THE IMPACT OF RENEWABLE ENERGY ON ECONOMIC GROWTH AND SUSTAINABLE DEVELOPMENT

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Abstract: Since 1997, when the Kyoto Protocol was signed, the era of renewable energy has begun. Due to the growth of its share in the total energy production and consumption, the world community is making efforts towards the transition to sustainable development. Developed and developing countries have significantly increased production and consumption of renewable energy in absolute terms trying to join this initiative. The purpose of this work is to study the impact of changes in the share of total production and consumption of renewable energy on the economic growth and CO_2 emissions. Secondary data of the World Bank, the countries that invest the most in renewable energy (the USA, China, the European Union) is used and a comparison with Ukraine, Russian Federation and general global indicators covering the period 1990-2015 is made. Modeling of the influence of the share of production and consumption of renewable energy sources in the total volume in the studied countries on the level of economic growth and CO_2 emissions using economic and mathematical modeling is carried out. Linear regression models of the studied countries and the world are estimated. The hypothesis on a link between economic growth and development of renewable energy has been confirmed. The results reveal that depending on the country under the research the level and nature of the impact of increasing the share of production and consumption of renewable energy on economic growth differs significantly and depends on a number of political and economic factors.

Keywords: renewable energy; renewable energy sources; renewable energy output; renewable consumption; sustainable development.

1. INTRODUCTION

Nowadays, renewable energy technologies are considered not only as a tool for mitigation of the climate change effects but more often as investments that can provide direct and indirect economic benefits due to reduction of the dependence on imported fuels and, consequently, improvement of trade balance, which is especially relevant for Ukraine, improvement of air quality at the local level, promotion of access to energy sources, improvement of economic development and job creation (Lezhniuk, et al. 2020).

It is obvious today that intensive use of fuel energy leads to economic growth but it also causes irreparable damage to future generations due to air pollution and CO_2 emissions (Sikder et al, 2019; Gautam et al, 2019). Fuel energy usage increase CO_2 emissions, cause an environmental damage, influence the greenhouse effect and human beings quality (Apergis and Danuletiu, 2014; Sirag et al., 2018; Zeppini and Van Den Bergh, 2020).

In Dietzenbacher et al. (2020) study noted that renewable energy sources do not increase CO_2 emissions and do not have a negative impact on the environment and the quality of life in future. However, it has significant energy potential (Gundebommu, 2020). In the study of Güney (2019) and Güney and Kantar (2020) researchers founded out that renewable energy sources are the most suitable energy sources to ensure sustainable development goals. High-income countries are thought to have the greatest impact on CO_2 emissions and economic growth, it was supported by studies analyzing the energy impact of high-income countries on CO_2 (Topcu et al., 2020) and GDP (Arminen and Menegaki, 2019).

In recent years, the study of the relationship between renewable energy and sustainable development has become increasingly important. Akadiri et al (2019) and Chen et al. (2019), use GDP as an indicator of sustainable development, their researches have demonstrated that renewable energy has a positive impact on economic growth.

GDP growth is one of the consequences of a significant development of renewable energy sources (RES) worldwide. According to a new IRENA analysis (2020), reaching 36% of the share of renewable energy in the global energy balance by 2030 will increase world GDP to 1.1%, or about $ 1.3 trillion. The impact of RES on the welfare of population is estimated to be three to four times higher than its impact on GDP, and global welfare will increase by 3.7%. Employment in the renewable energy sector is also expected to increase from 11.5 million jobs today to more than 24 million jobs by 2030. New jobs do not cause job losses in the fossil fuel sectors (which are more mechanized and capital-intensive), because RES are more labor-intensive than the conventional energy sector. For example, solar energy creates twice as many jobs per unit of electricity produced compared to coal or natural gas. And this is especially important for Ukraine, considering a current difficult situation in the labor market.

To improve the state policy on the promotion of the renewable energy development in Ukraine, it is important to conduct a thorough analysis of the experience of foreign countries in this area and identify key features and prospects for increasing the share of renewable energy in Ukraine in order to ensure its further sustainable development.

2. METHODOLOGY OF RESEARCH

In our research, renewable energy is considered in terms of two quantities: net energy and sustainable energy. Net energy is measured by Renewable Energy Output (REO), i.e. the share of electricity generated by renewable power plants in the total amount of electricity produced by all types of stations. Sustainable energy is measured by the share of Renewable Energy Consumption (REC) in the total energy consumption. GDP per capita is treated as an indicator of the economic growth. The years of analysis cover 90-s, which was marked by an active search for alternative energy sources in response to the growing popularity of the concept of sustainable development, the principles of which were officially proclaimed at the International Conference on Environment and Development (Earth Summit) in Rio de Janeiro in 1992. The study is based on the

annual data of 1990-2015 on the above-mentioned indicators of countries under the research, the latest data that are available from WB. The study was conducted at the global level and in terms of countries that are the leaders in attracting investments in renewable energy (the USA, European Union, China), Ukraine, and Russia. The study was conducted on the basis of information obtained from the World Bank database using a linear regression model (1).

$$Y_i = a_1 + \beta_1 X_{1i} + \beta_2 X_{2i}$$

(1)

where Y – the value of GDP per capita, an indicator for measuring the economic growth; X_1 – the share of REC in the total energy consumption, X_2 – the share of REO in the total energy production, β_1 and β_2 – coefficients of REC and REO, respectively.

