European strategy for the development of alternative energy

Nataliia KRAVCHUK[*], Olena KILNITSKA[**], Volodymyr KHODAKIVSKYI[***], Mykola MISEVYCH[****]

Abstract

The research is aimed at studying the European experience in terms of the strategy for development of alternative energy and possibilities for its implementation in Ukraine by taking into account the priorities of national economic policy on energy efficiency and energy preservation. The problems of the development of the fuel and energy sector in Ukraine are identified in the context of its energy security. The latest research in the field of alternative energy in the advanced countries of the world is analyzed. The problems of energy consumption and energy efficiency in Ukraine compared to the countries of the EU are outlined. The growth rate of renewable energy in the EU, including the structure of the energy balance, is analyzed. Ukraine's high potential for generating alternative energy is emphasized and the country's energy balance is investigated. The dynamics of consuming renewable energy in Ukraine is defined. The prospects for increasing the efficiency of using the energy potential of Ukraine are studied; the top-priority goals of the strategy for the development of alternative energy are outlined in the context of ensuring Ukraine's energy independence and prospects of integration into the EU.

Keywords: renewable resources, alternative energy, energy preservation, energy efficiency, energy strategy

Introduction

Ukraine's accession to the Energy Community of the EU and South East Europe in 2011 opens new prospects and opportunities for the development of the domestic energy sector, such as: attracting foreign investment, modernizing the fixed

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assets, free access of electricity consumers to the choice of its supplier, etc. At the same time, after gaining membership in the Community, Ukraine's commitment to the development of alternative energy sources becomes of particular importance. This will bring the country closer to the global model of economic growth, the prerogative of which lies in the following principles: thriftiness, economy, and environmental friendliness, rational use of exhaustive natural resources, energy efficiency and energy preservation.

However, there are a number of obstacles and problems that weaken the energy security of Ukraine and have a significant impact on the further development of the energy sector, placing it at the rank of a strategic state imperative. As stated in the national report of the Ministry of Economic Development and Trade of Ukraine[1], the main problems nowadays are: the depreciation of a significant part of energy generating facilities and energy supply networks; low volumes of recovered primary energy sources; high energy intensity of production; low efficiency of heat reclamation combined with loss of production; shortage of shunting and reserve capacities in the existing structure of power generation in combination with a significant imbalance in their regional distribution; insufficiency of technically achievable potential of renewable energy sources, along with its limited use, etc. Moreover, the energy sector is one of the main environmental pollutants, which accounts for about 40% of emissions from all sectors of the economy and 58% from stationary sources of pollution.

Reducing the energy security both of Ukraine and its individual regions significantly updates the need for the development of alternative energy. This is facilitated by a number of new factors of our time, such as: the dependence of the domestic economy on imported energy resources, in particular: natural gas, petroleum products, fuel for power plants (both thermal and atomic); loss of objects of the fuel and energy complex and promising territories for the development of hydrocarbon resources as a result of the annexation of Crimea and military activities in the East of the country; the destruction of oil and gas infrastructure in the Donetsk and Luhansk regions. The transition to alternative energy will contribute to achieving energy preservation and increasing energy efficiency, energy autonomy and security. This will boost the development of energy entrepreneurship, reduction of the energy intensity of production and increasing its profitability, creating new jobs and, consequently, improving the welfare of the population.

1. Analysis of the latest research and published works

In the academic literature of the world, there is a fairly large number of studies devoted to alternative energy related to various aspects of its implementation:

[1] Ministry of Economic Development and Trade of Ukraine (2017), Goals of sustainable development: Ukraine, National report, p. 58.

technical and technological, economic, environmental, social, legal, etc. Thus, A. Coram and D.W. Katzner (Coram *et al*., 2018) investigate the reduction of the load on the environment due to alternative energy saving technologies for producing zero-emission energy. S. Nižetić (Nižetić, 2018) studies production of carbon-free electricity, in particular the technical realization of the concepts of alternative energy through the production of heat energy under conditions of specific soil and climatic conditions of the country, including natural vortex phenomena such as tornadoes, water- and sandstorms, etc. In addition, the author considers the thermal energy of industrial waste, or solar energy, to be the main source of energy. The assessment of the power of wind energy and power turbines is investigated by S. A. Akdağ and Ö. Güler (Akdağ *et al*., 2018). At the same time, traditional wind turbines are harmful to the environment: huge blades kill birds, create noise and destroy the landscape. That is why Y.-H. Kiang (Kiang, 2018) suggests turfing and gasification of biomass (recycling of organic waste, municipal landfill, sewage) as an alternative source of stable energy recovery. His research is aimed at forming a system for collecting such excess energy.

A comprehensive review of various methods of application of solar energy and its evaluation is provided by S. K. Sansaniwal, V. Sharma, J. Mathur (Sansaniwal *et al*., 2018), D. Gao, Z. Li, P. Liu, J. Zhao (Gao *et al*., 2018). In their works, they provided valuable recommendations for the broad use of solar energy systems of a different purpose from the point of view of thermodynamics (solar drying, solar conditioning and cooling, heating water). The authors argue that solar energy is a cheap, rich and eternal source of renewable energy, and can thus be integrated with different systems relating to energy consumption in order to overcome the dependence of modern society on traditional fuels.

Taking into consideration the exhaustibility of oil and gas reserves, Chinese scientists D. Gao, Z. Li, P. Liu, J. Zhao (Gao *et al*., 2018) suggest a model for a national strategy of energy security based on alternative energy sources. The aforementioned authors argue that alternative fuel is an additional method to moderate the negative consequences of increase in oil prices and thereto related economic losses of countries dependent on imported energy sources.

The possibilities of producing biofuel from various renewable resources, in particular algae, are offered by E. S. Shuba, D. Kifle (Shuba *et al*., 2018) and others. They emphasize limiting the cultivation of agricultural crops used for producing biofuel. As the agricultural sector of economy is primarily a resource for the production of food products and feeds that, in one way or another, exhaust the supply of useful soil substances and deform its mechanical state, contribute to erosion. As an alternative, they suggest growth of microalgae and transition to third-generation biofuel, which is a promising source of energy. Algae can effectively convert sunlight, water and CO_2 into various products suitable for use in renewable energy sources.

The study of the social aspects of renewable energy is equally important. A number of authors substantiate high social efficiency of using energy from

alternative sources in countries with lower incomes per capita, primarily low income households, families with low income, and rural communities (McCabe, 2017).

Among the Ukrainian researchers, the works of T. Demianenko, O. Diachuk, M. Didukh, V. Dubrovin, S. Kuharets, M. Melnychuk, L. Romanchuk, V. Tkachuk, T. Zhelezna and others are quite significant (Demianenko, 2012; Diachuk *et al*., 2017; Melnychuk, 2016; Tkachuk, 2016; Zhelezna, 2017). They consider the technological and technical means of using alternative energy sources: wind, sun, water resources, geothermal sources, and also investigate the problems of production and use of biofuel. Ukrainian researchers emphasise energy efficiency and the establishment of a system for monitoring the production of energy sources from renewable sources of energy and alternative fuels in the Polissia region, taking into account the radioactively contaminated area after the accident at the Chernobyl nuclear power plant.

2. Objective and methodology of the research

The purpose of the article is to develop and substantiate theoretical and methodological principles and to provide some practical recommendations for the implementation of the European experience of strategic development of alternative energy in Ukraine taking into account the priorities of the national economic policy on energy efficiency and energy preservation.

