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**Article**

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# Issues of Developing the Tool for Diagnosis of Energy Efficiency Level of Russian Regions' Economy

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**ABSTRACT**

The article gives analysis of approaches to evaluation of energy efficiency of a territory's economy established in the global and Russian practice; identifies key features of implementation of index approach to diagnostics based on common techniques of decomposition, or factor, analysis of indices; indicative approach based on calculation of energy security and energy performance figures. Comparison of multi-dimensional and ranking approaches in usage of energy efficiency evaluation diagnostics tools was also performed. Based on application of the existing tools the characteristics of present-day state of energy efficiency of Russian economy was given and key problems of increasing thereof were emphasized. The authors suggested mechanism of usage of the indicative method in diagnostics of energy efficiency level of a territory's economy, which ensures identification of the weakest points of energy efficiency enhancement, forecasting of consequences thereof, taking of contemporary managerial solutions with regard to further actions.

**Keywords:** Regional Economy, Energy Efficiency Enhancement, Sustainable Social and Economic Development
**JEL Classifications:** O10, R10

## 1. INTRODUCTION

The key factor of the present-day stage of world economies transition (primarily, energy intensive) to sustainable development shall be increasing of their energy efficiency, which will allow to optimize structure of production and power consumption at the account of implementation of measures for energy saving, performance improvement, reduction of environment pollution, creation of new markets of ecological products and services, job places, and reduction of dependence from usage of ecologically unsafe energy sources. Enhancement of efficiency of public policy in the field of energy saving must be based on usage of knowledge of a real situation, selection of incentives relying on socio-economic peculiarities of certain territories, training of staff on real problems to usage of adequate methodological approach of diagnostics.

Accounting of energy performance figures, and the nature of their impact on the dynamics of internal and external medium factors, external and internal strategic factors, forecasted (controllable and uncontrollable) and random action factors of the state regional support tools is the basis for improvement of mechanism of strategic planning of socio-economic development of a territory in the context of unsteady economics.

From this perspective the need arises in development of mechanism of the regional economy energy performance level diagnostics with the account of evaluation of weak points of socio-economic development of regional territory and its preparedness to conduction of measures oriented to the economy's energy efficiency enhancement with the account of the nature of impacts on energy efficiency dynamics of the factors of external and internal medium of a region.

The essential thing is to determine which sectors are playing a dominative role in a territory's economy by the level of occupation, sales, tax returns and links with other sectors of economy, to identify the essential links between the local and "external" economy in order to evaluate the degree of impact of regional economy sectors on the change of "superior" and "inferior" levels – regional, national and international economies and vice versa. It is necessary to assess the territory's potential for the economic growth, stability and depression, to identify those possible circumstances which may cause or add to the emerging trends in a region's energy industry development, to identify circumstances important for the population and administration authorities of a territory which may cause the most strong effect on the level of employment, sales, incomes (both personal and public) and costs, economic performance, quality of labour and level of life on the territory.

## 2. METHODS

The authors of the survey elected the indicative method, which is the most relevant nowadays as compared with other evaluation methods, as one the main evaluation methods to diagnose the level of regional economy energy efficiency. The indicative method based on comparison of actual values of indicators with the threshold values thereof has a strong following among scientists and practitioners.

While working on the article the authors, besides the named methods, used systemic approach, comparative and statistical methods to analyze figures of regional situation from the perspective of their energy efficiency. The said methods used in aggregate, as well as normative analysis and forecast allow to analyze possible inconsistencies and to establish correlations in economic processes.

With the help of factor analysis the authors coped to establish interrelations and dependencies between the figures, when some factors act as independent ones, and the others as their derivatives. In particular, for the purpose of evaluation of changes in energy consumption figures of various regions, and in order to account impacts of external and internal medium factors, external and internal strategic factors, the forecasting and random factors on energy efficiency figures.

The article also used the method of scorecard evaluations which is specific for various fields of analysis and comparison of objects. This method provides for efficient processing and performance of the objects ranging, which leads to further analytical evaluation of data. The work determined the conceptual conditions for enhancing efficiency of a regional economy functioning connected with improvement of mechanism to diagnose a region's energy efficiency level. These problems were also subject matters of other scientific papers by the authors hereof (Chernyaev, 2014; Rodionova et al. Chernyaev and Korenevskaya, 2017; Chernyaev and Rodionova, 2017; Chernyaev et al., 2017).

For the purpose of ocular demonstration of dependencies of economic and other indices the authors appealed to the graphic presentation technique.

## 3. RESULTS

Development of mechanism of diagnostics suggests election of the most efficient diagnostic methods and instruments and fixing of their operation in statutory framework of the relevant institutes. Methodologically, the most undeveloped aspect of this issue is the mechanism of selection of optimal methods and tools of energy efficiency evaluation, and, primarily, development of economic indicator system and means of measurement. The factors influencing energy consumption efficiency have not been fully systemized and studied, and it results in impossibility to compare indicators.

In the world and Russian practice several approaches emerged to evaluation of energy efficiency of a territory's economy. Experts of the International Energy Agency (IEA) consider diagnostics from the perspective of the index approach based on common methods of decomposition, or factor, analysis of figures (The IEA, 2014), which disaggregate or divide by factors the changes in energy consumption in end-use sectors (residential, service sector, industrial production and transport), and in economy as a whole and of certain territories. The bare energy efficiency indices represent only a part of picture of energy consumption factors in a certain sector or subsector. Decomposition analysis is used for disaggregation of influence of different factors on the total energy consumption. Methods of the IEA for analysis of the end-use trends usually distinguish three main components which influence the energy consumption: Scope of business, its structure (number of types of activity inside the sector) and energy intensity. In decomposition analysis the impact of each certain factor receives a quantitative evaluation, hence the factors connected with energy policy may be separated from the changes in structural and quantitative (characterizing scope of business) components of energy consumption.

