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COMPARATIVE ESTIMATION OF POWER EFFICIENCY OF COUNTRIES AND WORLD REGIONS

The estimation of power efficiency of Russia's economy in comparison with other regions of the world by means of various indicators is carried out in the article. The rates of change in gross domestic product and manufacturing power-intensity are calculated. Dependencies between power consumption in various regions of the world, power-intensity, gross domestic product growth, and greenhouse gas emissions are analyzed. The reasons for high power-intensity of Russian economy are determined. The basic directions for increasing Russia's economic power efficiency are outlined.

Keywords: *power efficiency; gross domestic product; power consumption; power-intensity; greenhouse gas emissions.*

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ПОРІВНЯЛЬНЕ ОЦІНЮВАННЯ ЕНЕРГОЕФЕКТИВНОСТІ В КРАЇНАХ І РЕГІОНАХ СВІТУ

У статті проведено оцінювання енергоефективності економіки Росії у порівнянні з іншими регіонами світу за допомогою різноманітних індикаторів. Розраховано темпи змін ВВП та енергоємності виробництва. Проаналізовано залежність між споживанням електроенергії в різних регіонах світу, енергоємністю, ростом ВВП та викидами парникових газів. Визначено причини високої енергоємності економіки Росії. Запропоновано основні напрямки підвищення енергоефективності економіки Росії.

Ключові слова: *енергоефективність; валовий внутрішній продукт; енергоємність; енергоспоживання; викиди парникових газів.*

Рис. 2. Табл. 3. Літ. 19.

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СРАВНИТЕЛЬНАЯ ОЦЕНКА ЭНЕРГОЭФФЕКТИВНОСТИ СТРАН И РЕГИОНОВ МИРА

В статье проведена оценка энергоэффективности экономики России в сравнении с другими регионами мира с помощью различных индикаторов. Рассчитаны темпы изменения ВВП и энергоемкости производства. Проанализирована зависимость между потреблением электроэнергии в различных регионах мира, энергоемкостью, ростом ВВП, выбросами парниковых газов. Определены причины высокой энергоемкости экономики России. Намечены основные направления повышения энергоэффективности экономики России.

Ключевые слова: *энергоэффективность; валовой внутренний продукт; энергоемкость; энергопотребление; выбросы парниковых газов.*

Problem statement. Today the problem of efficient energy use is one of the most actual for the development of industrially developed countries. This problem is especially important for Russia. Nowadays Russia builds new economy on the basis of technical modernization and import substitution. Innovations in industrial area should provide sustainable development of the country. However, sustainable development cannot be identified only by steady economic growth, i.e. the maximum total revenue. It is crucial what the standard of this growth will be. This importance is

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defined by the need for situation diagnostics for the purpose of determining directions in power efficiency increase. The important area in this diagnostics is revealing the comparative dynamics, identification of tendencies and dependences in power efficiency formation.

Latest research and publications analysis. In the most widespread economic understanding energy efficiency is a relative index weighting the use of energy supply and results (effects). Individual scientists, research teams, and international organizations brought up the problem of energy efficiency as an urgent one. Research of such Russian scientists as I.A. Bashmakov (2003), S.N. Bobylev et al. (2010), V.I. Danilov-Danilyan et al. (2005) etc. are widely known. Energy efficiency indicators were research subjects for the Institute of Oil and Gas of the Russian Academy of Sciences, Institute of Sustainable Development of Public Chamber of Russian Federation, the Center of Ecological Policy of Russia, Russian Center on Effective Energy Use and other organizations. The analyses carried out regularly by the World Bank, the UNDP are also of huge practical and scientific importance.

The purpose of this study is to carry out the comparative assessment of energy efficiency of countries and regions of the world, basing on world and Russian experience, and to consider the Russian aspect of the power efficiency problem.

Key research findings. In various countries certain experience of the use of energy efficiency indices has been accumulated. In the range of energy efficiency measurement it is possible to distinguish two basic approaches. Both approaches are actively used in theoretical research and practice. According to the first approach, only the result (or effect) is energy efficiency assessment. For example, the economies of energy supply or decrease in electric power consumption (Zapivalov, 2002). It is impossible to call this approach correct from the economic point of view because the costs of result achievement are not taking into account. The other approach assumes the correlation of economic results (volume of output, gross domestic product etc.) and power inputs (energy supply consumption, costs of energy production etc.). For example, according to the statistics of the United Nations and the World Bank the energy efficiency index is considered to be a correlation of gross domestic product and the consumed energy in terms of oil equivalent (Power efficiency in Russia: the buried reserve; Oxford Economic Model, 2014). There are ample opportunities for adaptation of these indices for estimation of development stability of Russia and its regions.

