ROLE OF SCIENCE AND EDUCATION FOR SUSTAINABLE DEVELOPMENT

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ROLE OF SCIENCE AND EDUCATION FOR SUSTAINABLE DEVELOPMENT

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1.4. SOCIAL AND ECONOMIC TRENDS OF SUSTAINABLE DEVELOPMENT IN THE CONDITIONS OF DIGITAL ECONOMY

When the processes of human influence on nature have reached a global scale, there are only two possible areas for maintaining the stability of natural conditions on the planet in its arsenal. The first is to limit the growth of the Earth's population. The second is to learn to change the processes of social production and consumption of products, reducing their negative impact on nature. This can be done only by sharply reducing the nature (material consumption, energy) of human life support systems; moreover, the rate of this decline should overtake the rate of population growth or at least correspond to them[55, 56, 57].

Given the causal links, we can distinguish three levels of goals: the general-purpose – the preservation of man as a species and the progressive personal development of humanity; security goals – maintaining the conditions in which society can exist and develop; support goals – the preservation of the biosphere and local ecosystems that support the living conditions of humanity (Fig. 1).

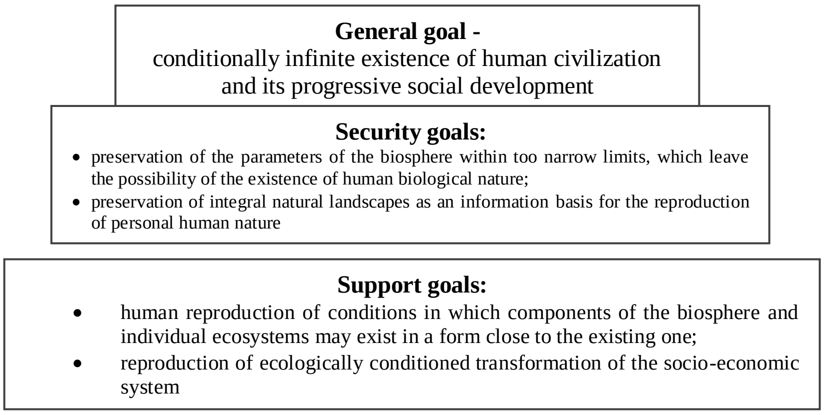

Fig. 1. Relationship between sustainable development goals
(complied by the authors)

We emphasize that the general goal has two levels of dimensions or breaks down into two groups of sub-goals: 1) necessary – the physical survival of biological man; 2) sufficient – personal development of a social person. Both groups are significant, although this is not always immediately apparent.

Security goals, based on the above, have two levels of benchmarks:

1) preservation within relatively narrow limits of parameters of the biosphere in which the biological nature of the person is capable of existing (that is, in which the human organism can maintain the level of the homeostasis); among these parameters, it is necessary to allocate key: characteristics of climate, physical parameters of environment (temperature, electromagnetic indicators, cosmic radiations, etc.), the structure of the atmosphere and water, the structure of soils for the production of agricultural products;

2) preserving integral natural landscapes and information contact, which is vital for reproducing a social person's characteristics.

Maintenance goals include creating conditions in which the biosphere and its constituent ecosystems can exist. They support (reproduce) the vital parameters of human existence as a biological being and personality.

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[55] Bobylov, S. N. (2012): “Green” economy and modernization. Series “On the way to sustainable development of Russia”, 2012, No. 60.

[56] Weizsacker E., Hargrose K., Smith M. (2013): Factor five. Formula for sustainable growth. Report of the Club of Rome / trans. from English / Moskva: AST-PRESS KNIGA, 2013.

[57] Sotnyk, I. M. (2012): Trends and problems of management of dematerialization of production and consumption. Actual problems of economy, 2012, No. 8.

Achieving these goals is an essential task that a person must take on. It is solved using conservation (preservation in an invariable kind) of different landscapes of wild nature (creation of reserves) or minimization of anthropogenic influence on ecosystems (creation of reserves and natural parks) and also restriction of possibilities of the intervention of the person in nature.

Based on the existing natural and ecological realities, which ultimately impose restrictions on the development of productive forces and the corresponding parameters of material and energy metabolism of human civilization in the Earth[58], the basic contours of Sustainable (or "green") economy are formed to implement the Third Industrial Revolution.