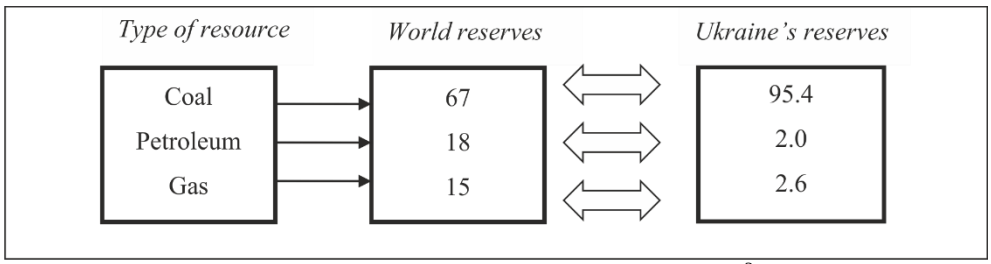
In the course of this study, a systematic approach was used to assess the structure of fossil fuel reserves by types of resources in Ukraine and in the world. Estimated calculations of world prices for energy coal, oil, gas by 2050 are used. There is an analysis of the production and consumption of primary energy in the European Community in the dynamics from 1990 to 2016. This made it possible to compare the results obtained with forecasted estimates for 2020. The authors of the article built the structure of renewable energy sources in the EU countries according to Eurostat. According to the results of the analysis of the dynamics of the use of alternative energy sources in the EU in the period between 1990 and 2016, there is a tendency of intense growth rates in the consumption of wind energy, solar energy, biogas, and liquid biofuels. The ranking of EU member states with the highest renewable energy consumption in the energy balance structure in 2016 is determined. The share of energy from renewable sources in the energy consumption structure of the EU member states and in Ukraine is calculated in dynamics. The energy balance of Ukraine is constructed, which illustrates the country's import dependence. The structure of electricity production by sources of supply is important in the research, which shows the dominant role of nuclear and thermal energy in Ukraine. At the same time, the dynamics of energy supply on the basis of renewable energy sources in Ukraine indicates its increase. Furthermore, estimates of the energy potential of Ukraine's biomass up to 2050 indicate the potential of increasing energy production from alternative sources.

3. Results of the research

3.1. The necessity to preserve energy and to develop it based on renewable resources

Owing to the sharp increase in the world population, the need for energy resources in all branches and spheres of economic activity and everyday life is growing. According to the forecast of BP's Energy Outlook, by 2035, the world's population will reach 8.7 billion people, and consequently, the energy consumption will grow by another 60%, 2/3 of which will account for developing countries (Dudley, 2014). At the same time, according to the anticipated projects of the European Commission, the World Energy Council and the International Energy Agency, the total explored deposits of fossil fuels of all types will be sufficient, respectively: coal – for 250-300 years, petroleum – for 30-40 years, natural gas – for 50-70 years (Zerkalov, 2012). In the structure of world reserves of fossil energy resources, coal accounts for the largest share (67%), in contrast to Ukraine (95.4%) (Fig. 1). Oil and gas in the world account for only 18 and 15% respectively. In Ukraine, these indicators are much lower – 2.0 and 2.6%, respectively, which can be explained by the exhaustion of fields and insufficient financing of exploration works.

Figure 1. Comparative structure of the reserves of fossil fuels (%)



Source: according to the data of the State Statistic Service of Ukraine[2].

Intensive consumption of organic fuel (primarily petroleum and gas), with a high level of costs of extraction and transportation, will lead to an increase in world prices for fossil energy resources. Thus, according to forecasts published by a group of researchers of the World Bank in the latest report "Commodities Market Overview" and the Institute for Economics and Forecasting of the National Academy of Sciences of Ukraine, by 2050, the greatest price growth can be expected: gas – by 2.3 times, petroleum – by almost 3 times (Table 1). At the same time, forecasted coal prices will grow at a much lower pace compared to the actual level reached in 2016.

[2] Energy sector of Ukraine: results of 2016. State Statistics Service of Ukraine (retrieved from http://razumkov.org.ua/uploads/article/2017_ENERGY-FINAL.pdf).

Table 1. Price forecast for fuel resources

Type of fuel	Actual data		Forecast			2050 % compared to:	
	2012	2016	2020	2030	2050	2012	2016
Power generating coal, dollar / ton	100	60	50-60	55-60	70	70,0	117.7
Petroleum, dollar /barrel	110	42	62	80	130	118.2	309.5
Natural gas, dollar /ths. m^3	270	260	270	300	600	222.2	230.8

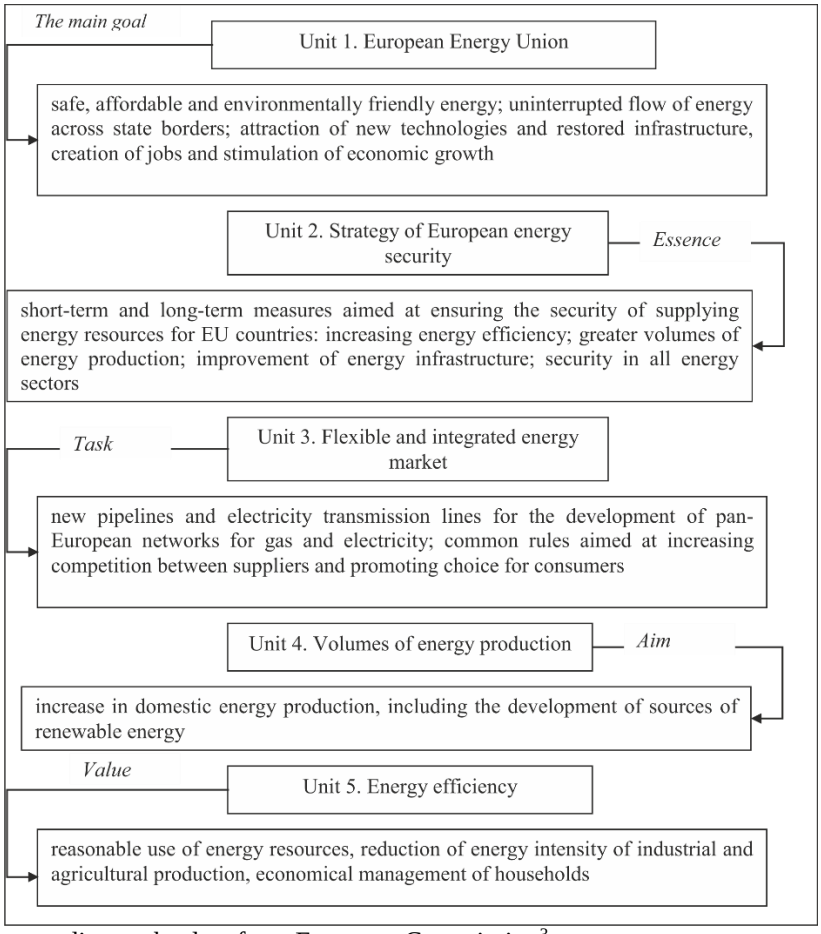
Source: according to the data from World Bank Group (2017).

