

# An energy efficiency forecast for the economy of Irkutsk region

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**Abstract.** The energy efficiency of the Russian economy lags far behind that in the developed countries of the world. The enhancement of the energy efficiency and, first of all, the energy saving, is the source that can provide an additional economic growth through organizational and technical measures. The object of research is the economy of the Irkutsk region, whose energy efficiency increase is of particular relevance due to the high energy intensity of the economy. The study aims to perform an energy-economic analysis of the Irkutsk region and to make a forecast of the increase in the energy efficiency of the economy. A methodological approach proposed for the research is based on balance and statistical methods. The research involves the development of retrospective energy balances of the Irkutsk region and the calculation of energy efficiency indicators on the basis of these balances. Moreover, based on the statistical methods, the equation of the energy-GRP ratio is devised. The forecast for the energy and economic development of the Irkutsk region is made, the forecast energy balances are developed, based on them, the energy intensity of the regional GRP is calculated for the long term, and measures to increase the energy efficiency are proposed.

## 1. Introduction and Background

The main indicator that gives an idea of the state of the energy efficiency of a particular country or its regions is the energy intensity of the gross domestic / regional product (GDP / GRP). The energy intensity of Russia's GDP significantly exceeds this figure in the most developed economies, for example, by 1.6 times that in the United States, by 2.2. times that in Japan, and by 3.7 times that in Switzerland. This results in high energy intensity of production which requires more material, labor and financial resources. The increased specific consumption of energy resources during production leads to environmental degradation, increased rates of development of fuel deposits and their accelerated depletion, which will have a negative impact on future generations of Russians. Therefore, the enhancement of the energy efficiency in the country and its regions is one of the most important priorities of the state energy policy and socio-economic development.

In the Irkutsk region, the energy-GRP ratio is 1.5–2 times higher than the national average, which makes it necessary to develop special methods and models for studying the energy development of the Territory in order to optimize the energy use.

The problem of energy efficiency increase is solved by a variety of methods and approaches that proved to be scientifically and practically sound [1-18]. However, each specific region has its own characteristics, which can be taken into account with an individual approach. There are also a number of tasks regarding the modeling of the influence of various factors on the energy intensity of GRP. The



problem of forecasting the energy intensity of GRP depending on the dynamics of production indicators of the energy sector and the development of the regional economy remains poorly studied.

All this indicates the relevance of the study aimed at determining the extent to which the production indicators of the energy sector impact on the dynamics of energy-GRP ratio of the Irkutsk region.

The Irkutsk region is one of the largest regions in Russia. Its area is 774.8 thousand km<sup>2</sup> (4.5% of the entire country). The population of the Irkutsk region is about 2.4 million people (1.6% of Russia's population). The share of the Irkutsk region in the country's GRP production is 1.6%, the volume of industrial production makes up 1.8% of Russian, and per capita cash incomes make up about 71.3% of the national average level.

The economy of the Irkutsk region is oriented to the capital-intensive and energy-intensive production based on rich natural resources; and to the production of intermediate products to be delivered to other regions of Russia and exported to the countries of FSU and non-FSU countries.

The share of the Region's energy sector products in the total volume of goods shipped in 2017 was 40%, of which the main share (above 80%) falls on the production of oil, natural gas and coal.

The state of energy efficiency indicators of the Irkutsk region is worse than the average in Russia, which depends both on the objective factors (colder and longer winters, high-energy-intensive industry specialization, low population density), and the technological lag in a number of industries (primarily in the energy sector). This is confirmed by higher specific consumption of fuel and energy for the production of energy carriers in the Region.

The importance of the energy efficiency enhancement in the Irkutsk region is recognized by the regional Government. As a result, the state program of the Irkutsk region "Energy Efficiency and Energy Development" was adopted. Its aim is to develop the energy sector at a fast pace for sustainable socio-economic development of the Irkutsk region. One of the main objectives of the program is to increase the efficiency of energy supply and consumption in the Irkutsk region. This will decrease the energy intensity of GRP by 5.5% by 2024 compared to 2017. The implementation of the program will significantly increase the energy efficiency of the region and improve the quality of life of the population in the Region.

