Merkulova, Elena Yu.; Margarita, Sysoeva S.; Svetlana, Samoilova S.

Article

Problems of ensuring energy security in the focus of sustainable development : from traditional resources to alternative ones

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2022, 12(2), 1-10.

Problems of Ensuring Energy Security in the Focus of Sustainable Development: From Traditional Resources to Alternative Ones

Elena Yu. Merkulova, Sysoeva S. Margarita*, Samoilova S. Svetlana

Derzhavin Tambov State University, 392000, 33, Internatsionalnaya Str., Tambov, Russia. *Email: ms_sysoeva@mail.ru

Received: 17 October 2021 **Accepted:** 15 January 2022 **DOI:** https://doi.org/10.32479/ijeep.12692

ABSTRACT

In the presented study, the development of energy-efficient technologies is studied using time series data for the years 1970–2020, which make it possible to ensure the sustainability of Russia's development. The threats to energy security in the economic, fuel supply, production, transit blocks and the block of reliability of functioning are identified, which give a signal about the need for measures to level them. Based on the synthesis of the theory of sustainability of economic systems, reliability theory, risk theory, system security theory, as well as analysis of modern factors of fuel and energy sector development, strategic guidelines for improving energy security and economically sustainable development of the fuel and energy sector are substantiated. The modern world is characterized by changes in the parameters and directions of the energy economy under the influence of scientific, technical, environmental, economic, organizational and other factors. The process of serious modernization is underway in the global energy sector. The transformation of the global energy sector is carried out within the framework of ensuring sustainable development through the introduction of new energy-saving technologies. Russia's energy security is based on a rich base of strategic resources and production potential created by the fuel and energy complex, which can ensure the gradual development of the country and its security. However, in recent decades, despite energy independence and independence, the issue of energy security has become more acute for various regions of Russia, which is associated with steadily growing energy needs. The study examines the dynamics of oil and gas production in Russia and the world. The factors of energy security of the Russian economy and the population with generated capacities, which are a barometer of the sustainability of economic development, are identified. The possibilities of transition from traditional energy sources first to REI, and then to inexhaustible natural sources, with the use of new digital technologies for their distribution and consumption in the economy are considered. The specific natural conditions of various regions of Russia are investigated for the possibility of developing alternative energy based on water, wind, solar energy, geothermal energy, wave energy, tides, and biomass energy. The economic, technological, social and environmental effects resulting from the use of energy-efficient technologies are substantiated.

Keywords: Energy Security, Energy Efficiency, Alternative Energy, Sustainable Development
JEL Classifications: Q01, Q42, Q53

1. INTRODUCTION

Energy security is one of the most important components that ensure the sustainable development of the economy of any country in the world. Comparing economic trends and cycles of energy development, one can see a high correlation between the existing technological structures and the energy resources used (Allcott and Greenstone, 2012). Since the second half of the XX century, problems of limited natural resources and environmental degradation have emerged all over the world, which creates obstacles to the progressive development of civilization. According to forecasts, the traditional energy industry based on hydrocarbon sources may significantly exhaust its resources during the XXI century. In this connection, scientists from all developed countries are developing new alternative ways and methods of obtaining energy in order to reduce dependence on hydrocarbon energy resources.

One of the promising directions in this area is the use of cheaper energy sources, the use of more efficient technological processes and equipment. At the present stage of development of science and technology, enterprises have the opportunity to choose between traditional and alternative energy sources. If the climatic and geographical conditions of the region ensure the availability of several energy supply options, then the choice of the most economical of them is based on a comprehensive solution of energy, economics and technology issues. In business structures, there is a constant and continuous increase in energy consumption. According to statistics, from 1980 to 2000, the increase in energy consumption was 300% every decade, then decreased to 150%. Currently, energy consumption in the world is more than 250 billion kWh per year. That is why an integrated, intelligent and comprehensive concept is required to protect modern power systems. Such a concept should cover the entire power system at all voltage levels and anticipate all possible risks. The main component of the protection of the power system is to ensure sustainability. A more sustainable energy infrastructure has a higher ability to withstand disruptive events, reduce their impact and accelerate recovery.

Since the reserves of traditional energy sources (oil, gas, coal, uranium, etc.) are not infinite and their cost is constantly increasing, energy savings are also becoming increasingly important. According to forecasts, oil and gas reserves will be exhausted this century, as well as uranium reserves for classical types of reactors. The use of hydrocarbon raw materials for energy production leads to the formation of carbon dioxide, which causes a "greenhouse effect." The product of the vital activity of nuclear power plants (NPP) is hazardous radioactive waste - irradiated nuclear fuel (SNF). The number of rivers and, accordingly, the possibilities for the construction of hydroelectric power plants are limited. Alternative energy sources can provide humanity without threatening its existence. Unlike traditional sources, their reserves are practically inexhaustible, have zero emissions, but are quite expensive to operate. These include: the energy of biomass, wind, sun, sea waves and currents, the heat of the earth.

The advantages of alternative energy sources in comparison with traditional ones are as follows:

- Ecological cleanliness;
- Operate without fuel consumption;
- Low noise or complete noiselessness of operation;
- Autonomy of work.

At the same time, alternative energy sources have the following disadvantages:

- Пере there may be interruptions in energy supply due to the variability of energy resources and, as a result, the need for energy storage;
- Higher unit cost per 1 kW of installed capacity.

Based on the results of the study of existing alternative energy sources: wind energy, geothermal energy, hydropower resources, biomass energy, solar energy, factors affecting the effectiveness of the introduction of alternative energy sources were identified (Table 1).

