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DOMINANT TRENDS OF INNOVATION AND INVESTMENT ACTIVITIES IN THE DEVELOPMENT OF ALTERNATIVE ENERGY SOURCES

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ДОМИНАНТНЫЕ ТЕНДЕНЦИИ ИННОВАЦИОННО-ИНВЕСТИЦИОННОЙ ДЕЯТЕЛЬНОСТИ В РАЗВИТИИ АЛЬТЕРНАТИВНЫХ ИСТОЧНИКОВ ЭНЕРГИИ

Summary. In order to determine the main tendencies of innovation and investment activity in the development of alternative energy sources (AES), the analysis of foreign experience of the countries of Europe, the USA and Asia was carried out. The innovative waves of development of industrial consumption of energy resources are considered in the article. The structure of regional energy consumption by fuel types is analyzed. The structure of world energy consumption in oil equivalent has been estimated. The distribution of world consumption of alternative energy sources by countries and types is investigated. The research identified the world leaders in the development of alternative energy sources, which are the EU countries. Alternative energy is dynamically developing not only in a number of developed countries, but also in developing countries, which have realized the benefits of using alternative energy sources and are actively developing this energy sector. The dynamics of investments in the development of alternative energy sources are considered. It is determined, that in the conditions of sufficient wind and solar potential and not always predicted prices for oil, as well as expensive infrastructure for oil transportation, alternative energy sources are beginning to compete successfully with traditional energy.

Аннотация. Для определения основных тенденции инновационно-инвестиционной деятельности в развитии альтернативных источников энергии осуществлен анализ зарубежного опыта стран Европы, США и Азии. В статье рассмотрены инновационные волны развития промышленного потребления энергетических ресурсов. Проанализирована структура регионального энергопотребления по видам топлива. Проведена оценка структуры мирового потребления энергоносителей в нефтяном эквиваленте. Исследовано распределение мирового потребления альтернативных источников энергии по странам и видам. В результате исследований определены мировые лидеры в развитии альтернативных источников энергии, которыми являются страны ЕС. Альтернативная энергетика динамично развивается не только в ряде развитых стран, но и развивающихся стран, которые, осознали выгоду применения альтернативных источников энергии и активно развивают эту отрасль энергетики. Рассмотрена динамика инвестиций в развитие альтернативных источников энергии. Определено, что в условиях достаточного ветрового и солнечного потенциала и не всегда предсказуемых цен на нефть, а также дорогостоящей инфраструктуры для транспортировки нефтепродуктов, альтернативные источники энергии начинают успешно конкурировать с традиционной энергетикой.

Keywords: *energy efficiency, alternative energy sources, energy market, energy consumption, energy resources, innovations, investments.*

Ключевые слова: *Энергоэффективность, альтернативные источники энергии, энергетический рынок, энергопотребление, энергетические ресурсы, инновации, инвестиции.*

Formulation of the problem. Energy as a basis economic and social development of the world, its for civilization affects the direction and pace of security and international relations. Almost all aspects

of human life in one way or another related to energy conversion and use.

The exclusive ownership of certain countries' energy reserves enables these countries to dictate their own conditions. Over the last fifty years, exploration of deposits has grown significantly, which has significantly strengthened the position of exporting countries, which are able not only to meet domestic demand for energy, but also to act as a major supplier in the world market. The increase in the number of exporters causes the complexity of harmonizing their behavior, which directly affects the structure of energy consumption.

The economic potential of a country largely depends on the state of its energy resources and the conditions of their use. Recently, more and more attention is being paid to the reliable and stable economically efficient provision of the world economy with energy resources, which is one of the main tasks, the solution of which is the basis for the existence and gradual development of civilization, the key to its energy security and an indicator of the quality of life of the population.

The rapid increase in the number of population, transport, and worldwide production leads to an

increase of energy consumption, which, in turn, causes a great load on the environment.

Therefore, it becomes evident, that in order to grow economically and improve the environmental situation, it is necessary to develop actively the use of alternative energy sources and to increase energy efficiency.

