concept of a “New Climate Economy”, which was developed (and published in 2013) by the group of the Global Commission on Economy and Climate, led by N. Stern (Stern et al. 2006). According to F. Calderon and N. Stern, an effective economic strategy for regulating climate change and its consequences should not blindly subordinate the climate stabilization task to all other global and national development goals. The main question that needs to be answered is not how to

reduce greenhouse gas emissions, but how public policies can help achieve basic development goals while reducing emissions and creating a climate-resilient economy (Calderon, Stern 2013).

- *The position of the Paris Agreement* (represented in Articles 2, 4) is to formulate an economic development strategy that balances the low level of current and future emissions and the absorption of greenhouse gases already emitted into the atmosphere with the adaptation and resistance to the negative effects of climate, population and changes in the economy.
- *The position of the authors' report of the Intergovernmental Panel on Climate Change* (IPSS) (as of October 2018): Non-exceeding the 1.5°C level of global warming until the end of 2100 is a target function of the development of the world economy, influencing all other parameters of socio-economic development. Moreover, only a comprehensive solution to the problem of climate change is possible – in conjunction with the solution to the problems of sustainable development and poverty eradication.

The total amount of investments in low-carbon development (transition to renewable energy sources and energy conservation) in the period 2015-2035 is determined in the amount of 2.4 trillion dollars. It means 2/5 of investments in achieving all the goals of sustainable development. However, the limited choice and high cost of existing technologies for the extraction of CO₂ from the atmosphere significantly reduce the effectiveness of their use, pushing the prospect of reaching a threshold of 2°C beyond the limits of the current century (*Climate Change 2014*, Synthesis Report 2015, pp. V-IX; 2-33; Porfiriev 2019, p. 115).

- *The concept of endogenous economic growth taking into account climate change, proposed by Nobel Prize winner V. Nordhaus*. The author began to study the issues of climate influence on the economy in the 1970s, but the contours of an innovative mathematical model took shape at the turn of the XX-XXI centuries (Nordhaus 1993; 2013). He proposed the “Integrated Assessment Model” (IAM) to combine climate change and economic growth. Two new variables were introduced into the production function, such as natural resources and environmental damage; the relationship between two components is reflected in the second part of the model devoted to climate change. The main value of the model is considered to be its applied nature, which allows evaluating scenario forecasts of various government measures aimed at combating environmental pollution. The integrated Nordhaus valuation models have served as one of the main tools in the economic analysis of climate change. But, according to the opponents, the use of these models is associated with a large number of assumptions, many of which are arbitrary (Zamulin, Sonin 2019, p. 24). Consequently, the model does not produce adequate forecasts.
- *The concept of promoting the transformation of the grid infrastructure of energy, initiated by the European Union*. This transformation contributes to achieving carbon-free energy generation through:
 - connection of energy systems of the EU countries,
 - construction of an energy storage system,

- digitalization of the energy network infrastructure, the development of “smart grids”,
- adequate energy management.

Due to the success of the concept, the countries of the European Union can count on world leadership in the process of greening the energy sector and the economy. Thus, based on creating adequate infrastructure, the European Commission is creating framework conditions for the greening of the energy sector. By 2030, the share of electricity consumption from renewable sources should be brought up to 35%, and the share of renewable sources in electricity production should exceed 50%. It is assumed that by 2050 the electric power industry in the EU will become completely carbon-free (Zimakov 2018, p. 52).

- *The concept of an effective strategy to reduce the risks of climate change and their consequences for the population and the economy in the context of solving the problems of sustainable development and ensuring national security for the foreseeable future.* The main idea of the concept is to “give impetus” to economic development, and subsequently, to maintain its steady pace. Without this, it is impossible to solve other problems of socio-economic development, including climate (Porfiriev 2019, p. 11).
- Within the framework of the concept, it is substantiated that in the *real sector of the economy*, primarily in energy-intensive industries, the *efficiency criterion should not be a decrease in energy intensity* (focusing on energy saving), but an *increase in energy productivity* (carbon efficiency), implying acceleration of economic dynamics. To illustrate their position, the authors refer to the experience of the economic crisis of the 1990s, when stagnation in production caused a significant reduction in emissions but did not contribute to the environmental sustainability of economic development; it led to a deterioration in the quality of life, and ultimately to a decrease in the carbon efficiency of national economics.

In a generalized form, the main approaches to managing economic development considering climate change are presented in *Table 1*.