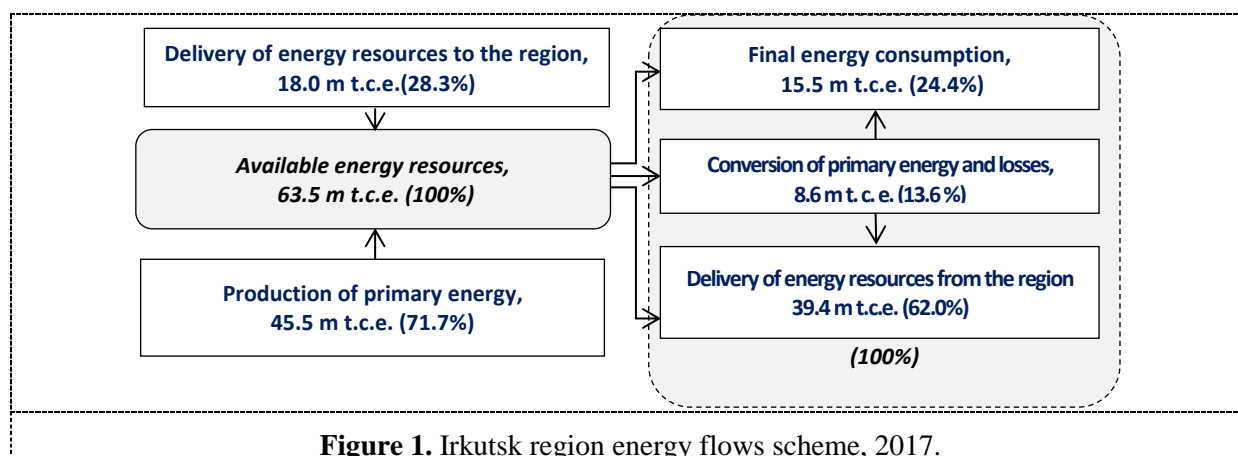
## 2. Materials and Methods

The objective of the research is to perform an energy-economic analysis of the economy of the Irkutsk region using the available retrospective data, and based on this analysis determine the effect made by the production indices of the energy sector on the energy efficiency of the region. A comprehensive energy-economic analysis of the economy of the Irkutsk region requires that the energy balances for the period of 2005-2017 be constructed. It is also necessary based on the statistical methods to build correlation and regression relationships between the main energy efficiency indicator of the regional economy, i.e. energy-GRP ratio, and the dynamics of gross energy resources consumption. A long-term forecast of the energy efficiency increase in the Irkutsk region is to be made.

We have developed a methodological approach to the energy-economic analysis and assessment of the regional energy-economic efficiency based on the energy balances [19, 20]. The approach is an extension of the research done by the Russian and world scientists in this field [1-18], since it allows for the regional specifics and investment policy of the region, and the state energy policy pursued by the Government of the Russian Federation. The research is based on the proposed information-computing system, consisting of an information-reference system and a system of models: of single-product balances of individual types of energy resources, consolidated energy balances, an energy-economic analysis and a statistical analysis of factors that influence the energy efficiency of the regional economy. The information-reference system is used to provide the researcher with access to the information presented in a form specified by the user and is convenient for analysis. In this study, we determine the impact of growing production indices of the energy sector on the energy-GRP ratio of the Irkutsk region.

### 3. Experimental Section

The energy efficiency analysis of the energy resources use in the Irkutsk region was made on the basis of the energy balance (Figure 1, Tables 1, 2).



Retrospective energy balances of the Irkutsk region are constructed for 2005-2017 to perform an energy-economic analysis (table 1).