In Russian statistics the energy intensity index is often applied as the key energy indicator. Logically, it is a converse indicator relative to energy efficiency. Energy intensity shows the relationship of consumed electric power volumes to gross domestic product. This indicator is also used by some organizations in other countries, for example, the US Department of Energy (International Energy Outlook, 2014).

The other indicator of energy efficiency is power consumption. This indicator identifies the quantity of energy used by a country for industrial and household needs (Baranov and Skufina, 2005). Various departments in many countries of the world actively use the power consumption estimation.

However, the imperfection of these approaches to energy efficiency assessment lays in the absence of ecological component. For estimating energy efficiency we suggest to take into account not only economic factors, but also the ecological ones.

Table 1. **World gross domestic product by regions expressed through purchasing power parity (bln 2005 USD),** *calculated based on the data from* (Russia in Energy Sphere)

Region/ Country	2005	2007	2009	2011	2015*	2025**	2035**	Growth rate of GDP, %		
								2015 by 2005	2025by 2015	2035 by 2025
America	15260	16035	15498	16267	18016	23279	29306	118.06	129.21	125.89
Europe	13826	14806	14262	14976	15476	19752	23972	111.93	127.63	121.36
China	5387	6934	8299	10019	13264	24055	38867	246.22	181.36	161.58
India	2432	2922	3364	3932	4722	8919	14272	194.16	188.88	160.02
Japan	3889	4040	3776	3927	4198	4661	4858	107.95	111.03	104.23
Russia	*1701*	*1997*	*1938*	*2108*	*2358*	*3168*	*3954*	*138.62*	*134.35*	*124.81*
Brazil	1586	1749	1833	2025	2197	3069	4267	138.52	139.69	139.04
Mexico/ Chile	1504	1639	1575	1735	1988	2793	3457	132.18	140.49	123.77
Canada	1132	1190	1165	1233	1336	1716	2098	118.02	128.44	122.26
South Korea	1097	1212	1244	1371	1529	2110	2560	139.38	138.00	121.33
Australia/ New Zealand	690	742	771	806	905	1163	1448	131.16	128.51	124.51
Total World	**59655**	**66112**	**67192**	**73227**	**83533**	**123220**	**173300**	**140.03**	**147.51**	**140.64**

In Tables 1, 2 and Figure 2, 3: * in 2015 – expected value; ** in 2025 and 2035 – forecasted values.

Energy efficiency assessment cannot be complete without environmental effect of factors of influence.

We will carry out the world gross domestic product (GDP) analysis by region expressed thorough purchasing power parity (Table 1).

According to short-term forecasts on GDP volume the leading place is occupied by America. Nonetheless, according to the Oxford Economic Model, it is expected that by 2025 America will be overpassed by China (Russia in Energy Sphere).

The analysis shows that in 2005–2015 China has the highest rates of GDP growth – by 246.22%. Hereafter the rate of GDP increase of China will decrease a little: in 2015–2025 it will make up 181.36%, and in 2025–2035 – 161.58%. India ranks second to China by GDP increase: in 2005–2015 its GDP increased almost twice. As predicted, in 2015–2025 its rate of GDP increase will be 188.88%, and in 2025–2035 – 160.02%. Russia's rate of GDP increase in 2005–2015 made up 138.62%. It is less than the average worldwide one (140.03%). In the long term this value will decrease even more. At present the economy of Russia is on the 6th place by GDP index. As predicted, Russia' economy might be the 7th by 2035 giving up its current place to Brazil (Oxford Economic Model, 2014).

World GDP by region expressed in purchasing power parity is the major index of economic development. However, power indicators characterize the stability of country's development as a whole and its manufacturing sector. These indicators enable estimating the energy efficiency.

According to experts' assessments by the Institute of Oil and Gas of the Russian Academy of Sciences (RAS), almost all models of sustainable development of terrestrial civilization proceed from the necessity for increase in power consumption per capita (Zapivalov and Smirnov, 2002). This conclusion is borne out with News agency researches at the US Department of Energy (International Energy Outlook, 2014). The World Total Primary Energy Consumption outlook till 2035 specifies the substantial growth in power consumption by many countries (Figure 1).

