

DECARBONIZATION AND ECOMODERNIZATION OF THE ECONOMY
AS A RESOURCE-ENERGY-EFFICIENT WAY
OF POST-WAR RECONSTRUCTION OF UKRAINE

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Abstract. Global climate changes are taking place on our planet, which cause an increase in the average annual temperature of the atmospheric air, and, therefore, rapid melting of glaciers on all continents and an inevitable rise in the level of the world ocean. This, in turn, can lead to “environmental” wars, a brutal struggle for survival resources, and powerful migration processes. At the same time, one of the main reasons for such global changes and processes is the huge amount of emissions of greenhouse gases and soot particles into the surface layer of the atmosphere (troposphere), caused by anthropogenic and man-made activities, outdated energy-intensive technologies that involve the excessive extraction and use of carbon-containing raw materials, their burning and emission into the atmosphere. However, an alternative to this in post-war Ukraine can only be decarbonization and eco-modernization of its economy based, first of all, on renewable energy sources (in particular, the inexhaustible energy of the Sun), resource-saving, closed, recycling, emission-free and other modern innovative environmental protection and energy-efficient technologies. That is, humanity must definitely go on the path of “green” transformation of not only the economy, but also the greening of all other spheres of life (Hura, Petruk, 2021).

Keywords: decarbonization, eco-modernization of the economy, renewable energy sources, climate change, “greenhouse” effect, solar generation.

1. Introduction

Ukraine, like Europe and the whole world, should reduce its dependence on fossil fuels as soon as possible, even though it is considered that renewable energy sources (RES) are comparatively more

expensive. However, the volume of RES today is constantly growing and has begun to lead from the position of the cheapest cost of energy resources, even taking into account the problems of supplying gas to Europe, it is more expensive than RES. (Bilyavskyi, 2021). Therefore, decarbonization (decarbonization) is a process of modern innovative measures, methods, methods and environmental protection and energy-efficient technologies aimed at limiting the rate of global warming and are based not only on: 1- limiting the extraction and use of carbon-containing raw materials (coal, oil, gas, fuels shale, fuel oil, peat, etc.), but also on: 2- reduction of emissions of greenhouse gases (primarily: CO₂, CO, CH₄, H₂O vapors, etc.) into the atmosphere. At the same time, global climate changes are taking place in the world, which can cause irreversible ecological disasters, risks and threats of severe agony, or even the death of all living systems and, first of all, of man as a separate biological species by the end of this century. Therefore, it is now necessary to unquestionably abandon obsolete and energy-intensive technologies, which at their core involve the violent use of supposedly free carbon-containing raw materials, in particular, the one mentioned above, and, therefore, a reduction to “zero” greenhouse gas emissions, which significantly increase the temperature of the atmospheric air by planet and the corresponding strengthening of the “greenhouse effect”. (Gnedina, Soroka, 2023).

The *purpose of the work* is the analysis of modern trends, trends and technologies of decarbonization and eco-modernization of the economy of post-war Ukraine in the conditions of global climate change.

2. Results and Discussion

As you know, in accordance with the Paris Agreement (Paris Agreement, 2015), Ukraine undertook to reduce the level of greenhouse gases by 40 % by 2030 (and according to updated data by 55 %) compared to the pre-industrial level, that is, from 1990 a year. At the same time, our state, together with most of the civilized countries of the world, undertook to completely reduce atmospheric emissions to “zero” by 2050. At the same time, carbon neutrality or “zero” waste (emissions) means that the volume of greenhouse gas emissions should not exceed the volume of carbon, which thanks to photosynthesis is absorbed by forests and vegetation on land and oceans thanks, in particular, to phytoplankton. To reach this level, it is necessary to reduce the extraction of coal, oil and gas by approximately 6 % per year. However, recently, contrary to this, the use of carbon-containing raw materials even increases by 2–3 %. And the trajectory of greenhouse gas emissions is the limitation of global warming, in accordance with the Paris Agreement, to a level of no more than 1.5–2 °C. However, by the end of the 21st century, the average temperature of the atmosphere, if the conditions of carbon neutrality are not met, may increase by 4.5 °C or even more degrees, not taking into account the increase in the temperature of the troposphere by more than 1 degree today compared to the beginning of the 20th century. The essence of the “greenhouse effect” is an increase in the temperature of the atmospheric air due to an increase in the concentration of greenhouse gases and soot particles from the combustion and emissions of carbon-containing raw materials, which, on the one hand, reflect and scatter high-energy incident sunlight, and, on the other hand, scatter in the surface atmosphere (troposphere) reflected from the earth's surface, to a large extent, infrared rays. And the greater the concentration of these gas emissions and soot particles in the atmosphere, the more it warms up with a corresponding rise in its average annual temperature indicators (Fig. 1).

