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INNOVATION AND INVESTMENT ASPECT ENERGY TRANSITION TO RENEWABLE ENERGY SOURCES

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ABSTRACT

The article comprehensively considers the economic aspects of the process of transition of the global economy to the use of renewable energy sources. An assessment was made of the potential investment and physical needs of energy based on renewable sources, and a study was made of the potential of the global economy to meet these needs. An analysis was made of the previously implemented actions of the governments of the countries of the world and business in the direction of the formation of an energy sector based on the use of renewable energy sources. Obstacles to the transition of the global economy to renewable energy sources of an economic and resource nature have been identified. The analysis of the experience of the countries of the world in overcoming the relevant obstacles and the formation of conditions by states to reduce the barriers for the entry of a global investor into the energy sector based on renewable resources was carried out. The most significant results from the point of view of the formation of energy based on renewable sources were studied and an assessment was made of their use for the formation of energy based on renewable sources in other countries of the world. Considerable attention is paid to the experience of the EU as an interstate integration group, the most integrated in the process of formation of energy based on renewable sources. Based on the results of the analysis of innovative and investment aspects of the energy transition to renewable energy sources, energy development trends until 2050 were formulated and a system of recommendations was developed for the implementation of the energy transition in the countries of the world.

KEYWORDS

Energy;
Renewable energy sources;
Innovations;
Investments;
State regulation;
Modernization.

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Introduction

The current stage of development of the global economy is characterized by the following features:

– a decrease in the level of provision with resources of the world economy in the context of an increase in the number of consumers;

– Growth in demand for energy outpacing the growth of the global economy due to increased energy consumption of computer equipment and automation of industrial production;

– increasing the role of compliance with environmental standards in the organization of production as a primary factor that determines the quality of life of the population in a given territory or country;

– increasing the importance of compliance by sellers with the conditions of environmentally friendly production as a

primary factor determining the demand for its products by the consumer;

– increasing opportunities for improving energy production technologies due to the rapid development of the 21st century society in the framework of scientific and technological progress and reforming production patterns.

The implementation of the energy transition based on the introduction and expansion of the practice of using innovative renewable energy resources is a highly discussed event in the scientific economic literature.

Supporters of the implementation of the energy transition through the use of renewable energy sources present it as a socially significant step that society should take in favor of new generations and improving the quality of life of the modern population of the earth.

At the same time, the practice of implementing an energy transition based on the use of renewable sources is currently heterogeneous by geographical criterion. The center for the development of energy based on the use of renewable

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sources is the European Union, while in other countries, including developed ones, this practice is not so widespread.

The purpose of this scientific article is to develop, based on the analysis of the energy transition to renewable energy sources, forecasts of qualitative and quantitative trends and trajectories for the implementation of the energy transition, as well as the possible timing and geographical coverage of such a transition. Taking into account the generated forecasts, the article presents a system of proposals regarding the formation of the energy transition within the framework of the macrosystem with the color of the already existing experience of the countries – the leaders of the energy transition, the state and forecasts of its innovation and investment component.

Assessment of the innovation and investment potential of the energy transition to renewable sources

The current quantitative projections for an energy transition based on renewables are based on [1]:

- plans for state innovation and investment support for the energy transition by states, taking into account applications submitted by potential participants in the energy transition for the development of relevant grants;
- statistics on the implementation of the energy transition of the global economy to renewable sources in 2000-2021;
- innovation and investment plans of organizations involved in the implementation of the energy transition;
- conjuncture of the global energy market and the market of innovative energy solutions;
- other factors that determine the innovative and investment potential of the energy transition to renewable energy sources, in particular, the replacement by a number of European countries of traditional suppliers of hydrocarbon energy raw materials.

Figure 1 shows the dynamics of energy generation by energy organizations based on renewable sources in 2009-2021 and forecasts of changes in these indicators until 2026.

In the form of columns in figure 1, the estimated and forecasted values of the change in energy generation from all types of renewable sources are presented, in the form of rhombuses – the gross value of energy generation due to the total use of renewable sources.

As forecasts of the dynamics of energy generation from renewable sources, the following are presented:

- a realistic forecast based on extrapolation of current quantitative trends in increasing energy generation from all types of renewable sources (main case) [3];
- an optimistic forecast formed on the condition that all innovative and investment programs of the energy transition until 2026 are implemented in full (accelerated case);
- a hyper-optimistic forecast based on an assessment of the increase in energy generation from renewable sources exclusively from existing capacities with a guaranteed pay-back and sources that will be created at the expense of the budget funds of the states participating in the energy transition provided for allocation until 2025 with the maximum involvement outside investment (IEA net zero by 2050) [4].