Table 1: Classification of factors affecting the efficiency of the introduction of alternative energy sources

Classification feature of the group	Factors
Climatic conditions	Wind speed (m/s), the class of openness of the terrain; insolation (W/m^2), the presence of natural and artificial watercourses, the presence of geothermal sources, etc.
Technical and economic	The price of equipment, the cost of transportation and installation of equipment, the service life of equipment, the fee for environmental pollution, the condition of power generating equipment, efficiency, electricity tariffs for traditional energy sources, etc.
Ecological	The impact on animals and birds from the rotating blades of a wind turbine, the impact on marine animals from electromagnetic fields, the amount of harmful emissions and greenhouse effect from traditional energy sources, etc.
Geographical	Distance from the centralized power supply system, distance from suppliers of organic fuel, minimum distance from the installation to settlements, etc.

Source: Compiled by the authors

This classification of factors can serve as a basis for identifying problems of assessing the economic efficiency of innovation and investment projects for the introduction of alternative energy sources.

The main condition for accelerating economic growth is the implementation of highly effective innovation and investment projects. In turn, the efficiency of investment activity and the pace of economic growth are largely determined by the perfection of the system of selection of innovative investment projects for implementation, its adaptation to the existing and changing conditions of the functioning of the economy. Decisions made on the basis of methodological tools for evaluating the effectiveness of innovation and investment projects affect not only the interests of enterprises, but also national interests, since the totality of frequent decisions ultimately forms the appearance and characteristics of the country's productive forces.

Currently, energy saving is the most popular and relevant topic all over the world. The problem of energy saving is associated with the efficient and rational use of fuel and energy resources, reducing energy consumption at industrial facilities.

The definition of target strategic priorities for improving energy security is necessary for the sustainable development of the fuel and energy complex, which provides uninterrupted supply of fuel and energy resources to consumers and is able to withstand external and internal threats in a timely manner (Table 2). The basic element is the financial, economic and organizational conditions for attracting investments in the fuel and energy sector, including the introduction of the method of economically justified return on invested capital.

Increasing energy security is the result of sustainable development of the fuel and energy complex despite the impact of internal and

Table 2: Fragment of threshold values of indicators of sustainability of fuel and energy sector development

Indicator	Levels of the state of stability of the fuel and energy complex		
	Normal	Pre-crisis	Crisis
Economic block			
Return on assets	x≥4.1	1.3<x < 4.1	x≤1.3
Profitability of products sold	x≥3.6	1.2<x < 3.6	x≤1.2
The coefficient of availability of own working capital	x>0.3	0.1≤x ≤ 0.3	x<0.1
Energy intensity of production, GRP (kg usl.topl/thousand rubles)	21–24	24<x < 30	x≥30
Fuel supply unit			
The share of the dominant type of fuel in the total amount consumed (%)	x≤50	60≤x < 50	x>60
The unit of production and consumption of fuel and energy complex			
Share of CHP plants in total installed capacity (%)	x<40	40≤x < 60	x>60
Share of alternative energy sources (%)	x>1	0<x ≤ 1	x=0
Share of advanced technologies (%)	x>50	10≤x ≤ 50	x<10
Transistor block			
The level of the reserve for intersystem communications (MW)	x≥2	1≤x < 2	x<1
Share of electricity imports (%)	x<65	75≤x < 65	x<75
Natural and climatic block			
Storm warning, m/s	V≤8	8<V < 16	V≥16
Abnormal temperature	Blocking anticyclone (cyclone)	−35°C≤t ≤−25°C +25°C≤t ≤+35°C	t>+35°C t<−35°C
The block of reliability of fuel and energy systems			
Number of accidents in the system	0	0<x ≤ 3	x>3
Number of incidents in the gas supply system	x<43	43≤x ≤ 93	x>93
Number of incidents in the power supply system	x<300	300≤x ≤ 500	x>500
Number of incidents in the heat supply system	x<139	139≤x ≤ 407	x>407
Equipment wear rate (%)	x<39.3	39.3≤x ≤ 64.64	x>64.64
Electricity losses (million kW.hour)	x<479 (x<12)	479≤x ≤ 527 (12≤x ≤ 14)	x>527 (x>14)
Heat energy losses (million Gcal.)	x<507 (x<9)	507≤x ≤ 593 (12≤x ≤ 11)	x>593 (x>11)
Environmental block			
The level of emissions of harmful substances from industry enterprises in comparison with the maximum permissible values	$Ci<Ci^{ПДК}$	$Ci=Ci^{ПДК}$	$Ci>Ci^{ПДК}$

Source: Compiled by the authors

external threats, in which timely and uninterrupted provision of fuel and energy consumers is carried out in the required volume and at reasonable prices. In modern economic conditions, the smooth functioning of economic markets and the efficient operation of the commodity-monetary mechanism of the state depend on the well-coordinated work of the fuel and energy complex. The energy sector can create constraints that hinder economic growth. Such restrictions include: resource, structural and environmental. Resource constraints reduce the volume of production and types of services to the population. Due to resource constraints, the possibility of connecting new production facilities and buildings to gas, heat and electricity systems is excluded. Structural constraints arise due to the extraction of price rents by energy companies, which causes an excessive flow of resources into the energy sector, which are transformed into an outflow or death of capital. Environmental regulations create restrictions on the development of fuel and energy complex capacities. To assess the degree of influence of the sustainable development of the fuel and energy complex on the parameters of economic growth, the following model has been identified:

$$Y = -500451.673+33,797x1+15643,\ 046x3-43124.546\ x5-1,221x6 \quad (1)$$

Where Y is GRP per capita;

x1 – Average salary; x2 - GRP energy intensity;

x3 – Electricity generation; x4 - electricity consumption;

x5 – Is the capacity of power plants; x6 is the volume of fuel and energy sector goods shipped.