The method under study is based on the conceptual structure of the index pyramid and reflects hierarchy of energy figures, from the most detailed to the least detailed ones. The upper level of the pyramid (the most consolidated index) is defined as a relation of energy consumption to GRP (gross domestic product [GDP]) or to the number or inhabitants of a region (country). Figures of this row give only common concept on reasons of the emerging trends of energy consumption. The second row of elements may be defined as energy intensity of each of the main sectors being measured as energy consumption per activity unit in each sector. The lower level represents the certain types of activity or end-usage types in each sector and is characterized by certain energy services, physical processes and key technical devices of the energy end usage. The figures of the low level are necessary to understand the key factors of energy consumption and to analyze the policy of action on emerging trends in the field of energy saving and energy efficiency enhancement.

One of the approaches is so called indicative approach based on calculation of energy security and energy performance figures and comparison thereof with the threshold values (Gayfullina et al., 2017). The main problem when using of this method is identification of the indices that, when compared with threshold values, will give a complex assessment of the state of energy security and energy efficiency of certain enterprises, companies and territories, and to identify the objectively dangerous trends and threats (Marchenko and Belova, 2016).

Usage of multi-dimensional approach within the framework of energy efficiency diagnostics (Burnashev, 2015) is based on the analysis of energy saving and energy efficiency enhancement nature analysis from the perspective of innovativeness in the contemporary economic process. The author considers the whole energy sector as innovation indicator with considerable multiplicative effect in all fields of socio-economic development. Such complex evaluation takes into account the nature of energy efficiency processes in energy production, transfer and consumption, and factors influencing measurement procedure and the very energy efficiency indicators (nature of objects under study; technical development level determining the value of energy intensity and resource usage efficiency; agroclimatic resources characterizing various types of energy loss).

The scorecard approach for performance of country-to-country analysis and comparison by the level of energy efficiency is used in the process of application of the following diagnostic tools: International Energy Efficiency Scorecard System of the American Council for an Energy-Efficient Economy (International Energy Efficiency Scorecard system ACEEE), ODYSSEE MURE project being coordinated by the French Agency of Ecology and Energy Management and supported within the framework of Intelligent Energy Europe Programme of the European Commission, the International Energy Efficiency Scorecard system of the World Energy Council (World Energy Trilemma), the International System of Global Energy Architecture of the World Economic Form and the number of others. The scorecard system is also used as the basis for criterion score of energy efficiency in the majority of the countries of the world (Burenina et al., 2014).

Each of the tools analyzed is used based on target priorities of policy in the field of energy saving, the subject matter of analysis (separate industry sectors or regional economy as a whole) and the nature of information necessary for evaluation of the progress achieved in the field of energy saving and future needs of territories under study (Belova, 2016).

The International Energy Efficiency Scorecard system of the ACEEE (2012; 2014; 2016) uses various indicators taking into account measures of policy, quantitative efficiency figures, institutes and scope of activities to evaluate how efficiently the energy is being used in countries and how successfully and with what policy measures and tools they are progressing on the way of energy efficiency enhancement. The rating system is comprised of four blocks: National efforts, industry, buildings and transport. Each metric is assigned with its own weight, and for each of them the evaluation rules are formulated.

Determination of energy sustainability of the World Energy Council is based on three main aspects: Energy security, energy fairness and environmental sustainability. Energy security is being evaluated from the point of view of efficient organization of supply of primary energy from national and foreign sources, reliability of energy infrastructure and ability of energy suppliers to meet the current and future demand. Energy equality is characterized by presence and availability of energy for population. Environmental sustainability is determined by the efficiency of power supply and demand, and by development of power supply from recoverable sources and other low-carbon sources. Trimming of these three goals forms a "trilemma" and is the basis for prosperity and competitiveness of certain countries (Shilets et al., 2017).

The annual energy efficiency ranking by Russian Ministry of Energy backed by Interfax (Russian Federation (RF) Ministry of Energy, 2017) is the official diagnostic tool of energy efficiency of the RF constituent entities. This tool evaluated implementation of key public policy sectors in the field of energy saving and energy efficiency enhancement by constituent entities of the RF. Monitoring data concerning implementation of public policy in the field of energy efficiency enhancement in economy sectors and in RF regions are included in the State Report on Energy Saving and Energy Efficiency Enhancement in Russia.

Energy performance rating of the RF regions takes into account three groups of indices: GRP energy intensity, energy saving performance characteristics (5 indices) and organizational figures of energy efficiency enhancement (Figures 1-4 and Table 1).

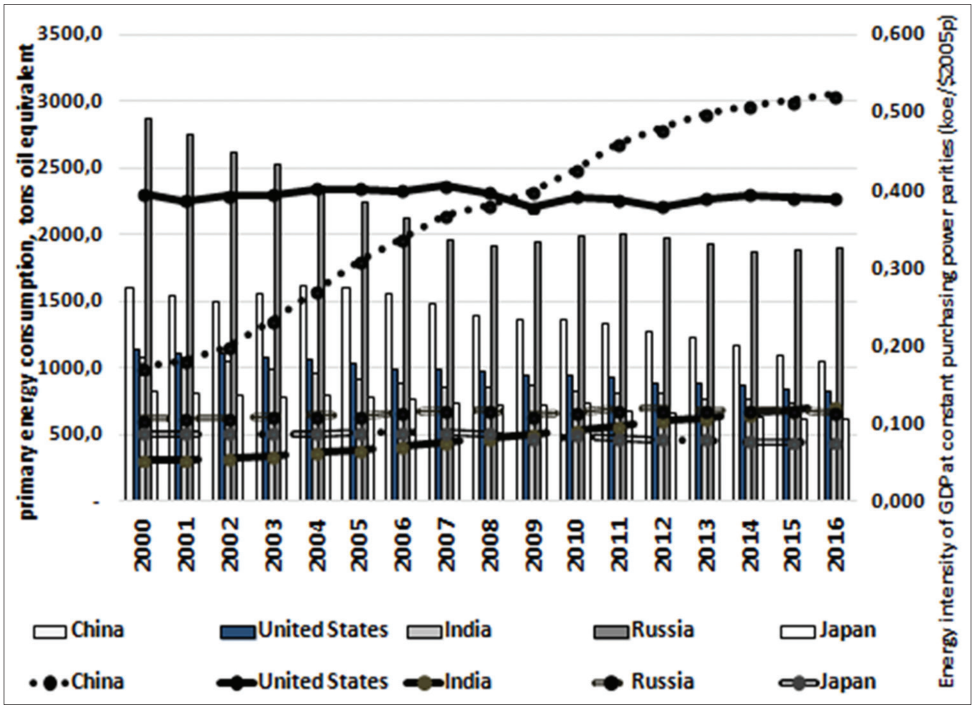
Indicators of the blocks reflect the nature of influence of two types of factors on the energy efficiency processes: Factors of implementation of the main energy efficiency technologies and high-priority administrative measures. The data may be derived from the sets of statistical data of the Federal State Statistics Service of the RF, the data being provided by the regional public authorities in preparation of energy saving report and the data on energy efficiency of buildings that are provided in State Information System "Energy Efficiency" by budget-funded organizations (energy declarations).