It is possible to formulate the necessary features of a Sustainable economy. At the same time, they will mark the directions in which the economy's sustainable development should move. The main ones are:

- renewable resources; renewable resources should become the principal basis of the "green" economy;
- dematerialization; cardinal reduction of material consumption, energy consumption, and nature consumption;
- transformational; constant progress towards improvement through progressive transformations;
- innovation; susceptibility to the rapid implementation of advanced innovations;
- naturalization; approximation of the form of involved materials, types of energy, and technological processes to those that exist in nature;
- social orientation; the dominant goal is the transition from the priority of economic plans to the importance of the goals of human social development;
- information orientation; preference is given to informatization of the spheres of production and consumption of products;
- ethics and humanization of the economy; implementation of ethical principles of sustainable justice;
- synergetization; integration of separate economic entities into integral systems ("systems of systems"), which can acquire the scale of local, regional, continental, or global networks;
- decentralization; increasing the freedom of individual economic entities in decision-making and implementation of activities on principle: "the center is everywhere, the periphery – nowhere";
- self-organization; increasing the degree of self-organization of systems on principle: "think globally – act locally."

We will call the process of economic transformation in the interests of sustainable development *sustainization*.

Sustainization is the process of forming a holistic system that would lead to the constant reproduction of the economic system processes to the sustainable development of primary production factors (including material basis, technical means, and people) to manage them.

In each case, the mechanism for implementing the tasks of sustainization involves forming four interconnected components of the system, which form a "square" of the management mechanism, particularly greening (Fig. 3): target settings; objects of greening.

The purpose of greening can be formulated as the elimination or reduction of one or more eco-destructive factors. This can prevent getting into the components of the environment or food chains of a harmful substance, reducing the processes that lead to landscape disturbance and others.

Concretization of the goals of sustainization allows formulating separate tasks of the transformation of a national economic complex to which can be carried:

- restructuring of the economy, industries and regions;
- re-profiling of enterprises;
- elimination (reduction) of the need for environmentally unfavorable types of products or services;

[58] Global Footprint Network. Ecological Wealth of Nations.

- replacement of environmentally damaging technological processes with their more perfect analogs;
- reduction of resource consumption of products, etc.

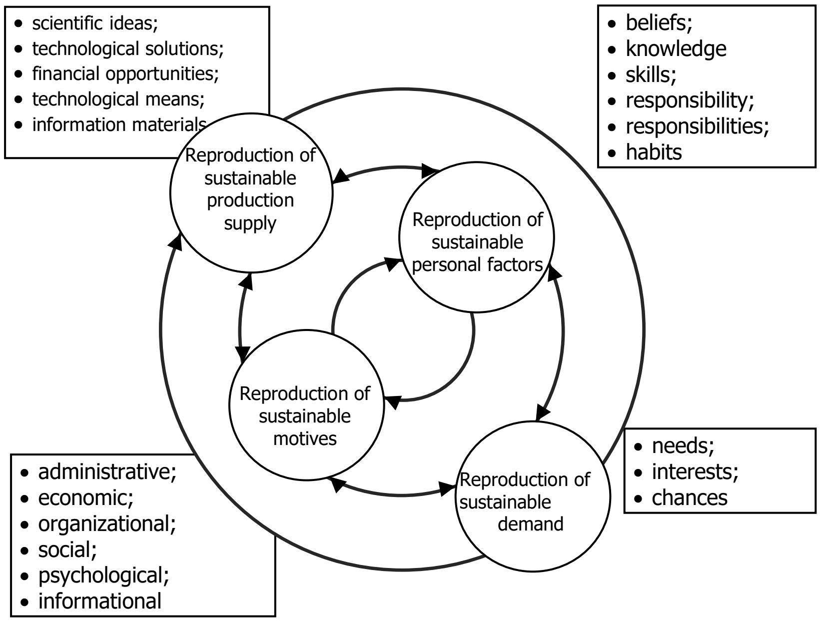

Fig. 2. Scheme of the reproductive mechanism of sustainization of the economy
(complied by the authors)

Economic preconditions for sustainization of energy: the experience of the EU. Energy is an essential part of any economy. The price of energy largely determines the price of goods and services produced. And the degree of technogenic load of society on natural systems depends on the environmental friendliness of energy production processes. Thus, the environmentally conditioned transformation of energy plays a crucial role in the sustainization of the economy.