For the constructed dependence model, the correlation index turned out to be equal to R = 0.87. The value of the coefficient of determination R2 = 0.76, which shows that 76% of the variation of the effective indicator is due to the influence of factors included in the model. At the same time, the calculation of partial elasticity coefficients showed that with a change in the level of electricity production by 1%, GRP per capita will change by 0.62%, and with a change in the capacity of power plants by 1%, GRP per capita will change by 0.41%. The typology of regions by the level of energy supply is presented in Table 3.

2. DATA SOURCES

The information and empirical base of the study was composed of data from national and international statistics on the production and consumption of energy resources, energy efficiency and energy conservation, and the development of alternative energy.

Table 3: Typology of regions according to the correspondence of socio-economic and energy indicators

Type	Region
Energy dependent energy	Yamalo-Nenets Okrug, Magadan, Sakhalin Regions, Republic of Sakha (Yakutia), Kamchatka Krai, Chukotka Autonomous Okrug
Deficient	Belgorod, Bryansk, Vladimir, Voronezh, Ivanovo, Kaluga, Kostroma, Lipetsk, Oryol, Ryazan, Tambov, Tula, Yaroslavl, Republics: Komi, Karelia, Arkhangelsk, Vologda, Kaliningrad, Murmansk, Novosibirsk, Omsk, Tomsk, Novgorod, Pskov, Astrakhan, Amur, Kirov, Nizhny Novgorod, Penza, Ulyanovsk, Kurgan regions. Republics: Kalmykia, Adygea, Dagestan, Ingushetia, Kabardino-Balkarian, Karachay-Cherkess, North Ossetia (Alania), Chechen, Mari El, Mordovia, Udmurt, Chuvash, Altai, Buryatia, Tyva. Krasnodar Krai, Altai Krai, Zabaikalsky Krai, Primorsky Krai, Khabarovsk Krai, Jewish Autonomous Region, St. Petersburg
Energy safe	Kursk, Moscow, Smolensk, Tver, Leningrad, Volgograd, Samara, Saratov, Sverdlovsk, Rostov, Orenburg, Kemerovo, Irkutsk, Chelyabinsk regions. Republics: Bashkortostan, Khakassia, Tatarstan. Perm Krai, Krasnoyarsk Krai, Stavropol Krai
Energy reliable	Moscow, Tyumen, Khanty-Mansiysk district

When assessing the state of the problems studied, the authors turned to the data of the Ministry of Energy, UN organizations, Eurostat, Rosstat, the World Data Atlas, forecast data on the development of energy in the world and Russia, prepared by the Energy Studies Institute of the Russian Academy of Sciences and the Energy Center of the Moscow School of Management SKOLKOVO, state report on energy conservation and energy efficiency in the Russian Federation, prepared by the Ministry of Economic Development, etc. In order to assess the degree of the knowledge problems and the level of their analytical work in the preparation of the article, the following were used: scientific papers of native and foreign scientists and economists, materials of international and national conferences, publications in periodical scientific journals on the energy development in the world and Russia, analytical reports and forecasts prepared scientific organizations and individual authoritative experts, as well as the authors' own elaborations (Vertakova et al., 2017; Vertakova and Plotnikov, 2017; Merkulova et al., 2019; Zlobina et al., 2019).

3. RESEARCH METHODOLOGY

The authors rely on the hypothesis that one of the factors ensuring the sustainability of Russia's development is the use of energy-efficient technologies and more active use of alternative energy. The dialectical method of cognition is used as a methodological basis for research at various spatial and temporal levels of dimension, which allows to identify the main characteristics of Russia's sustainable development through the use of energy-efficient technologies, to determine the factors and conditions of their transformation.

The authors solve the task of analyzing the current state of development of energy-efficient technologies by using the method of content analysis with the use of comparative elements in the context of types of energy-efficient technologies.

The application of a complex of general scientific approaches, abstract-logical, deductive, complex, systemic, allows us to identify the structural components of modern types of energy resources and assess their impact on the competitiveness and independence of countries from each other.

In the course of the research, methods of economic and statistical analysis (comparison, calculation of absolute, relative and average values, tabular, graphical display of information, mapping), expert assessments are applied.

The applied software products Microsoft Word, Excel and IBM SPSS Statistica are used in the study to build descriptive, graphical, analog and digital models, which in turn makes it possible to increase the reliability of calculations.

The use of economic and mathematical tools is a necessary condition for modeling the impact of energy-efficient technologies on the sustainable economic development of socio-economic systems and regions.

The theoretical basis for the analysis of tasks is the works of domestic and foreign scientists in the field of sustainable development and organization of lean production and labor productivity improvement. When considering the subject area of the study, normative legal acts and world standards and standards of the Russian Federation regulating the processes of ensuring sustainable development based on the use of modern energy technologies are applicable.

The conducted research made it possible for the first time to summarize some of the empirical data on the prospects for the development of unconventional energy sources in various regions of Russia.