Experts estimate that the main reserves of fuel resources are concentrated in countries such as: Saudi Arabia (34 USD trillion), Iran (27 USD trillion), Russia (26 USD trillion), Canada (USD 21 trillion), Iraq (15 USD trillion). Of them, 40% of all world gas reserves are concentrated in Russia and Iran. In Saudi Arabia, Iraq and Iran, petroleum accounts for 85% of all national natural resources. In Kuwait, coal is the only raw material. Norway, which is one of the world's largest petroleum exporters, became the leader of the European list of countries with the most expensive petrol (Countries with the greatest reserves). This situation is of concern to other countries in the world, whose energy security depends on the energy policy of the countries that export fossil fuels. A striking example was the 2009 gas conflict between Russia and Ukraine, which is a transit country for many EU countries; the conflict resulted in the shutdown of the gas flow to Europe. The EU imports more than half of all energy consumed. Particularly high is its import dependence on crude petroleum (90%) and natural gas (69%). The total import expenses in the EU exceed 1 billion euros per day (Energy Security Strategy, 2014). The following countries are almost completely energy dependent on all types of energy resources: Cyprus, Malta, Luxembourg and Ireland, along with Italy, Portugal, and Spain, which are more than 80% dependent Countries such as Belgium, Austria, Greece, Germany, and Finland still remain at a high level of energy dependence (Forecast evaluation and course of assimilating, 2013). Ukraine is also import dependent, in particular on Russia, but the share of gas purchases decreases each year. Thus, if in 2008, Ukraine purchased 52.6 billion m^3 of gas in Russia, which accounts for 100% of imports, in 2016, imports amounted to 11 billion m^3 (by 4.8 times less) with a change in the supply structure, which was made from Slovakia – 9 billion m^3, Hungary – 1.0, Poland – 1.0 (Energy sector of Ukraine: results of 2016, 2017). There are approximately 70 importers of petroleum and petroleum products in Ukraine. Among the leaders, there is a subsidiary of ZAT (a private limited company) "Belarusian Petroleum Company", which accounted for about 53% of all domestic gasoline imports last year (Kudinov, 2017). In addition, the further use of fossil fuels in the world jeopardizes the climate change, contributes to global warming and environmental pollution.

3.2. Strategic direction of the EU Energy Policy

In this situation, EU member states identified the main goals and directions of their energy policy: to ensure the safe supply of energy anywhere, at any time and in sufficient quantity; to create an effective competitive environment in the energy market, which will encourage the affordable housing prices, profitable businesses and low-energy industries; to reduce emissions of greenhouse gas.

Figure 2. Strategic directions of Energy Policy in the EU

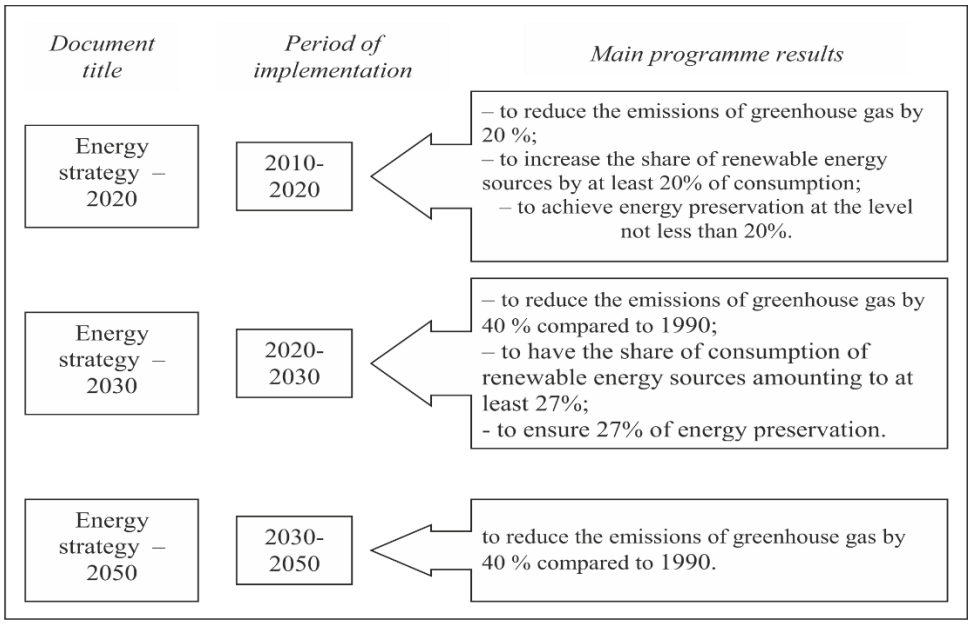


Source: according to the data from European Commission[3].

[3] Energy Strategy and Energy Union. Secure, competitive, and sustainable energy. European Commission (retrieved from https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union)

These goals will help the EU overcome major energy issues, among which are the dependence on energy imports and policy of countries that supply energy resources; an increase in global demand and a scarcity of fuel, in particular petroleum and gas, which leads to higher prices; environmental pollution and the destruction of biodiversity. To achieve these goals, the EU countries identified some key strategic elements and directions (Figure 2). In order to implement these directions within the framework of the coordinated long-term strategy of the EU the goals for 2020, 2030 and 2050 were formulated. In each document, priority is given to alternative energy as the main direction of diversification of energy supply of the region (Fig. 3).

Figure 3. Stages and main programme results of implementing the energy strategy of the EU



Source: according to the data from Energy 2020[4] , Energy Efficiency[5], Energy Roadmap[6]

[4] Energy 2020, A strategy for competitive, sustainable and secure energy. European Commission. Luxembourg, 2011 (retrieved from https://ec.europa.eu/energy/sites/ener/files/documents/2011_energy2020_en_0.pdf).

[5] Energy Efficiency and its contribution to energy security and the 2030 Framework for climate and energy policy European Commission. Brussels, 23.7.2014 (retrieved from https://ec.europa.eu/energy/sites/ener/files/documents/2014_eec_communication_adopted_0. pdf)

[6] Energy Roadmap 2050, *Commission staff working paper. Final report of the Advisory Group on the Energy Roadmap 2050.* Brussels. 13 December 2011 (retrieved from https://ec.europa.eu/energy/sites/ener/files/documents/sec_2011_1569_1_0.pdf)

By 2020, the EU intends to reduce its greenhouse gas emissions by at least 20% to increase the share of renewable energy sources to 20% in total energy consumption and to achieve energy preservation of at least 20%. All EU countries are also expected to achieve 10% usage of renewable energy in the transport sector (Energy 2020. A strategy for competitive, sustainable and secure energy, 2011). In other words, according to a preliminary estimation of the Eurostat, the EU made a commitment to consume no more than 1483 mln tons of oil equivalent (toe) of primary energy, and ultimately, in 2020, no more than 1086483 mln toe. In fact, as of January 1, 2017, the consumption of primary energy in the EU (Table 2) for the period from 1990 to 2016 decreased by only 1.7%.

Table 2. Production and consumption of primary energy, EU-28, mln toe

Type of resource	**1990**	**2000**	**2010**	**2016**	**Forecast 2020**	**2016 compared to 1990, %**	**Variance from forecast, %**
Primary energy	***1570.0***	***1617.6***	***1657.5***	***1542.7***	***1483***	98	96
Solid fuel	452.7	320.1	281.5	238.9		53	
Petroleum and petroleum products	549.8	566.5	518.8	484.7		88	
Natural gas	282.4	380.7	433.5	369.4		131	
Nuclear heat	205.2	243.8	236.6	216.7		106	
Renewable	72.1	98.5	175.2	216.6		300	
Other	7.7	8.0	11.9	16.5		214	
Consumed energy	***1084.6***	***1132.7***	***1163.2***	***1107.7***	***1086***	102	98
Solid fuel	124.1	61.9	50.1	45.2		36	
Petroleum and petroleum products	448.8	490.3	458.1	437.1		97	
Natural gas	230.9	267.5	272.0	245.3		106	
Electricity	185.8	217.4	244.0	239.4		129	
Waste heat	55.1	45.3	53.5	47.9		87	
Renewable	38.9	49.1	82.8	88.9		229	
Non-renewable waste	0.9	1.0	2.7	3.8		422	