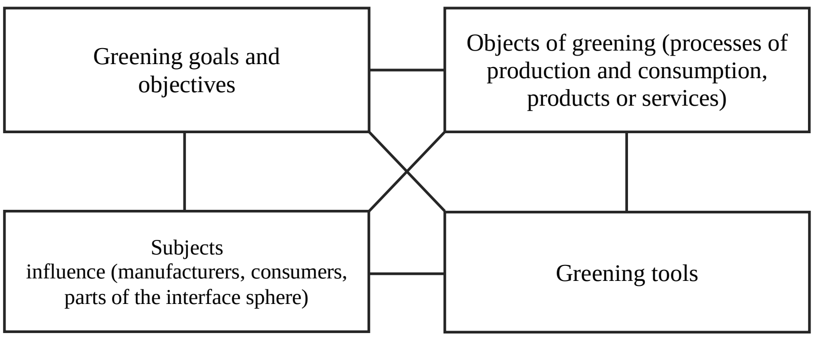

Fig. 3. Scheme of the mechanism of realization of tasks of greening
(compiled by the authors)

It is evident five directions (principles) of the Third Industrial Revolution in the EU countries, adopted as directive planning tasks by the EU Parliament in June 2007, four are directly related to changes in the energy sector, and the fifth depends entirely on them[59].

Here are these areas.

1. Development of renewable energy sources.

[59] Rifkin, J. (2016): The third industrial revolution: how horizontal interactions are changing the energy, economy and the world as a whole / per. from English 3rd ed. Moscow: Alpina nonfiction, 2016.

2. Use of spaces of existing social and industrial facilities (for example, roofs and facades of buildings, road surfaces, etc.) for installation of generators of renewable energy sources (solar, wind, geothermal, etc.).

3. Development of highly efficient means of energy storage.

4. Integration of distributed renewable energy sources into a single pan-European information and energy network (EnerNet).

5. Electrification of transport.

Under the directive, the EU has made commitments, which in administrative circles have been referred to as the “Three Twenties (20-20-20)”. By 2020 the following must be achieved: increasing the efficiency of energy systems by 20%; reduction of carbon dioxide emissions by 20%; increase the share of renewable energy sources in the energy balance of the European Union by an average of 20%.

As already mentioned, renewable energy sources have undeniable advantages. They are more environmentally friendly than traditional methods of energy production based on the combustion of fossil fuels. Also, they have several apparent properties that distinguish them from conventional energy facilities.

First, renewable energy sources are characterized by relative stability and inexhaustibility, which allows them to ensure a stable mode of operation of energy systems, and at the same time – the whole economy. These words may surprise someone. What kind of stability can we talk about if the sun does not shine continuously and the wind does not always blow? It's true. But this instability is characterized by stable regularity. Also, technical solutions ensure wind farms' operation at minimum wind speeds and even complete calm. An even more stable source is geothermal heat. In combination with efficient means of energy storage and storage, these sources provide a genuinely steady mode of operation of the power system in terms of energy supply and (which is extremely important) and the price of energy produced. It allows you to establish a stable order of regulation (diversification of selling prices depending on the time of day and seasonality of consumption).

“Green” energy (sun, wind, geothermal heat, tidal energy) allows you to do without fuel and chemical processes of its combustion. This means that entire industry units are removed from production cycles, which provide: extraction of fossil resources, reclamation of disturbed landscapes, transportation of raw materials, fuel combustion in power plants; manufacture of treatment equipment and waste utilization, as well as processes of creation of machine-building and construction enterprises, where capacities for the realization of all mentioned processes are formed. However, we must not forget that creating renewable energy generation installations cannot do without high costs. It is also essential to keep in mind the costs that will be required to dispose of alternative energy generators when they run out of time. However, with significant volumes of spent generators, we can use stream instead. This will be significantly facilitated if the development and disposal of generators are provided constructively during the generators’ design.

However, almost all renewable energy areas, including solar and wind, provide energy production with minimal labor costs at their operation stage. The American economist J. Rifkin called this phenomenon “energy with zero variable costs.” Also, compared to carbon and nuclear energy during the process of renewable energy sources, the costs materialized in the extraction and processing of energy sources are virtually impossible[60].

The US Energy Information Administration (EIA) has forecast the specific cost of producing 1 MWh of electricity for the period up to 2022 for various energy sources, provided that it is obtained at newly built facilities. The forecast took into account the dynamics (for 30 years) of the given indicators of the total cost (LCOE) throughout the production cycle (Table 1).