In the period of 2005-2017, the production of primary energy rose by 3 times (mainly due to the production of hydrocarbons), and the export of energy resources - by 4 times. A negative fact is the increase in total losses of energy resources by 2.6 times (mainly due to the losses in the oil and gas industry). It is also worth noting that the indices of energy efficiency in the Irkutsk region are considerably worse than those average in Russia (table 2).

**Table 1.** Irkutsk region energy balance\*, m. t.c.e.

Year	Production of primary energy	Energy delivery to the region	Energy delivery from the region	Generation of electricity and heat	Energy consumption for electricity and heat production	Total energy losses	Final energy use
2005	15.1	13.5	-10.0	13.6	-15.6	-3.3	-15.3
2006	15.5	14.0	-10.2	13.5	-15.5	-4.1	-15.2
2007	15.7	15.0	-10.6	12.8	-15.7	-5.3	-14.8
2008	17.5	16.0	-13.2	13.0	-16.9	-6.4	-13.9
2009	18.3	17.1	-15.1	12.7	-15.2	-6.1	-14.2
2010	21.3	18.3	-19.1	14.2	-16.6	-5.9	-14.6
2011	27.6	19.3	-25.5	13.7	-16.4	-6.1	-15.3
2012	33.0	20.0	-29.7	13.9	-17.9	-7.2	-16.1
2013	34.0	20.0	-30.5	12.6	-15.7	-7.7	-15.8
2014	36.7	19.3	-32.2	12.6	-15.0	-7.7	-16.1
2015	40.6	18.0	-34.7	11.7	-13.8	-7.8	-16.1
2016	45.0	18.3	-39.3	11.8	-14.1	-7.8	-16.2
2017	45.5	18.0	-39.4	11.4	-14.1	-8.6	-15.5

The equation of the multiple regression model for the energy-GRP ratio of the Irkutsk region was formed based on the data obtained from retrospective energy balances, i.e. gross consumption of primary energy (a sum of primary energy resources produced, delivered to and from the region) (table 1).

**Table 2.** Main energy efficiency indicators.

Indicator	Irkutsk region					RF***
	2005	2010	2015	2016	2017	2017
GRP in 2017 prices*, billion rub	678	919	1127	1159	1192	74927
Energy-GRP ratio**, kg c.e./thousand rub	27.4	22.3	21.2	20.5	20.2	10.9
Electricity-GRP ratio, kWh/rub	77.5	59.1	45.8	46.3	45.2	14.5
Heat-GRP ratio, Gcal/rub	73.4	44.1	36.9	37.1	37.7	17.0
Specific fuel consumption to generate:						
- electricity at thermal power plants, g.c.e./kWh	323.1	327.2	331.6	327.2	336.4	303.7
- heat at thermal power plants, kg c.e./Gcal	156.9	152.4	158.8	157.8	160.8	156.6
- heat at boiler plants, kg c.e./Gcal	181.7	183.7	191.2	193.3	182.7	166.6

Note - \*GRP in 2017 prices is calculated by the data of Russian Statistics Agency "Rosstat"; \*\* energy-GRP ratio is calculated by gross consumption of primary energy; \*\*\* for comparison

The least-squares method was used to develop an equation of the multiple regression model for the energy-GRP ratio of the Irkutsk region:

$$Y_1 = 21.201 + 1.3 \cdot X_1 - 0.028 \cdot X_2, \quad (1)$$

where  $Y_1$  – energy-GRP ratio, kg c.e./thousand rub;

$X_1$  – gross consumption of primary energy, million t.c.e.;

$X_2$  – GRP in 2017 prices, billion rub.

Gross consumption of primary energy is:

$$X_1 = 17.037 + 0.168 \cdot X_3, \quad (2)$$

where  $X_3$  – production of primary energy, million t.c.e.

The correlation coefficient of equation (1) (0.985) showed the presence of a considerable statistical relationship between the variables and the energy-GRP ratio. The statistical validity of the obtained equation (1) is estimated by the level of significance of the Fisher criterion, where  $p = 2.11 \cdot 10^{-8} < 0.05$ , which confirms the good adequacy of the description of the relationship between the energy-GRP ratio of the Irkutsk region and the explanatory variables.