3. RESULTS

Nowadays, the world's largest economies are actively investing in the development of renewable energy sources. The level of investments in renewable energy has been rather stable since 2014 and ranges within $ 50 billion from $ 265 billion to $ 315 billion. The dynamics of increasing the global investment potential of renewable energy is presented in Fig. 1.
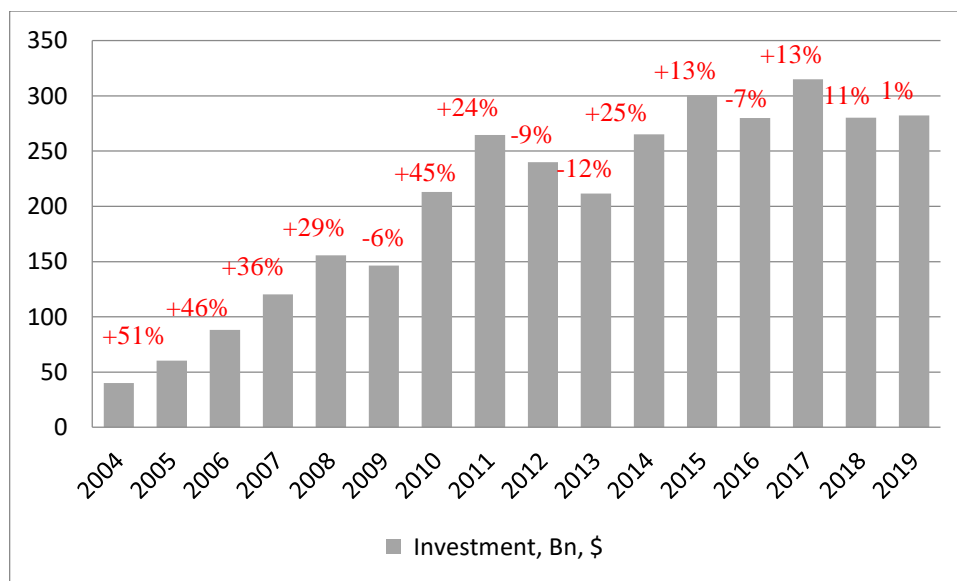

Fig. 1. Dynamics of increasing the global investment potential of renewable energy (UNEP, 2020)

Fig. 2 represents the global investment potential of renewable energy by the sectors. It is obvious that the wind and solar energy are the most investment-attractive areas.
In 2019, a record $ 138.2 billion was invested in wind energy, which was 6% more than in 2018, while $ 131.1 billion was invested in solar energy, which was 3% less than in the previous year and that has become the lowest indicator since 2013.
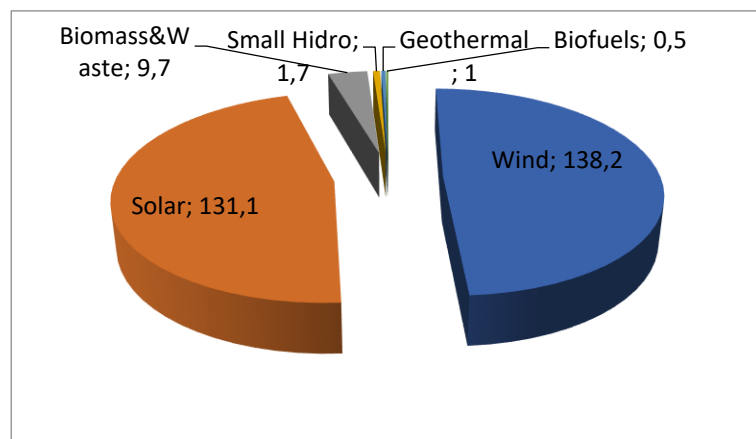
Fig. 2. Global investment potential of renewable energy by the sectors as of 2019 (UNEP, 2020)

Biomass and waste stably rank third among the renewable energy sectors in terms of investment, while the level of investment in 2019 increased by 9% up to $ 9.7 billion. Geographical distribution of investment attractiveness of renewable energy was more dynamic in 2019 than the industrial one. The figure shows that China, the United States, and Europe were the most active in attracting investments in renewable energy. However, their relative contribution has changed, the level of China's investments has decreased, and the United States, on the contrary, have shown a positive dynamics being ahead of the European Union by several points. The ranking of 20 best countries and markets is shown in Fig. 3. Ukraine is included in the second ten holding 17th position with a figure of 3.4 BN$ and an annual growth of 56%.