4. RESULTS AND DISCUSSIONS

The problem of energy security first appeared in industrialized countries with an economic effect in the 70s of the last century, when two trends arose as a result of the transition period: a dramatic reduction in oil exports from this region to industrialized countries and economic growth in oil prices. In conditions of a substantial, and for some of these countries critical, dependence of their energy and especially oil supply on oil imports, this led to the largest energy crisis. Overcoming the crisis was made possible thanks to measures taken at the state and interstate levels, as well as at the level of corporations and business as a whole. Among these measures: coordination of energy policy, including through the International Energy Agency; active energy-saving policy; wide involvement in the energy balance of own energy resources which may be considered as alternative to imported oil, including nuclear energy, oil of Alaska and the North Sea, non-conventional energy resources, as well as state support for the coal industry in a number of countries; diversification of hydrocarbon imports at the expense of other exporters - Mexico, the USSR, Africa, Southeast Asia;

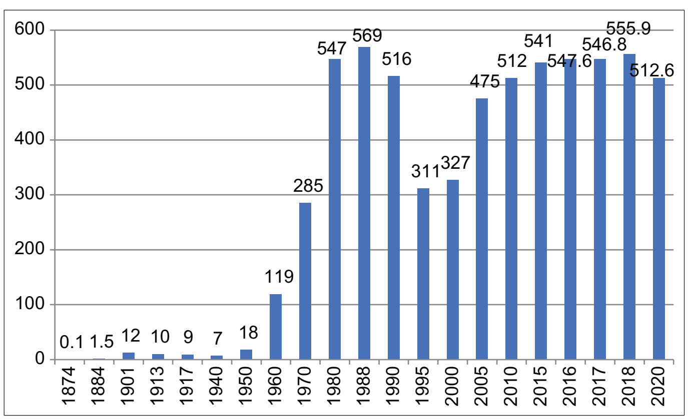
creation of strategic oil reserves, etc. (Apergis and Danuletiu, 2014; De La Cruz-Lovera et al., 2017; Menegaki and Gurluk, 2013).

One of the characteristics of resource availability is oil and gas production. Figure 1 presents data on the dynamics of oil production.

From the data in Figure 1 it can be seen that active oil production in Russia began in 1960, the maximum production was achieved in 1988–569 million tons. The decline in production was observed during the 90s. Since 2000, the extent of oil production has been increasing annually and in 2018 the extent of oil production amounted to 555.9 million tons. In 2020, there was a slight decrease to 512.6 million tons. Over the past 20 years, the increase in gas production and consumption in the world amounted to more than 70%, which is associated with its environmental friendliness, manufacturability and efficient use (Table 4).

The global natural gas market is one of the fastest growing energy markets. Over the past 20 years, the increase in gas production and consumption in the world settled to more than 70%. The increased use of gas in the economy is associated with its environmental friendliness, manufacturability and efficient use in industry and the household sector. In 2017, global gas demand increased by 1.7%, to 3.6 trillion m3. In 2018, there was a slight acceleration in the production and use of this energy source, which is associated with the expansion of shale gas production and a decrease in the cost of fossil hydrocarbons. In 2020, production decreased to 692 trillion m3.

Figure 1: Dynamics of oil production with gas condensate (million tons)



Source: Compiled by the authors according to the collections of the National Economy of the RSFSR, Rosstat, materials of SO UES JSC and other sources.

At the fastest pace, global demand for natural gas is growing from industry and the electric power industry. It is expected that in the next five years it will increase annually by an average of 1.6% and by 2022–2023 it can reach 4 trillion m3 per year. In 2017, Russian share in world natural gas production increased by 1.2 percentage points, to 19.2%. In 2017–2018, there was a sharp increase in gas production and export to European countries due to interruptions in the supply of energy generated from renewable sources.

Also, one of the factors of energy availability is the security of the Russian economy and population with generated capacities. From the data presented it can be seen that the crisis of the 90s affected the consumption of electricity and power. If in 1991 it was consumed 153.5 thousand MW, then in 1998 it was 124.3 thousand MW. Then, in subsequent years, there has been a significant increase in power and electricity consumption. The maximum power consumption is in 2012–157.4 thousand MW (Figure 2). Thus, the consumption of electricity and capacity is a barometer of the ustainability of economic development.

Looking at dynamic data, you can see the following trends. For the period from 1960 to 1980, the growth dynamics of generating capacities in Russia was age-related. Further, until 2000, the growth decreased as much as possible from 35 to 4 GW. Over the past 15 years, the dynamics has increased, and the number of generating capacities on average has reached 20 GW in five years.

An analysis of Table 5 shows that, on average, installed capacities in 2020 were used by 50.36%, while nuclear power statuions accounted for the maximum capacity utilization, which amounted to 11.98% of the installed capacity. The maximum specific weight of installed capacities is accounted for by thermal power plants at 67.66%, however, the utilization rate of their capacity is 46.51%. In the last two years, the specific gravity of installed capacities of wind and solar power plants has significantly increased, however, their utilization ratio amounted to 18.29% and 14.65%.