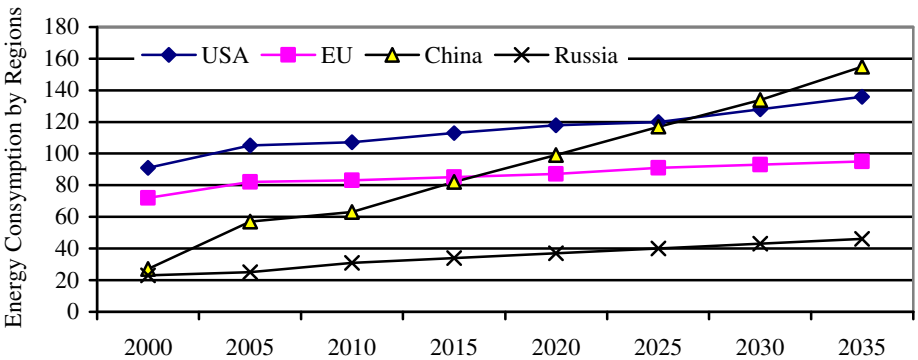

Figure 1. **The dynamics of power consumption by some countries (Joule*1018),** *calculated according to* (International Energy Outlook, 2014)

Nowadays and in near future America has the greatest power consumption. The European Union takes the second place. However, according to the US Energy Information Administration projection, it is expected that by 2030 both regions will be overtaken by China (International Energy Outlook, 2014).

Table 2. Power intensity of the selected economies (megaJ/USD), *calculated according to* (International Energy Outlook, 2014)

Region/ Country	2005	2007	2009	2011	2015	2025	2035	Rate of power intensity decrease %		
								2015 by 2005	2025 by 2015	2035 by 2025
Russia	*17.06*	*16.64*	*12.97*	*11.32*	*10.08*	*9.01*	*7.89*	169.25	111.88	114.20
Canada	14.63	14.27	13.47	11.95	11.03	10.18	9.43	132.64	108.35	107.95
South Korea	13.43	13.27	10.31	8.55	7.76	7.14	9.28	173.07	108.68	76.94
USA	10.06	9.92	8.49	7.58	6.74	5.97	5.37	149.26	112.90	111.17
Australia and New Zealand	9.61	9.59	8.80	7.85	6.97	6.20	5.50	137.88	112.42	112.73
China	7.47	8.14	6.58	5.48	4.65	3.99	3.46	160.65	116.54	115.32
European Union	7.73	7.68	6.75	6.00	5.26	4.70	4.20	146.96	111.91	111.90
Japan	7.12	7.09	6.41	6.01	5.75	5.53	5.32	123.83	103.98	103.95
Mexico	7.03	6.85	6.78	6.16	5.58	4.97	4.44	125.99	112.27	111.94
Brazil	6.66	6.64	6.51	5.59	5.10	4.68	6.09	130.59	108.97	76.85
India	4.42	4.36	3.33	2.94	2.57	2.24	1.92	171.98	114.73	116.67

Calculations show that China has the greatest rate of power consumption increase – 5.39. India and South Korea follow China: India – 3.99, South Korea – 3.57. Russia has insignificant power consumption increase – only 1.07.

We should pay attention to decrease in the rates of power consumption increase for all countries in 2010 due to the world economic crisis. Decrease in volumes of output and economic "failures" led to power consumption decrease (Baranov, 2012; Skufina, 2013).

Power intensity is one of basic power indices. In this regard power intensity is the indicator, necessary for programs and strategies on development of states and world regions (Bashmakov, 2003; Samarina, 2012; Danilov-Danilian and Losev, 2000).

Let us analyze the dynamics of power intensity of some developed countries (or regions in case of the European Union) and developing countries with high rates of economic growth (Table 2).

The comparison shows that as of 2015 power consumption of Russia' economy is 1.5 times above the power intensity of the USA, 1.9 times above the power intensity of the European Union, 1.8 times above the power intensity of Japan. The power intensity analysis shows the backlog of Russian Federation not only from economically developed countries, but also from rapidly developing China, Brazil and India.

Herewith the rate of power consumption decrease in Russia is high enough: the indicator of 2015 is 69.25% lower than that of 2005. By the rates of power consumption decrease during 2005–2015 Russia concedes only India (71.98% decrease) and South Korea (73.07% decrease).