The "ABC-energy economics" regional development model (Gaynanov and Popov, 2017) allows to evaluate efficiency and balance of energy-economic assurance of development of the Russian Federation constituent entities based on elaboration of scenario variants of regions' balanced development strategy. Concept of energy-economic assurance of a region's development square the concepts of energy self-sufficiency, energy security, energy saving and energy efficiency. The proposed concept of a region development management is based on the principles of balanced energy resources assurance of a regional economy development and consists of three key components characterized with the relevant set of figures:

1. Energy self-sufficiency and energy security of a region (GRP electric intensity, region's self-sufficiency in energy, electric power transmission reliability level, degree of asset depreciation of power facilities etc.)
2. Comfort and availability of energy saving for consumers;
3. Investment attractiveness of regional energy economy.

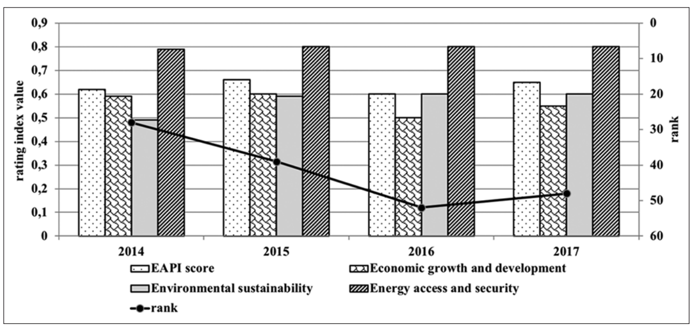
Present-day state of Russian economy as a whole, and therefore its separate regions, is characterized by extremely low efficiency of

**Figure 1:** Dynamics of gross domestic product energy intensity of the countries leading in primary energy consumption in 2016 (2000–2016)




Source: Compiled by the authors based on enerdata statistical data, 2017

**Figure 2:** Dynamics of energy architecture performance index figures (according to the data of the World Economic Forum 2014–2017)




Source: Compiled by the authors based on files and information of the world economic forum

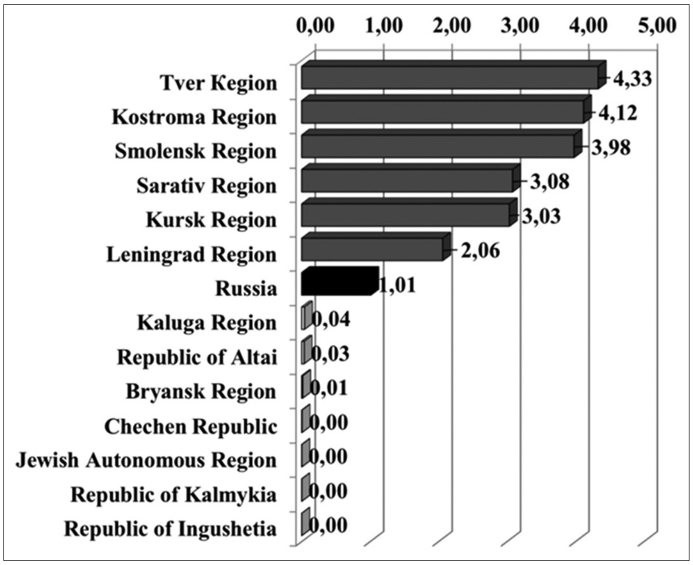
power energy usage. Energy intensity of Russian GDP (calculated by purchasing power balance of currencies) exceeds average world index by 2.3 times, and among the countries of European community - by 3.5 times. Diagnostics of energy efficiency level of Russian economy with usage of these instruments and methods shows extremely low positions of the country in international rankings.

In Russia, as one of the most energy intensive countries of the world the essential potential for reduction of inefficient energy consumption has been formed. In 2008, within implementation of certain events on increasing the energy and ecological efficiency of Russian economy the task was set to reduce the GDP energy intensity of the country by 40% by 2020 as compared with 2007. Comparison of dynamics of GDP energy intensity and primary energy consumption volume indices in the leading consuming countries allows to make a conclusion on a difficult-to-control nature of energy intensity reduction of Russian economy (Figure 1).

Analysis of the statistical data by the Internal Energy Agency revealed that the energy intensity of Russian economy during the period from 2007 through 2016 reduced only by 4% and continues to remain 1.5–2 times higher than the figures of not only economically developed countries, but also of the countries with similar conditions of socio-economic development and natural resources potential. During the period 2014–2016 in the context of relatively stable level of energy consumption the gross domestic product volume reduced by 2.8% (2015 as compared to 2014). Such high values of energy intensity in Russia are partially connected with specific climatic conditions, and with nature of arrangement and structure of the Russian economic complex (Makarov et al., 2013):

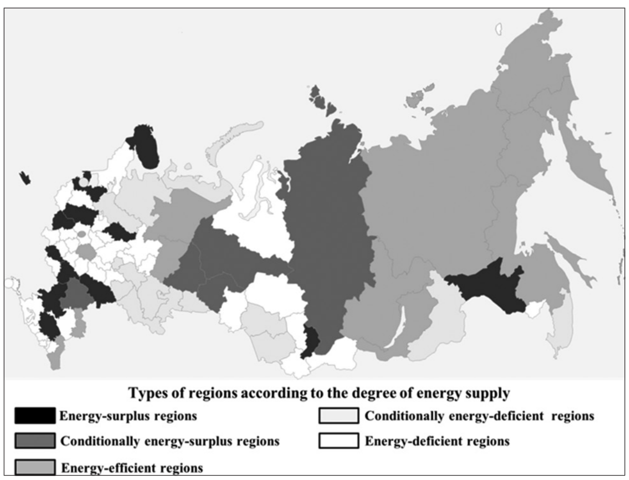
1. Considerable extension of the territory of the country: Around 5 thousand km from the North to the South, and around 10 thousand km from the West to the East, with a very low customer density of energy resources and energy infrastructure on the large part of the territory (average in Russia is 7 times less than in the USA) and the high focal concentration of production of the main types of fuel;
2. The disproportion that appeared in the second half of the 20th century and is now growing, in allocation around the territory of the country of the demand for energy resources and possibilities of their production, which strongly increases the costs of energy saving of the economic complex;
3. Especial severity of natural climatic conditions on the large part of the country's territory and significant variation thereof (from arctic deserts to subtropics). This causes high differentiation of energy space, and, what is the most important, justifies (in combination with additional energy