The developed economies were generally the first to introduce renewable energy technologies such as wind, solar and biomass. According to the international agency IRENA (2017), Ukraine has the greatest potential for the use of renewable energy sources among the countries of South-Eastern Europe – 408.2 GW. This proves a great potential of this industry and the ability to create relative autonomy and independence from energy supplies from other countries. In Ukraine, wind and solar power plants are the most profitable.
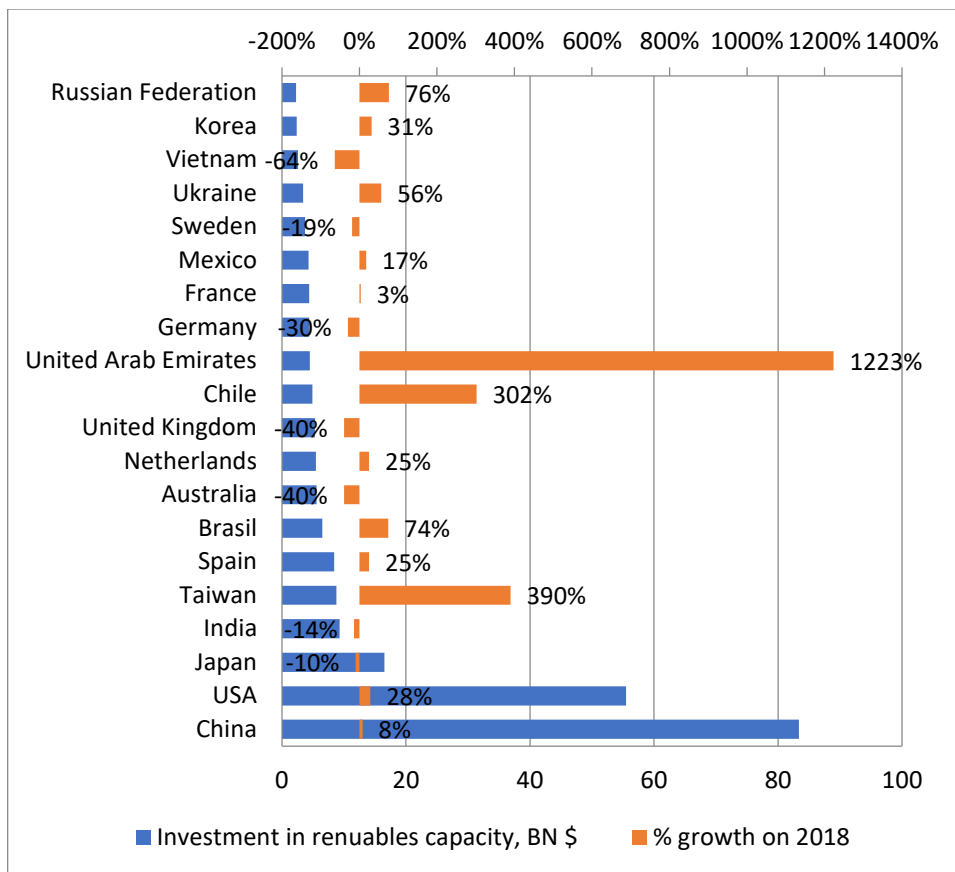
Fig. 3. Ranking of leading countries in RES investment capacity, 2019 (UNEP, 2020)

The results of modeling the impact of the renewable energy development level on the economic growth of the studied countries and the world are shown in Fig 4.

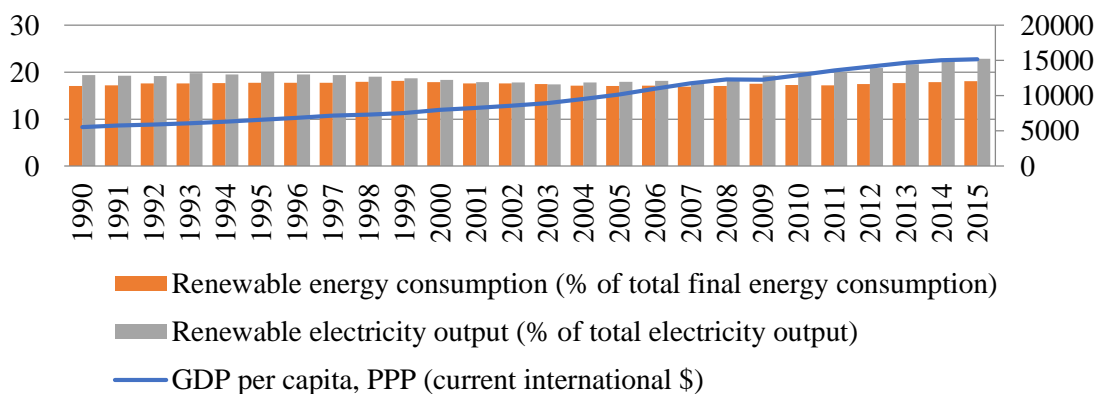$$y=45432,8-3747,35X_1+1546,7X_2, R\text{-}square=0,38$$

Renewable energy consumption (% of total final energy consumption)

Renewable electricity output (% of total electricity output)

GDP per capita, PPP (current international $)

Fig. 4. Influence of REC and REO on the world economic growth according to the data of 1990-2015

$$y=5081,1-414,1X1+534, 97X2, R\text{-}square=0,96$$
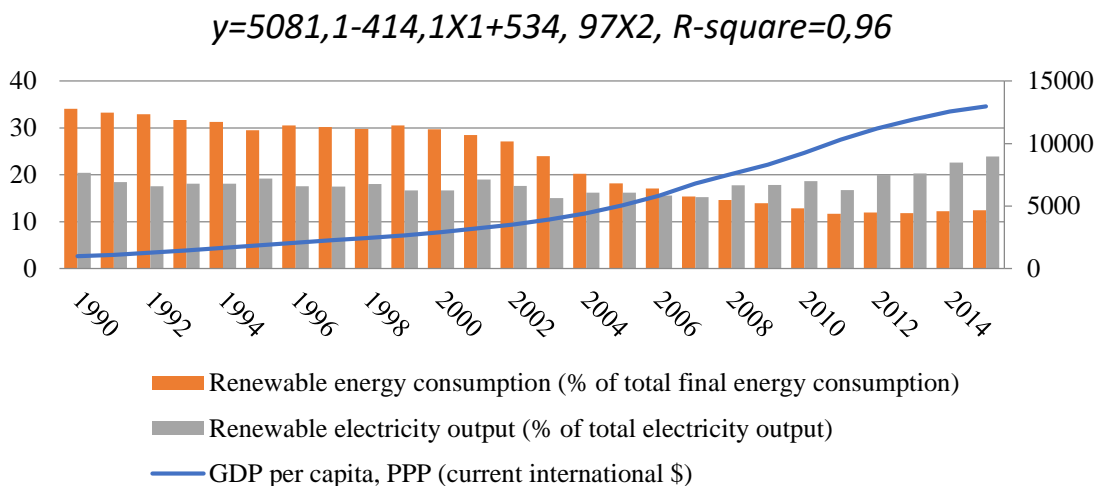
Fig. 5. Influence of REC and REO on the economic growth of China according to the data of 1990-2015