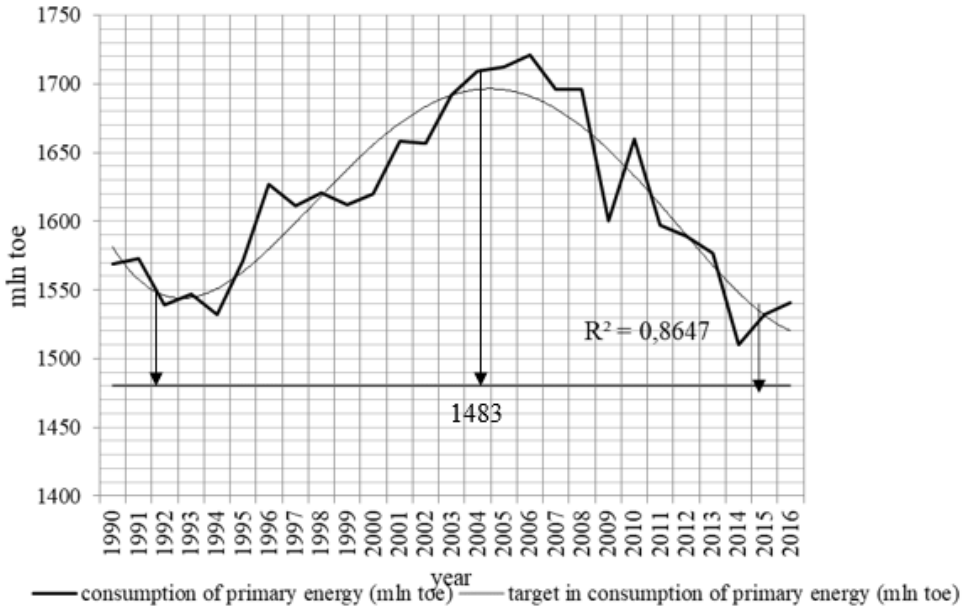
Source: build by the author according to the data of Eurostat (2019).

Thus, in the EU countries, during 1990-2016, coal extraction decreased by 47%, and petroleum (including petroleum products) by 12%. At the same time, the production of fuel gas increased by 31%, atomic energy – by 6%, and the production of renewable energy sources doubled. The production of primary energy reached its peak in 2006, however, by 2016 it decreased by 10%. The share of coal in the

structure of primary energy decreased from 29% in 1990 to 15% in 2016. Petroleum and petroleum products remain the most important source of primary energy sources, share of which accounted for 31% in 2016, compared to 35% in 1990. The total share of fossil fuels (solid, gaseous and liquid) decreased from 82% in 1990 to 71% in 2016. The renewable sources reached a record level in 2016. The share of nuclear energy remains relatively stable and is 13-15% during the studied period.

Thus, the distance to the target of 20% in primary energy consumption, as stated in the Strategy 2020, reached a record low level in 2014 (exceeding the target level was only 1.7%). In 2016, consumption increased slightly, which led to a 4.0% reduction from the expected target concerning efficiency of primary energy in 2020 – 1,483 million toe (Fig. 4).

Figure 4. The distance to the target "Europe 2020" concerning the consumption of primary energy in the EU during 1990-2016, mln toe



Source: Eurostat (2019).

EU countries approved a new climate and energy framework for 2030. Its main objective is to achieve a more competitive, reliable and stable energy system as well as long-term indicators of reducing greenhouse gas emissions in 2030. This strategy should increase the volume of investment in low carbon technologies. The goals of the strategy are: to reduce greenhouse gas emissions by 40% compared to 1990; to achieve at least 27% share of the consumption of renewable energy sources along with 27% energy preservation (Hodson, 2014).

According to the Strategy, by 2050, EU member states should reduce greenhouse gas emissions by 80-95% compared to 1990. In order to achieve this target, the Energy Roadmap of the European Commission was adopted in 2011. The latter identified four main directions for a more stable, competitive and secure energy system in 2050: energy efficiency, renewable energy, nuclear energy and carbon capture and storage. It combines seven possible scenarios of EU energy development by 2050 (Energy Roadmap 2050, 2011).

On November 30, 2016 the European Commission presented a new package of measures aimed at ensuring a stable legal framework necessary to facilitate the transition to environmentally-friendly energy, and thus created the preconditions for the establishment of the Energy Union (Clean Energy for All Europeans, 2018). The main objective is to enable EU countries to meet the commitments set out in the Paris Agreement. Particularly, to offer "clean energy for all Europeans" in order to help the EU energy sector become more stable, competitive, sustainable and relevant for the 21st century.

Consequently, in the European Community, economic growth in the next 30 years is seen in the creation of a high level of energy security, based on energy preservation and transition to alternative energy sources. Taking into account Ukraine's course towards European integration, it is essential to align with the European benchmarks and the strategy for the further development of the domestic energy sector.

3.3. Current state and prospects for the development of alternative energy in EU and in Ukraine

Basic sources of alternative energy are the basis for the Law of Ukraine "On the Alternative Energy Sources"[7]. On their basis, there are different types of alternative energy (Figure 5).

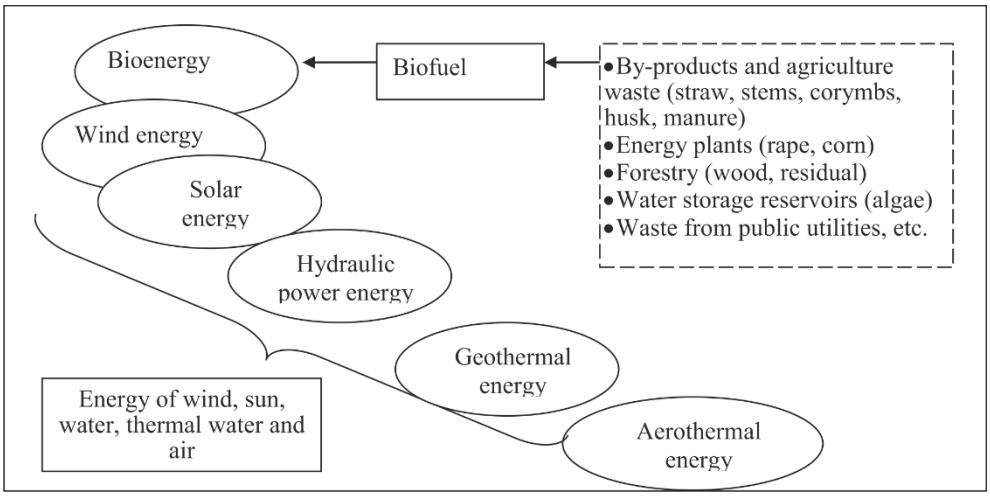
They provide environmental benefits, since their use reduces harmful emissions of CO^2, hydrocarbons and particulates, as well as reducing the greenhouse effect. In fact, burning biofuels also leads to carbon emissions in the environment, but much fewer than burning fossil fuel.

The distinctive feature of alternative energy is that it is extracted from non-fossil sources that constantly exist, self-recover or periodically appear in the natural environment. In contrast to renewable energy sources, the use of fossil fuel is devastating to the environment owing to greenhouse gas emissions and, consequently, global warming. Rittman V.E. (Rittmann, 2008) described the danger of using fossil fuel from three perspectives: depletion of fuel resources; geopolitical

[7] Legislation of Ukraine (2003), On the alternative energy sources: Law of Ukraine of 20.02.2003, No 555-IV, Information of the Verkhovna Rada of Ukraine, 2003, 24, p. 155 (retrieved from http://zakon3.rada.gov.ua/laws/show/555-15/page).

conflict through competition for a limited resource; climate change as the result of increased CO^2 concentration in the atmosphere. Therefore, the search for "pure" energy has become one of the most urgent tasks of modern science.

Figure 5. Types of alternative energy



Source: author's research.

The research which proves the interrelation between energy consumption and economic growth in ten countries around the world, such as China, the USA, Russia, India, Japan, Canada, Germany, Brazil, France and South Korea (Shahbaz and Zakaria, 2018) is of particular interest. The authors used quintle-on-quintle method (QQ) Sima and Zhou. The results indicate a positive relation between economic growth and energy consumption, which differs from the economic development of each country significantly. The weak impact of economic growth on energy consumption is marked by lower indicators of growth in China, India, Germany and France, which is indicative of the fact that energy as an initial source is less important at low levels of economic growth. A weak influence is also observed in the highest quantitative income indicators of the United States, Canada, Brazil and South Korea, which suggests that demand for energy decreases with economic growth, as these countries have become more energy efficient. The weakest effect of energy consumption on economic growth is observed with lower quantitative indicators of energy consumption in China, Japan, Brazil and South Korea.