**Figure 3:** Regional differences of the RF regions energy self-sufficiency factor




Source: Calculated and compiled by the authors based on the data of the federal state statistics service of the Russian federation

**Figure 4:** Classification of the RF regions by the degree of energy self-sufficiency (map)




Source: Compiled by the authors based on the data of the Federal State Statistics Service, 2016

transport costs caused by previous peculiarities) the increased power consumption per output unit and per capita.

As the result more than 40–45% of heat power consumption was allocated to heating and hot water supply of non-productive sphere. It being understood that heat capacity shortage in more than 190 cities of Russia amounts to around 20% of need. In case that a part of heating capacities shortage is covered by population by way of usage of gas-fired boilers, this results in overconsumption of fuel as compared with boiler stations minimum by 2–2.5 times, and in case of electric heating - by 3.5–4 times. Heat consumption on heating and hot water comprises around 75% of the total power being consumed in households. Big country with low winter temperatures and long heating season consumes a lot of power.

It is essential that Russian fuel and energy complex in industrial and economic aspects represents a difficult multi-level and multi-dimensional hierarchy of energy systems, which are being formed by the distance as one the main factors of impact. During the period of Russian transition to market economy the harmful gap arose in approaches to energy development planning on the federal and regional levels. Regional aspects of energy development are almost completely lost in forecasting and planning developments of the federal authorities. As the result, regions when elaborating forecasts, programs and plans of energy industry development has faced absence of distinct regional priorities of the state.

The low efficiency of public policy in the field of energy efficiency is connected, including but not limited to with blind imitation of foreign approaches, ignorance of real situation, lack of understanding of key reasons of "non-efficiency," pre-occupation with "market" tools. Significant difficulties in realization of Public Policy in the field of energy saving are connected with nonoperation of government support instruments for energy saving in many fields; difficulties in mass implementation of ESKO projects; inefficient correction of energy saving government programs, cancellation of regional subsidies for 2015.

In the international energy efficiency scorecard of the countries of the world (the ACEEE) Russia in 2016 (the last published version) was the 17th out of 23 participating countries (Table 2). The most difficult situation is in the sphere of energy efficiency of buildings (the 20th position) and industrial enterprises (the 19th position out of 23).

And Russian economy has not ranked higher than 44th place in the energy sustainability ranking of the World Energy Council (Table 3).

According to the experts of the World Energy Council the most negative factors determining the problems with energy efficiency of economy include high dependency of the economy from the export of energy carriers and sensitivity to fluctuations of prices for energy carriers, development of shale gas in other regions of the world and efforts of Europe to reduce dependence from Russian gas.

In the World Economic Forum Global Energy Architecture Ranking (2017) Russia ranked 48, having come 15 positions down since 2009. Comparing positions of Russia with the best (Switzerland) and the worst (Bahrain) values, it should be noted that the most significant losses during the analyzed period were in the block "economic growth and development," while the number of points being received by Russia in blocks "environmental sustainability" and "energy availability and security" is relatively stable (Figure 2 and Table 4). At the same time the significant degradation of positions may be connected with underactive usage of tools for enhancing energy efficiency of the economy both in Russia as a whole, and in its separate regions.

## 4. DISCUSSION

Methodological framework for development of authors' diagnostics of a regional economy energy efficiency level was

**Table 1: Characteristics of energy efficiency ranking indices by the Ministry of Energy of the RF**

| Ranking indices blocks | Indices | Characteristics | Maximum number of points |
|---|---|---|---|
| | Gross regional product energy intensity | GRP energy intensity reduction dynamics in constant prices for the previous 3 years | 5 |
| Performance figures | Energy efficiency of public sector buildings | Share of buildings with preliminary energy efficiency Class D and higher | 10 |
| | Energy efficiency in outdoor lighting | Share of sodium-vapour and light-emitting diode light sources in outdoor lighting systems | 10 |
| | Energy efficiency of public sector lighting | Share of LED light sources in public sector lighting | 10 |
| | Energy efficiency of heat supply in public sector | Share of equipping with automated control domestic heating plants upon capital repairs for the amount of 5 mln RUR and more, and in new buildings constructed as from 2011 | 10 |
| | Share of thermal send-out from thermal power plants | Send-out share dynamics | 10 |
| Organizational figures | Inclusion of energy efficiency figures in state programs | Share of industry state programs of a RF region that include energy efficiency figures | 10 |
| | Energy efficiency in construction and capital repairs | Availability of standard recommendations and requirements to energy efficiency in construction and capital repairs | 5 |
| | Popularization of energy-saving lifestyle | Participation in federal events for popularization of energy-saving lifestyle | 5 |
| | Energy declaration mechanism implementation | | 10 |

Source: Compiled by the authors based on the data of the Ministry of Energy of the Russian federation, RF: Russian Federation

**Table 2: Energy efficiency scorecard around economies of the countries of the world (according to ACEEE)**

| Year | Total rank | State backing | Buildings | Industry | Transport |
|---|---|---|---|---|---|
| 2012 12 countries | | | | | |
| Points | 36/100 | 6/25 | 8/28 | 9/24 | 13/23 |
| Rank | 12 | 11 | 12 | 10 | 5 |
| 2016 23 countries | | | | | |
| Points | 38/100 | 11/25 | 6/25 | 10/25 | 11/25 |
| Rank | 17 | 16 | 20 | 19 | 14 |

Source: Compiled by the authors based on the files and information available at the official website of the ACEEE (2012; 2016). ACEEE: American Council for an Energy-Efficient Economy

**Table 3: Energy sustainability ranking (world energy trilemma)**

| Indicator | 2015 | 2016 | 2017 |
|---|---|---|---|
| Total rank | 48 | 45 | 44 |
| Energy security | 8 | 6 | 13 |
| Energy balance | 42 | 42 | 38 |
| Environmental sustainability | 117 | 116 | 113 |

Source: Compiled according to the data of the World Energy Council (2015; 2016; 2017)

based on the widely recognized concept of energy sustainability evaluation Energy Trilemma, developed and being applied by the World Energy Council, which determines appearance of complicated connections between public and private entities, government and regulatory authorities, economic and social factors, natural resources, ecological problems and individual conduct of each economic entity.