$$y=17541,2+7073,7X_1-1986,4X_2, R\text{-}square=0,93$$
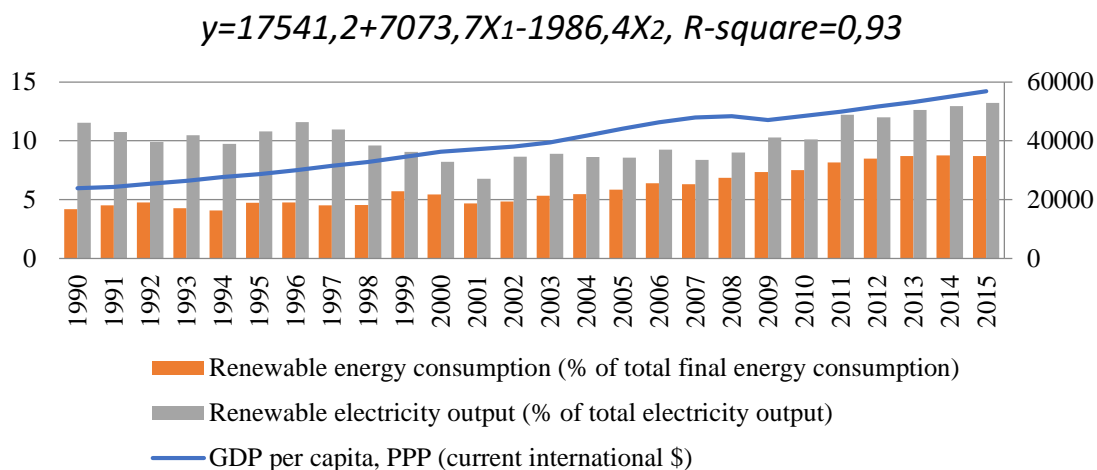
Fig. 6. Influence of REC and REO on the economic growth of the USA according to the data of 1990-2015

$$y=6433,1+4624,11X1-1705,14X2, R\text{-}square=0,97$$
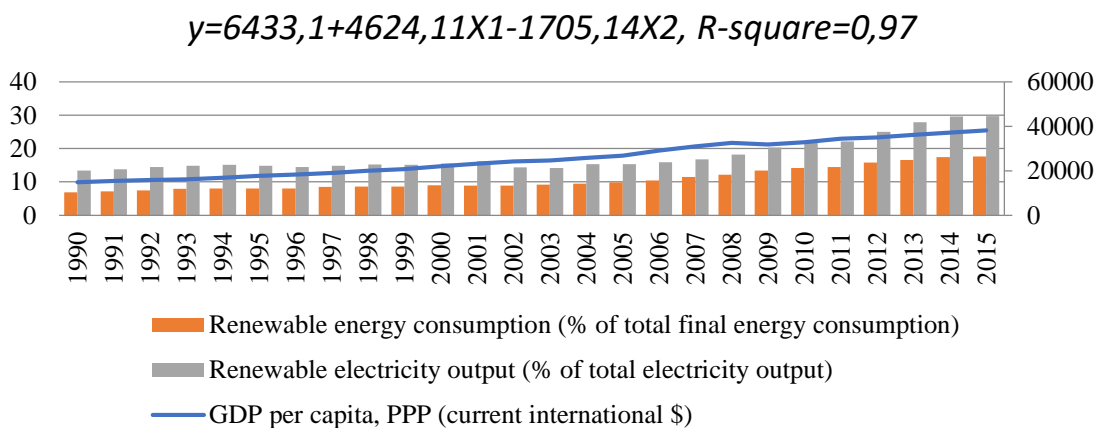

Fig. 7. Influence of REC and REO on the economic growth of the European Union according to the data of 1990-2015