The result of the increase in the average annual temperature of the atmospheric air is the “greenhouse” effect, which is already causing a powerful mechanism of melting of the planet's glaciers (Arctic, Antarctic, Greenland, ice “caps” of mountains, etc.). At the same time, it is known that, according to scientists' estimates, approximately 30–40 million km³ of

ice is concentrated on the Earth. Therefore, knowing the area of the globe – 510100000 km², the land area – 29 % (149939063.133 km²) and the area of the world ocean – 71 % (360160936.867 km²), you can easily calculate that in the event of complete transformation of ice into water, the world ocean will rise to a height of 83 to 111 meters! It is clear that at the same time it is necessary to take into account which low-lying part of the land this water will flood, then the heights of these levels will decrease slightly, and the area of the land may decrease from 29 to 20–25 %. Suppose that by the end of the 21st century, under a realistic scenario of climate change and the “greenhouse” effect, the amount of ice can decrease, for example, by 10–20 %. Then, all the same, the level of the world ocean will increase to at least 5–8 meters. This, in turn, will lead to the almost complete disappearance of, for example, the Netherlands, New York, flooding of the Caspian, Amazon, Dnieper, Black Sea, Hindustan, Mesopotamian lowlands and other territories. As we can see, this process of flooding can significantly affect our southern Ukrainian regions as well. At the same time, the reduction of the land area due to the rise of the ocean level will clearly lead to the migration of the population of those countries, cities and territories to unflooded land, which will be affected. As a result, it will lead to “environmental wars”, a fierce struggle for survival resources and other dangerous risks, threats and catastrophic consequences for humanity. Therefore, in this context, the development of the economies of the countries of the world and, in particular, of Ukraine, has no other alternatives than undeniable and comprehensive decarbonization and greening of all spheres of life. (Kyzym et al., 2020).

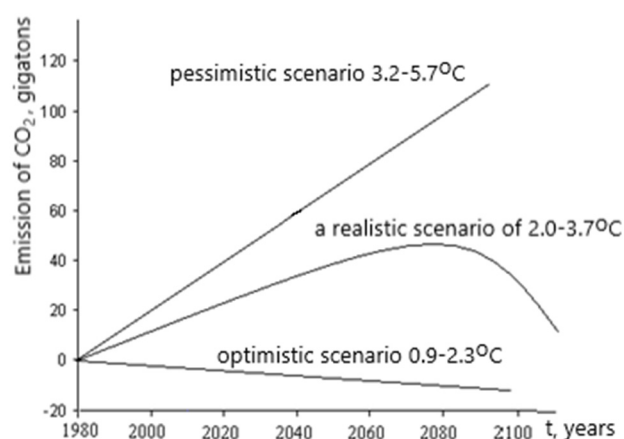


Fig. 1. Temperature scenarios of greenhouse gas emissions

At the same time, the main sources of greenhouse gas emissions are known and summarized in the Table 1.

Table 1

The main sources of greenhouse gas emissions

Greenhouse gases	The most significant anthropogenic and natural sources of greenhouse gas emissions
CO ₂	Metallurgy, chemical industry, agriculture, cement production, deforestation and forest fires (currently approximately more than 7 gigatons of CO ₂ per year), volcanoes, flares for crude oil and gas extraction, thermal power plants, and others.
CH ₄	Fossil fuels, livestock, sewage, rice cultivation (anaerobic decomposition of organic matter), melting of permafrost, swamps, biotanks at sewage treatment plants, etc.
CO	Chemical industry, production of graphite elements, incomplete combustion of fuel at thermal power stations, furnaces, boilers, etc.
N _x O _y	Agriculture, transport exhaust gases, chemical industry (in particular, production of ammonia and mineral fertilizers), etc.
SO ₂	Volcanic eruptions, chemical industry, thermal energy (in particular, from the combustion of high-ash coal with a significant sulfur content), metallurgy, etc.