Areas of sustainization of the energy sector are related to three main areas of energy use:

1) electricity generation;

2) heating and cooling of premises;

3) driving vehicles.

[60] Ibidem.

Table 1. Indicators of reduced specific world average costs (LCOE) of energy production from different sources[61]

Type of production capacity	Net present value, (USD/MWh)
Offshore wind farms	138,0
Coal e / s with 30% residual CO2 content	130,1
Coal e / s with 90% residual CO2 content	119,1
Biomass power plants	95,3
Modern nuclear power plants	92,6
Gas e / s (with CO2 capture)	74,9
Photovoltaic (PV) SES	63,2
HPP	61,7
Ground wind farms	59,1
Gas (without CO2 capture)	50,1
Geothermal	44,6

The increase in the share of renewable energy in each of these areas is associated with complex technical problems that are systemic. The first direction is related to developing technical means of electricity generation and long-term energy storage (storage) systems. The second direction requires solving a set of engineering, architectural and urban planning tasks. The third direction determines the development of engineering solutions for electrification and hydrogenation of transport.

One of the crucial areas of the struggle of "green" energy for its consumers is economics. The price per unit of energy produced is often the determining factor in making decisions in favor of developing this type of energy.

Based on Swanson's law, general estimates of solar energy production cost are presented in Table 2.

Table 2. Indicators of the dynamics of solar energy according to Bloomberg New Energy Finance (BNEF) [62]

Indicator	Indicator value
Reduction of the unit cost of photovoltaic (PV) panel modules from 2010 to 2020	90%
The average specific cost of PV modules is expected to decrease by 2030	34%
The average specific cost of PV modules is expected to decrease by 2050	63%
The estimated value of the unit cost of 1 kWh of solar (PV) energy by 2050, USD / kWh	0,025
Reduction of the price for the unit capacity of storage batteries from 2010 to 2020	84%
Estimated share of solar energy produced in private households in total electricity generated in the world in 2050	11%
The diversity of increase in the amount of solar energy produced in the United States by 2025, times	2
The share of renewable energy in global energy production (50% - sun, 50% - wind) by 2050	50%
Reducing the cost of large-scale energy storage systems by 2050	64%
The total installed capacity of large-scale energy storage systems by 2050	360 ГВт
The share of coal-fired power generation by 2050 (halving in absolute terms compared to 2020)	12%

This tendency to reduce the specific cost of installed capacity is also observed for wind farms and even for biogas plants, which can be seen from the graphs in Fig. 9.3[63]. In particular, for onshore wind farms, the cost of installed capacity is reduced by 17% during each doubling of a wind farm[64]. For traditional fuels, such a pattern is not observed.

The transition to renewable energy is of paramount importance to most countries. It is one of the most critical steps towards ensuring their energy independence and restructuring economic

[61] Solar Power Costs Dropped Dramatically In 2013-2018. CleanTechnica.
[62] Will solar panels get cheaper? (updated for 2021). Solar Industry.
[63] Mokhtar, T. (2019): On the verge of a solar revolution. Noteworthy. The Journal Blog.
[64] Kellner, L. (2019): Report confirms wind technology advancements continue to drive down the cost of wind energy: wind energy costs at all-time lows, as wind turbines grow larger. New Center.

systems to form a “green” economy. It is gratifying that, along with other countries, Ukraine is making its efforts in this.

Today, the development of “green” energy in Ukraine is experiencing a significant rise. Every two days, one powerful solar power plant and about 25 small stations appear in Ukraine[65]. It is worth noting that the increase in alternative energy capacity is much ahead of the once approved plans, which were planned to increase the share of alternative energy to 2% by 2025[66].

In 2019, 4.5 GW of new alternative energy capacity was installed, which increased its total capacity almost three times to 6.8 GW. In general, these power plants can generate more than 8.4 billion kWh of electricity or 5.5% of the total. All this is due to 3.7 billion euros of investment[67].

The rapid development of alternative energy raises the question of reorganizing the management of the energy sector. First, the industry can no longer withstand the financial burden of "green" tariffs. Production of 8% of the total share of electricity, "green" energy assumes up to 20% of all energy payments[68]. Today, the country has launched an auction mechanism to sell specific amounts of electricity, designed to solve excessive growth in energy prices. It is all the more appropriate because "green" energy, due to its rapid price reduction, no longer requires the full application of tariff incentives.