In general, the position of renewable energy sources in the energy market is characterized by their relatively small share in the global energy sector. Along with this, the period 2010- 2020. characterized by a more than threefold increase in

the share of renewable energy from 3; in 2010 to 12; in 2020 with a systematic decrease in the share of hydrocarbons, as shown in figure 2.

The contribution of renewable energy sources to the overall energy balance of the countries of the world is heterogeneous in its value.

The most important in the energy balance among renewable energy sources is wind energy, whose share in the total energy balance is relatively stable, and solar energy, whose share in the period 2010-2020 is steadily growing thanks to state innovation and investment support in the most developed economies of the world [6].

All other renewable energy sources account for less than 10% of the total energy generation from renewable sources, including from those identified in the EU plans as promising for the period 2026-2050, namely biofuels and geothermal energy. The dynamics and structure of energy generation for the global economy through the use of various categories of renewable energy is shown in figure 3.

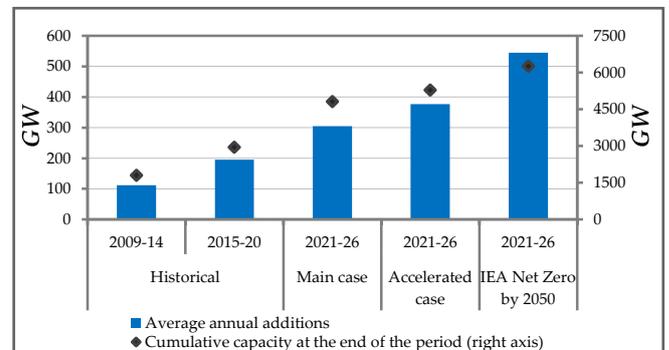


Fig. 1. Dynamics of energy generation by energy organizations based on renewable sources in 2009-2021 and forecasts of changes in these indicators until 2026, in GW [2]

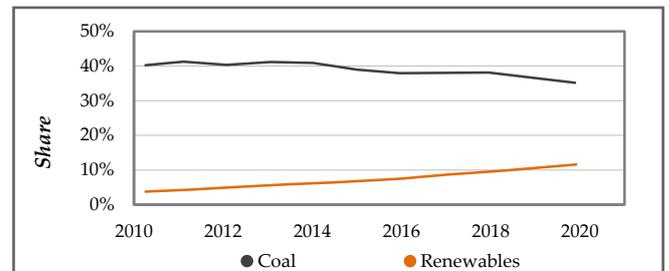


Fig. 2. Dynamics of the ratio of the share of renewable energy sources and hydrocarbons in global energy, 2010-2020, as a percentage of gross energy generation [5]

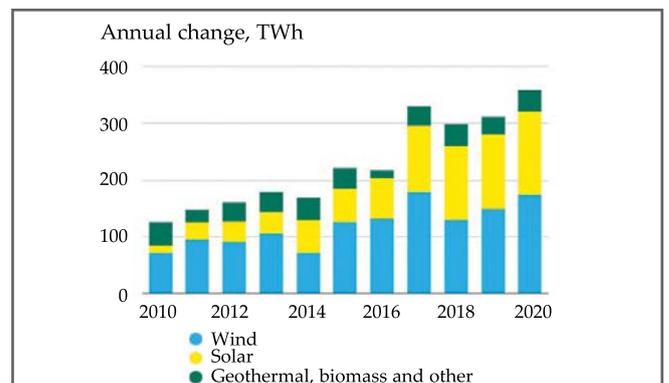


Fig. 3. Dynamics and structure of energy production for global economy through the use of various categories of renewable energy [7]

In 2002-2026 the current trends are expected to continue with a gradual increase in the share of currently underrepresented types of renewable energy.

Although the main trends in the development of energy based on renewable sources are currently set by the tools of state regulation of the energy sector in developed countries, more accurate forecasts will depend on market conditions [8].

Its most important part, which will have the most significant impact in the future, will be the state of investment sites that ensure the attraction of financing for the development of renewable energy sources.