The experience of Poland is valuable to Ukraine as this country also uses coal reserves to generate electricity in order to ensure the country's energy security. At the same time, there are economic and financial difficulties for the enterprises of the mining industry; huge investment costs, which exceed the financial capacity of the energy sector and the country, are needed to radically change the structure of fuel

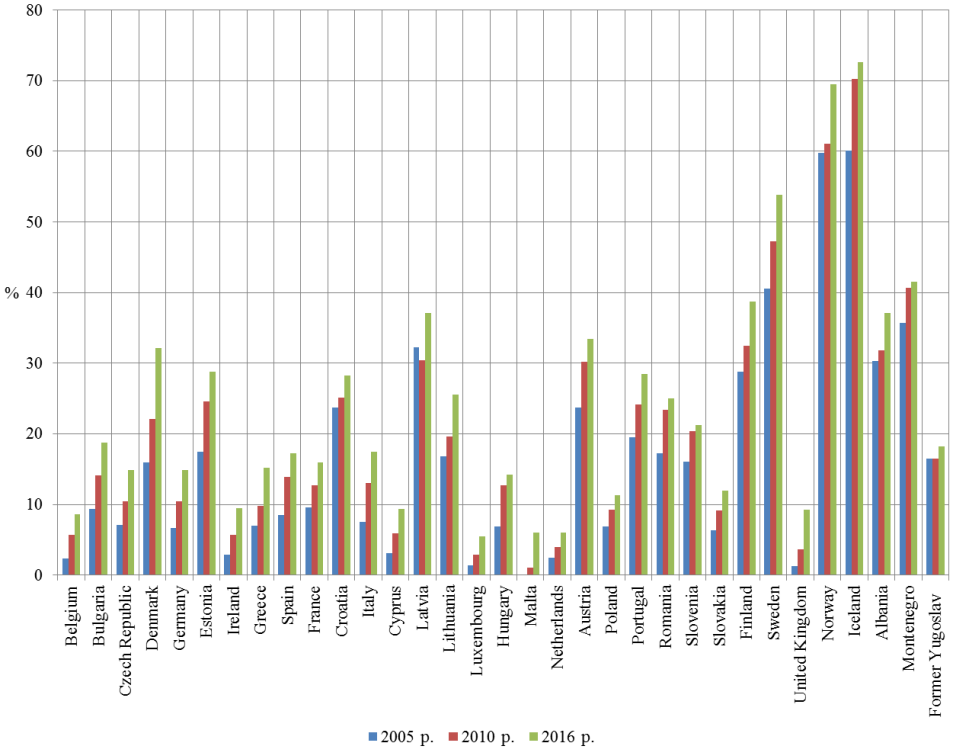
consumption in the energy sector in accordance with the EU priorities. Poland's transition of energy to a low carbon economy is heavily based on energy saving ideas and efforts on energy efficiency. There is also a significant increase in the production of renewable energy sources, especially wind energy. However, it causes problems regarding the stability of energy systems as well as supply and demand balance (Gawlik, 2017). The Polish government, like the Ukrainian one, faces the task of building a long-term energy policy and energy transformation strategy that should take into account internal and external determinants and priorities. At the same time, it is important to discuss the path of development, which is in line with the direction of change proposed by the European Union, and takes into account Ukraine's capabilities.

As the conducted analysis shows, in recent years, the pace of development of renewable energy in the EU has increased dramatically. The share of energy from renewable sources in gross final energy consumption has almost doubled over the past 12 years: from 8.5% in 2004 to 17.0% in 2016. This positive development is determined by the legally binding targets for increasing the share of renewable energy approved by Directive 2009/28/EC on the promotion of using energy from renewable sources[8]. In spite of the fact that the EU as a whole tries to achieve its goals by 2020, some member countries will need to make additional efforts to meet their commitments to achieve the required level of total share of energy from renewable sources in gross final energy consumption (fig. 6). Such countries include Luxembourg – 5.4%, Malta and the Netherlands – 6% each, Belgium – 8.7%, Great Britain and Cyprus – 9.3%, Ireland – 9.5% of energy from renewable sources in the structure of gross final consumption and others. At the same time, by 2016, a number of countries had already reached the level of consuming energy from renewable sources stated in the Energy Strategy – 2020: Slovenia – 21.3%, Romania – 25%, Lithuania – 25.6%. There is a group of countries that reached and exceeded their planned level of energy consumption – 27%, as indicated in the EU energy strategy – 2030: Croatia – 28.2%, Portugal – 28.5%, Estonia – 28.8%, Denmark – 32.2%, Austria – 33.5%, Latvia – 37.2%, Finland – 38.7%, Sweden – 53.8%, Norway – 69.4%, Iceland – 72.6%.

The primary production of renewable energy within the EU-28 in 2016 amounted to 211 million toe. The amount of renewable energy sources produced in the EU-28 increased by a total of 66.6% between 2006 and 2016, which is an average annual growth rate of 5.3%.

[8] The European Parliament and the Council of the European Union (2009), Directive 2009/28/EC of the European Parliament and of the Council, *Official Journal of the European Union* (retrieved from http://data.europa.eu/eli/dir/2009/28/oj).

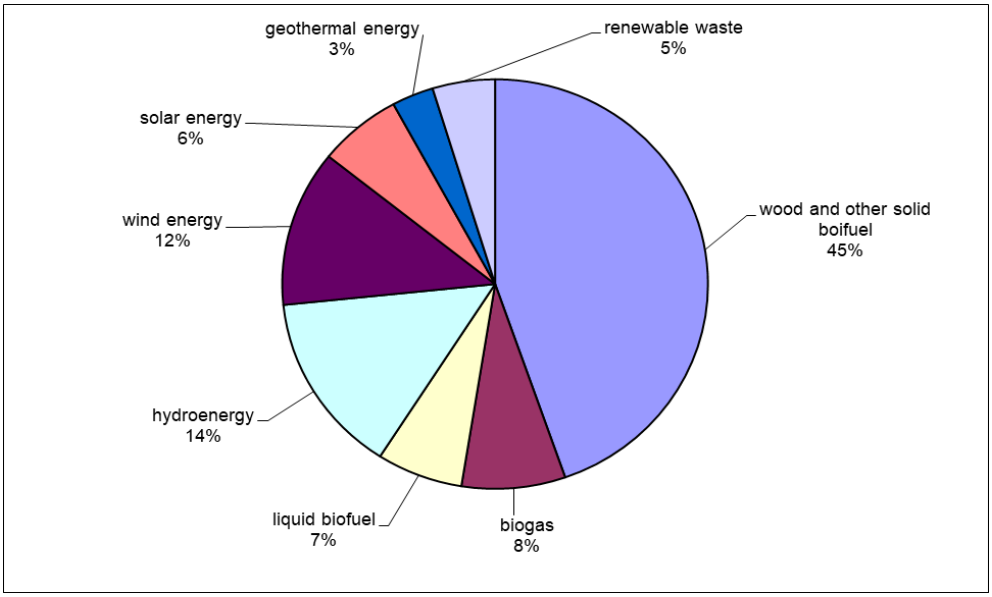
Figure 6. The share of renewable energy in the total ultimate consumption of energy in the countries of EU-28 in 2005, 2010, 2016, %



Source: built according to the data from Eurostat (2019).