Analysis of recent research and publications.

Issues of energy security and innovation and investment development of alternative sources in this field have recently been increasingly covered by domestic and foreign scientists, such as Twidel J., Weir A., Schumpeter J. [1], Ivanov A.S. [4], Romanchuk Y. [10].

Formulating the goals of the article. Research of world trends of innovation and investment activity in the development of alternative energy sources.

Presenting of the main research material. J. Twidel and A. Weir [1], based on the historical formation of the world energy market, distinguish four innovative waves of its development according to the concept of J. Schumpeter, which are related to the industrial consumption of certain types of energy resources (Fig. 1).

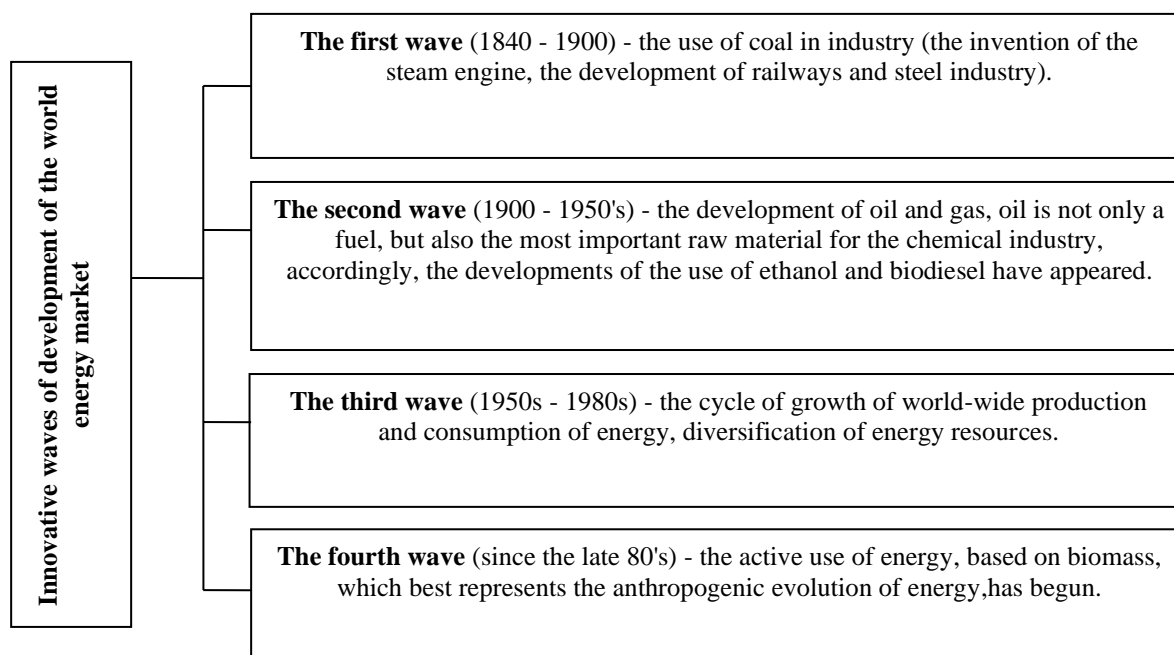


Fig. 1. Innovative waves of development of industrial consumption of energy resources
Source: compiled by the author [1].

The third innovation wave culminated in an increase in global energy production and consumption, as a result, the environmental load has increased by five times in fifty years. This cycle actualized the problems of caring for energy and set before humanity the question of the possibility of complete depletion of non-renewable natural resources. Accordingly, the concept of sustainable development was formed, through which previously unrelated trends in energy intensity and energy efficiency have begun to be considered in a single direction of reducing overall energy consumption.

Thus, becoming the first open-source fuel, biofuel has retained its importance and, through the improvement of innovative technologies, has made its way from one of the most environmentally damaging sources of energy to the status of promising and clean fuel.