Key indicators of economic growth after the crisis of the 1970s significantly changed from 5% to 3% per year, which affected the

Table 4: Dynamics of natural and associated gas production in Russia and the world for 1970-2020

Year	World, billion m^3	Russia, billion m^3	World share,%
1970	1021	83	8,1
1980	1456	254	17,4
1990	2000	641	32,1
2000	2436	584	24,0
2010	3209	650	20,3
2015	3531	635	18,0
2016	3552	640	18,0
2017	3670	691	19,2
2018	3860	725	18,7
2020	4007	692	17,2

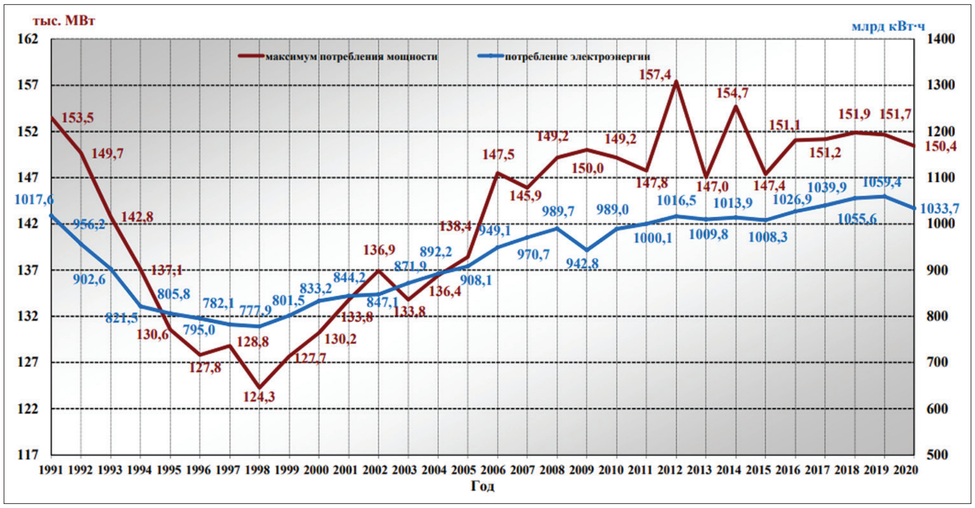
Source: Compiled by the authors according to the collections of the National Economy of the RSFSR, Rosstat, materials of SO UES JSC and other sources.

Table 5: Structure of installed and used capacity of power stations of UES in Russia in 2020

Power stations	Installed capacity, MW	Installed Capacity Structure, %	Power factor
UES of Russia, total	243243,2	100,000	50,36
Thermal Power Stations	164586,6	67,66	46,51
Hydroelectric power stations	48506,3	19,94	43,27
Wind power stations	183,9	0,08	18,29
Solar power stations	834,2	0,34	14,65
Nuclear power stations	29132,2	11,98	78,41

Source: Calculated by the authors based on data from the UES system operator https://www.so-ups.ru/?id=2045.

Figure 2: Dynamics of changes in electricity and capacity consumption in UES of Russia



Source: Report on the functioning of the UES of Russia in 2020 https://www.so-cdu.ru/fileadmin/files/company/reports/disclosure/2020/ups_rep2020.pdf

energy consumption growth rate of less than 2% from the previous 5% per year. In the world, the need arose to change the paradigm of energy development; in particular, the problem of using renewable energy sources (RES) was solved. Long-term forecasts of energy development indicate a transition from traditional energy sources, first to RSE, and then to inexhaustible natural sources, using new digital technologies for their distribution and consumption in the economy.

In 2021, the International Economic Forum presented a rating of 115 countries ranked using the Energy Transition Index, which assesses by many indicators the level of readiness of national energy for integration into the future sustainable, safe, affordable universal energy system. The creation of such a system is one of the main tasks of the World Energy Council. Russia has a modest 73rd place in the ranking with an index of 56, which is 7 positions better than the level of the previous year (Report on Promoting an Efficient Energy Transition of the World Economy, Contributing to an efficient Energy Transition, edition 2021, 2021).

The modern world is characterized by a change in the parameters and directions of the energy economy under the influence of factors such as scientific, technical, environmental, economic, and organizational. The global energy sector is undergoing a process of serious modernization (Porfiryev, B.N.,2012). The transformation of world energy is carried out in the framework of sustainable development through the introduction of new energy-saving technologies. In the electric power industry, distributed generation is developing on a large scale, active consumers appear in the owners form of small generation, energy storage systems, new business practices. There is a transition to intelligent control systems: a new architecture of electric networks with a flexible changing appearance, the cyberphysical infrastructure of streets and houses fulfilling the wishes of people, hydrogen energy, direct current electric networks, flexible transformation of residential and non-residential premises, autonomous transport. New opportunities for organizational and economic relations are opening up.

It is expected worldwide by 2050 that the share of renewable energy sources (RES) will reach 50%. The UK is a leader among industrialized countries in the use of alternative energy. In the country, windmills operate effectively on the coast. For the first time in the United States and Great Britain, the amount of energy produced from renewable sources exceeded the amount of energy produced in the traditional way based on hydrocarbons.

UN resolutions up to 2050 mandate minimizing the use of thermal power plants to avoid the greenhouse effect and climate disaster. To do this, it is necessary to invest in "green energy" until 2035 at 2.4 trillion dollars a year.

Germany was one of the first to demonstrate that in order to dominate the world market it is not necessary to have in excess of oil, gas, and other energy resources. It is quite effective to organize economic activity and rationally use energy resources (Pearce and Miller, 2006; Ringel and Knodt, 2018; Ringler et al., 2013).

The German economic development model aims to use the latest technology. For this, patents and licenses are acquired in other countries. And this provides a 10–20% increase in industrial production per year. Germany in recent years has been actively abandoning traditional energy and currently receives 70% of its energy from renewable energy sources.

The unique natural conditions of Russia make it possible to use the energy of water, wind, sun, geothermal energy, wave energy, tides, biomass energy. The possibility of implementing projects for the construction of generating energy sources based on renewable resources in the Russian Federation is unequal.