Among the renewable energy sources, the most important source in the EU-28 was wood and other solid biofuel, as well as renewable waste, which is 50% of primary energy production in 2016 (Fig. 7). Hydroenergy became the second most important source in the total amount of renewable energy sources (14% of the total amount), followed by wind energy (12%). Although the level of their use remained relatively low, the production of wind and solar energy increased particularly rapidly. Their share in renewable energy sources in the EU-28 in 2016 amounted to 6.3%. Geothermal energy was 3.2% of the total amount of energy from renewable sources.

Figure 7. The structure of renewable energy sources in the countries of EU-28 in 2016, %



Source: built according to the data from Eurostat (2019).

Table 3. Production of primary energy from renewable sources, EU-28, 1990-2016, mln toe

Type of resource	1990	2000	2010	2016	2016 compared to 1990, times
Wood and other solid biofuel	40.6	53.8	86.2	94.1	2.3
Biogas	0.7	2.2	8.7	16.6	23.7
Liquid biofuel	0.0	0.7	11.6	13.8	13.8
Hydroenergy	25.0	30.7	32.4	30.1	1.2
Wind energy	0.1	1.9	12.8	26.0	260.0
Solar energy	0.1	0.4	3.7	13.4	134.0
Geothermal energy	3.2	4.6	5.5	6.7	2.1
Renewable waste	2.1	3.8	8.1	10.0	4.7
Total	71.8	98.1	169	210.7	2.9

Source: built according to the data from Eurostat (2019).

Currently, there is a very low level of producing tidal, wave and ocean energy and moreover, these technologies are found mainly in France and the UK.

Generally, over the past 26 years, energy from renewable sources in the EU has increased by 3 times: from 71.8 mln toe in 1990 to 210.7 mln toe in 2016 (table 3). The analysis of the dynamics of the use of alternative energy sources in the EU from 1990 to 2016 clearly illustrates the tendency of intensive growth of consuming such resources as: wind energy – by 260 times, solar energy – by 134 times, biogas – by 23.7 times; liquid biofuels – by 13.8 times.

Energy production is growing at a less intensive pace: renewable waste – by 4.7 times, forest and other solid biofuel – by 2.3 times, geothermal energy – by 2.1 times, hydropower – by 1.2 times.

The value of renewable energy sources in gross internal energy consumption (table 4).

Table 4. EU member countries with the highest consumption of energy from renewable sources in the structure of energy balance in 2016 (%)

Country	Share of renewable energy in the balance	including				
		biofuel and renewable waste	water energy	wind energy	solar energy	geothermal energy
EU-28	13.2	8.6	1.8	1.6	0.8	0.4
Denmark	28.7	21.7	0.0	6.3	0.7	0.0
Estonia	15.5	14.7	0.0	0.8	0.0	0.0
Croatia	28.2	15.2	6.9	1.0	0.1	0.1
Italy	16.8	8.5	2.4	1.0	1.4	3.6
Latvia	37.2	32.0	5.0	0.3	0.0	0.0
Lithuania	20.8	18.7	0.6	1.4	0.1	0.0
Austria	29.6	17.3	10.1	1.3	0.8	0.1
Portugal	24.1	12.3	5.8	4.6	0.7	0.7
Romania	19.1	12.0	4.8	1.7	0.5	0.1
Slovenia	16.5	9.7	5.7	0.0	0.5	0.7
Finland	30.7	26.0	3.9	0.8	0.0	0.0
Sweden	37.1	23.6	10.8	2.7	0.0	0.0
Iceland	82.7	0.6	20.7	0.0	0.0	61.4
Montenegro	33.6	17.5	16.0	0.0	0.0	0.0

Source: built according to the data from Eurostat (2019).

The EU strives to get 20% of the share of gross final energy consumption from renewable sources by 2020. This target is shared by all member countries of the EU with national action plans aimed at creating the directions of development of renewable energy sources in every country of the union. At present, as of the

beginning of 2017, the share of 17% of renewable energy in the gross final energy consumption in EU-28 was achieved (to compare, in 2004, it was 8.5%).

Leading countries in consuming energy from renewable sources in gross final consumption are: Iceland (82.7%), Latvia (37.2%), Sweden (37.1%), Finland (30.7%), Austria (29.6%) and Denmark (28.7%). At the opposite end of the scale are Luxembourg (5.4%), Malta and the Netherlands (6.0%), Belgium (8.7%), Great Britain and Cyprus (9.3%). Compared to the latest available data (2016), France, the Netherlands and Ireland should increase their share of renewable energy in final consumption by at least 6 percentage points. In contrast, eleven EU member states have already exceeded their target for 2020, especially Croatia, Sweden and Estonia.

According to the data from Eurostat, in 2016, the production of electricity from renewable sources in the EU countries amounted to more than a quarter (29.6%) of the total electricity production. The increase of electricity generated from renewable energy sources over the period from 2006 to 2016 considerably reflects an increase in the three renewable energy sources in the EU. Mainly, it is wind and solar energy, and solid biofuels (including renewable waste). Despite the fact that hydroenergy remained the only major source of producing renewable energy in the EU-28, the share of this type of energy in 2016 amounted to 36.9% of the total volume, the amount of electricity generated by this source in the last ten years did not change much. In contrast, in 2016, the amount of solar energy and energy from wind turbines produced in the EU-28 increased by 446 times compared to 2006. As a result, the share of wind and solar energy in the total amount of electricity produced from renewable energy sources increased in 2016 to 31.8% and 11.6% respectively. During the 10-year period, the contribution of solar energy to the total electricity produced in EU-28 from renewable energy sources increased from 0.3% to 11.6%. The tidal energy as well as the energy of waves and the ocean, used in the energy sector was only about 0.05% of the total volume.

Altogether, the consumption of energy from renewable sources in the European Union in the period from 2005 to 2016 doubled. However, there is a significant difference in the dynamics of consuming renewable energy among EU member states (Table 5). Thus, in ten years, the following countries have the highest growth rates: Denmark, Portugal and Romania – by 1.5-2 times, while in Latvia, Austria, Slovenia, and Finland the growth rate did not exceed 10%. According to the data of 2016, the potential of renewable sources in the structure of energy consumption is almost fully used in Norway – 104.7% (this country imports 4.7% of renewable sources from other countries), Iceland – 95.3%, Albania – 86%, Austria – 72.6%.

Table 5. The share of energy from renewable sources in the structure of energy consumption of the member countries of the EU-28 in 2005, 2010, 2016 (%)

Country	2005	2010	2016	2016 vs 2005, +/- of relevant points
EU-28	14.8	19.7	29.6	14.8
Denmark	24.6	32.7	53.7	29.1
Croatia	35.6	37.6	46.7	11.1
Latvia	43.0	42.1	51.3	8.3
Austria	61.9	65.7	72.6	10.7
Portugal	27.7	40.7	54.1	26.4
Romania	26.9	30.4	42.7	15.8
Slovenia	28.7	32.2	32.1	3.4
Finland	26.9	27.7	32.9	6.0
Sweden	50.9	56.0	64.9	14
Norway	96.8	97.6	104.7	7.9
Iceland	94.9	92.4	95.3	0.4
Albania	72.1	74.6	86.0	13.9
Montenegro	39.1	45.7	51.0	11.9

Source: built according to the data from Eurostat (2019).

The EU set the criterion: to reach the level of 10% in production of renewable energy (including liquid biofuel, hydrogen, bioethanol, "green" electricity, etc.) in the transport sector by 2020. In 2016, the level of 7.1% was reached. Among the EU member states, the relative share of renewable energy sources in consumption of transport fuel varied from 30.3% in Sweden, 10.6% in Austria to less than 2.0% in Croatia, Greece, Slovenia and Estonia.