The current structure of primary energy consumption in different countries is diverse and is determined by the availability of natural resources, transport capacities and the formed specificity of internal needs (Fig. 2).

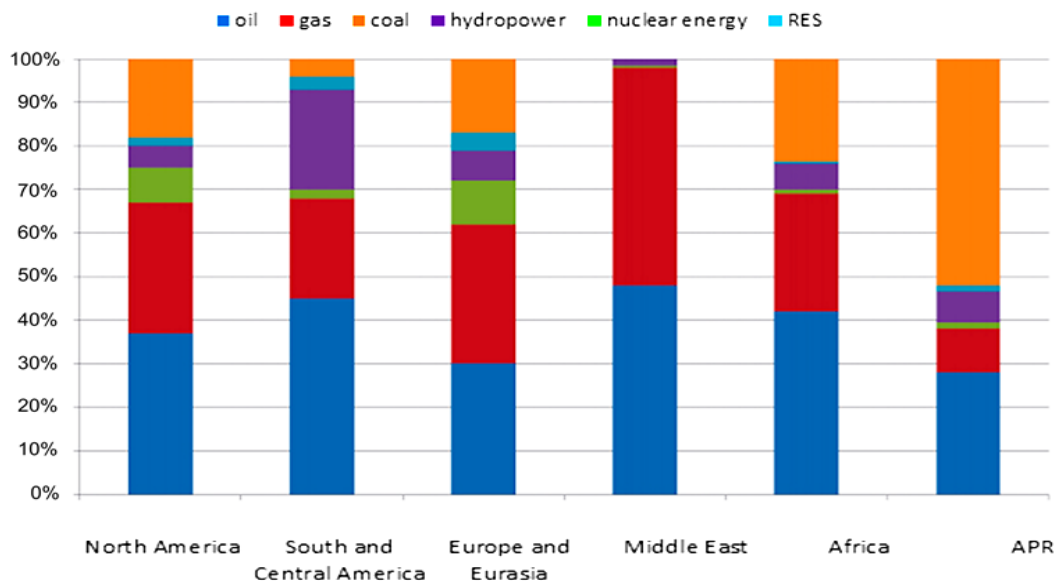


Fig. 2. Structure of regional energy consumption by fuels at the beginning of 2019,%.
Source: compiled by the author [2].

The structure of regional energy consumption proves that most countries focus on the use of local and regional energy, which determine the priorities of industrial and household consumption. In particular, coal remains the main fuel in

some countries, the highest share of which in energy consumption in 2018 was:

South Africa - 72.4%, China - 67.2%, India - 55.3%, Poland - 55.6% .

Some countries realize the benefits by providing hydropower, for example, in Norway the share of hydroelectric power in total primary energy production is 65.2%, in countries such as Brazil, Colombia, Canada, Austria, Sweden, Switzerland water consumption ranges from 24% to 28% [2].

The current situation on the world energy market is characterized by the intensification of globalization processes – mono-product and local energy markets have evolved towards global markets for individual energy resources, which is accompanied by increased competition and contradictions between major players in international energy markets (the main consumers of energy resources are highly developed countries and Asian countries while the major share of the world's

hydrocarbon reserves is concentrated in a relatively small group of developing countries).

Therefore, the world energy market can be considered as a global market ,at the same time it remains segmented. This is mainly due to the fact, that the energy capacity of certain regions depends on the extraction of energy from specific fields. In particular, the range of many refineries have little adaptation to oil of different varieties.

It should be noted that the oil market as a system component of the global energy market is influenced by three main factors that determine pricing: supply and demand (but, unlike other markets, this factor is not determinative), geopolitics, and the desire for oil producers to generate a steady flow of financial resources from the sale of raw materials.

To assess the dynamics of the structure of world energy consumption in Table 1. the growth rates of each type of energy in oil equivalent are calculated.

Estimated growth rates show, that the renewable energy market has been most actively developing in the last nine years, the growth of which amounted to 211.1%. A significant increase is observed in the coal market, which is 36.7%, and in the hydropower market - 24.5%.