Russia has enormous potential for the development of alternative energy based on renewable sources (Table 6). Each Russian region in a certain amount has various renewable energy resources. Based on Table 4, we note the clear predominance of the solar energy potential over other renewable resources, as well as the fact that the technological and technical levels of useful energy extraction are quite small.

Thermonuclear reactions constantly occur in the depth of the sun, accompanied by the release of a huge amount of energy. On the surface of the sun, the intensity of energy radiation is about 70–80 thousand kW/m2, and the temperature reaches 6000°C. 180,000 billion kW of radiant energy, or 1.5 1018 kWh, reach the earth's surface. The earth's surface reaches 71017 kWh. Energy when moving to the ground is lost due to dispersion and reflection by aerosols and atmospheric gases. The intensity of solar radiation at the surface of the earth depends on the following factors: geographical latitude, inclination angle of the surface to the sun, cloud cover, altitude, dustiness, local climate, time of day, and season of the year (Table 7).

The energy of the sun falling on the surface of the earth has certain characteristics: intensity, power, level of insolation (Figure 3).

The energy from the sun has great entropy. If we take the middle zone of Russia, then in the summer (May-August) you can generate 5 kWh/day, in spring and autumn (March-April, September-October) 3–4 kWh/day, and in winter (November-February) 1 kWh/day. These figures correspond to ideal sunny weather, the panels are perpendicular to the rays of the sun or there is an automatic tracking system for the sun.

According to the Institute of Energy Strategy, the theoretical potential of solar energy in Russia is approximately equal to 2,300 billion tons of standard fuel (tons of reference fuel), and the economic potential is 12.5 million reference fuel tons. The following regions are considered the most promising from the point of view of using solar energy: Krasnodar Territory, Crimea, Kalmykia, Rostov Region, Volgograd Region, Stavropol Territory, Bashkortostan, Altai, Orenburg, Astrakhan and Amur Region.

Table 6: RES potential in Russia (mln tons of reference fuel)

Power type	Gross potential	Technical potential	Technical potential share, %
Solar power	2300000	2300	0,1
Wind power	26000	2000	7,69
Biomass power	10000	53	0,53
Low potential heat	525	115	21,90
Minor water resources	360	125	37,27
Geothermal energy	180	20	11,11
Total	2337065	4593	0,2

Source: Calculated by the authors based on data from the GIS RENEWABLE ENERGY SOURCES OF RUSSIA website. http://gisre.ru/maps

The technical potential of wind energy in Russia is estimated at ~ 6,000 billion kWh/year. The economic potential is approximately 31 billion kWh/year. Russia has significant wind energy resources, including in those regions where there is no centralized energy supply. The coast of the Arctic Ocean, the Black and Caspian Seas, the Gulf of Finland, Chukotka, Yakutia, Kamchatka and Sakhalin have high average annual wind speeds (Gis renewable energy sources of Russia,2020). These areas are economically most favorable for the construction of wind power stations. For 2018, the total capacity of existing wind farms in Russia is 134 megawatts. The Ulyanovsk wind farm (35 MW) has the greatest capacity for 2018, a large wind power complex operates in the Crimea.

Wind speed is a major factor in wind turbine performance (Figure 4). Experts distinguish the minimum wind speed which provides rotation of the blades with a nominal frequency and idle speed, and the nominal wind speed at which the wind turbine reaches maximum power. The technical potential of wind energy in Russia is estimated at over 50,000 billion kWh/year. The economic potential is approximately 260 billion kWh/year, that is, about 30 percent of electricity production by all power stations in Russia.

An innovative type of energy is bioenergy, which converts biomass into thermal and electric energy. The concept of biomass refers to materials of plant origin, animal waste and household waste. Bioenergy, using highly efficient biotechnologies and thermochemical reactions, allows producing usage-convenient types of fuel, such as solid fuels, biogas and liquid biofuels. Favorable conditions for the use of bioenergy are in the agricultural regions and territories of large forests. On the territory of Russia, there are 40 million hectares of abandoned land that can be used for growing energy crops (soybeans, rapeseed, corn, sunflower). It is economically feasible to obtain bioethanol and biodiesel out of these crops. Biogas is obtained by methane fermentation of biological waste under anaerobic conditions.

Zones with no centralized energy supply, which occupy more than half of the territory in the Russian Federation, usually have large land and forest area and peat reserves. Huge forest reserves in Siberia make it possible to obtain solid wood fuel (wood, wood chips, granules) and biogas as a result of planned logging, sanitary felling and harvesting of fallen trees, woodworking waste. The total energy potential of waste in the Russian Federation is shown in Figure 5.

Every year in Russia, 230 million tons of waste are generated in agriculture from them: 100 million tons in crop production, and 130 million tons in animal husbandry. Processing of agricultural waste in the amount of 100 million tons will give the economy

Table 7: Monthly and annual total solar radiation, kWh/m2. Optimal decline of solar panels

City	January	February	March	April	May	June	July	August	September	October	November	December
Moscow	20,6	53	108,4	127,6	166,3	163	167,7	145	104,6	60,7	34,8	22
Voronezh	30,7	60,1	117	129	169	166	176	151	120	81,8	50,3	37,1
Krasnodar	42,8	77,8	127	147	178	171	194	172	148	123	81,7	55,6
Makhachkala	48,2	77	128	168	200	190	208	196	161	132	93	77,2
Ryazan	21,2	55	109	130	168	165	169	147	106	62,3	35,2	23