Therefore, after a comprehensive analysis of the energy sector in the EU, the European Commission identified several energy strategies for a more secure, sustainable and low carbon economy. Apart from struggling against climate change by reducing emissions of greenhouse gas, using renewable energy sources will lead to a more secure energy supply, diversification of energy sources, less air pollution and possibility to the creation of jobs in the environmental and renewable energy sectors. Ukraine belongs to the group of countries with a high potential for generating alternative energy. The updated Energy Strategy of Ukraine by 2035[9] forecasts that the share of imported components in the energy balance can be significantly reduced due to the development of renewable energy sources, domestic production of natural gas as well as energy preservation and energy efficiency[10]. However, as of 2016, in Ukraine's energy balance, imported energy resources still account for a high proportion – 46% or 29.1 mln toe (table 6).

[9] Ministry of Energy and Coal Industry of Ukraine (2017), Energy strategy of Ukraine by 2035 (retrieved from https://ua-energy.org/uk/posts/opublikovano-tekst-enerhostratehii-do-2035-roku).

[10] Ministry of Energy and Coal Industry of Ukraine (2013), Energy strategy of Ukraine by 2030 (retrieved from mpe.kmu.gov.ua/minugol/doccatalog/document?id=260994).

Table 6. Energy balance in Ukraine in 2016, ths. toe*

Supply and consumption	Coal and turf	Crude pettroleum	Petroleum products	Natural gas	Nuclear energy	Hydroelectric energy	Wind, solar energy	Biofuel and waste	Electric energy	Heat energy	Total
Production	20146	2304	-	15172	21247	660	124	3348	-	599	63600
Import	10617	527	9155	8807	-	-	-	38	7	-	29151
Export	-495	-25	-24	-	-	-	-	-553	-329	-	-1427
International bunkering	-	-	-157	-	-	-	-	-	-	-	-157
Change of stock	-541	-	-586	1619	-	-	-	-1	-	-	491
General supply of primary energy	29727	2806	8387	25598	21247	660	124	2832	-323	599	91658

* excluding temporarily occupied territory of the Autonomous Republic of Crimea and Sevastopol and a part of the ATO zone.
Source: calculated according to the data of State Statistics Service of Ukraine[11].

Table 7. Structure of electricity production according to the source of supply to Ukraine in 2016*

Type of electric power plant	**Established electric capacity, ths. kW**	**Volume of produced electrical energy, mln. kW/h**	**Structure, %**
Nuclear power plant	13835	75931	51.4
Heat power plant	27489	50215	34.0
Combined heat and power plant	10569	11078	7.5
Hydropower plant	6167	9004	6.1
Solar power plant	324	408	0.3
Wind power plant	387	949	0.6
Other energy generating plants	405	192	0.1
Total	59176	147777	100.0

Note: excluding temporarily occupied territory of the Autonomous Republic of Crimea and Sevastopol and a part of the ATO zone.
Source: calculated according to the data of State Statistics Service of Ukraine[12].

[11] Energy balance of Ukraine for 2016. State Statistics Service of Ukraine (retrieved from http://www.ukrstat.gov.ua/).
[12] Production of Electricity according to the source of supply in Ukraine in 2016. State Statistics Service of Ukraine (retrieved from http://www.ukrstat.gov.ua/).

As of the end of 2016, the largest share in the structure of electricity production in Ukraine is occupied by nuclear and heat power plants – 51 and 34%, respectively, alternative power plants account for only 7% of electricity produced, taking into account large hydroelectric power plants (table 7).

When analyzing the energy consumption of Ukraine on the basis of renewable energy sources in the dynamics over the last ten years, a significant decrease in total energy supply should be noted, which is by 47.7 mln toe, i.e. less than? by 34.2% (table 8).

Table 8. Dynamics of energy supplying based on the renewable energy sources in Ukraine, ths. toe*

No.	Indicator	2007	2009	2011	2013	2015	2016	2016 compared to 2007, +/-
1	General supply of primary energy	139330	114420	126438	115940	90090	91658	-47672
2	Including general supply of energy from renewable sources	2384	2463	2514	3166	2700	3616	1232
3	Of them: - hydroenergy	872	1026	941	1187	464	660	-212
4	% to result	0.6	0.9	0.7	1.0	0.5	0.7	0.1
5	- energy of biofuel and waste	1508	1433	1563	1875	2102	2832	1324
6	% to result	1.1	1.3	1.2	1.6	2.3	3.1	2.0
7	- wind and solar energy	4	4	10	104	134	124	120
8	% to result	0.0	0.0	0.0	0.1	0.1	0.1	0.1
9	Share of energy from renewable sources, %	1.7	2.2	2.0	2.7	3.0	3.9	2.2

Note: 2015-2016 excluding temporarily occupied territory of the Autonomous Republic of Crimea and Sevastopol and a part of the ATO zone.
Source: calculated according to the data of State Statistics Service of Ukraine[13].

At the same time, there is a gradual increase in energy consumption from alternative sources from 2.4 mln toe in 2007 to 3.6 mln toe in 2016. Accordingly, the share of energy from renewable sources in the structure of energy consumption

[13] Energy consumption based on renewable sources in 2016. State Statistics Service of Ukraine (retrieved from http://www.ukrstat.gov.ua/).

increased from 1.7% in 2007 to 3.9% in 2016 by 2.2 percentage points, or 1.2 mln toe. The structure of energy from renewable sources changed significantly: the energy of biofuel and waste increased by 1.3 mln toe; wind and solar energy – by 120 ths toe, at the same time hydropower decreased by 212 ths toe.

The given data testifies to the high dependence of the energy sector of Ukraine on fossil resources, which does not comply with the current EU development strategy for the transition to "clean" energy. Therefore, domestic scientists are searching for solutions to the problems of the formation and development of alternative energy in Ukraine. The greatest potential for substitution is predicted for using biomass, solar and wind energy. According to the National Action Plan for Renewable Energy (NAPRE) for the period up to 2020, approved by the Cabinet of Ministers of Ukraine on October 1, 2014, bioenergy should reach the level of substitution of natural gas in the amount of 8.3 billion cubic meters per year. According to the estimation of Bioenergy Association of Ukraine, the potential of biomass energy in 2015 was 20.2 mln toe (Zhelezna, 2017). By 2050, it will have grown approximately twice and will amount to 43.42 mln toe (Table 9).

The largest potential belongs to energy crops – 25 mln toe and by-products of plant production – 9 mln toe.

According to the State Department of Energy Efficiency of Ukraine, over the past three years, more than 1.6 GW of thermal power plants operating on alternative fuel have been introduced in the country. The potential for the use of solar energy is significant. It is estimated at 1070 kW/h in the northern part of the country and 1400 kW/h and higher in the Autonomous Republic of Crimea compared to the average annual amount of total solar energy entering the 1 km^2 surface of the territory of Ukraine. Thus, only in 2016, the number of installed solar panels increased by 4.5 times. At the same time, their capacity increased by almost 7 times: from 2.2 MW by the end of 2015 to 16.7 MW by the end of 2016 (Alternative energy in Ukraine, 2017). Ukraine has a significant natural potential for the development of wind energy; these are the steppe and mountain areas of Odessa, Mykolaiv, Kherson, Donetsk, Luhansk regions, mountainous regions of the Crimea and the Carpathians. Thus, over the past three years, three wind power plants with a total capacity of 11.6 MW have been put in operation. The potential of wind energy in the near future may account for 15-20% of electricity. Furthermore, in 2016, small hydroelectric power stations with a capacity of 3.3 MW and other plants producing electricity from biogas with a capacity of 3.1 MW were installed.

Consequently, Ukraine has a significant potential for the development of alternative energy, which increases its ability to participate in the European community. At the same time, according to individual forecast calculations, the expedient aggregate power of renewable energy sources in Ukraine will be 12.6% of the total installed capacity by 2030 (Energy strategy of Ukraine by 2030, 2013), which does not comply with the strategic benchmarks of the European Union. Therefore, it is worth building an energy strategy that takes into account the

European energy vector of development. The main tasks of the strategy for the development of alternative energy should be identified in various areas: economic, environmental and social (fig. 8).

