Global Trends and Assessment of Possibilities of Energy Transition in Ukraine

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Abstract: The article examines global trends in the development of renewable energy. The possibility of Ukraine to make an energy transition is analyzed. The main problems of modern humanity have been identified: climate change, the exhaustion of traditional energy sources, rising global temperatures. It is emphasized that the main way out of the current situation is the energy transition. To this end, it is necessary to achieve greenhouse gas reduction and initiate the development of a low-carbon economy. The main indicators of energy balances of the world, OECD and Ukraine are given. The final consumption of energy resources by their types is analyzed. A set of economic and mathematical models for forecasting energy development has been applied. Possibilities of development and transition to a new model of the world energy system are proved.

1 INTRODUCTION

The main feature of modern processes in the global economy is the rapid growth of competition between countries, which is associated with the struggle for limited natural resources. The main ones are energy resources. There is no country in the world that provides itself with such resources in full. According to a large number of scientific studies, the use of traditional energy resources, such as coal, oil, gas, has a detrimental effect on the ecosystem of our planet and is the cause of climate change. This has a negative impact on people's health and worsens their living conditions. As a result, both the world and national economies suffer. Thus, over the past few decades, the world community has been quite active in the development of technologies, tools and tools for the use of renewable energy sources. Sources of clean energy include wind, solar, bioenergy resources and others. The urgency of the problem of energy transition, ie the abandonment of traditional exhaustible energy resources and the introduction of safe renewable energy sources, is quite obvious. This will build a strong world economy, end social decline, solve global climate problems and increase the well-being and security of society. Ukraine is actively involved in low-carbon economic development initiatives. Proof of this is the gradual transition of all sectors of the national economy to renewable energy sources. The Government of Ukraine seeks to actively care for its citizens and protect future generations from the negative and harmful effects of global warming. That is why the main task of scientists, researchers and experts in these matters is to implement a comprehensive analysis of the relationships and dependencies of energy security of the state and the problems of energy transition.

2 RELATED WORKS

The authors (Gielen et al., 2019) analyze the energy efficiency and possible technologies of renewable energy and emphasize that their symbiosis and synergy are the main elements of the global energy transition. In Scientific Paper (McCollum et al., 2019), the authors devote their own research to developing a new approach to quantitative analysis of

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future events. The authors use econometric analysis and the Monte Carlo model to investigate four possible scenarios for changes in the energy system. Models of interdependence of different technologies for the use of renewable energy sources are studied (Pye et al., 2019). To this end, the authors use hierarchical clustering in several scenarios. The authors identified some features of different technological systems that can compete with each other in terms of cost. In scientific article (Tukker et al., 2019), researchers analyze concepts and use dimensions, namely: changes, possible events, drivers and ways to use renewable energy. The authors focus on the issues of energy transition management and emphasize the relationship between the scale of change and resistance to change.

3 METHODOLOGIES

Changing views on the development of world energy in the context of energy transition leads to increased attention to the problems of combating global climate change and sustainable economic development. This was the driving force behind the introduction of the Concept of Green Energy Transition in Ukraine. Adapting energy policy to the new realities of global climate change will provide a lasting effect in ensuring sustainable development and energy transition. The possibility of realizing such intentions is quite real and will help increase the competitiveness of our country in the global world. The main goal in this context is to reduce greenhouse gas (GHG) emissions in order to ensure the transition to a climate-neutral economy of Ukraine in 2070 in a way that is consistent with social acceptability.

It should be noted that the adoption of the Paris Climate Agreement was a landmark decision for the world community. This will have a significant impact on the development of the world economy and energy (IRENA, 2021).

In addition, for some countries, the priority is to keep the average temperature on the planet rising. This figure should not exceed 2° C, compared to pre-industrial levels. Every effort should be made to limit the temperature rise to 1.5° C (IRENA, 2021). To do this, it is important to convert the energy sector into carbon-neutral, ie greenhouse gas (GHG) emissions should not exceed the level of their absorption. This is the essence of the energy transition on the principles of sustainable development. The transition from traditional types of energy resources to renewable energy sources, as well as stimulating energy efficiency and rational consumption of energy resources will save our planet from irreparable consequences (Kim & Wilson, 2019).