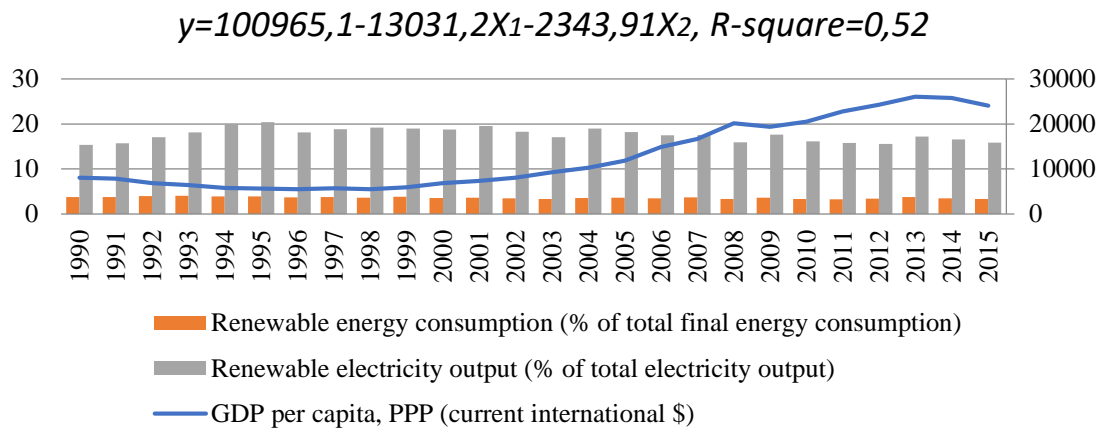$$y=100965,1-13031,2X_1-2343,91X_2, R\text{-}square=0,52$$

Fig. 8. Influence of REC and REO on the economic growth of Russia according to the data of 1990-2015

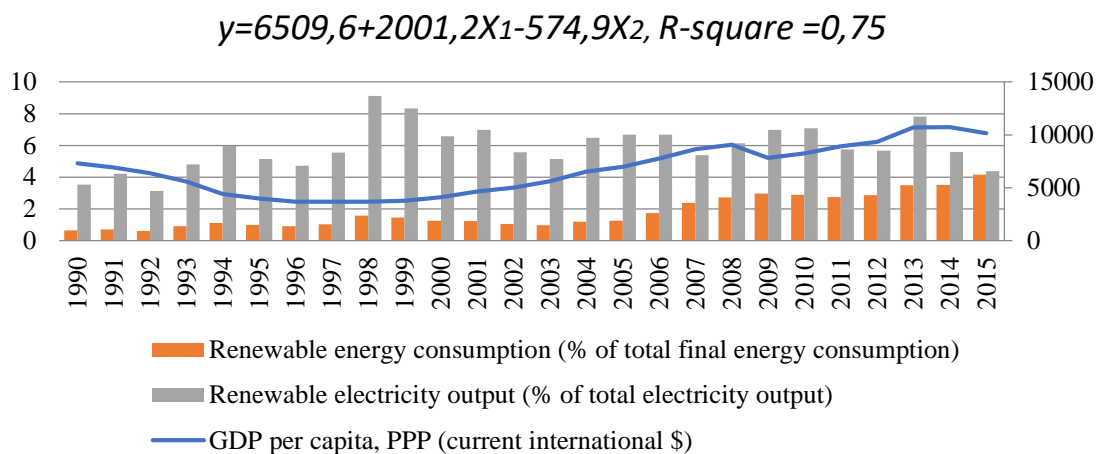$$y=6509,6+2001,2X_1-574,9X_2, R\text{-}square =0,75$$

Fig. 9. Influence of REC and REO on the economic growth of Ukraine according to the data of 1990-2015

Modern conditions of the society development force the world make a difficult but extremely important choice concerning the future for itself as well as for future generations. And this choice is based on the strategy of energy sector development, i.e. to continue supporting the extensive conventional energy with the use of fossil fuels that is steadily growing in price, or to transit to a qualitatively new and cost-effective and eco-friendly use of renewable energy sources.

As the welfare of the world population is gradually increasing and the world economy is developing, global demand for energy is going to be set in the coming decades, and the background of its impact on the climate is forcing us to make a choice on how to generate electricity, and the ratio of how much we consume compared to how much we save and how this will affect the quality of life of future generations is crucial. Therefore, it is important to assess the impact of the share of REC and REO on the environment, namely on CO_2 emissions when analyzing the impact of renewable energy on sustainable development of countries. Fig. 10, 11, 12, 13, 14, 15 present the results of the conducted correlation-regression analysis of the studied countries.
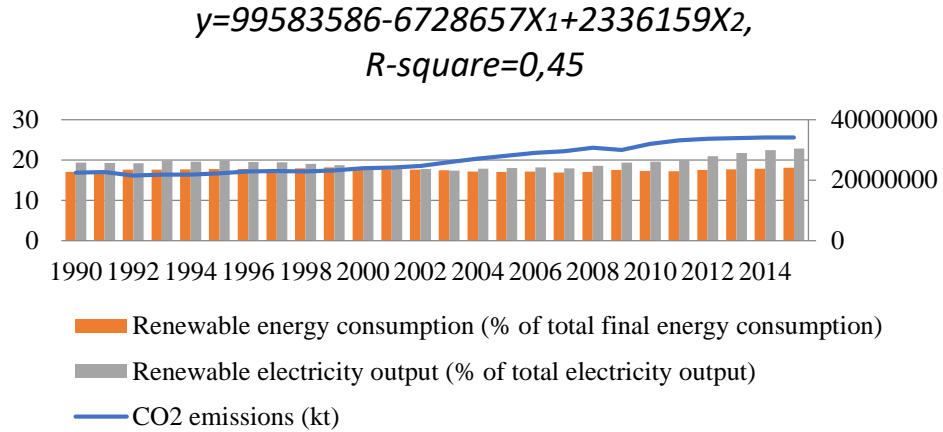
$$y=99583586-6728657X_1+2336159X_2,$$
$$R\text{-}square=0,45$$