The correlation coefficient of equation (2) is 0.963, the Fisher criterion is  $p = 1.36 \cdot 10^{-7}$ .

#### 4. Results and Discussion

Equation (1) was used to forecast the energy-GRP ratio of the Irkutsk region in 2020–2050. To this end, we made a forecast of the economic and energy development of the Irkutsk region. Scenario 1 corresponds to the lower limit of moderate economic and energy development, and Scenario 2 corresponds to a more optimistic development (table 3). Energy consumption growth over the period of 2020-2030 was calculated using the energy balance models. According to the forecast, Scenario 1 suggests that the average annual growth rate of the production of primary energy for the period 2017-2050 will be 2.0, Scenario 2 indicates 2.5%. The average annual growth rate of GRP in Scenario 1 is 1.1%, in Scenario 2 - it is 1.5%.

In 2050 (versus 2017), the energy-GRP ratio of the Irkutsk region will decline by 32% in Scenario 1 and by 67% - in Scenario 2 (Table 3).

The growth of energy efficiency of the economy in the Irkutsk region depends on the energy-saving measures to be implemented in all spheres of economic activity, which will allow reducing the costs of energy production and consumption, minimizing their losses, achieving planned indicators of socio-economic development with lower energy expenditure and financial costs.

**Table 3.** Irkutsk region energy-GRP ratio forecast.

Year	Production of primary energy, m. t.c.e.		Gross consumption of primary energy, m. t.c.e.		GRP*, billion rub		Energy-GRP ratio*, kg c.e./thousand rub	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
2017	45.5		24.1		1192.0		20.2	
2020	48.3	49.0	25.2	25.3	1231.9	1246.5	19.9	19.7
2025	53.3	55.4	26.0	26.4	1301.1	1342.9	19.1	18.4
2030	58.9	62.7	27.0	27.6	1374.3	1446.7	18.3	17.2
2035	65.0	71.0	28.0	29.0	1451.5	1558.5	17.5	15.9
2040	71.7	80.3	29.1	30.6	1533.1	1678.9	16.8	14.6
2045	79.2	90.8	30.4	32.3	1619.3	1808.7	16.0	13.3
2050	87.5	102.8	31.8	34.4	1710.4	1948.4	15.3	12.1
Growth (+), reduction (-)	+1.92	+2.26	+1.32	+1.43	+1.43	+1.63	-1.32	-1.67

Note - \* in 2017 prices; Scenario 1 – lower bound of the moderate economic and energy development; Scenario 2 – upper bound of the moderate economic and energy development

## 5. Summary and Conclusion

In the course of the research, we constructed retrospective energy balances for the period of 2005–2017 and used them to make an energy-economic analysis. Some of the problems facing the energy sector of the Irkutsk region have been identified: high specific fuel consumption for the production of electricity and heat from thermal power plants and boiler plants compared to the average Russian indicators; growth of total energy losses in the oil and gas industry; the large dependence of electricity generation on hydropower. All these factors have an impact on the energy-GRP ratio of the Irkutsk region.

The least-squares method was applied to devise an equation of the multiple regression for the energy-GRP ratio of the Irkutsk region depending on the gross consumption of energy resources. The multiple regression equation was applied to forecast the reduction in the GRP energy consumption. A preliminary forecast of the energy and economic development of the Irkutsk region was made. In the period of 2017-2050, the energy-GRP ratio can decrease by 1.3-1.7 times, depending on the growth rate of the economy and the energy sector.

The obtained results can be used to predict the dynamics of changes in the energy-GRP ratio, depending on the development of the economy and energy industries of the Irkutsk region. Based on the proposed model, the executive authorities of the region can receive information about the planned change in the main indicator of the energy efficiency, i.e. energy-GRP ratio in the Irkutsk region.

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