Assessment of investment and innovation prospects for the energy transition to renewable energy sources

Investment and innovation prospects for the development of energy from renewable sources will depend on the following factors:

- the state of traditional resource markets; higher prices for traditional hydrocarbon carriers, widely used in less developed countries, will create significant reasons for producers to abandon traditional hydrocarbon sources, while lower prices for them will impede the energy transition on a planetary scale;
- the volume of state support for the energy transition in the countries that are leaders in clean energy; in turn, the amount of such support will depend on the popularity of green ideas among voters in these countries in the medium term and the macroeconomic condition of the leading economies in the energy transition [9];
- the effectiveness of already implemented environmental projects based on the use of renewable sources; in this sense, pilot projects launched at the European site are indicators not only of the effectiveness of individual areas of the energy transition, but of its entire concept as a whole;
- the state of the scientific, technical and resource potential of the energy sector based on renewable resources, their availability and the ability of businesses to absorb them on acceptable terms.

The European Plan for the Reduction of Hydrocarbon

Emissions into the Atmosphere, the indicators of which are presented in figure 4, will serve as a framework trigger to ensure the development of energy from renewable resources until 2050 [10].

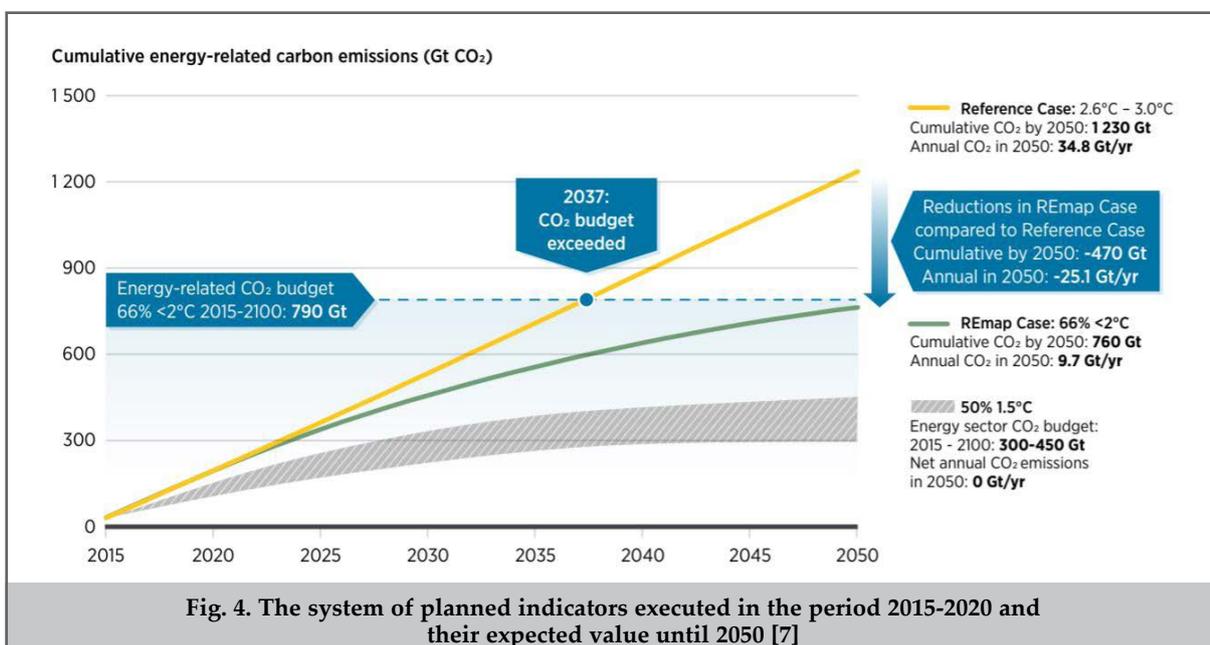
Plans to replace hydrocarbon energy sources with renewable sources will determine the intensity of state support. In the event that the investment process in renewable technologies lags behind the planned indicators, at the junctions of the stages of energy transformation, one should expect an intensification of state support.

On the contrary, in the case of an influx of investments in the sphere of creation and implementation of technologies for the use of renewable resources in the energy sector, it is possible at the junctions to reduce the intensity of state support and transfer the system of investment relations to the plane of commercial indicators.

At present, there is a lag in the indicators of the introduction of renewable technologies from the planned indicators, which is accompanied by an already sharpening of the system of state regulation. For example, at the meeting of the Commission and Energy in September 2021. In Brussels, it was proposed to already cut off the tax burden both on national consumers of hydrocarbon energy resources and on foreign exporting companies.