It is suggested to compile rankings of typology being developed based on analysis of 7 indices built on statistical figures and taking into account both energy efficiency parameters, and the context of the very energy efficiency, which indices are grouped in the following blocks reflecting all groups of factors of energy sustainability of a region's economy.

1. Economic sustainability (energy safety) reflects the nature of fuel and energy balance of a region's economy, reliability of energy infrastructure, financial and economic return of economic entities of a region's fuel and energy complex.
2. Social sustainability (energy equality) characterized presence and availability of energy for population.
3. Environmental sustainability takes into account the role of energy in the level and nature of a region's environment pollution, and energy production out of recoverable sources.

4. Socio-economic sustainability is considered from the perspective of qualification of staff engaged in fuel and energy complex and the situation on the labour market of the industry as a whole.
5. Eco-economic sustainability, the analysis of which is based on the evaluation of GDP energy intensity dynamics.
6. Socio-ecological sustainability is assessed on the basis of per capita figures of environment pollution.
7. Management of energy efficiency of a region's economy is considered based on methods of the RF regions energy efficiency ranking (by the Ministry of Energy of the RF) which evaluates implementation of key directions of public policy in the field of energy saving and energy efficiency enhancement by the RF regions.

In the course of study several indicators were selected into each of the blocks reflecting the nature of each of the main and interim directions of sustainable development (Table 5).

Based on the number of indicators, the degree of their impact and nature of the content of the phenomenon being measured, each index is assigned with its weighting factor: From 0.1 up to 0.3. In the final ranking various indices are adjusted to a common scale and are comparable with each other.

In order to distinguish figures being used for calculation within the framework of each index, multilateral monitoring of open statistical data of the RF regions was performed in order to determine the most appropriate ones with the account of the following criteria:

- Conformity of ideology for each block (index).
- Equal weighting (equivalence) of figures within one block.
- Absence of correlation between the figures inside the index.
- Availability of a figure or parameters included into it (sufficiency of figures, transparence of calculations, possibility of calculations).

For this purpose principles of index selection were also complied with, which principles include the following criteria: Objectivity, adequacy, specificity (single-valuedness), comparability. In the process of selection possible figures are determined so that to exclude the high degree of correlation between them.

The index of economic sustainability is calculated based on three figures reflecting both technico-economical, and the financial and economical peculiarities of fuel and energy complex development.

The level of energy self-sufficiency was assessed via energy self-sufficiency factor calculated as relation of the volume of the energy produced to consumption on the territory of a region:

ESSF=PrE/CsE, Where,

**Table 4: Dynamics of Russia's positions in the global energy architecture ranking**

| Rating indices | 2014 | | 2015 | | 2016 | | 2017 | |
|---|---|---|---|---|---|---|---|---|
| | Rank | Points | Rank | Points | Rank | Points | Rank | Points |
| Total | 28 | 0.62 | 39 | 0.66 | 52 | 0.6 | 48 | 0.65 |
| Economic growth and development | n/a | 0.59 | n/a | 0.6 | 57 | 0.5 | 62 | 0.55 |
| Environmental sustainability | n/a | 0.49 | n/a | 0.59 | 80 | 0.6 | 75 | 0.6 |
| Energy availability and safety | n/a | 0.79 | n/a | 0.8 | 42 | 0.8 | 37 | 0.8 |

Source: Compiled by the authors based on files and the information of the world economic forum

**Table 5: Developed system of indicators of a regions typology by the nature of their FEC impact on the socio-economic development of a region**

| Direction of a region's development within sustainable development | Suggested list of indicators for the RF regions typology by the nature of FEC impact on a region's economy | Weighting factor |
|---|---|---|
| Economic sustainability | Energy self-sufficiency of a region's economy, degree of depreciation of plant and equipment in FEC, share of investments in FEC from the total volume of investments into a region | 0.2 |
| Socio-economic sustainability | Share of high performance jobs in FEC from the total number of high performance jobs of a region, share of employed in FEC from the total number of the employed in a region's economy | 0.1 |
| Social sustainability | Electric power availability-to-population ratio | 0.1 |
| Eco-social sustainability | Volume of emissions from FEC enterprises/per capita | 0.1 |
| Environmental sustainability | Share of emissions into air of FEC enterprises from the total volume of pollution | 0.1 |
| Eco-economic sustainability | Declination of GDP energy efficiency value of a RF entity from the average in Russia | 0.1 |
| Management of sustainable development of a region's fuel and energy complex | Energy efficiency of a region's economy, share of off-budget funds in the total volume of financing of events in the field of energy saving and energy efficiency enhancement | 0.3 |

Source: Compiled by the authors, GDP: Gross domestic product

ESSF - Energy self-sufficiency factor.
PrE - Volume of electric power produced on the territory of a region (according to the data of the unified inter - Department Information and Statistical System (EMISS)).
CsE - Volume of the electric power consumed on the territory of a region (according to the data of the Unified Inter-Department of Information and Statistical System (EMISS)).

Regional differences of the factor values are essential: From 4 to 4.5 times exceeding a region's own needs (Tver and Kostroma region) to the necessity of receipt of almost all electric power from beyond the limits of a region (Republic of Ingushetia, Republic of Kalmykia, Jewish Autonomous Region) (Figure 3).

