Energy consumption and energy intensity of the Russian GDP, taking into account the development of the transport network

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Abstract. The article studies energy consumption and energy intensity of gross domestic product (GDP) in the Russian Federation. Primary energy consumption and the structure of fuel and energy resources consumption in the Russian Federation during 2015-2019 were studied, the analysis of the achievement of target energy intensity of the Russian GDP was carried out, the dynamics of curtailment on demand for fuel and energy resources based on the use of technology was studied. The authors’ definition of energy efficiency, a strategy for the development of energy efficiency, an information system for the optimization and improvement of energy efficiency are presented as a scientific novelty in this paper. The authors substantiated that the informatization of the energy and production structure of an enterprise is one of the issues in the area of energy preservation and energy efficiency development.

1. Introduction
At modern production enterprises energy preservation represented by the implementation of economic, technological, organizational, regulatory and other measures is aimed at reducing the use of energy resources, provided that there is a certain beneficial effect from their use (including the volume of manufactured products, services).

Energy efficiency and energy intensity of consumed resources are technical and economic characteristics that reflect the ratio of the beneficial effect obtained from their use to the cost of energy resources necessary to obtain this effect in relation to the technological process, products, etc. In this case we mean the amount of energy spent on the implementation of this activity. In addition, energy consumption is subject to measurement by available types of resources (thermal energy, gas, electricity, etc.), including energy intended to ensure life support.

I.N. Makarov, O.A. Makarov, E.A. Barbashina carried out an analysis of the need to take into account and solve problems related to energy preservation and energy efficiency in the process of development and implementation of the national industrial policy, as well as the use of energy preservation and the organization of work aimed at the improvement of the energy efficiency of state fuel and energy industry enterprises. Their works provide for the following:

- A significant decrease in shortfalls in income and current costs incurred by chain enterprises generating energy resources.
- Emergence and release of additional resources for the transmission and distribution of energy.
- A decrease in costs for the development of electricity grids and an increase in transfer capabilities associated with a decrease in the load on grids per amount of loss of generating capacities in them.
- A decrease in tariffs for thermal and electric energy for end consumers.
- An increase in the profitability of electricity grids of enterprises.
- An increase in the state energy security and independence of the domestic electrical energy industry from external sources [10].

The Russian economy has a significant potential in the field of energy preservation characterized by the fact that energy intensity of the domestic GDP is significantly higher as compared to the world level - by 45%, and to the level of Canada - by 18%. The use of the accumulated promising reserves allows releasing additional amounts of fuel and energy resources for export, reducing harmful emissions into the atmosphere, implementing environmental measures balanced with energy consumption, and improving the quality of life of the country’s population.

An increase in the level of energy efficiency, first of all, is achieved through the introduction of high technology and modern technical means, including through the use of combined-cycle plants, gasification and electrification of vehicles, the use of combined supply of electricity and heat, the use of modern energy-efficient structures and heat-insulating materials for construction, the use of energy-efficient lighting, introduction of lighting control systems and other modern devices for energy consumption metering. The technological factor in energy preservation is the basic driver for the reduction of energy intensity of the Russian GDP in the main and most energy-intensive types of economic activity: mining and manufacturing, energy, transport, housing and public utilities.

2. Materials and Methods
The research structure is logically justified:
- The introduction contains the relevance of the research topic and issues to be analyzed.
- The discussion uses a statistical method that represents analytics in the field of energy intensity of the GDP, energy efficiency and energy preservation improvement.
- The following methods were used in the work: the method of statistical sampling, the balance method, the method of dynamics of target indicators, and the factor method.
- Based on the classification of approaches to energy efficiency of enterprises and industries, the authors used the method of optimizing dynamic parameters of economic entities presented as a functional system based on the informatization of energy supply and energy consumption evaluated by the criterion of dynamic assessment systems.
- To control and monitor energy efficiency, as well as to synchronize and optimize electricity supply and consumption, the model of informatization of energy supply of business entities was used.

3. Results

![Figure 1. Algorithm for the creation of the scientific novelty of the study.](image-url)
Based on the study of energy consumption and energy intensity of the GDP, the authors propose to domestic economic entities a number of measures aimed at the development of energy efficiency that allow reducing energy consumption. Based on the classification of approaches to energy efficiency of enterprises and industries, this term is used to mean managerial, organizational, economic, technological and technical measures directed towards the optimization of dynamic parameters of economic entities presented as a functional system based on the informatization of energy supply and energy consumption evaluated by the criterion of dynamic assessment systems. The algorithm for scientific novelty creation is presented in Figure 1.

The authors consider an increase in energy efficiency of economic entities through the strategy of energy efficiency as part of goals, plans, resources, time and indicators, as a set of managerial, organizational, economic, technical and technological measures that can ensure the optimal use of energy resources, improve energy efficiency and create competitive industries and branches based on informatization systems [4].
Figure 2. Development and implementation of the energy efficiency strategy at business entities.