Source: Compiled by the authors based on the GIS RENEWABLE ENERGY SOURCES OF RUSSIA website http://gisre.ru/maps

Figure 3: Map of solar activity in Russia (Gis renewable energy sources of Russia (2020), maps of renewable energy facilities in Russia

Source: Available from: http://gisre.ru/maps)

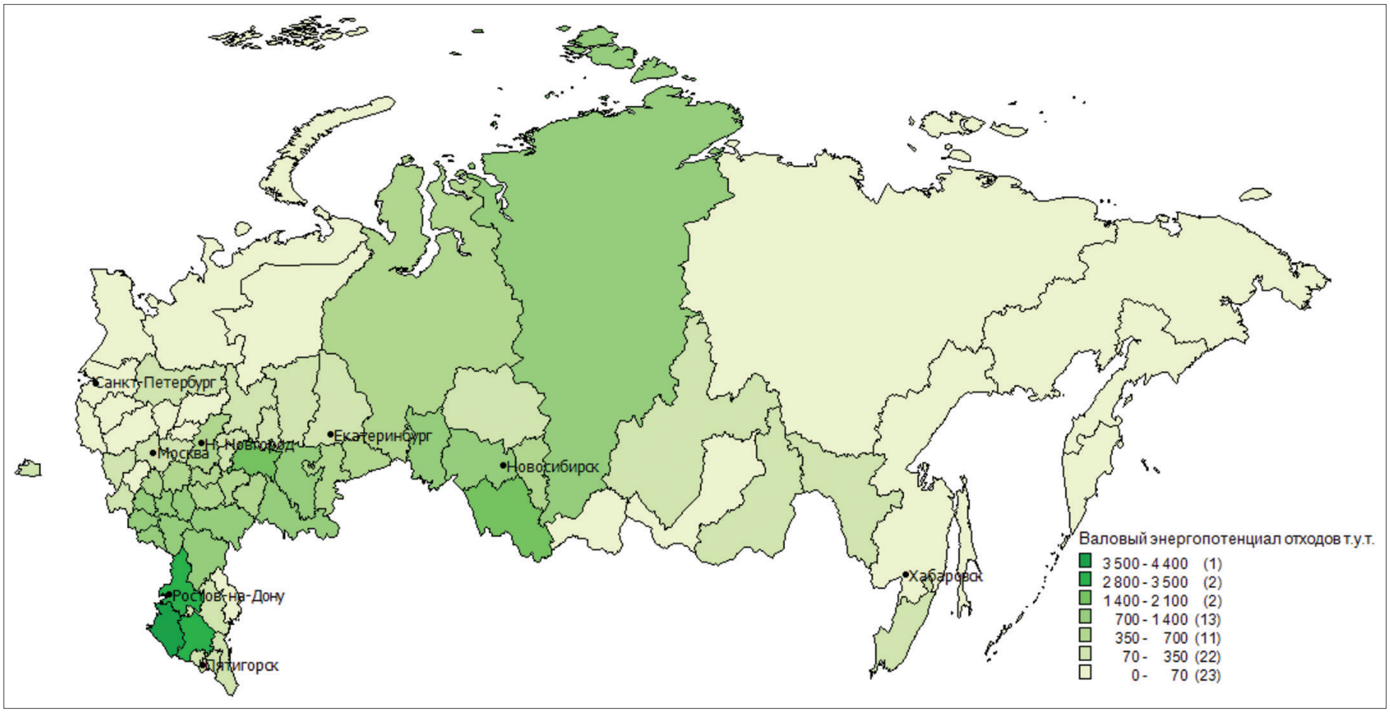
Figure 4: Map of wind activity in Russia (Gis renewable energy sources of Russia (2020), maps of renewable energy facilities in Russia

Source: Available from: http://gisre.ru/maps)

20 billion m^3 of methane. From 1 ton of poultry droppings, 70–80 m^3 of gas is obtained; from 1 ton of rapeseed oil, 1197.6 m^3 of gas is obtained.

According to experts of the company "Alternative Energy Systems," the total technical potential of biomass in Russia is 15,000-20000 MW. According to the research of the National Union on Bioenergy, Renewable Energy and Ecology, the Russian agro-industrial complex generates 773 million tons of waste annually, which is equivalent to 66 billion cubic meters of biogas. 450 million tons of livestock waste are generated (of which 58 million tons of dry matter), utilizing which through anaerobic digestion, 33.4 billion cubic meters of biogas can be obtained. In Russia, it is advisable to organize the production of energy from biomass where agriculture is developed, namely in the Black Earth region, central Russia, southern Siberia and the

Figure 5: Gross energy potential of waste in Russia (Gis renewable energy sources of Russia (2020), maps of renewable energy facilities in Russia



Source: Available from: http://gisre.ru/maps)

Krasnodar Territory. In the Belgorod region, biogas production from agricultural waste has been launched.

It is economically feasible to use geothermal sources in the Kuril Islands, Kamchatka, the North Caucasus, Baikal, the Urals and Western Siberia. Currently, Russia has three geothermal power stations in Kamchatka and two in the Kuril Islands. The largest geothermal station is the Mutanovskaya GeoPP (design capacity is 80 MW, installed capacity is 50 MW), and locates in Kamchatka.

A promising area is the use of tidal energy as alternative energy sources. Vast coastal areas have the potential to accommodate not only wind turbines, but also osmotic stations. These types of alternative energy are appropriate on the coasts of the seas of the Arctic Ocean and the Black Sea. In Russia, on the Kola Peninsula, an experimental Kislogubskaya marine tidal power station operates with an installed capacity of 1.5 MW. Using alternative sources in combination with diesel generators, it is possible to create an independent energy system in remote areas, which contributes to the development of these lands. Increasing the usage pace of alternative energy improves energy efficiency as well as the environmental situation.