Calculation of energy self-sufficiency factor made it possible to distinguish several types of regions by the nature of this process. The most high values of energy self-sufficiency factor of a region's economic complex is inherent for the regions on the territory of which the major nuclear and heat power plants are located (Figure 4). The special role is played by nuclear power stations which are technologically oriented to significant volumes of energy production ensuring development of average energy intensive productions (due to the self-cost of the energy produced). Thus, Balakovskaya Nuclear Power Station (Saratov Region) produces almost 1/5 of power of all Russian nuclear power plants and 25% of energy of Privolzhsky Federal District. 3 major Russian nuclear power plants produce considerable volumes of electric power: Kalinin (Tver) Region, Kursk and Leningrad Region. Kostromskaya state district power plant is one of the major heat power plants not only in Russia, but also in Europe, where for the first time in the world practice of energy building the block with a capacity of 1.2 GW has been installed.

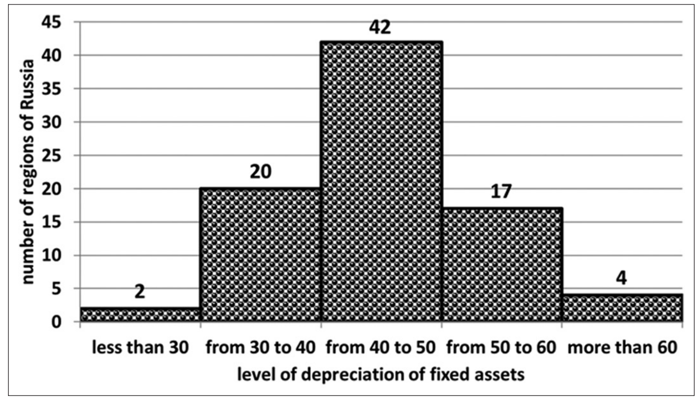
Nature of the present-day technological development was assessed via analysis of the capital funds depreciation figures of the enterprises of fuel and energy complex (Figure 5).

In a half of the RF regions depreciation of plants and equipment in heat and electric power industry amounts to 40–50%, while only in 2 regions (Tule region and the Republic of Altai) it is <30%.

We applied investment as an index characterizing the level of immobilization of possibilities to enhance the degree of novation implementation on FEC enterprises and making it impossible to impact on the energy efficiency of production in this field, in the context of evaluation of possibilities of technical development potential providing for both energy and economic sustainability as a whole.

Regional peculiarities of the investment process are characterized by the significant disproportions. Analysis of dynamics of investments into extraction of fuel and energy resources reveals considerable growth of investment volumes into the capital assets of mining companies only in the Uralsky Federal District, which is also the leader in the share of this type of investments in the total volume of investments of the federal district. The basic enterprises of major state oil and gas companies of the country are situated on the territory of the federal district.

**Figure 5:** Groups of regions by the level of capital funds depreciation on the enterprises of the RF fuel and energy complex




Source: Compiled by the authors according to the data of the federal state statistics service

Investments into production and distribution of electric power, gas and water are the most considerable in regions of the central federal district (amount to around 15% from the total volume of investments) as the main consumer of electric power both for industrial and household use.

The significant investments come to the most populated regions - the federal cities (Moscow, Saint-Petersburg) and leaders in extraction of fuel and energy resources (Khanty-Mansi Autonomous Area, Yamalo-Nenets Autonomous Area).

For analysis of energy social sustainability factor the electric power availability-to-population factor was calculated making it possible to form a quantification of ability of the population to realize satisfaction of energy needs of the population:

$$EAF=(\frac{Tec}{Ter})/(\frac{Smins}{Sminr})$$ , Where

EAF - energy availability factor,
Tec - value of the straight-line regional tariff for electric power for population
Ter - value of the straight-line average Russian tariff for electric power for population (calculated as weighted average value)
Smins - subsistence minimum in a region.
Sminr - value of Russian average subsistence minimum.

In order to calculated indices of environmental and eco-social sustainability the most representative figures were chosen characterizing the role of fuel and energy complex in the environmental situation of a region's territory.

Environmental sustainability is valued based on the figure of the share of emissions into the air by FEC enterprises form the total volume of pollution of a region.

Analysis of figures of environmental sustainability makes it possible to distinguish several emerging groups of regions by the nature of impact of FEC enterprises on this process. The most difficult situation is in major industrial centers of the Siberian Federal District, where in the context of significant volumes of emissions their share in the total structure is extremely low (Figure 6). Primarily at the account of development of multi-sector and, as a rule, energy intensive economy. And the most favourable situation is in Russian regions the most problematic from the perspective of socio-economic development: Republics of North caucuses and the Southern Siberia.

A region's GRP energy intensity is the indicator of eco-economic sustainability evaluation. Calculation of energy intensity of a region's GRP is reasonable to be conducted based on the developed methods and algorithms of GRP energy intensity calculation by components of regional fuel and energy balance suggested by the team of Samara state university of economics (Tsybatov, 2016).

Evaluation of GDP energy intensity dynamics may be characterized by a certain conflict between the requirements to reduce the energy intensity of the economy and the district-forming role of energy intensity industries, in the conditions when transition to priority development of the service sector is possible in by no means all Russian regions. That is why the key indicators of energy-efficient development of a RF region's economy should be balanced with the key indicators of socio-economic development of that region, and they must not conflict with each other (Figure 7).