Table 1.

Structure of world energy consumption in oil equivalent for 2010 – 2018, million tons.

| Type of energy | Years | | | | | | | | | Growth rate 2018/2010 % |
|-----------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|-------------------------|
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | |
| oil, million tons | 4040.2 | 4085.1 | 4138.9 | 4185.1 | 4210.4 | 4265.7 | 4278.4 | 4314.6 | 4328.4 | - |
| in% compared to the previous year | - | 101.1 | 101.3 | 101.1 | 100.6 | 101.3 | 100.3 | 100.8 | 100.3 | 107.1 |
| gas, million tons | 3180.8 | 3233.0 | 3310.0 | 3347.6 | 3378.3 | 3416.2 | 3443.7 | 3462.8 | 3513.6 | - |
| in% compared to the previous year | - | 101.6 | 102.4 | 101.1 | 100.9 | 101.1 | 100.8 | 100.6 | 101.5 | 110.4 |
| coal, million tons | 3469.1 | 3630.3 | 3723.7 | 3826.7 | 3928.5 | 4085.8 | 4172.6 | 4280.2 | 4396.4 | - |
| in% compared to the previous year | - | 104.6 | 102.6 | 102.8 | 102.7 | 104.0 | 102.1 | 102.6 | 102.7 | 126.7 |
| nuclear energy, million tons | 626.2 | 600.7 | 559.9 | 563.2 | 561.4 | 552.3 | 549.7 | 545.3 | 548.1 | - |
| in% compared to the previous year | - | 95.9 | 93.2 | 100.6 | 99.7 | 98.4 | 99.5 | 99.2 | 100.5 | 87.5 |
| hydropower, million tons | 783.9 | 795.8 | 833.6 | 855.8 | 882.3 | 906.8 | 924.5 | 951.4 | 976.2 | - |
| in% compared to the previous year | - | 101.5 | 104.7 | 102.7 | 103.1 | 102.8 | 102.0 | 102.9 | 102.6 | 124.5 |
| AES, million tons | 168.0 | 204.9 | 240.8 | 279.3 | 314.6 | 373.5 | 421.3 | 485.5 | 522.7 | - |
| in% compared to the previous year | - | 122.0 | 117.5 | 116.0 | 112.6 | 118.7 | 112.8 | 115.2 | 107.7 | 311.1 |

Source: calculated by author [3]

The accelerating growth rates of natural gas markets in comparison with the oil market are significant – 10.4% against 7.1%. It should also be noted the

reduction of the nuclear energy market, which is 12.5% (Table 1).

Thus, the world market of energy resources in modern conditions is characterized by increasing of the degree of uncertainty, which is manifested in the following trends:

- reduction of global energy resources;
- increase of demand and level of prices for fuel and energy resources;
- diversification of energy sources;
- monopolization of the energy market by the countries with the largest FER reserves;
- innovative renewal of energy production processes;
- exacerbation of environmental problems.

Each country wants to have its own energy resources and not to be dependent on energy donor-countries. Therefore, in the modern conditions of management, the energy market is becoming more

diversified, in particular, both the ways of extracting energy and the directions of its use are being updated.

The market for alternative (renewable) energy sources began to form relatively recently, and is in the stage of its active development now. Demand for the industrial use of alternative energy sources has formed in the second half of the twentieth century, when the transformation of the oil market, the creation of the OPEC oil cartel and further oil and economic crises of the 1970s found the vulnerability of Western countries - importers of hydrocarbons from foreign supplies of raw materials.

At the beginning of the 21st century, these states directed the accumulated experience of scientific development to their realization, choosing the course of transition to the new (6th) technological way and outlined the innovative goal – the creation of low carbon economy based on the latest achievements of science and technology.

As a result, alternative energy, such as energy efficiency, energy conservation, and the sector of environmental pollution reduction, has been given

the status of "new growth points" and has become a priorities for large-scale state

support [4].