Particular attention when approaching the development of alternative energy should be paid to the following figures and facts. 2/3 of the territories in Russia do not have access to a centralized power system. 20 million people do not have reliable energy supply. Over the past 20 years, 11 thousand settlements have disappeared from the map of Russia. In the nearest future, 13 thousand settlements will also cease to exist.

Energy efficiency is affected by rising energy costs. Energy costs are a direct component of the total energy intensity of production. The share of energy costs in the Russian economy is 1.5–3.5 times higher than the average level of industrially developed countries of the world. High energy intensity and electric intensity determines a large share of energy consumption in the cost of production.

According to experts, the energy efficiency potential is 45–50% of the current energy consumption in Russia, which is equivalent to 480 million tons of reference fuel a year. A third of this potential has the fuel and energy complex, another third is concentrated in industry and construction, the rest falls on housing and communal services, transport and agriculture. Energy efficiency indicators show the results of work done in the field of energy conservation. An assessment in rubles of energy savings or costs for them will allow us to transfer energy efficiency from a subjective concept to a perceived value.

5. CONCLUSION

The use of energy-efficient advanced technologies allows to achieve the following advantages:

a. Economic - the cost of production is reduced due to production costs, fuel and energy resources are rationally used, the payback period of investments is reduced;
b. Technological - increases the efficiency of the equipment, efficiently uses production facilities, increases reliability and safety, reduces the energy intensity of production;
c. Environmental - the amount of pollutant emissions into the troposphere and polluted effluents into the hydrosphere is reduced, the products are environmentally friendly;
d. Social - increases labor safety and improves working conditions. However, in order to control the process of rational expenditure of energy resources, a tool is needed in the form of systematic indicators with relevant criteria

It is impossible to completely abandon traditional energy, however, in order to live up to date and enter the world energy community, it is necessary to develop energy based on renewable resources in those regions where it is economically profitable. The use of renewable energy sources will give impetus to the development of mechanical engineering for the production of equipment for alternative energy. Providing electricity to isolated territories through renewable energy sources and crowding out obsolete and expensive diesel generators using them.

The innovative development of green energy will lead to the development of wind energy, solar energy and bioenergy engineering. The introduction of smart grids and the adoption of relevant laws governing the development of green energy will allow consumers who generate energy based on renewable resources to become active market participants. The result will be an increase in the living standard of the population.

REFERENCES

Allcott, H., Greenstone, M. (2012), Is there an energy efficiency gap? Journal of Economic Perspectives, 26(1), 3-28.

Apergis, N., Danuletiu, D.C. (2014), Renewable energy and economic growth: Evidence from the sign of panel long-run causality. International Journal of Energy Economics and Policy, 4(4), 578-587.

De La Cruz-Lovera, C., Perea-Moreno, A.J., de la Cruz-Fernández, J.L., Alvarez-Bermejo, J.A., Manzano-Agugliaro, F. (2017), Worldwide research on energy efficiency and sustainability in public buildings. Sustainability, 9(8), 1294.

Gis Renewable Energy Sources of Russia. (2020), Maps of Renewable Energy Facilities in Russia. Available from: http://gisre.ru/maps

Menegaki, A.N., Gurluk, S. (2013), Greece and Turkey; Assessment and comparison of their renewable energy performance. International Journal of Energy Economics and Policy, 3(4), 367-383.

Merkulova, E., Kondrakov, O., Menshchikova, V., Vertakova, Y. (2019) Impact of Energetic Development on the Sustainability of the Regional Economy. E3S Web of Conferences.

Pearce, J.M., Miller, L.L. (2006), Energy service companies as a component of a comprehensive university sustainability strategy. International Journal of Sustainability in Higher Education, 7(1), 16-33.

Porfiryev, B.N. (2012), Green economy: Realities, prospects and growth limits. Economy Taxes Law, 5, 34-42.

Report on Promoting an Effective Energy Transition of the World Economic Forum for Shaping the Future of Energy. (2019), Available from: https://reports.weforum.org/fostering-effective-energy-transition-2019/overall-findings

Report on the Functioning of the UES of Russia in 2019. (2019), Available from: https://www.so-cdu.ru/fileadmin/files/company/reports/disclosure/2020/ups_rep2019.pdf

Ringel, M., Knodt, M. (2018), The governance of the European energy union: Efficiency, effectiveness and acceptance of the winter package 2016. Energy Policy, 112, 209-220.

Ringler, C., Bhaduri, A., Lawford, R. (2013), The nexus across water, energy, land and food (WELF): Potential for improved resource use efficiency? Current Opinion in Environmental Sustainability, 5(6), 617-624.

Vertakova, Y., Plotnikov, V. (2017), Problems of sustainable development worldwide and public policies for green economy. Economic Annals XXI, 166(78), 4-10.

Vertakova, Y.V., Babich, T.N., Polozhentseva, Y.S., Zvyagintsev, G.L. (2017), Prospects for development of hydrocarbon raw materials resources reproduction. IOP Conference Series: Earth and Environmental Science, 87(9), 092031.

Zlobina, N., Kondrakov, O., Merkulova, E., Muratova, O., Vetakova, Y. (2019) Impact of Energy Economy Development on the Region's Population Life Quality, E3S Web of Conferences.