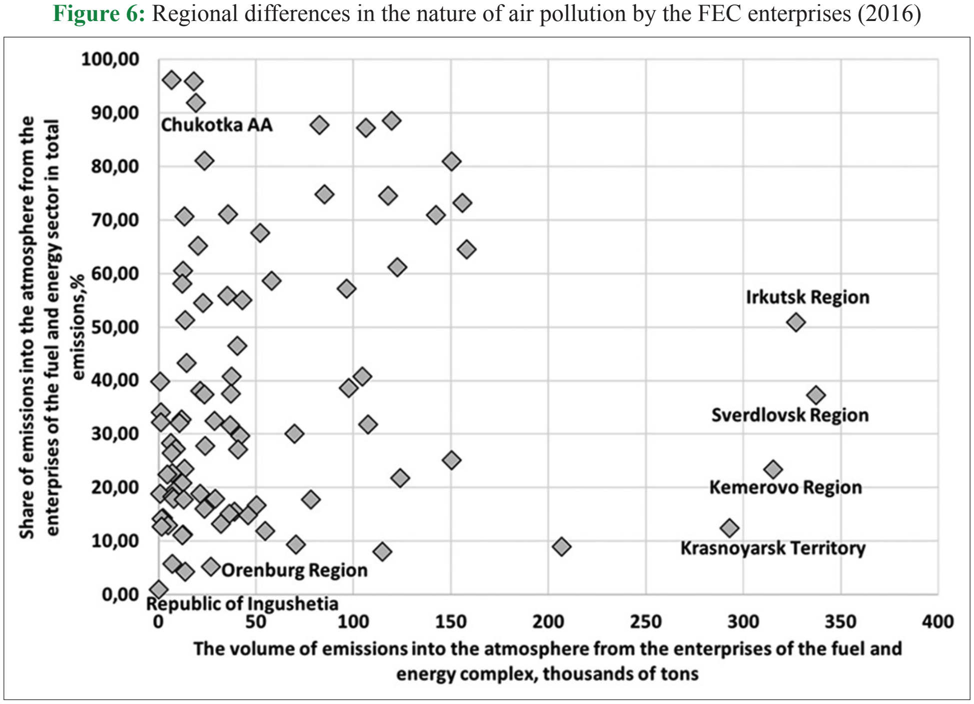
Besides, evaluation of GDP energy intensity dynamics through the traditional figures being applied in analysis methods widely-recognized abroad (a ton of reference fuel per unit of cost measurement of gross domestic product for economy as a whole or turnout for an industry) fails to give any clear understanding of changes in technological level of production. For example, when evaluating dynamics of energy intensity using values measured in terms of money, one may see a negative dynamics in metallurgy, in paper-pulp industry, in production of construction materials, and positive dynamics in machine building, agriculture and chemical production. The question of how strongly such dynamics was influenced by the pricing environment of the relevant markets, and shifting of the intra-industry turnout structure towards production of goods with a higher added value, remains to be open (Bashmakov and Myshak, 2012).

Analysis (study) of dynamics and forecasted value of energy intensity of gross regional product must be based on factor analysis. Traditionally, study of processes that form figures of GRP energy intensity is built on the analysis of gross regional product structure, the level of physical depreciation and obsolescence of the equipment, potential for energy saving in various sectors of the economy and the regulatory framework governing energy efficiency of energy consumption (primarily, the fiscal system with the developed system of incentives, open and clear for all the interested parties), and on the diversity of tools and methods used in the field of energy saving by all economic entities, and energy literacy (level of awareness and interestedness of the staff in energy saving, necessity in economical and efficient usage of energy resources).

Change of GRP energy intensity is possible in three variants (scenarios). The most problematic one is energy intensity growth in the context of increase of the consumed energy volume and reduction of the produced GRP volume. But reduction of energy intensity may also be ambiguous, as it may be achieved at the account of growth of both figures in the conditions of higher rates of GRP growth or at the account of increase of GRP volumes in the context of reduction of the consumed energy volume (Gasho and Stepanova, 2015).

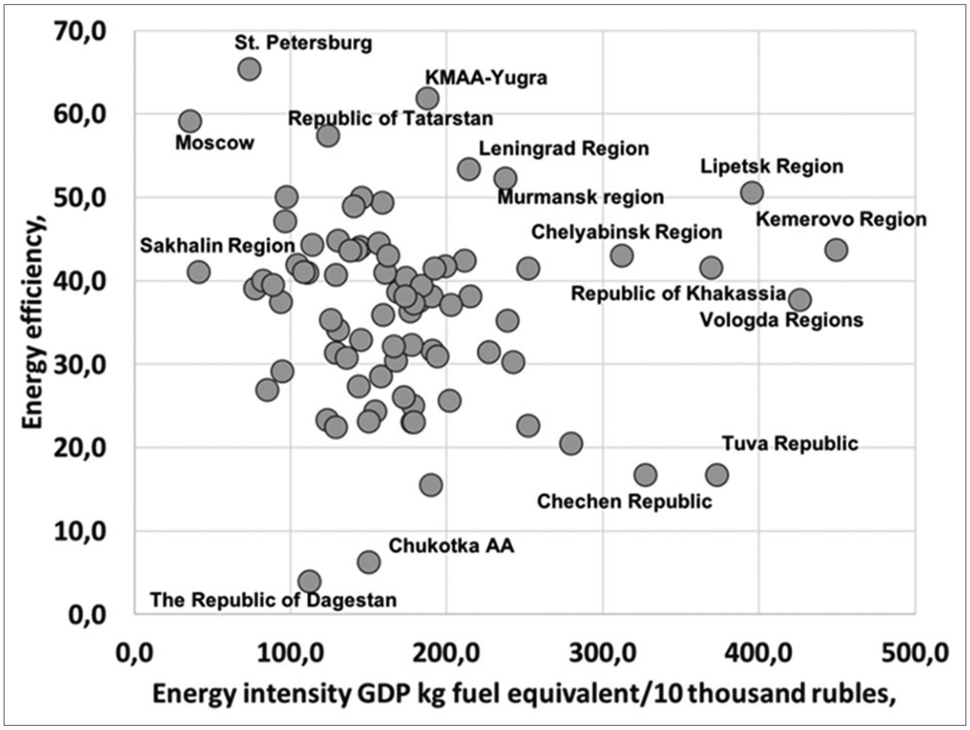
We suggest as methodological approaches to this evaluation to consider the internationally-accepted approach being used both in ODYSSEE program (Directorate for Energy of the European Commission) and in methodology of the IEA.