Fig. 10. Impact of REC and REO on global CO_2 emissions based on data of 1990-2015

$$y=7525258-309065X_1+282049X_2,$$
$$R\text{-}square=0,97$$
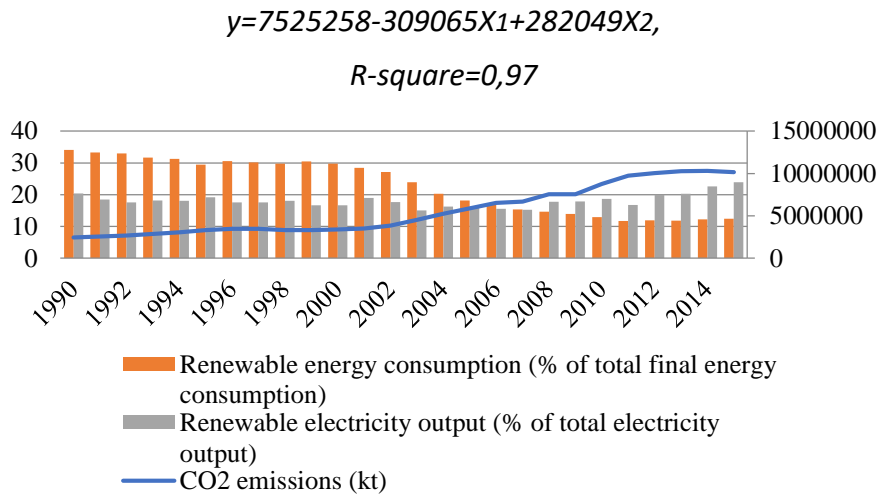
Fig. 11. Impact of REC and REO on China's CO_2 emissions based on data of 1990-2015

$$y=4094889+25768,9X1-57757,9X2, R\text{-}square=0,93$$
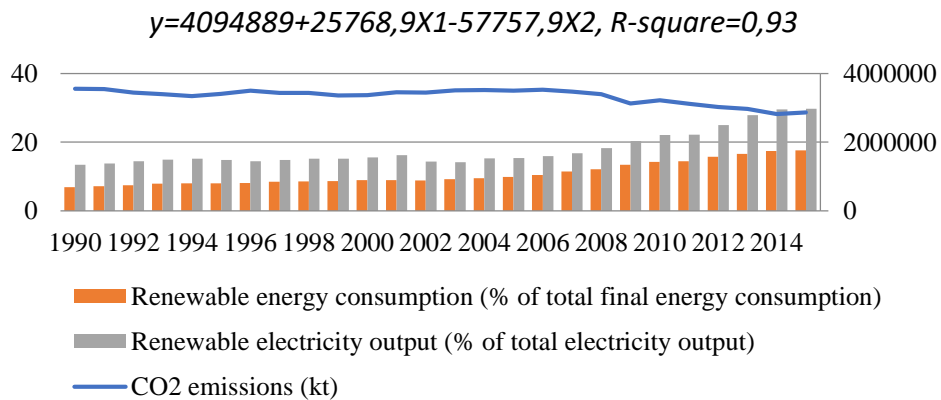
Fig. 12. Impact of REC and REO on the EU CO_2 emissions based on data of 1990-2015

$$y=6559630+100655{,}9X1-177908X2, R\text{-}square=0{,}68$$
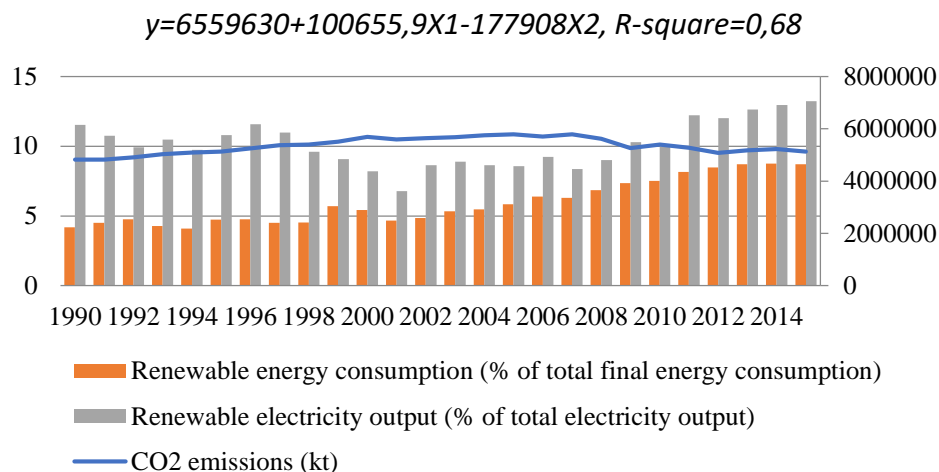
Fig. 13. Impact of REC and REO on the US CO_2 emissions based on data of 1990-2015