At the same time, taking into account the state of the European energy market in late 2021 - early 2022. it can be stated that it is impossible to ensure the development of energy from renewable resources mainly by restrictive measures. The mechanical replacement of hydrocarbon energy with energy based on renewable resources will mean that organizations - innovators, engaged in the creation of technologies for introducing renewable resources into the energy supply process, will not be motivated to increase the efficiency of their activities [11]. In other words, the experiment on planting an energy sector focused on renewable resources will inevitably degenerate into an inefficient system of state subsidies for a limited number of imitators, which is clearly unacceptable.

The main obstacles to the implementation of the energy transition for the economies of the world most involved in the



transformation process in 2022-2030. will become:

- lack of opportunities for a systematic transfer of the national economy of at least one European country, with the exception of small European countries, to the use of renewable sources; this will create and is already creating a situation where there will be two energy systems competing with each other and mutually reducing the pace of their development;
- difficulties associated with confrontation between the energy alliance of countries and concerns that are suppliers of traditional hydrocarbon fuels, primarily OPEC;
- general macroeconomic instability inherent in economies oriented towards the use of renewable energy sources; It is characteristic that the period of 2021 - early 2022, during which the EU has a pilot project to diversify the national energy sector through the use of alternative hydrocarbon energy sources, experienced an energy crisis in the EU associated with an increase in prices for the most significant environmental traditional energy resource for countries – gas.

As with any other innovation and investment process, the main barrier to an energy transition based on renewable energy sources remains the lack of demand. As noted earlier, the effectiveness of the innovation and investment process cannot be achieved through its exclusive administration and financial support from the state.

Let us determine the potential of the energy market based on renewable sources. This assessment is complicated by the fact that in the absence of ready-made offers, business and end users are not able to formulate a final answer, since this requires a comprehensive assessment of such parameters of an innovative product as:

- prices for the entire range of energy products during a certain period of time;
- the social and environmental benefit felt by society, which may arise after the introduction of renewable energy sources; in this sense, the market for renewable energy technologies and their introduction into production can be considered in accordance with the public sector market model;
- the quality of the proposed product.

At the same time, qualitative assessments of potential consumers of energy based on renewable sources are important for assessing the investment potential of this market, since they have a direct impact on the behavior of state structures that make decisions on the allocation of funds, and corporations that make decisions on introduction of innovative energy technologies in their production, which is associated

with certain costs on their part.

Figure 5 presents an assessment of the willingness of young consumers to pay extra for the use of renewable energy sources if the energy transition is not subsidized by the state for the specified amount. The survey was conducted in the UK among students – potential participants in the labor market of industries focused on the use of renewable energy sources.

Thus, about 80% of environmentally conscious European consumers are not ready to pay more than € per month for the transition to renewable energy sources before 2050. It should be noted that this amount of payments includes both direct payments, formed as an increase in the bill for electricity, and indirect payments. The latter, in the conditions of the European energy system, will most likely look like:

- an additional tax levied on the use of one or another type of energy source in order to stimulate the energy transition to renewable energy sources and equalize the chances of being on the market between suppliers of traditional energy products and renewable energy sources;
- increase in the price of products created in the conditions of voluntary or economic incentives for the manufacturer to abandon traditional energy sources and switch to renewable sources.

An effective incentive for the development of energy based on renewable resources is the mouth of the global market demand for energy. As shown in figure 6, the trend towards increasing energy use has not been able to reverse even the self-isolation caused by the spread of a new coronavirus infection in 2021-2022.

Thus, in the period 2022-2030. it is possible to ensure the implementation of renewable energy sources through state support instruments in countries focused on the energy transition without prejudice to traditional energy supplies, the disruption of which carries the risk of destabilizing the global energy market for national economies [11].

Social objectives are still the main investment trigger for the development of the global energy market. Along with the greening of energy production, which is the main goal of the energy transition, social goals should be indicated.