Depletion of traditional energy resources, increasing the negative impact of energy on the environment, increasing environmental requirements, sharp fluctuations in energy prices, strengthening energy and economic security, politicization of energy supply and other factors require urgent action. It is necessary to assess the current state of the energy sector and look for ways to upgrade and restart the energy system (Ekins et al., 2019).

Ukraine is one of the many countries experiencing all the problems associated with the energy transition. Much of the social and economic problem is caused by dependence on imports of expensive energy resources. In addition, the high level of wear and tear of domestic infrastructure, low efficiency of energy resources are the factors that explain the high energy intensity of the domestic economy (Voynarenko et al., 2021). Thus, the level of energy intensity of Ukraine's gross domestic product (GDP) is 2.8 times higher than that of OECD countries. The same situation is observed with regard to the high level of carbon intensity of GDP. Due to the significant level of energy costs and the lack of modern environmental requirements for the acceptable functioning of the energy system in Ukraine, there is one of the highest mortality rates caused by diseases from polluted air. Problems with climate change observed since the middle of the twentieth century is the result of human activity and wasteful treatment of the environment (Feindouno et al., 2020). For this reason, in 2015, 195 countries from around the world participated in the adoption of the Paris Agreement. The essence of this agreement is to find ways to avoid the threat of climate change, overcome poverty, curb the growth of global average temperatures. Note that in 2015-2016, world temperature increased by more than 1 C°. This provoked an immediate reaction from the world community to take immediate action to address greenhouse gas emissions. The implementation of the energy transition from fossil fuels to renewable sources is the starting point for a comprehensive solution to the issue of adaptation to climate change that has already taken place. Numerous studies prove that the modern development of scientific and high-tech technologies opens up real prospects for large-scale development of renewable energy. A significant number of world practices prove the possibility of replacing fossil traditional energy sources with alternative sources. However, in this sense, Ukraine lags far behind in the level of implementation and use of renewable energy. Thus, the share of renewable sources in Ukraine in 2015 was 4.2% in gross final consumption of energy resources, while this figure in the world was 20%. However, in Ukraine there are positive dynamics in accelerating the energy transition, namely the growth of investment in renewable energy (Voinarenko & Mykoliuk, 2017).

This process is facilitated by the emergence of appropriate economic incentives, such as the green tariff and cost recovery programs for energy efficiency measures.

Ukraine has a huge natural potential for the implementation of wind energy projects, which determines the country's interest in the development of the industry and attracts a large number of potential domestic and foreign investors. According to the latest assessment of the Ukrainian Wind Energy Association, a 16 GW wind farm is a real potential of the Ukrainian wind energy industry (Diachuk et al., 2018).

According to the National Agency for Energy Efficiency, the theoretical potential of Ukrainian solar energy is over 730 billion kilowatt-hours per year, and technically - only 34.2 billion kilowatt-hours per year. According to the Ukrainian Bioenergy Association, the economically viable bioenergy potential is about 20 million tons, and by 2050 it could reach 42 million tons (Outlook, 2018).

Global trends show that active measures are being taken to introduce energy-saving technologies that can promote higher economic growth, reduce the cost of renewable energy and increase accessibility for all people. Successful implementation of energy efficiency policies of leading energy-saving countries with the most active use of modern energy-saving technologies and alternative energy can be used for reference by the country (Lange et al., 2020). It is necessary to analyze the effective experience of foreign countries in this regard and assess the feasibility of its implementation in Ukraine in combination with national conditions. The successful experience of many countries over the past 30 years shows that the implementation of national support measures and various tools to stimulate investment in alternative energy will not only help address global climate change and energy security, but will also have a significant impact. on the environment and the economic performance of a competitive economy.

The trust of domestic and international investors has helped Ukraine move closer to transforming the strategic balance of its energy market into renewable energy sources. Local and foreign investors from Austria, Belgium, Canada, China, the United Kingdom, Norway, Spain, Switzerland, Turkey and the United States have raised funds for Ukraine's green energy through a fair and stable regulatory framework and active partnership. Leading international financial institutions and banks, such as the European Bank for Reconstruction and Development, US private foreign investment companies, and investors from France, Denmark, Finland, Sweden, the Netherlands and other countries are seeking long-term financing for recycling projects in Ukraine.