$$y=614267{,}3-62098{,}5X1-25333{,}8X2, R\text{-}square=0{,}66$$
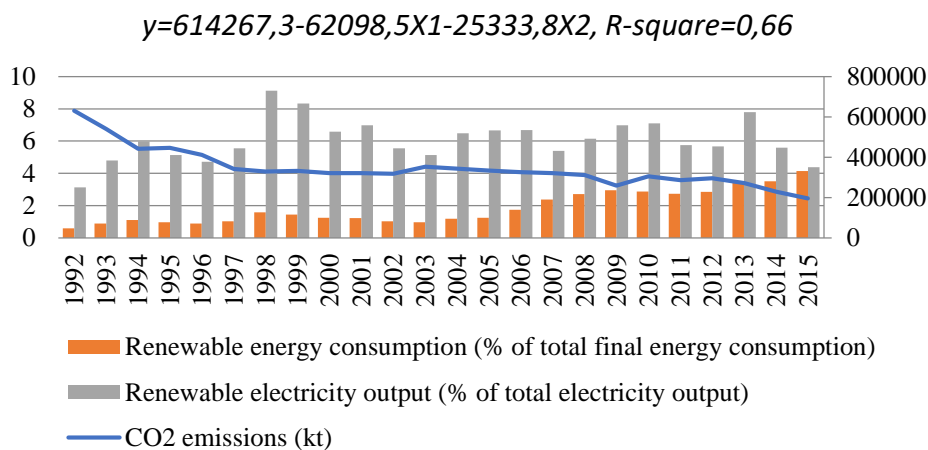
Fig. 14. Impact of REC and REO on Ukraine's CO_2 emissions based on data for 1990-2015

$$y=1488281+1529774X_1-294075X_2, R\text{-}squre=0{,}59$$

Fig. 15. Impact of REC and REO on CO_2 emissions of the Russian Federation based on data of 1990-2015

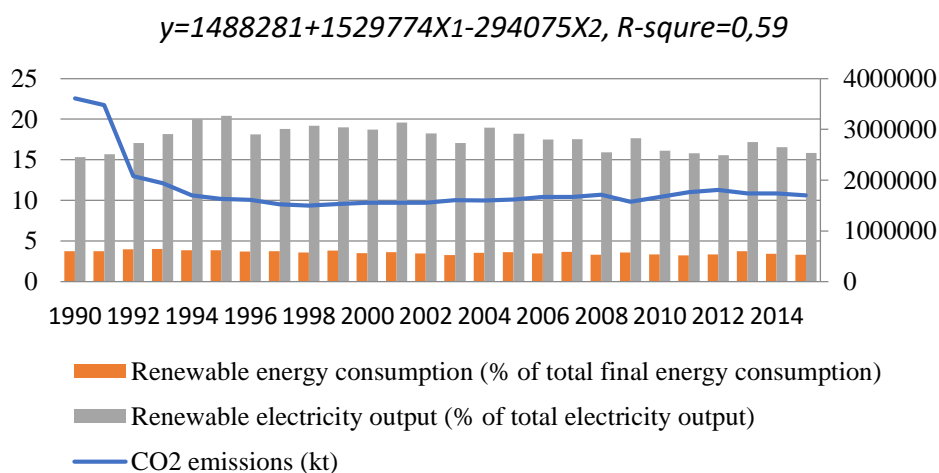According to the research results, it can be stated that the model is adequate for the countries having a share of REC and REO close to 30% in total consumption. For other countries, the model is not reliable due to the low coefficient of determination. The effect of CO_2 reduction with increasing consumption and production of renewable energy is the most obvious for EU countries. Data obtained for China prove that the renewable energy production can have an opposite effect and lead to increased emissions. However, for a more accurate comparison, it is necessary to consider the level of industrial production of emitting countries.

According to Energy Darwinism II, the cost of switching to low-carbon energy will be $ 190.2 trillion over the next quarter of the century that is well below the cost of further consumption of conventional fuels ($ 192.0 trillion). Such figures are explained by the rapid reduction of renewable energy costs, reduction of fuel consumption due to investments in improving energy efficiency measures and, hence, reduction of the fuel component in the cost of electricity. As a result, in the long term perspective the consumer accounts will be cut down. A significant decrease in prices for alternative energy can already be observed today (Fig. 16).
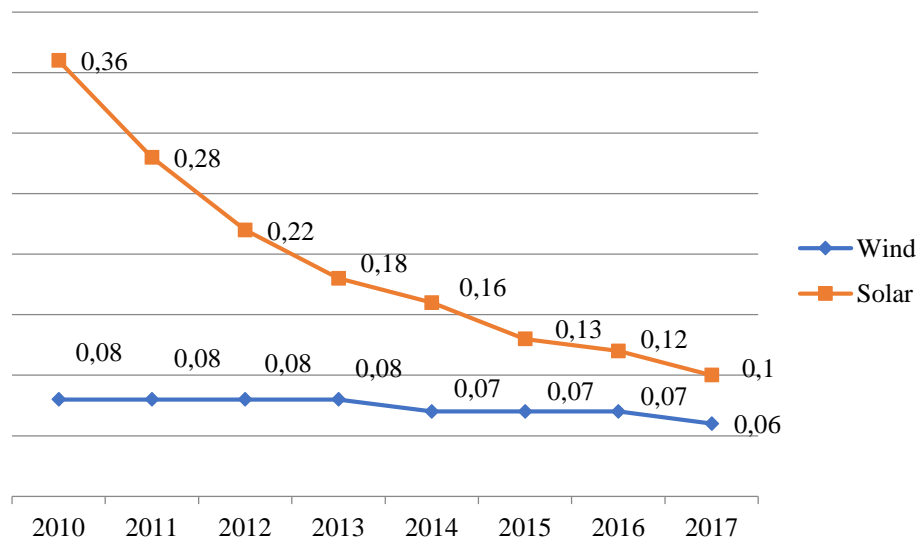

Fig. 16. Global levelised cost of electricity (LCOE) generation (USD/kWh)
(KPMG, 2019)

According to KPMG (2020) analysis "solar photovoltaic (PV) modules declined in price by more than 80 per cent between 2010 and 2017 and with it, the average cost per kWh generated has tumbled by 73 per cent to USD 0.10 (LCOE), with the potential to drop to USD 0.03 given the right operating conditions. Onshore wind too, has seen significant improvement in cost per kWh to a global weighted average of USD 0.06 (LCOE), 23 per cent lower than 2010, with some projects regularly delivering electricity for USD 0.04 per kWh".