The use of informatization systems is currently the main way to improve energy efficiency of business processes carried out by business entities. The software of these systems provides the formalization, regulation and algorithmization of strategic planning processes, the sequence of plans implementation and the optimization of energy consumption. One of the initial and possible ways to improve energy efficiency is to solve problems related to reducing non-production losses of electric power by introducing automated systems for electric power control and metering at the stages of its delivery to the ultimate consumer [6].
The proposed model of informatization of energy supply to business entities in an automated mode allows controlling electrical supplies, energy consumption and intensity reduction processes. It controls and monitors energy efficiency, synchronizes and optimizes the supply and consumption of electricity. This model helps evaluate energy efficiency of business entities in dynamics.

4. Discussion

Currently, the main ways to reduce energy intensity of the industrial sector and the population of the country are the modernization of energy-supplying and energy-consuming complex equipment, the introduction of energy preservation and energy efficiency programs at enterprises and in the housing and public utility sector.

It is stated in the State report of the Ministry of Economic Development of the Russian Federation “On the state of energy preservation and improvement of energy efficiency in the Russian Federation in 2019” dated December 27, 2019 that “…for the purposes of implementation of the above programs and measures there is significant potential for the development of energy supply:

- It is possible to save up to 20% of potential energy in the sector of energy generation and transportation in the fuel and energy complex (oil and gas industry and electrical energy industry).

- It is possible to save up to 25% of energy resources for the purposes of energy preservation in the housing and utilities sector.

- It is possible to save up to 15% of energy resources in the industrial complex of the Russian Federation.

- It is possible to save up to 15% of energy resources in construction, transport and agriculture” [5].

It is noted in the studies of V.V. Storozenko that “...at the present stage of development energy intensity of the GDP in the developed countries of the world is 2-3 times less as compared to Russia. In the ranking of countries in terms of energy intensity Russia ranks 49th, while Canada - 28th, Finland - 26th, USA - 22nd, Sweden - 21st, Japan - 16th, Germany - 16th. Over a ten-year period energy intensity of the Russian GDP has decreased by only 9%, and over the past four years it has not decreased” [12].

Assessing "...the total amount of investment in energy preservation and the development of energy efficiency O.F. Lapaeva, O.A. Inevatova and S.A. Dedeeva note its insufficiency - in 2018 it
amounted to 0.2% of the total GDP of the Russian Federation. It is also noted that the share of private investment in energy efficiency has been declining. In addition, the spread of indicators of investment in energy preservation among the constituent entities of the Russian Federation reaches 300 times” [9].

The total costs for energy resources in the Russian Federation in 2019 amounted to 8.5 trillion rubles, and the total annual amount of investment in energy preservation, according to the concluded performance contracts, is only 44 billion rubles (0.5% of the total costs for energy resources) [10].

As for the housing and utilities sector, according to I.F. Gareeva and M.A. Shavshina, “... it is shown that the consumption of electric and thermal energy in the housing and utilities sector among regions with similar climatic conditions differs up to 3-4 times” [4].

The process of installation of collective metering devices for consumed resources in apartment buildings is still in progress, but it should have been completed by July 1, 2012 according to the plan. As of January 1, 2019 the share of installed metering devices amounted to only 61% [1].

As of January 1, 2018 modern technologies in the field of energy preservation put into operation accounted for only 27% of the total number of technologies used. Energy efficiency classes of apartment houses in Russia are high (A++, A+, A, B, C), and only 5% of commissioned houses are equipped with energy metering devices that can be customized depending on the weather conditions. So, currently more than a half of all apartment houses in the country (54% of the total number of houses) consume twice as much energy compared to their modern foreign counterparts [11].

The balance of primary energy consumption in the Russian Federation is significantly differentiated - it consists of hydropower, natural gas, petroleum products, coal, nuclear energy and alternative or renewable energy sources. Their structure is presented in Table 1.

Table 1. Primary energy consumption in the Russian Federation in 2015-2019, % [2].

| Types of energy resources            | 2015 | 2016 | 2017 | 2018 | 2019 |
|-------------------------------------|------|------|------|------|------|
| Gas                                 | 57   | 57   | 59   | 60   | 60   |
| Nuclear fuel                        | 8    | 8    | 8    | 8    | 8    |
| Hydraulic power                     | 2    | 2    | 2    | 3    | 2    |
| Renewable energy source             | 1    | 2    | 1    | 1    | 3    |
| Coal                                | 18   | 17   | 16   | 15   | 15   |
| Oil and oil products                | 14   | 14   | 14   | 13   | 12   |

The above table shows that the main role in energy consumption belongs to gas resources (including due to an increase in the use of oil-associated gas) and accounts for 60% of the total amount. Coal consumption has been declining, its share in the total amount decreased from 18% to 15% in 2015-2019. The total primary energy consumption increases by an average of 1.9% annually. The use of “non-hydrocarbon” energy - renewable energy, nuclear fuel and hydropower - increases by 1.5% every year.