The factors mentioned below explain the high level of power consumption within Russian economy:

1. Severe climatic conditions on the biggest part of the country's territory compel to spend electric power on additional heating and light. According to our estimations, the duration of the heating period (the number of days with daily average temperature below 8 degrees Celsius) on the territory of Russia fluctuates from 100 to 350 days; on Northern territories (67% of Russia's territory) 225 to 350 days (Samarina, 2009).

2. Spatial distribution of power consumption objects leads to high costs of transport in the course of manufacturing and realization of Russian production. Economic relations cover various regions of the huge territory of Russia. Mineral deposits are the main source of Russia's well-being. They are distributed very non-uniformly on the territory of the country. In particular, the basic part of iron ores is in European part of the country; nonferrous metal ores – in the East (including the Ural Mountains). Forest resources on the whole are also on the East (about 80%). More than 90% of all fuel and energy resources of the country are located in the Eastern regions (including 95% of national coal reserves). And at the same time the main part of population is concentrated in the West and Southwest of Russia.

3. In the structure of Russian economy staple industry and extracting & processing sectors prevail. They give more than 30% of gross domestic product of Russia. Staple industry enterprises have very high power consumption in comparison with trading enterprises or services (Bashmakov, 2003; Bobylev, 2010).

4. Ageing of key production assets and technologies leads to inefficient use of power and other resources (Baranov, 2012; Skufina, 2010).

At the same time, Russian economy has considerable potential of power consumption decrease. According to the estimations of the World Bank, presented in the report "Energy efficiency in Russia: the buried reserve", Russia at the expense of realization of actions for energy efficiency increase could save up to 45% from the total amount of primary energy consumption. As a result, the country's budget could increase by 112 bln RUB a year (Power efficiency in Russia: the buried reserve).

Consumption of power resources is accompanied by human impact on the environment. We compare the indicators values of greenhouse gas (carbon dioxide CO_2) emissions in different countries (Figure 2).

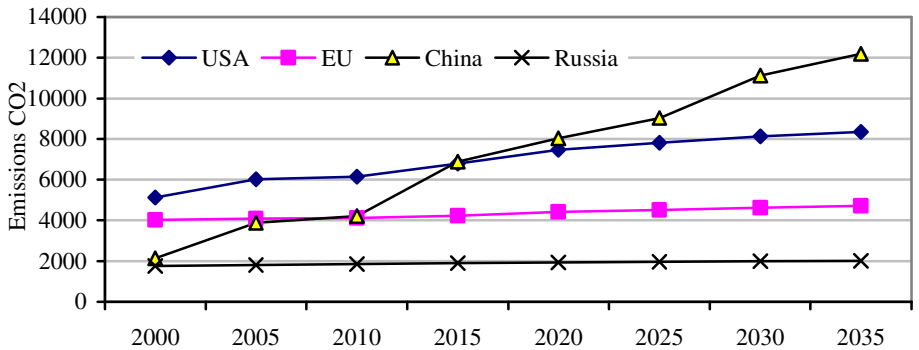

Figure 2. **Greenhouse gas emissions in different countries and regions of the world,** *mln tons, calculated according to* (International Energy Outlook 2014)

The USA takes the leading position in atmosphere pollution by carbon dioxide. However, as forecasted, since 2010 China has taken the advanced positions, leaving considerably behind other countries. It is necessary to note that high level of pollution in China causes a lot of alarms of ecologists around the world. Transnational nature of polluting substances distribution can be an essential factor of environment integrity infringement of the countries near China, including Russia.

Our research shows that carbon dioxide emissions lead to acid rains, reservoirs acidulation, baby fish damage, and degradation of vegetation (Samarina, 2007). Besides, this substance is the basic component of greenhouse gas and its congestion into the atmosphere leads to global climatic changes (Danilov-Danilyan and Losev, 2005).

Research on the dynamics of carbonic gas emissions in different countries has revealed the following regularity: trends on the diagram illustrating power consumption of countries and regions (Figure 1) practically coincide with trends on the diagram of carbon dioxide emissions (Figure 2).

For identification of the contingency of energy efficiency factors we will consider the correlation dependence between gross domestic product, power indicators and greenhouse gases emissions (Table 3).

We have revealed high inverse correlation between power consumption and power intensity of the economy (Table 3). Against the general background (the average value To = -88%) Russia, Brazil and South Korea have the most insignificant correlation (To = -63%, To = -58% and To = -46%). In our opinion, it may be the result of discrepancy in the rates of power consumption increase and the rates of power intensity decrease. Besides, in Brazil and South Korea (as well as in China, Mexico

and India) the rates of power consumption increase several times as many rates of power intensity decrease. Russia shows opposite results close to the indicators of the USA and the European Union.