The main directions of changing energy priorities were set out in the UN Conceptual Documents adopted at the conferences of this organization: in 2012 (transition to sustainable development and “green” economy) [5], in September 2015 (adoption of Sustainable Development Goals for Humanity and All countries by 2030) [6], in December 2015 (ways to reduce greenhouse gas (GHG) emissions due to the problem of global climate change) [7].

It should be noted the growing interest of international organizations in the development of alternative energy sources, in particular, several landmark international conferences, discussing the importance of AES and their development prospects: (The World Summit for Sustainable Development 2002 in Johannesburg (WSSD)) in 2002; The World International Renewable Energy Conference in Bonn; (The G-8 Gleneagles Dialogue), Gleneagles, Scotland (UK), in 2005; The International Conference on Renewable Energy in Beijing (Beijing International Renewable Energy Conference, 2005).

At the Bonn conference, it was decided to create an International Renewable Energy Agency (IRENA). Later, in January 2009, during the constituent conference held in Bonn with the participation of 120 countries, the first large international organization for the development of alternative energy sources was created, the initiative of which was created by Germany [8]. The Agency aims to take a proper place in the global energy sector, alongside the International Atomic Energy Agency (IAEA) and the International Energy Agency (IEA). At present, 152 countries are members of IRENA and 28 countries have begun the process of joining the organization.

In 2016, the process of joining the IRENA was started in Ukraine. Thus, according to the Decree of the President of Ukraine of May 10, 2016 No. 200/2016 [9], an application for membership of Ukraine in IRENA was sent, on which the IRENA member states did not express any objections or remarks.

The main areas of IRENA's activity are the creation of framework conditions for the use of alternative energy sources (as well as financing and

granting of appropriate technologies for their application), as well as granting of consulting services. The purpose of formation of this agency is to stimulate the development of renewable energy sources, which in turn must resolve the issues of energy security, environmental protection, unemployment and economic development of countries.

Ukraine's membership in IRENA primarily provides an opportunity to apply for an Abuban Development Fund to finance "green" projects, which offers long-term preferential loans of 1–2% for up to 20 years. In addition, Ukraine's accession to IRENA will allow:

- to receive IRENA's assistance in improving the legislative framework, attracting investment and capacity building of alternative energy;
- to provide additional guarantees to potential foreign investors in investing in “green projects” in Ukraine;
- to work closely with developed countries in the development of alternative energy sources;
- to access IRENA databases on the latest technologies and developments, world best practices and effective financing mechanisms for “clean” energy projects.

Recently, the use of alternative energy sources has become quite popular, but their share in the overall structure of global energy consumption is small. The leaders in the development of alternative energy sources are EU countries, where a share of alternative energy in total energy consumption is 14% (Fig. 3).

As it is shown in Fig. 3, the EU countries account for 42% of world renewable energy consumption. In the last decade, the share of alternative energy sources in the EU's energy balance increased more than 5 times: from 1.8% in 2008 to 6.9% at the end of 2018. Some countries' progress in alternative energy development is already noticeable: the share of alternative energy sources in energy consumption has increased in Spain from 2.5% to 12.6%, in Germany - from 1.9% to 9.1%, in Italy – from 1.4 % to 8.2%, in the UK – from 0.7% to 5.4% in, France – from 0.4% to 2.4%.

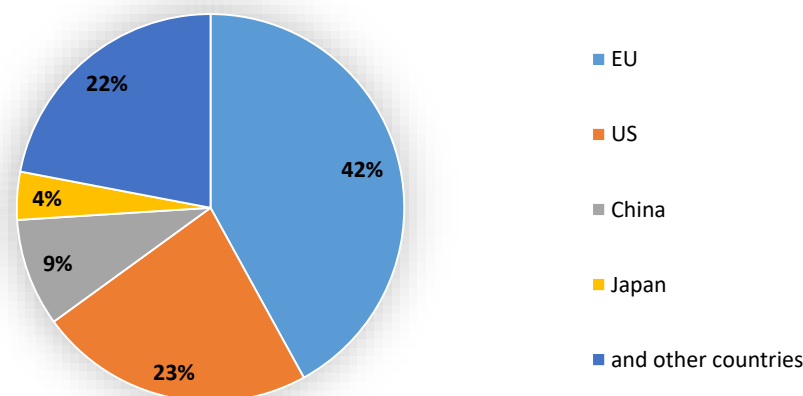


Fig. 3. Distribution of world alternative energy consumption by countries, 2018.
Source: calculated by author [10]