In addition to these and other gaseous pollutants, a significant amount of solid particles enter the atmosphere in the form of dust, soot, ash, soot and other emissions.

Therefore, the main directions and technologies of carbon-free development are presented in Table 2.

Table 2

The main directions and technologies of carbon-free development

Number	The direction of carbon-free development	Technologies implementing this direction
1	Renewable energy sources	Solar generation with the help of panels and collectors, wind generators, geothermal energy, biofuel and others.
2	Accumulation of energy	Electrochemical current converters, storage batteries, lithium-ion storage sources, carbon dioxide capture technologies, etc.
3	Hydrogen technologies	Electrolytic conversion of seawater into hydrogen, gas holders, technologies of hydrogen combustion with condensation of water vapor, etc.
4	Decarbonization of transport	Transition to hydrogen and electric transport using lithium-ion technologies of electric energy storage, complete rejection of internal combustion engines following the example of Scandinavian countries, etc.
5	Heat pumps	Technologies for extracting heat from the air, water, and underground using heat pumps, air conditioners, etc.
6	Energy saving	Modern energy-saving technologies of "passive" buildings, their insulation, use of modern construction technologies of thermal insulation, etc.
7	Regenerated agriculture	Regenerative agriculture technologies aimed at protecting and restoring soil, increasing organic matter, resisting soil erosion, crop rotation, composting and applying humus, using permaculture, Strip-till minimal tillage technology, etc.
8	The concept of new urbanism	Technologies of mixed neighborhood development with pedestrian accessibility to various infrastructure facilities, "smart" city, "green" buildings, reorientation of transport to public transit, cycling, landscaping of the city, etc.

In addition, it is necessary to apply quotas and interest-free loans for carbon-free technologies, comprehensive eco-modernization of the economy, persistently implement the greening of all spheres of life, that is, implement resource-efficient and ecologically clean production, closed-loop economy, recycling

and zero-emission technologies and other measures of green transformation of people's life activities (Marshall Plan, 2023).

All these measures of decarbonization and greening, which are presented in Table 2, are possible, first of all, thanks to the use of RES and,

first of all, solar energy. As you know, this resource is unlimited for humanity. At the same time, the intensive development of solar generation began only at the beginning of the 21st century,

however, in different countries in different ways. China, USA, India, Germany, Italy, Spain started this process around 2000–2005, and Ukraine – in 2005–2010, Fig. 2.

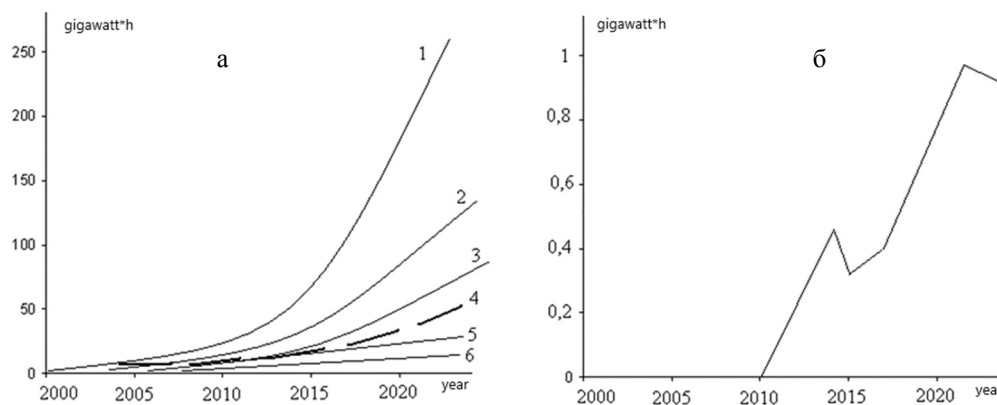


Fig. 2. The dynamics of electricity produced by SPPs in different countries: a) 1 – China, 2 – USA, 3 – India, 4 – Germany, 5 – Italy, 6 – Spain; b) Ukraine