From the point of view of purely economic approaches, renewable energy sources have stronger environmental competitors, such as:

- two-component nuclear energy, providing more efficient energy production both in terms of the cost of creating 1 kWh, and in terms of ensuring the availability of energy for large production and industrial centers [10];

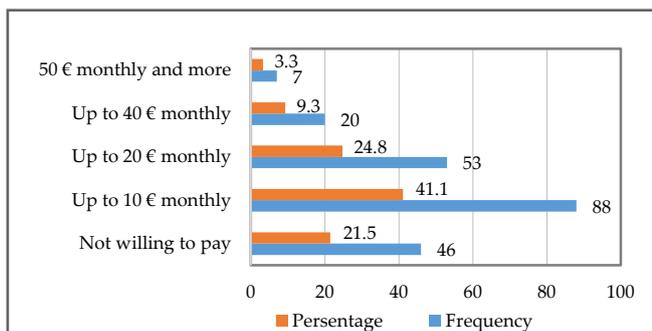


Fig. 5. Estimates of the willingness of young consumers to pay extra for the use of renewable energy sources [12]

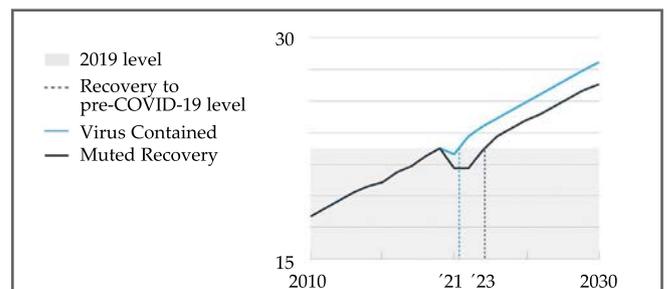
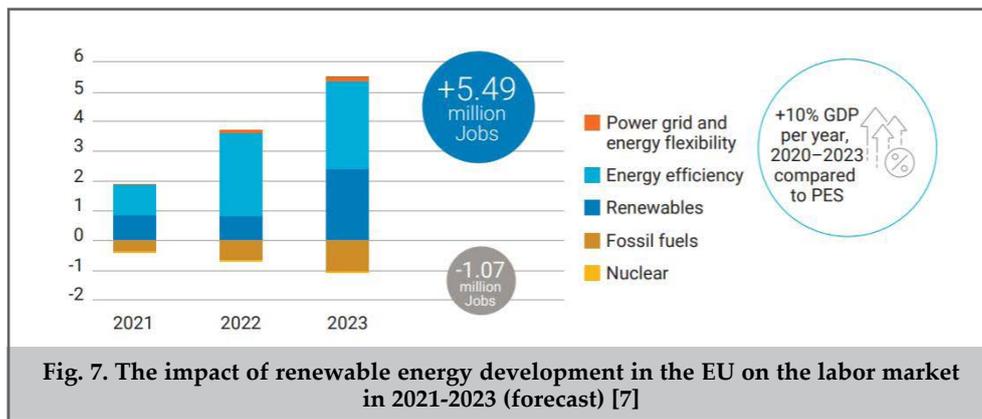


Fig. 6. Dynamics of the needs of the global economy in energy resources and a forecast of changes in these needs until 2030, taking into account the impact on the economy of self-isolation caused by the spread novel corona virus infection, TWT [12]



– the gas industry, which is significantly more environmentally friendly in terms of the final product being formed, on the one hand, and does not require significant costs from the state and society, as well as the adaptation period preceding the energy transition, on the other.

At the same time, the development of an energy sector focused on the consumption of renewable resources will contribute to the solution of a number of social problems, such as ensuring an increase in demand for labor in the energy industry, while nuclear energy, on the contrary, will create problems in terms of creating jobs for which is indicated by the data presented in figure 7.

In general, the market for investment in energy based on renewable sources is not currently formed as a single institutional entity on a global scale. On the contrary, this market represents disparate fragments, united by technological solutions, but differing significantly in economic parameters.

The assessments of each geographical «core» of the innovation and investment market of technological solutions in the energy sector focused on renewable sources are given.

European Union. The market for innovative and investment solutions on this site is provided mainly by demand from the state and restrictions also imposed by the state. The main characteristics of this investment and innovation platform for the energy transition are:

- significant state subsidies provided to a limited number of large companies from the EU, which are traditional grant recipients and have no affiliated interests with other energy market participants [13];

- high environmental fines and direct prohibitions that prevent the participants of economic relations in the EU from maintaining traditional energy partners – suppliers of hydrocarbons.