In its latest World Energy Outlook, the International Energy Agency (IEA) states that countries' compliance with their commitments in the preparation and ratification of the Paris Agreement by 2040 must be respected. Their main purpose is as follows (IRENA, 2021):

- achievement of electricity production from renewable sources at the level of 37% in the overall structure of electricity generation;
- the new facilities will use renewable sources at the level of 60%. This will increase the competitiveness of the energy sector without attracting subsidies;
- increase in the number of electric cars will increase from 1.3 to 150 million units;
- replacement of coal with natural gas will increase by 50% in the global energy balance.

4 ANALYSIS AND RESULTS

According to the results of the study, under the conditions of implementation of these forecasts, CO2 emissions will grow annually by 0.5%, while in 2000 their increase was 2.4%. However, according to the International Energy Agency, this figure is not enough to achieve the goals of the Paris Climate Agreement (International Energy Agency., 2007).

In the table. 1 shows a comparison of Ukraine's energy balance with the world energy balance of OECD and EU countries. Thus, coal consumption in Ukraine is much higher than in the world and in OECD countries. However, the consumption of oil and oil products in Ukraine is much lower than the world and OECD indicators. This is due to the fact that in Ukraine oil products are mainly used in the transport sector, but compared to OECD countries, they are almost never used for electricity generation and heating. On the other hand, in our country the consumption of petroleum products in the transport sector is lower than the average for OECD countries.

In the structure of final consumption of energy resources by their types there is a decrease in the share of gas - from 38-39% in 2010-2018 to 32% in 2012-2016. At this time there was an increase in the share of electricity - from 14% in 2017 to 19 % in 2018 (Fig. 1).

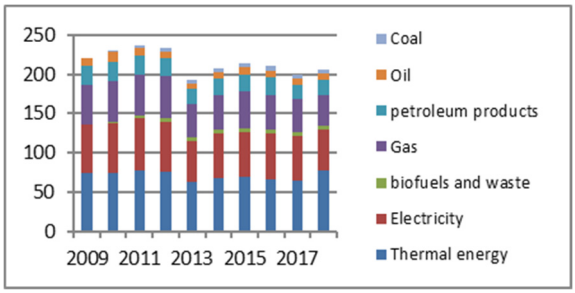

Figure 1: Final consumption of energy resources by their types (million toe).

As can be seen from table. 1. and fig. 1 Ukraine lags behind not only the economically developed countries of the world in terms of the use of renewable energy sources, but also the global indicator. In September 2015, the international environmental organization Greenpeace and the Institute of Engineering Thermodynamics, Systems Analysis and Technology Assessment (DLR), Global Wind Energy Council, SolarPowerEurope presented a new study that reflects models of global scenarios of global energy transition.

The State Agency "Institute of Economics and Forecasting of the National Academy of Sciences of Ukraine" simulated three scenarios of energy development. The conservative scenario, which is actually the baseline scenario, assumes that technology remains at the current level (Sabishchenko et al., 2020). Under the liberal scenario, the development of the energy sector is expected in conditions of free competition, and the revolutionary scenario envisages the rapid development of renewable energy, which by 2050 will account for 91% of final energy consumption. It should be noted that these scenarios concern the energy sector of Ukraine. However, they can be the basis for further research on practical steps in Ukraine's "energy transition" to renewable energy.

The developed scenarios envisage a gradual transition from the consumption of traditional energy resources to 100% of the use of renewable energy by 2050. The scenarios are aimed at curbing global warming within 2 C^0. The basis for the development of the baseline scenario for the development of the energy sector are forecasts for GDP growth and the level of energy intensity (Lange, 2020). The data show an increase in energy demand globally. According to the baseline
scenario, total final energy consumption is expected to increase by 65% from the current level.

Table 1: The main indicators of energy balances of the world, OECD and Ukraine in 2018.