Therefore, our country lags far behind other leading countries in the world in the context of SES construction. But this is not catastrophic, because Ukraine also increases the amount of solar energy generation every year, and the introduction of the “green” tariff in 2008 (actually – 2009) became an incentive for its intensification, in particular for private solar power plants (generating units up to 30 kW): 0.164 EUR per 1 kWh if the plant is connected in 2020–2024, and EUR 0.146 per 1 kWh if the plant is connected in 2025–2029. State legislation creates favorable conditions for investment in RES-based technologies, and the state is obliged to buy back the energy that the participant of the “green” tariff gives to the grid. These are some of the best interest rates in Europe. At the same time, the payback period of investments in the field of RES decreases every year and is currently 5–7 years, Fig. 3.

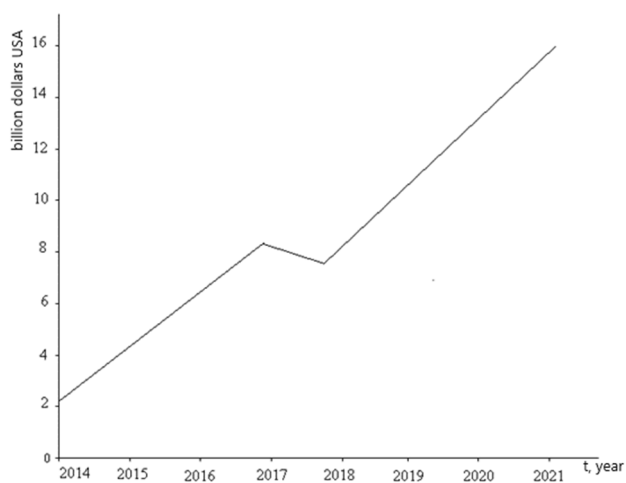


Fig. 3. Investments in renewable energy sources

It is also worth noting that the cost of building solar generation facilities is decreasing every year. Likewise, the cost of lithium-ion batteries has been decreasing over the past 10–15 years, Fig. 4, a, b.

At the same time, the total share and dynamics of RES in the energy sector of Ukraine increased from 5.9 % in 2014 to 11 % in 2020, and the installed capacity of RES under the “green” tariff in MW increased: from 967 in 2014 to 3169 in 2019. Special growth is noted for SES, namely: from 411 MW in 2014 to 2072 MW in 2019. Since the beginning of 2015, more than 2,202 MW have been commissioned and more than 2 billion euros of investments have been attracted. We also add the dynamics of the increase in the number of solar power installations for private households: from 132 in 2015 to 8,843 in 2019.

At the same time, it is worth noting successful examples of the implementation of renewable energy projects in Ukraine: Teofipol biogas complex with a capacity of 15 MW (investment – 40 million euros), Khmelnytsky landfill gas degassing plant with a capacity of 659 kW (investment – 34 million UAH), Kamianets-Podilska TPP with an ORC module with a capacity of 45 MW (investment – 8.2 million euros), Nikopol thermal power plant with a capacity of 246 MW (investment – 230 million euros) is among the TOP-3 largest thermal power plants in Europe, Vinnytsia plant for the production of solar panels of the KNESS Group (investment – 5 million euros), one of the world's largest biogas complex in Vinnytsia region of Myronivsk Hliboproduct (MHP) with the name “Biogas Ladyzhyn” with a capacity of 12 MW (first

stage) for the processing of organic waste from broiler chickens. In it, the annual production of “green” electricity will reach 87,000 MWh, which replaces gas with “green” heat in the volume of 4–6 million m³. Its

operation makes it possible to significantly reduce greenhouse gas emissions and obtain excellent organic fertilizer for agricultural land (the initial investment of the complex is \$27 million). (Kuznetsova, 2021).