The share of the United States in the global consumption of alternative energy is 23%, China – 9%, Japan – 4%. At the same time, most countries continue to use traditional fuels and energy, despite the fact that the UN strategic direction for 2030 is to double the share of renewable energy in the global energy balance.

The most important indicators, that characterize the development of alternative energy sources, are the dynamics of renewable energy production in the world and in individual countries, the structure of renewable energy production by sources of generation, investments in this industry and their profitability.

The installed capacity of alternative energy in the world as of 2018 reaches 2 011 GW (for comparison, in 2008 it was less than 1 thousand – 992 GW). 55% or

1,122 GW of this value accounts for hydropower (Fig. 4.).

Wind and solar power account for most of the remaining capacity – 467 and 296 GW respectively, bioenergy – 110 GW. Other sources include 13 GW of geothermal power and 500 megawatts of marine (wave, tidal) power.

In the structure of alternative energy sources, except for hydropower, wind energy is the most important, accounting for 23% of total ADE capacity. It is used in many countries around the world, among which China is a leader (91 GW),

USA (61 GW), Germany (34 GW), Spain (23 GW), Italy (8.6 GW) and India (20 GW) [12].

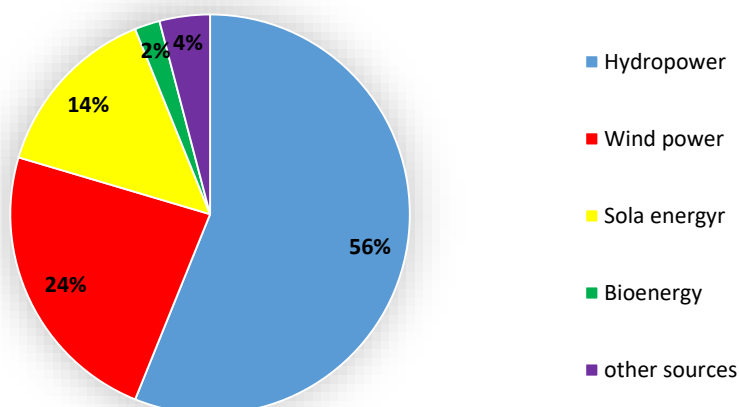


Fig. 4. Distribution of world consumption of alternative energy sources by types 2018.
Source: calculated by author [11]

The second largest source of alternative energy is solar energy, which converts solar energy into electricity by photoelectric or thermodynamic methods. The first method is more common (14% of total alternative energy sources at the end of 2018), especially in the US and some European countries, where solar power plants are large enough. The leaders in this resource are the same countries – China (19.9 GW), USA (12.1 GW), Germany (36 GW), Spain (5.6 GW), Italy (17.6 GW) and India (2.2 GW).

Biomass is the third largest alternative source (2% of total alternative energy sources, or 16% without hydropower), but its rapid development is prevented by limited agricultural land. The fourth place is occupied by geothermal energy, but its share is insignificant – only 2% of alternative energy sources without hydropower.

Experts predict that in the future, alternative energy will be dominated by wind power, which will increase to 75%, as other types of alternative energy sources will focus on heat production. In developed countries, alternative energy will reach 21% of electricity production by 2030 and 31% by 2050 (in the European Union – up to 38% and 50% respectively). In developing countries, its

share will be no more than 19% by 2050 [12].