USA. This market is characterized by a more liberal attitude towards buyers of traditional energy sources, including hydrocarbons. This circumstance is determined by the strong hydrocarbon lobby in the United States, resulting from the large amount of hydrocarbon reserves in the country and the involvement of the United States in their trade. At the same time, in the country, as well as in the EU, considerable attention is paid to energy from renewable resources, however, other factors act as triggers for the energy transition, namely:

- attractiveness for large businesses of renewable sources in the long term;

- significant attention to renewable sources on the part of the military-industrial complex and innovative companies

focused on the development of new territories, including alien ones in the ultra-long term. For example, American billionaire innovator Elon Musk pays considerable attention to the innovative and investment potential of renewable energy sources.

China. In this country, the attractiveness of renewable sources stems from the ongoing policy to ensure the energy security of the national economy.

Thus, the triggers for the energy transition to the use of renewable resources in 2010-2020 in China have become:

- import substitution programs in the energy sector;
- comprehensive urban planning support programs;
- the general innovation program of China.

Assessment of the innovation and investment potential for the development of the energy sector based on renewable resources in Russia

Russia's key competitive advantage as a platform for attracting investments in the field of renewable energy resources is its natural potential. The following resources are the most investment-attractive:

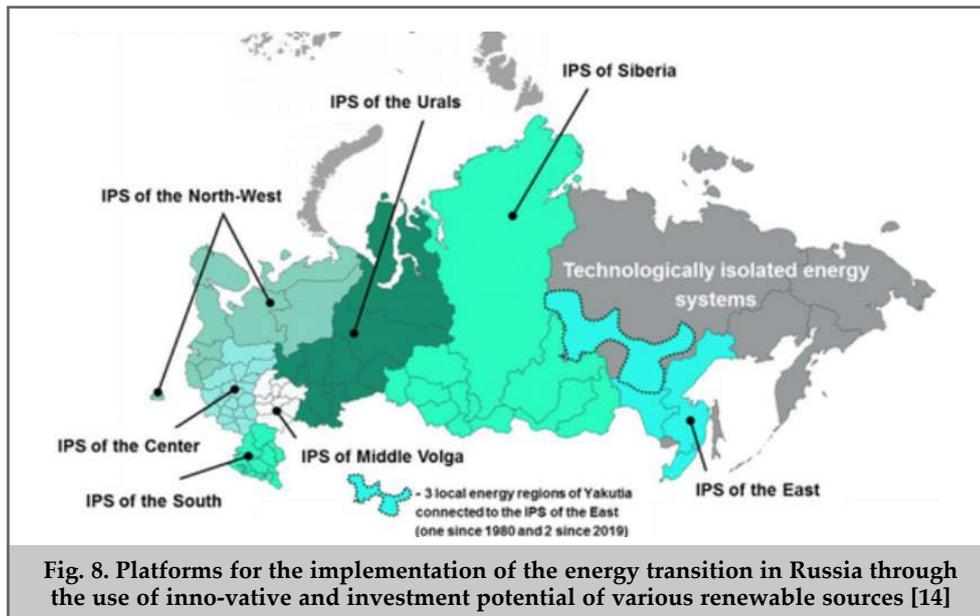
- the potential of large rivers in Russia, which has been actively used by the domestic electric power industry since the times of the USSR; at the same time, most of the domestic HPPs require modernization both in terms of increasing their environmental friendliness and in terms of scaling up their energy potential, including export;

- significant areas not occupied by the area of human activity and vulnerable ecosystems, suitable for the development of solar energy;

- a significant amount of land unsuitable for agriculture without prior expensive processing, but which can be used for the production of biofuels.

In more detail, the innovation and investment potential of Russia as a platform for ensuring the energy transition to renewable sources is shown in figure 8.

Another strength of the domestic economy in terms of the implementation of the energy transition is a significant scientific and research potential. Russia is a technologically independent participant in the hydroelectric power market, actively supplies this product to neighboring countries, which creates the potential for innovative and investment growth through the Chinese market. Both technological and resource partnerships are areas of international cooperation that can replace a part of the country's hydrocarbon revenues in the event that the global economy turns away from hydrocarbons by 2050 [15-20].



Conclusion

Thus, it has been proven that the key trigger for the energy transition to renewable sources is the system of public and private support for greening processes. In the context of the implementation of expanded support for the quality of life of the population, the state creates growth points for investment in renewable energy sources. At the same time, the mechanism for introducing innovative and investment solutions in the field of using renewable energy sources in real production and their coexistence with traditional hydrocarbon sources has not been fully developed. The emerging innovation-investment collisions of superimposing energy transition models on the old hydrocarbon model of the energy market economy are the causes of many crisis phenomena, including the rise in energy prices in Europe. Uncertainty in the energy market creates unique opportunities for Russia to use its resource and technological potential to diversify the traditional vector of hydrocarbon exports by exporting energy generated using renewable resources.