Total supply of primary energy resources	World		OECD		EU		Ukraine	
	thousand tons of oil equivalent.	%	thousand tons of oil equivalent.	%	thousand tons of oil equivalent.	%	thousand tons of oil equivalent.	%
Coal	3918491	28,6	1012463	19,2	268433	17,2	35576	33,7
Oil	4349857	31,8	2061714	39,1	591918	37,8	3043	2,9
Petroleum products	-64557	-0,5	-180603	-3,4	-82930	-5,3	7645	7,2
Gas	2900579	21,2	1343845	25,5	342846	21,9	33412	31,6
Nuclear energy	661353	4,8	516273	9,8	228456	14,6	23191	21,9
Hydropower	334945	2,4	120471	2,3	32248	2,1	729	0,7
Electricity	181072	1,3	98024	1,9	40069	2,6	134	0,1
Thermal energy	1412908	10,3	299787	5,7	141641	9,1	1934	1,8
Total	2383	0,0	395	0,0	1333	0,1	-725	-0,7

5 METHODOLOGICAL APPROACH

Under the conditions of modeling the energy system, it should be considered as a single integrated production and economic system. Such a system consists of independent integrated subsystems, the interaction of which takes place in the dynamics of economic development. This takes into account changes in market conditions, environmental and social constraints. During 2006-2008, the Institute of Economics and Forecasting of the National Academy of Sciences of Ukraine developed the economic and mathematical model "TIMES-Ukraine" for strategic planning of fuel and energy development and forecasting the energy balance of Ukraine in the scientific framework (Dyachuk et al., 2017). The fundamental difference between the TIMES-Ukraine model and many other models developed for

forecasting energy consumption in Ukraine is the shift of the analytical subject from final energy to useful energy and energy services. In order to model scenarios for the development of the energy sector of Ukraine, a system of economic and mathematical models was used, which is based on the dynamic optimization model TIMES-Ukraine and the dynamic computational model of general equilibrium (MGE). The structure and algorithm of the study of economic and energy scenarios is shown in Fig. 2.

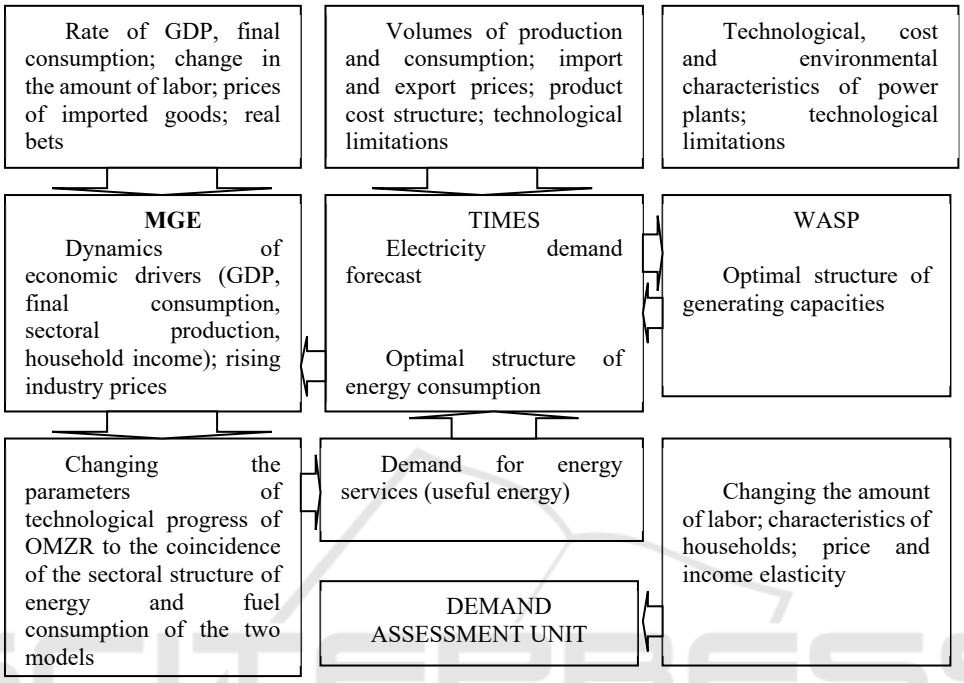

Figure 2: A set of economic and mathematical models for forecasting energy development

It should be noted that macroeconomic indicators were used to develop energy development scenarios, which determine changes in the main control parameters of demand for energy services, such as GDP, value added, industrial production, household income, housing, energy prices and other macroeconomic and demographic indicators.