Table 1. Relevant approaches to developing a strategy for sustainable economic development based on effective management of climate change

General concept content	Initiators / Authors	Key ideas for effective climate change management	Date of publication
Sustainable polycentric climate regime	Elinor Ostrom; Peter A. Victor; David G. Victor; Herman E. Daly; Robert O. Keohane	- development of normal modes of functioning of common resources; - stabilization of economic growth rates within the limits of biophysical capabilities; calculation of the limits of unprofitable growth	1987-2019

General concept content	Initiators / Authors	Key ideas for effective climate change management	Date of publication
Sustainable development based on renewable energy sources	The World Energy Outlook (WEO); Annual Energy Outlook (AEO); John Mitcell; Beth Mitcell; Dr. Valery Marsel	Optimization of the energy balance by increasing the share of renewable energy sources	1977-2020 1996-2020 2016
New climate economy – a climate resilient economy	Group of the Global Commission on Economics and Climate; Nicholas Stern; Felipe Calderon	Development of an algorithm for achieving the basic goals of sustainable development, considering the progressive reduction of greenhouse emissions	2006-2013
Development strategy based on the balance of greenhouse emissions	Initiators of the Paris Climate Agreement	Strict control over the level of greenhouse gas emissions by accounting for national “contributions”	2015-2020
Comprehensive program for sustainable development, considering the solution of the problems of climate change and the eradication of poverty	Assessment Report of the Intergovernmental Panel on Climate Change – IPCC; Special Report on Global Warming of 1.5°C	Subordination of all technoeconomic processes to the target function of not exceeding 1.5°C the level of global warming	1990-2014 2018
Strategy for sustainable endogenous economic growth considering climate change	William D. Nordhaus	Integrated assessment model (IAM) for economic growth adjusted for climate change	1994-2018
Sustainable development based on carbon-free electricity generation	European Union countries; European Commission Resolution; European Commission Report “Towards a Sustainable Europe by 2030”	Efficient energy management based on smart grid infrastructure	2015 2019
Policy for optimizing the risks of climate change for the foreseeable future	The Institute of Forecasting of the RAS; Boris Porfiriev	Investment impetus for economic growth with the subsequent maintenance of its sustainable rates for a comprehensive solution to the problems of socio-economic development	2011-2019

Source: Based on own research

Conclusions

The problem of climate change requires an integrated approach to its solution based on the achievement and maintenance of sustainable economic growth. It should be borne in mind that, in a broad sense, climate change reflects only part of the risks to economic growth and development, and human life and health. This is evidenced by the Sustainable Development Goals (SDGs) adopted by the world community. SDGs not only combat climate change and their consequences but include 16 more Global Goals aimed at harmonizing its economic, social, and environmental components.

The most important initiative of the world community is the concept of sustainable development based on low-carbon technologies. All economic agents received a message to move to a new level of competitiveness. Successful adaptation to the new economic reality largely depends on the correctly chosen strategy for managing common resources. In this regard, scientific and expert communities offer a number of key models: the subordination of all techno-economic processes to the target function of not exceeding 1.5°C the level of global warming; optimization of the energy balance by increasing the share of renewable energy sources; development of normal modes of functioning of common resources; stabilization of economic growth rates within the limits of biophysical capabilities; calculation of the limits of unprofitable growth; increasing energy efficiency through the introduction of smart grid infrastructure and others. The verification and implementation of such models is an urgent need, because today, despite the actively announced initiatives since 2015, the world community has not made progress in realizing the goals of the Paris Agreement on climate (Editorial Article of the Journal Economist 2018, p. 3).

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TECHNOLOGIE NISKOWĘGLOWE JAKO CZYNNIK ROZWOJU GOSPODARCZEGO W OKOLICZNOŚCIACH ZMIAN KLIMATU

Streszczenie: Dobry klimat jest dobrem publicznym, wskaźnikiem wysokiej jakości życia i wysokiego poziomu dobrobytu publicznego. Korzystne znaczenie dla przepływów pracy wynikających z migracji determinuje pozytywne synergiczne efekty rozwoju gospodarczego. W latach siedemdziesiątych naukowe podejście do problemu poprawy komponentu środowiskowego otoczenia zostało połączone z ideą rozwoju społeczno-gospodarczego i przyczyniło się do opracowania koncepcji zrównoważonego rozwoju społeczności światowej. Dzisiaj jednym z pilnych problemów środowiskowych jest ryzyko zmiany klimatu – globalne ocieplenie, które może prowadzić do nieodwracalnych zmian w ekosystemie planety. Porozumienie paryskie przyjęte w 2015 roku zakłada odnotowanie globalnego wzrostu średnich temperatur, w celu uniknięcia katastrofy klimatycznej. Inicjatywa niskoemisyjnego rozwoju gospodarczego oznacza nową jakość i styl życia dla wszystkich podmiotów gospodarczych. Taki rozwój z jednej strony zakłada przejście na nowy poziom konkurencyjności indywidualnej i krajowej, a z drugiej strony – bez odpowiedniej pomocy materialnej, społecznej i finansowej – może przekształcić się w dalsze rozwarstwienie społeczeństwa, wzrost ubóstwa i stagnację gospodarczą. W tym zakresie analiza teoretycznych podejść do uzasadnienia przesłanek zrównoważonego rozwoju z uwzględnieniem wprowadzenia technologii niskoemisyjnych oraz wyjaśnienie kluczowych pomysłów na efektywne zarządzanie procesami zmian klimatycznych są pilną agendą dla podmiotów gospodarczych różnych szczebli.

Słowa kluczowe: zmiany klimatyczne, zagrożenie globalnym ociepleniem, zrównoważony rozwój gospodarczy, porozumienie klimatyczne z Paryża, technologie niskoemisyjne, efektywne zarządzanie wspólnymi zasobami