The policy of the Government of the Russian Federation related to the support of renewable energy sources is reflected in Resolution No. 17 of January 23, 2015 “On amending certain acts of the Government of the Russian Federation regarding the promotion of renewable energy sources in various electric energy markets” is aimed at preserving the increasing dynamics for at least the next 10-15 years.

Above 80% of the total fuel and energy resources consumption is observed in four energy-intensive sectors of the Russian economy (see Table 2). This consumption structure has not changed since 2015. The minimum consumption among the presented types of economic activity is typical for the budget sector - the consumption in 2019 amounted to about 3% of the total energy consumption.

Table 2. Structure of fuel and energy resources consumption in the Russian Federation by types of consumers for 2015-2019.

| Energy consumption pattern                     | 2015 | 2016 | 2017 | 2018 | 2019 |
|------------------------------------------------|------|------|------|------|------|
| Electrical power, thermal power generation    | 28   | 28   | 28   | 28   | 28   |
According to Decree of the President of the Russian Federation No. 889 of June 4, 2008 “On certain measures aimed at the improvement of the energy and environmental efficiency of the Russian economy”, the Government of the Russian Federation was “… set a goal to reduce energy intensity of the domestic GDP by at least 40% by 2020 relative to the values of 2007” [3]. According to the data as of January 1, 2020, energy intensity of the the Russian GDP decreased by 28% compared to 2007, which reflects a significant deviation from the target values. If this rate of decrease in energy intensity of the country’s GDP continues to persist (2007–2020), equal to 1.1% annually, it will be possible to reach the target indicators equal to 40% only by 2043 (see Table 3).

**Table 3. Dynamics of achievement of target energy intensity of the Russian GDP [10].**

| Year       | 2007 | 2009 | 2011 | 2013 | 2015 | 2017 | 2018 | 2020 | 2043 |
|------------|------|------|------|------|------|------|------|------|------|
| Power consumption, % | 100 | 98  | 100  | 91  | 87  | 88  | 88  | 72  | 60  |

As for longer observation periods, in the period from 2000 to 2020 energy intensity of the Russian GDP decreased by more than 40%, taking into account the growth of the GDP by 181%. The progress in decreasing energy intensity of the GDP is attributed to the period from 2000 to 2008, since at that time significant structural changes were introduced in the GDP, which created less energy-intensive types of economic activity (see Table 4).

**Table 4. Dynamics of energy intensity of the Russian GDP relative to the level of 2000 [10].**

| Year       | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|------------|------|------|------|------|------|------|------|------|------|
| Power consumption, % | 100 | 97  | 92  | 88  | 83  | 79  | 74  | 68  | 65  |

An increase in the GDP up to almost 60% in the period from 2000 to 2019 was accompanied by an increase in the consumption of primary energy by economic entities. Consumption began to increase immediately after 2008 and continued until 2011, which caused an increase in energy intensity of the GDP. During 2013-2015 energy intensity of the GDP increased slightly. This period is characterized by a decrease in the rates of economic development and growth accompanied by an increase in energy-intensive types of economic activity in the structure of the domestic economy and a decrease in improvements in its structure in relation to less energy-intensive industries. The end of this period was marked by zero dynamics of energy intensity of the GDP.

The main factor that was holding back the growth of energy intensity of the Russian GDP in 2015–2020 is the technological factor (an increase in energy efficiency of energy consumption equipment). The contribution of this factor to the reduction of energy intensity of the Russian GDP in 2015-2020 amounted to 1.2% per year or 4% in 2018 relative to the level of 2015 (see Table 5).

**Table 5. Dynamics of fuel and energy resources decreasing consumption based on the use of technological factors.**

| Indicators                                      | 2016 | 2017 | 2018 | 2019 | 2020 |
|------------------------------------------------|------|------|------|------|------|
| Dynamics of changes in GDP energy intensity (relative to 2015) | +3   | +1   | +1   | +1   | +2   |
Degree of influence of technological factor on dynamics of changes in energy intensity of GDP (relative to 2015)  

|   | -1 | -3 | -4 | -5 | -6 |
|---|----|----|----|----|----|

According to the results of the study, the authors concluded the following: in the development strategies of domestic companies issues of energy preservation and energy efficiency improvement are not strategic priorities in their activities, and existing program measures solve mainly current problems [7].

5. Conclusions

The focal points "... of the state policy in the area of energy preservation and the development of energy efficiency in the near future should be:

- Implementation of a comprehensive plan of measures aimed at the improvement of energy efficiency of the economy of the Russian Federation (approved by Order of the Government of the Russian Federation of April 19, 2018 No. 703-p).
- Ensuring energy efficiency in the course of procurement of goods, works, and services for state and municipal needs.
- Introduction of energy efficiency classes of buildings, structures and facilities.
- Reforming the system of energy surveys and introducing the institute of declaring energy resources consumption by state institutions.
- Creation and development of state information system "Energy Efficiency" (GIS)” [8].

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