The TIMES-Ukraine model focuses on the following tasks: formation of forecasts and studies of energy balance, qualitative analysis of energy, material and financial flows, taking into account factors of resource interchangeability depending on the parameters of specific technology for forecasting greenhouse gas emissions, estimating the optimal technical structure based on minimizing total costs, ie assessing the structure and level of use of energy production and consumption technologies to meet the needs of consumers in the cheapest way. Energy can be interpreted as the actual market price of shadow or regulated tariffs, the level of surcharges or subsidies that can be imposed on consumers, as well as additional or lost benefits.

Note that the initial forecasts of control parameters are consistent with each other and are used to determine the parameters of MGE.

Satisfaction of demand for energy resources according to the macroeconomic scenario is determined at the next stage. The TIMES-Ukraine energy system model is used. In this model, taking into account budgetary and technological constraints, it is possible to determine the optimal combination of energy technologies for the use of energy resources, ie the formation of the forecast energy balance of the country (Feindouno, 2020).

Models such as TIMES-Ukraine can be used for the following purposes:

- assess the optimal technological structure of the energy system in order to reduce the total discounted cost;
- analyze the structures of energy, material and financial flows in the overall system, taking into account sales of energy resources;
- assess energy saving potential, renewable energy sources, prioritize investments based on cost optimization;
- implementation of the forecast of dynamics of greenhouse gas emissions;

- identify possible potential threats to the country's energy supply and find ways to prevent them;
- assess the impact of such policies on the development of the energy sector, namely: energy, environmental, economic, industrial, climate, transport, agricultural and innovation;
- identification of potential benefits and possible risks of integration processes and commitments in the energy, environmental, climate sectors.

Therefore, the TIMES-Ukraine Model is an optimization model of Ukraine's energy flows. The energy system in the TIMES-Ukraine model consists of seven sectors: the energy supply sector. This sector includes production, imports, exports, international bunkering, stock changes, production of secondary energy resources such as petroleum products, briquettes and more. The TIMES-Ukraine sector also includes electricity and heat production; industry; transport; people; trade and services; Agriculture.

6 CONCLUSIONS

The article examines global trends, opportunities for development and transition to a new model of the global energy system. For this purpose, the economic-mathematical models TIMES-Ukraine and the model of general equilibrium of Ukraine are analyzed and reflected. The possibility of large-scale use of renewable energy sources in contrast to traditional fossil sources of Ukraine by 2050 was assessed. It is investigated that the existing potential of renewable energy sources and existing technologies allow Ukraine's energy transition in the coming years.

Policies to promote energy efficiency measures and renewable energy technologies need to be further developed. In the case of a significant reduction in energy consumption of traditional energy resources and intensive consumption of renewable sources, the share of energy obtained from RES will be 91% by 2050. This means that the saved energy resource is the cheapest "resource", and investment in its savings is more appropriate than those that are not necessary for the production of additional electricity and heat to meet the needs of the population and the economy as a whole.

The TIMES-Ukraine model focuses on the following tasks: formation of forecasts and studies of energy balance, qualitative analysis of energy, material and financial flows, taking into account factors of resource interchangeability depending on the parameters of specific technology for forecasting greenhouse gas emissions, estimating the optimal technical structure based on minimizing total costs, ie assessing the structure and level of use of energy production and consumption technologies to meet the needs of consumers in the cheapest way. Energy can be interpreted as the actual market price of shadow or regulated tariffs, the level of surcharges or subsidies that can be imposed on consumers, as well as additional or lost benefits.

Under such conditions, by 2050 all existing technologies of electricity production in Ukraine will be transferred to renewable energy, as they are rapidly becoming cheaper and improving. Among them, the most promising are the technologies of wind energy and solar energy. Bioenergy technologies can become a leader in thermal energy technology. It is projected that the share of wind farms in the structure of electricity production may reach 45%, SES - 36%, and the share of biomass and waste in the structure of heat production - up to 73%. The above results show that the most ambitious energy and environmental goals, such as achieving 90-100% of the transition from final consumption to renewable energy by 2050, can bring significant benefits to the economy and society as a whole and should be taken into account when formulating strategies or plans action on climate policy development.

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