Thus, a sharp decline in the cost of renewable energy sources enables to make a global transition to RES and at the same time make it less expensive. In 2014, the cost of renewable energy technologies was more cost-effective than conventional energy, and a gradual annual reduction in price results makes "green" energy unalterable. Thus, wind energy is the cheapest technology in many regions of the world, mainly due to the reduction of prices for wind turbines (almost by a third over the past 6 years)

(Gundebommu, et al. 2020). According to Bloomberg forecasts, wind power worldwide can reach more than 2,000 GW in 2040 (compared to ~ 370 GW at the end of 2014). Solar energy has also shown a sharp decline in its cost: prices for solar modules have fallen by 75% since 2009, and this trend is expected to continue in the future. According to Bloomberg, new construction in this sector will increase worldwide to almost 5,000 GW of installed capacity by 2040 (from 177 GW in 2014). In general, the expected projected share of RES (solar, wind, hydro) in Europe could be about 70% by 2040.

Therefore, there is currently no doubt concerning the need to increase the share of renewable energy sources due to a wide range of benefits provided. Transition to a low-carbon economy will have a positive effect from both environmental and economic points of view, since the costs required for such transition are much lower than the costs provided that the development of fossil fuels continues to be stimulated. The potential impact of climate change on water resources, food production, health and the environment will cause significant losses for the economy. Instead, the development of renewable energy sources will have a positive impact on the life quality in general.

4. DISCUSSION

The results obtained reveal that there is a rather high positive relationship between REC and REO and economic growth of the countries that invest most in renewable energy. The value of coefficients of R^2 determination of these countries exceeds 90% (China – 96%, the European Union – 97%, and the USA – 93%), which indicates that the dependence of economic growth can be explained by some selected factors, the rest – by other factors influencing economic growth but not included in the regression model. While there is no such strong relationship worldwide, the value of R2 is quite low. The study of figures of the Russian Federation predictably reveals a low level of dependence of its economic growth on renewable energy that is primarily explained by its raw energy reserves and lack of political will to develop this area. In Ukraine, R2 equals 0.75, which may be the result of a relatively low share of renewable energy compared to more developed countries.

It should be specified that REO has a positive effect on China and the world's GDP growth, though REC has a negative effect. While at the level of the USA, the European Union and Ukraine, on the contrary, consumption itself has a positive impact. Economic growth of the Russian Federation is negatively influenced by the development of alternative energy by both indicators.

In the process of identifying correlation-regression relationships between economic growth of the studied countries and factor values, in addition to building an economic-mathematical model, coefficients of multiple regression, coefficients of determination, standard errors, Student's t-test have been calculated. Considering high values of coefficients of multiple regression and determination, it can be concluded that this dependence is quite natural. The indicators of variance, significance of F and indicator of F-statistics indicate a sufficient level of reliability of the evaluation results.

The results obtained show that depending on the country under the research, the level and nature of the impact of increasing share of production and consumption of renewable energy on the economic growth varies significantly. This is caused by different opportunities of countries to transform resources, technologies, knowledge and skills into economic growth through public policies and support schemes, subsidies, prioritization of the fields and sectors of renewable energy. The applied model of linear regression does not consider characteristics of the studied countries, but clearly

demonstrates that the development and compliance with strategic goals in the field of renewable energy inevitably leads to economic growth.

According to the research results (Fig. 10-15), it can be stated that the model of REC and REO impact on countries CO_2 emission is adequate for the countries having a share of REC and REO close to 30% in total consumption. For other countries, the model is not reliable due to the low coefficient of determination. The effect of CO_2 reduction with increasing consumption and production of renewable energy is the most obvious for EU countries. Data obtained for China prove that the renewable energy production can have an opposite effect and lead to increased emissions. However, for a more accurate comparison, it is necessary to consider the level of industrial production of emitting countries.

5. CONCLUSION

In recent decades, renewable energy sources have experienced a growth of their potential and occupied an increasing share in the production volumes and energy consumption of most developed economies. The relationship between economic growth and the production and consumption of renewable energy as well as between these variables and CO_2 emissions has been studied on the example of the most developed countries and the world. Our results reveal that an increase in the share of RES at the initial stage may have a negative effect on the country's economic growth, which is clearly proved by China's experience; however, it will help to reduce CO_2 emissions. Therefore, governments of the countries that are developing in this area, including Ukraine, need to supplement the renewable energy support with a number of policies aimed at managing the demand and improving energy efficiency. Political support of the development of renewable energy will help to achieve the highest environmental effect under optimal costs. Technical changes are currently helping to reduce the cost of renewable energy, which leads to the competitiveness enhancement. Alternative energy is still at the early stage of development, but it does not meet all the goals of sustainable development. The number of observations (26 for each country) is relatively small, so we consider it appropriate to expand the sample of countries and expand the research methodology by a wider range of factors influencing the increase in the share of renewable energy and sustainable development in general.

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