As the end of 2018, the total installed capacity of alternative energy sources

(together with large hydrogeneration) reached 1,712 thousand GW or 27.7% of the global electric capacity, which was the result of increasing the production of hydropower, bioenergy, geothermal, solar photoelectric, concentrated solar and wind energy. In this case, the total capacity of all AES generating units (excluding large hydroelectric power plants) was 656 GW. This expansion of the use of alternative energy sources allowed to prevent a total of 1.2 gigatons of carbon dioxide from being emitted into the atmosphere [13].

Analyzing the dynamics of increasing the capacity of AES, we can predict a significant increase in the share of alternative energy sources in the global energy balance in the coming decades.

Since the development of alternative energy sources is impossible without the development of new technologies, it is possible to speak about the positive impact of the alternative energy strategy on the development of national science and technology, as well as production, which has a positive impact on the international prestige of the countries in the field of renewable energy.

In 2018, according to the annual UNEP investment research[14] global investments in alternative energy technologies have reached \$ 413 billion, that is, almost four times in the last ten years (Fig. 5).

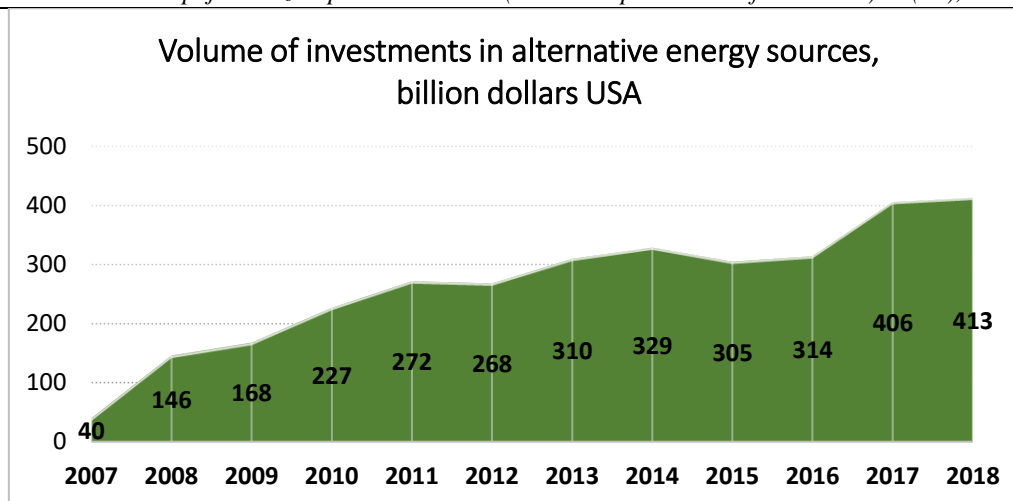


Fig. 5. Dynamics of investments in the development of alternative energy sources, 2007 - 2018, billion dollars.
Source: compiled by the author [14]

When analyzing global investments in alternative energy sources, it was found that, based on the results of 2014, a record for the whole history of investments in renewable energy was set - \$ 328.9 billion dollar, of which the maximum amount \$ 161 billion US dollars has been invested in solar power. It is worth noting, that investments in traditional hydrocarbon-based energy sources amounted only \$ 130 billion in the same year. According to the results of 2015 – 2016, the index of investment activity decreased slightly. Significant successes in environmental protection, minimizing production costs and innovative improvements in the efficient use of alternative energy sources have attracted new private investors in 2017 and 2018, adding them to state and public investments, which have had a positive impact on dynamics.

Conclusions. Based on the above data, we can conclude, that alternative energy is dynamically developing not only in a number of developed countries, but also in developing countries, such as China, that have realized the benefits of using alternative energy sources and are actively developing this energy sector. It is quite clear, that the global economy is moving towards a significant diversification of fuel supply, and much will depend on both technological innovations and trade and political decisions of energy market participants.

The introduction of technological innovations has led to the production of alternative energy sources with lower consumption of resources and improved products from them. With sufficient wind and solar potential and not always predictable oil prices, and expensive oil transportation infrastructure, alternative energy sources are beginning to compete successfully with traditional energy.

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