The second problem is the technical issues of balancing energy capacity. Ukraine is already starting to produce more electricity than needed. It is necessary to temporarily limit nuclear power, thermal power, and even alternative generations to balance power systems.

Creating a significant amount of energy storage capacity could partially solve the problem. Incentive financial mechanisms are also beginning to work in the country to solve this problem.

Humanity today is on the threshold of a phase transition, the driving forces of which are the Third, Fourth, and Fifth Industrial Revolutions. The colossal rate of change of individual indicators that characterize socio-economic systems' technological state demonstrates the beginning (Table 3).

Table 3. Changes in some indicators of the world economy for the period 2017-2020
(compiled by the authors based on Internet publications)

Indicator	Increase of indicator, %
Solar energy production for the period	70
Wind energy production for the period	52
The efficiency of solar panels	42
Total energy storage capacities	120
Sale of robots for the period	74
Sales of 3D printers for the period	88
Sale of electric cars for the period	108

Economic factors are critical components of the changes taking place, which can be called avalanche-like processes without exaggeration. One of the Third Industrial Revolution's essential tasks is to make the progressive conquests of science and technology (particularly those mentioned at the beginning of this section) as cheap as possible. It makes them accessible to a wide range of users. In particular, PCs, mobile phones, the Internet, Wi-Fi, and GPS appeared in most households. Only then could there be a qualitative breakthrough to a new technological and social level, preceding the phase transition.

The latter is extremely important because the very concept of “transition to new technologies” implies not only the theoretical feasibility of certain processes (changes), but also the practical implementation of this phenomenon on a mass scale, taking into account economic and

[65] The tension rises. Green energy is developing at a record pace in Ukraine. NV Business.
[66] Orel, I. (2017): Renewable energy in Ukraine: a step forward, two steps back. Finance.ua. news.
[67] Líga.net. A ghostly “green” future. Special project.
[68] Sergach Y. U. (2019): Akhmetov, Khoroshkovskiy i Ko: who built the largest "green" power plants in 2019. OILPOINT.

environmental constraints characterized by the relevant properties of the systems and the situation in society.

Such changes are happening. It is enough to look at the data in Table 4. It shows some indicators that characterize the dynamics of reducing the cost of specific technical means or services (works) that ensure the implementation of the most critical production processes.

Table 4. Decrease in the cost of technical means/implementation of a unit of work for the last 35 years

(compiled by the authors according to online publications)

Technical means/process	The diversity of change, times
The processor in a computer	10 000
Sensor and RFID tag	1 000
Performing one conditional operation on an automatic device	1 000
Video surveillance	500
Production of 1 kWh of electricity on a solar battery	150

However, even such astonishing figures must be taken conditionally because the qualitative properties of modern technical means and their analogs 35 years ago cannot be compared either in terms of functions performed, in terms of their complexity, or terms of quality of action.

Suffice it to say that the microprocessor of a modern computer performs several billion operations in 1 second. In contrast, a device with similar functions in the early 1980s performed only a few thousand. Another example: thanks to fiber-optic communication, information transmission speed has increased by more than five orders of magnitude.

It is appropriate to note three crucial points. First, the most significant part of these changes (including cost reductions) fell in the last decade, i.e., the period when the Third and Fourth Industrial Revolutions began.

Secondly, cost indicators cannot fully reflect the full depth of improving the efficiency of technical systems. The latter is much deeper and is measured by many other parameters. In particular, progressive development of batteries is manifested in a significant reduction in size and weight of batteries per unit of their useful capacity, a significant reduction in their charging time (which in some cases reaches only a few tens of seconds), increase in operating time between gas stations (including the mileage of electric vehicles at one gas station, which for record samples is already more than 1,000 km), growth, which develops with the help of batteries of technical systems (in particular, the speed of electric vehicles reaches 700 km/h).

Third, there have been phenomena (including technical means and processes), which did not exist before, but which can radically, abruptly increase production systems' efficiency. We are talking about digital and “cloud” technologies during the transmission, capture, and processing of information and 3D printers during the manufacture of products. This list should be added by GPS and other satellite technologies, subject to the control of spatial processes and communication between cyber-physical systems, the “Internet of Things” and “smart” networks in managing industrial and social systems.

These changes could not have taken place without the hundreds of daily innovations already being born in the depths of the Third Industrial Revolution. These innovations do not suddenly. They must be generated by the business itself, whose tasks change significantly in the process of industrial revolutions.

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