Table 3. **Correlation factors between energy efficiency indicators for different countries,** *calculated according to* (Oxford Economic Model, 2014; International Energy Outlook, 2014)

Region/Country	Power consumption and power intensity	Power consumption and CO_2 emissions	Power consumption and GDP
South Korea	-0.46	0.99	0.93
Brazil	-0.58	1.00	0.97
Russia	-0.63	0.99	0.82
Japan	-0.74	1.00	0.91
China	-0.90	1.00	0.97
European Union	-0.94	0.92	0.88
Australia and New Zealand	-0.96	0.00	0.95
India	-0.98	1.00	0.97
Mexico	-0.98	1.00	0.98
USA	-0.99	0.99	0.98
Canada	-0.99	0.99	0.98

Earlier by mean the comparison of the diagrams (Figures 1 and 2) the direct relation between power consumption and CO_2 emissions has been revealed. This regularity is confirmed by extremely high correlation (Table 3).

We should note high correlation between gross domestic product and power consumption of various countries and regions (Table 3).

Against the general background Russia has the least, but nevertheless considerable, correlation (To = 82%). It explains the direct relation between the volume of gross domestic product and consumed energy.

Energy efficiency increase in Russia will lead to the following positive changes:

1. Power security of the country will rise.
2. Anti-recessionary stability of enterprises, sectors and national economy will strengthen.
3. At the expense of power intensity and power consumption decrease the problem of energy shortage in some regions of the country can be solved.
4. Development of Russian energy efficiency projects will promote integration of science and education with real economy and realization of the import substitution strategy.
5. Technological innovations concerning energy efficiency increase and fixed assets modernization will lead to economy diversification under import substitution and creation of new workplaces.
6. Energy economy domestically can promote the increase of volumes of power resources export.
7. At the expense of power resources economy regional and federal budgets will receive additional inflows.
8. Competitiveness of Russian goods at domestic and foreign markets will rise.
9. Anthropogenic load on the environment will decrease due to reduction of greenhouse emissions.

Due to the stated reasons the fact that energy efficiency increase plays a significant role in conversion to essentially new economy is apparent. This position should get coverage in all Russia's strategic documents.

Russian Federation government makes certain attempts concerning energy efficiency increase. In November, 2009 the Federal law "On power savings, energy efficiency increase and modification of Russian Federation legislative acts" was passed (23.11.2009, # 261-FZ). Many by-laws have been developed as well. Actions concerning power efficiency increase were included into the Concept of sustainable development of Russian Federation (Danilov-Danilian and Losev, 2000); the Concept of long-term social and economic development of Russian Federation up to 2020 (17.11.2008 # 1662-r); Strategy of innovative development of Russian Federation for the period up to 2020 (8.12.2011, # 227-r); Strategy for development of various subjects of Russian Federation and municipal unions.

Measures taken by public bodies of Russian Federation are certainly vital. However, it is also necessary to recognize that it is impossible to raise energy efficiency only by administrative measures of the government. There is a need to carry on an active dialogue between state structures, business, academia and NGOs about the operation of additional market mechanisms of power consumption decrease and minimization of human impact on the environment.

The necessity for information campaigns and trainings aimed at creation of social interest in building a new economy on the basis of energy efficiency is alsp of significant importance.

Conclusion:

1. Power consumption underlies technological development of all states and is a vital activity of their population. Nowadays the economy of Russia takes the 6th place according to GDP index. As predicted, Russian economy might take the 7th by 2035 giving its current place to Brazil.

2. Stability of the country's development on a whole and its industrial sector are characterized by power indicators, allowing estimating the energy efficiency. One of the basic indicators of energy efficiency is the dynamics of power consumption. Russia has a insignificant rate of power consumption increase.

3. The research has shown very high value of power consumption of Russia' economy: it is 1.5 times above the power intensity of the USA, 1.9 times above the power intensity of the EU, 1.8 times above the power intensity of Japan. Environmental conditions, spatial distribution of production factors, industrial composition and poor condition of fixed capital are the reasons for high level of power consumption of Russia's economy.

4. Power consumption and CO_2 emissions have revealed rather high correlation.

5. The government of Russian Federation makes certain attempts to increase the energy efficiency. The necessity for more awareness campaigns and training aimed at social interest in building new economy based on energy efficiency is also recognizable.

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