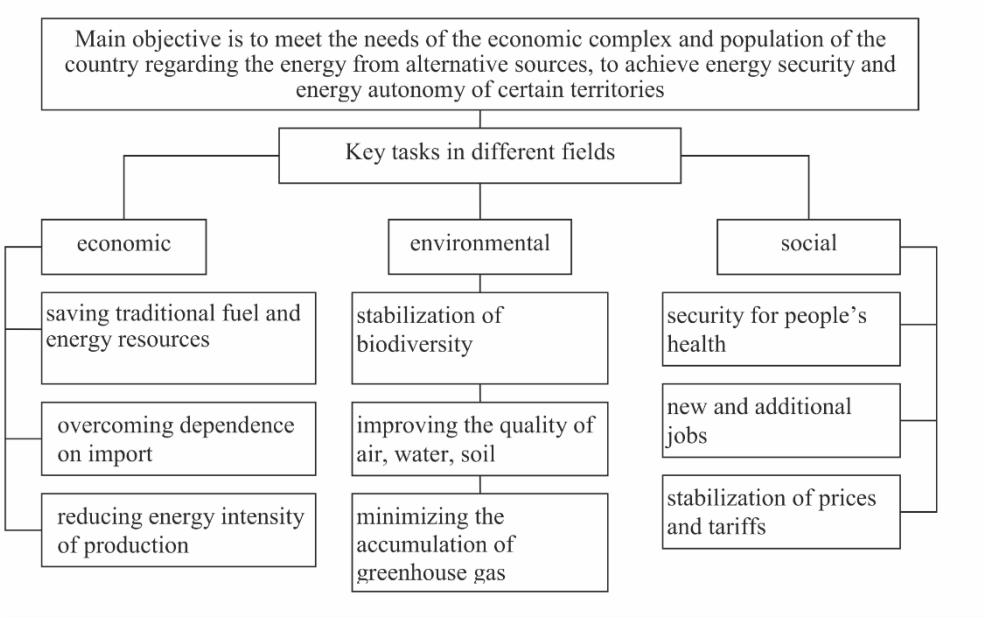
Table 9. Energy potential of biomass in Ukraine up to 2050

Type of biomass	Theoretical potential, mln tons	Share available for energy industry, %	Potential available for energy industry, mln toe
Straw of cereal crops	52.7	30	5.48
Straw of rape	4.7	40	0.65
By-products from production of corn grains (stems, scapes)	45.5	40	3.48
By-products from production of sunflower (stems, corymbs)	21.2	40	1.22
Secondary agriculture wastes (sunflower husk)	1.9	74	0.5
Wood biomass (firewood, felling residue, wood waste)	9.0	94	2.08
Wood biomass (dead wood, wood from forest belts, wood cuts)	8.8	41	1.03
Biodiesel (from rape)	-	-	0.19
Bioethanol (from corn and sugar beet)	-	-	0.54
Biogas from waste and by-products of agribusiness	11.2*	100	2.38
Biogas from organic part of solid domestic waste	5.8*	100	0.6
Biogas from sewage (industrial and utility)	9.0*	100	0.39
Energy crops:			
- willow, poplar, silver grass (1.5 mln ha in 2015, 3 mln ha in 2050)	51.8	90	19.74
- corn for biogas (0.5 mln ha in 2015, 1 mln ha in 2050)	6.68*	90	5.15
Total	-	-	43.42

Note: *- mlrd m^3 CH4

Source: according to the data from Practical guide on the use of biomass as a fuel in the municipal sector of Ukraine (for representatives of agribusiness). Bioenergy Association of Ukraine, 2017, p. 72 (retrieved from http://www.uabio.org/activity/uabio-analytics).

Figure 8. Tasks of the strategy for the development of alternative energy in Ukraine



Source: author's research.

A generating element of the energy strategy of Ukraine should be the creation of an efficient organizational and economic mechanism for stimulating the development of alternative energy by taking into account the reduction of the costs for building powerful energy facilities at the expense of the accumulation of relevant experience, the introduction of advanced technologies, and the search for investment sources, the main of which should be state regional development programs.

Conclusions

The conclusions of the research identify the main results, generalized proposals on strategic directions of energy policy, which determine the significance of the work. The most significant provisions are expressed below.

The situation in the world and its certain parts highlight the aggravation of the problem of supply and consumption of energy resources due to limited conventional fuels (oil, gas, coal). The regional unevenness of the concentration of fuel resources reserves was established, which leads to a decrease in the energy security of import dependent countries. Accordingly, there is an increase in oil and gas prices. A striking example was the 2009 gas conflict between Russia and Ukraine, which is a

transit country for many EU countries. The conflict led to a stopover of gas supplies to Europe.

The strategy for the development of the energy policy of EU member states envisages overcoming the most important problems, including dependence on energy imports and policy of countries supplying energy resources; rising global demand and fuel shortages, in particular oil and gas, which leads to higher prices; environmental pollution and the destruction of biodiversity. The main tasks are: to ensure safe, uninterrupted and optimal energy supply; to create an effective competitive environment in the energy market; to achieve energy efficiency; to reduce greenhouse gas emissions.

Achieving the strategic objectives of energy policy involves developing and expanding the use of alternative energy sources. The conducted analysis shows that, over the past 26 years, EU countries have reduced the production of conventional coal, oil and gas. In the dynamics, there is a planned increase in the volumes of supply and consumption of alternative energy resources. In the energy strategy of the EU-2030, there is a group of countries that have reached and exceeded the planned level of energy consumption – 27%. These are Iceland – 72.6%, Norway – 69.4%, Sweden – 53.8%, Finland – 38.7%, Latvia – 37.2%, Austria – 33.5%, Denmark – 32.2% Estonia – 28.8%, Portugal – 28.5%, Croatia – 28.2%. At the same time, the EU has countries that are far from the target indicator. These include Luxembourg – 5.4%, Malta and the Netherlands – 6% each, Belgium – 8.7%, Great Britain and Cyprus – 9.3%, Ireland – 9.5%. Overall, over the past 26 years, the production of renewable energy in EU countries has increased 3-fold: from 71.8 million toe in 1990 to 210.7 million toe in 2016.

Taking into account Ukraine's course on European integration, it is crucial to align with the European benchmarks and the strategy for further development of the domestic energy sector. In the energy balance of Ukraine, imported energy resources still account for a considerable share of 46%, or 29.1 million toe. As of the end of 2016, the largest share in the structure of electricity production in Ukraine is occupied by nuclear and thermal power plants – 51 and 34% respectively, while alternative power plants account for only 7% of the electricity generated, taking into account large hydroelectric power plants. There is a gradual increase in the consumption of energy from alternative sources from 2.4 million toe in 2007 to 3.6 million toe in 2016. Accordingly, the share of energy from renewable sources in the structure of energy consumption increased from 1.7% in 2007 to 3.9% in 2016 by 2.2 percentage points, or 1.2 million toe. The given data shows the high dependence of the Ukrainian energy sector on fossil resources, which does not comply with the current EU development strategy for the transition to "clean" energy.

Ukraine has a considerable potential for the development of alternative energy, which increases the opportunities for its participation in the European Community. Thus, the gradual implementation of the strategy for energy preservation based on the expansion of alternative energy will contribute to

achieving three effects: environmental – limiting the impact of the traditional energy sector on the environment; social – the creation of additional jobs, increasing employment and incomes of population, stabilization of energy prices; economic – diversification of energy supply will ensure energy efficiency and energy autonomy of certain areas, and will also strengthen the energy independence of the country. The concept of energy transformation of the country, which is relatively inexpensive, will allow society to benefit from the use of alternative energy sources and create environmentally safe, uninterrupted supply of energy.

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