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Иновационно-инвестиционный аспект энергетического перехода к возобновляемым источникам энергии

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Реферат

В статье комплексно рассмотрены экономические аспекты процесса перехода глобальной экономики на использование возобновляемых источников энергии. Проведена оценка потенциальных инвестиционных и физических потребностей энергетики, основанной на возобновляемых источниках, осуществлено исследование потенциала глобальной экономики по удовлетворению этих потребностей. Проведен анализ ранее осуществленных действий правительств стран мира и бизнеса в направлении формирования энергетики, основанной на использовании возобновляемых источников энергии. Выявлены препятствия для перехода глобальной экономики на возобновляемые источники энергии экономического и ресурсного характера. Проведен анализ опыта стран мира по преодолению соответствующих препятствий и формированию государствами условий по снижению барьеров прихода глобального инвестора в сферу энергетики, основанной на возобновляемых ресурсах. Исследованы наиболее значимые с точки зрения формирования энергетики, основанной на возобновляемых источниках, результаты и проведена оценка их использования для формирования энергетики, основанной на возобновляемых источниках в иных странах мира. Значительное внимание уделено опыту ЕС как межгосударственной интеграционной группировке, в наибольшей степени интегрированной в процесс формирования энергетики, основанной на возобновляемых источниках. По результатам анализа инновационно-инвестиционных аспектов энергетического перехода к возобновляемым источникам энергии сформулированы тренды развития энергетики до 2050 года и разработана система рекомендаций для осуществления энергетического перехода в странах мира.

Ключевые слова: энергетика; возобновляемые источники энергии; инновации; инвестиции; государственное регулирование; модернизация.

Bərpa olunan enerjİYə energetik keçidin innovasiya – investisiya aspekti

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Xülasə

Məqalədə global iqtisadiyyatın bərpa olunan enerji mənbələrindən istifadəsinə keçid prosesinin iqtisadi aspektləri kompleks şəkildə nəzərdən keçirilmişdir. Bərpa olunan mənbələrə əsaslanan potensial investisiya və energetikanın fiziki tələbatın qiymətləndirilməsi aparılmış və bu tələbatları ödəyən global iqtisadiyyatın potensialının tədqiqi həyata keçirilmişdir. Bərpa olunan enerji mənbələrinin istifadəsinə əsaslanan və energetikanın formalaşması istiqamətində dünya ölkələrinin hökumətləri və biznesi tərəfindən əvvəllər aparılmış fəaliyyətin analizi verilmişdir. İqtisadi və resurs xarakterli bərpa olunan enerji mənbələrinə global iqtisadiyyata keçid zamanı maneələr üzə çıxarılmışdır. Dünya ölkələrinin müvafiq maneələri aradan qaldırma təcrübəsi və bərpa olunan resurslara əsaslanan energetika sahəsində dövlətlər tərəfindən global investora keçid zamanı səhhlərin zəifləməsi şərtlərinin formalaşması təhlil edilmişdir. Bərpa olunan mənbələr əsasında energetikanın formalaşması nöqteyi nəzəridən əhəmiyyət kəsb edən nəticələr tədqiq olunmuş və dünyanın digər ölkələrində bu məsələnin istifadəsinin qiymətləndirilməsi aparılmışdır. Bərpa olunan mənbələr əsasında energetikanın formalaşması prosesində daha çox dərəcədə inteqrasiya olunan AI dövlətlərarası inteqrasiya qruplarının təcrübəsinə xüsusi diqqət yetirilmişdir. Bərpa olunan enerji mənbələrindən energetik keçidin innovasiya- investisiya aspektlərinin analizinin nəticələrinə görə energetikanın 2050-ci ilə qədər trendləri ifadə olunmuş və dünyanın müxtəlif ölkələrində energetik keçidin həyata keçirilməsi üçün təkliflər sistemi işlənilib hazırlanmışdır.

Açar sözlər: energetika; bərpa olunan enerji mənbələri; innovasiyalar; investisiyalar; dövlət tənzimlənməsi; modernləşmə.