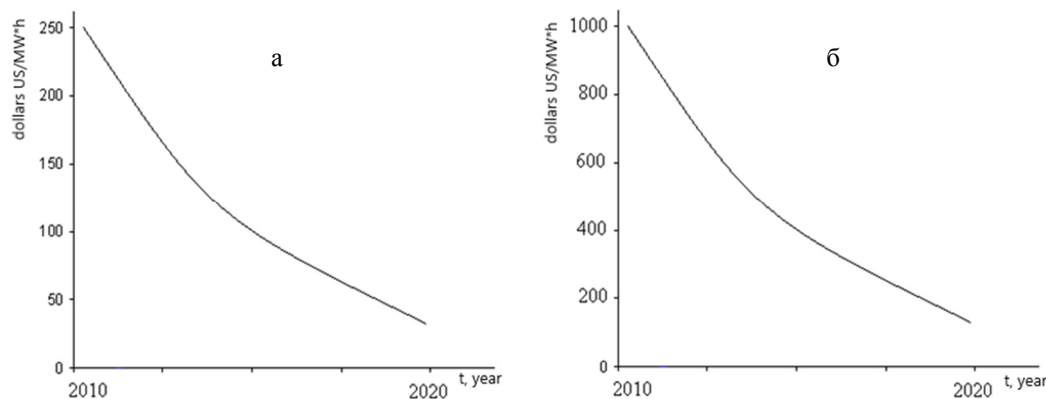


Fig. 4. Dynamics of trends in the cost of production of solar generation facilities (a) and the cost of lithium-ion batteries (b).

So, the sun, like some other natural sources (wind, geothermal, biogas, etc.) is a giant renewable and inexhaustible source of energy for mankind. And the growth trend of solar generation, like other RES, is irreversible. This unique natural energy resource needs to be implemented even more actively on the way to complete decarbonization and eco-modernization of the economy of Ukraine and the world (Stubbe, Zachmann, 2021).

3. Conclusions

Since global warming is recognized as one of the main problems on Earth, it is already possible to assert the urgent need for climate mobilization of mankind. Therefore, already now the world should be directed to the unquestionable rejection of the consumption of carbon-containing resources, and the fight against global climate change should become the most important problem for all countries. At the same time, Ukraine, the EU and the whole world must move towards final decarbonization and greening together, and the post-war recovery of our country's economy must be carried out exclusively using the decarbonization paradigm based on innovative energy-efficient and environmental protection technologies.

Therefore, the path of decarbonization and ecomodernization will make the economies of countries more modern and stronger, and the ecological state of the planet much better, which will lead to the stabilization of the climate on Earth and the proper

quality of life for mankind and the harmonious functioning of all other ecosystems.

References

- Bilyavskiy, M. (2021). *Ukraine and the global policy of decarbonization*. Centr Razumkova. Retrieved from https://rasumkov.org.ua/uploads/article/2021_Ukraine
- Gnedina, K. V., & Soroka, A. V. (2023). Decarbonization of the economy as a factor of ensuring a climate-neutral future: current challenges and prospects in Ukraine and the world. *Economy and society*, 54. doi: <https://doi.org/10.32782/2524-0072/2023-54-76>
- Hura, K. Ju., & Petruk, V. H. (2021). Analysis of Current Trends of Decarbonization and Ecomodernization of Energy of Ukraine and the World. *Visnyk of Vinnytsia Polytechnical Institute*, 5, 19–26. doi: <https://doi.org/10.31649/1997-9266-2021-158-5-19-26>
- Kyzym, M. O., Chaustova, V. Je., & Špiljevs'kyj, V. V. (2020). *Teoretyko-prykladni aspekty dekarbonizaciji ta rozvytku rozpodilenoji elektroenerhetyky Ukraïny*: kol. Monohrafija. Charkiv: FOP Liburkina L.M.
- Kuznetsova, M. O. (2021). Decarbonization as priority for sustainable development of energy company. *Ekonomika ta derzhava*, 1, 171–174. doi: <https://doi.org/10.32702/2306-6806.2021.1.171>
- Paris Agreement (2015). Retrieved from https://zakon.rada.gov.ua/laws/show/995_161?lang=en#Text
- Marshall Plan for the post-war reconstruction of Ukraine. Proposals of the UN Global Compact Ukraine. (2023). Retrieved from <https://globalcompact.org.ua/en/news/marshall-plan-for-the-post-war-reconstruction-of-ukraine-proposals-of-the-un-global-compact-ukraine/>
- Stubbe, R., & Zachmann, G. (2021). Towards a Green Modernisation Programme for Ukraine, *Voľ Ukraine*. Retrieved from <https://voxukraine.org/nazustrich-programi-zelenoyi-modernizatsiyi-ukrayiny>