**Figure 6:** Regional differences in the nature of air pollution by the FEC enterprises (2016)




Source: Compiled by the authors according to the data of the federal state statistics service

**Figure 7:** Groups of RF regions by the level of energy efficiency and GRP energy intensity




Source: Compiled by the authors based on the data of the Federal state statistics service and the ministry of energy of the RF

The general algorithm involves the following stages of forecasting (Dolmatov and Shutova, 2014):

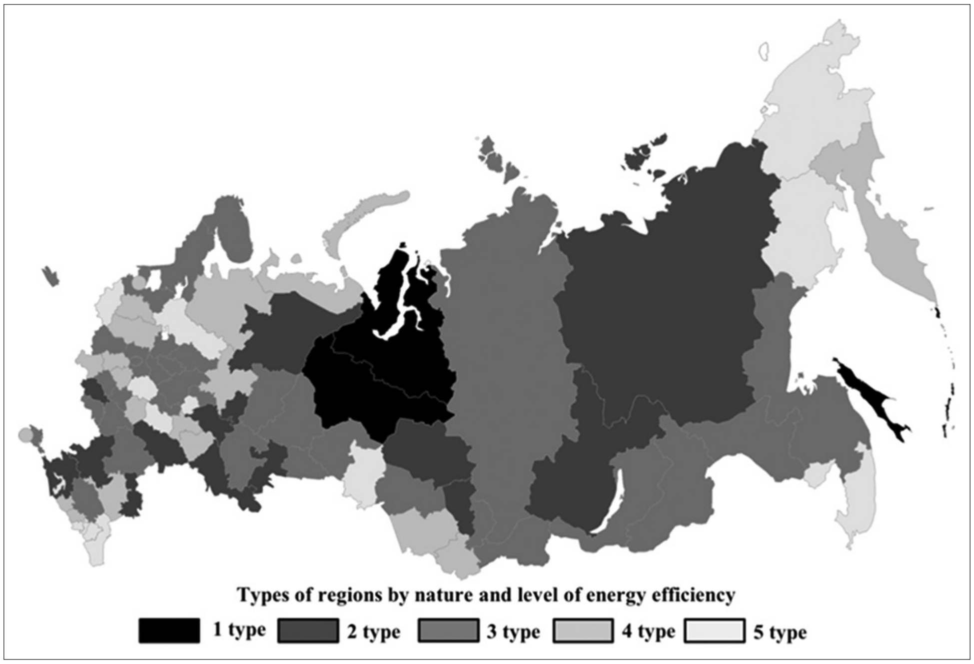
a. Factor analysis of GDP energy intensity change in retrospective. With such factors as structure factor (being measured through the change of economic activity indicators by economy sectors), technical progress (being measured through specific consumption of fuel and energy resources for product output in monetary terms), structure of fuel and energy balance (being measured through the share of consumption of separate types of fuel and energy resources in total consumption) being distinguished. ODYSSEE program also involves possibility of analyzing impact on the energy intensity of such factors as climatic factor, the level of housing improvement (expressed though the share of centralized heating) and the average household size. The result of factor analysis is coefficients reflecting input of each factor change into the aggregate change of GDP energy intensity.
b. Long-term forecast of the studied factors change. In this context based on the experience of implementation of the best available technologies the so called energy efficiency indices are separately forecasted, which make it possible to take into account the long-term input of the technological progress.
c. GDP energy intensity forecast based on coefficients calculated within factor analysis. The advantages of this approach implementation should include the high level of the necessary original data aggregating, possibility of international comparisons of the forecasted figures. The disadvantages of the approach as it pertains to its implementation in Russia are as follows: Absence of comparable statistical data on the change of the main energy intensity factors in the long-term and difficulty of implementing the wide-spread methods of correlation analysis due to essential fluctuations of figures being calculated in monetary terms, for the long term and retrospectively (Bashmakov, 2011).

Therefore, we find it necessary to take into account the following factors as the set of the main factors with an essential impact on GRP energy intensity:

- Climatic and special group of factor
- Group of factor reflecting sectoral and territorial structure of a region's economy
- Group of factors of a territory's self-sufficiency in energy resources
- Factors of energy consumption sector structure
- Pricing group of factors
- Group of technological factors (technologies in electric power and heat supply of end-users, and the nature of production capacity use).

Evaluation of efficiency of a RF region's sustainable energy development management was performed based on analysis of the RF regions' energy efficiency ranking being compiled by the Ministry of Energy of the RF according to the statistical data of the Federal State Statistics Service and the data of the RF regions' energy declarations and the share of non-budgetary funds in the total volume of financing of events in the field of energy saving and energy efficiency enhancement. Values of the energy efficiency index were adjusted with the account of its dynamics. For regions where the index growth for the analyzed period amounted to more than 5%, the final values were received with the account of 1.25 factor, and for regions where the index reduction (full in energy efficiency level) amounted to more than 5% with 0.75 factor, and if more than 50% with 0.5 factor.

**Figure 8:** RF regions typology by the nature of influence of economy energy efficiency enhancement processes on the socio-economic development




Source: Compiled by the authors according to the data of the Federal State Statistics Service, 2016 and the Ministry of Energy of the RF, 2017

## 5. CONCLUSION

The developed authors' methods of regional economy energy efficiency diagnostics reflect high correlation between technical-and-economic figures with energy efficiency and energy security of the regions under study (Figure 8).

Therefore, 5 types of regions by nature of impact of the fuel and energy complex on the social and economic development of a territory was distinguished. The 1st type is energy excessive regions with export-oriented fuel and energy complex, which fall into the area of interest of major public energy companies. The 2nd type is regions with the developed diversified FEC infrastructure and multi-sector structure of economy. The 3rd type is regions with energy intensive sector structure of economy and insufficiency of own energy resources. Regions with weak energy base and difficult natural and geographical conditions, and low social and economic development fall into the 4th and the 5th types.

The conducted analysis of methods emerged in the world and Russian practice to evaluate the energy efficiency level revealed absence of the shared vision to interpretation of figures. At the present moment two approaches in application of energy efficiency figures prevail: Diagnostics is conducted either through the analysis of GDP or GRP energy intensity (Russia, Kazakhstan) or through the analysis of carbon dioxide emissions dynamics on the analyzed territory (European Union countries). As the result, evaluation of energy efficiency has no signs of comprehensiveness.

The writing teams see solution of this problem in implementation of the authors' methods of a territory's economy energy efficiency diagnostics, which are conceptually based on the accounting of figures within analysis of 7 criteria characterizing the sustainable development of a territory's social and economic system: Economic, social, environmental, socio-ecological, socio-economic, eco-economic criteria and the energy efficiency management mechanism. The suggested approach makes it possible to evaluate the role of various factors, including the nature of their impact on the tools of government support in implementation of events in the field of energy saving and energy efficiency enhancement of certain territories.

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