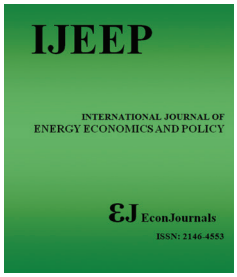

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Gross Domestic Product Energy Intensity Level as a Criterion for Evaluating the Energy Security of National Economy

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ABSTRACT

The study deals with the dynamics of the actual Ukrainian gross domestic product (GDP), the level of its energy intensity as a criterion of evaluating the energy security of the national economy. The level of consuming fuel and energy resources in Ukraine for the last 7 years was evaluated. The author built a correlation model of dependency of the actual Ukrainian GDP on total fuel consumption volume by Ukrainian industry, industrial production volume, degree of wear of fixed production assets, number of enterprises using advanced production technologies. National economic losses due to non-efficient use of fuel and energy resources were calculated on the basis of the correlation model. The pace of GDP increase was also calculated. The model of functional dependency of national economy energy efficiency on the level of actual Ukrainian GDP energy intensity and transfer from separate values to determinants was made by index method.

Keywords: Gross Domestic Product, Correlation Model, Energy Intensity, Energy Efficiency, Economic Losses, Fuel and Energy Resources, Strategy
JEL Classifications: B41, R13, O11, E60

1. INTRODUCTION

Organization of energetics under market principles of the single European energy area is one of the sources of sustainable development and increasing the well-being of the national economy. Preservation and protection of the vital interests of every member-state is the basic premise of its development. But the need of researching the dependency of the energy security of the country through the lens of state GDP energy intensity becomes current due to the constant change of internal and external factors of national economy development. Determining the state of factors that influence GDP energy intensity is a very important and topical question as this allows timely preventing the threat to the increase of the actual GDP and making a decision on the efficiency and rationality of managing the factors that influence the energy security of the national economy. GDP energy intensity level is a mirror reflection of the energy security of national economy.

On one hand, GDP is a sum of additional cost, the distribution and redistribution of which allows financing the measures for providing the national security and, on the other hand, GDP itself should be protected as a key element of the national security. So providing the national energy security under the conditions of reforming the Ukrainian energy market and other spheres of the national economy is a current and important emerging topic for research and it requires constant continuation of the scientific thought.

2. LITERATURE REVIEW

Review of scientific literature on the researched questions allows distinguishing the following proposals of authors on studying and evaluating GDP energy intensity and on studying the criteria of evaluating the energy security of the national economy. So, Cattaneo (2019) studies the impact of consuming behavior on the energy efficiency, among which he distinguishes the need to reduce

the energy consumption level and raise investments for developing advanced energy-saving technologies. Cupek (2017) focuses on the efficiency of processing data on energy consumption. This article proposes the methods of analyzing data on energy consumption. The goal of research by Esenl and Bayrak (2017) is to study the impact of energy consumption on the economic growth with cluster analysis of data from 75 countries-net energy importers for 1990 to 2012. For the purpose of analysis countries are divided into 2 groups: (1) Those that depend on the energy carrier import; (2) based on the income level. The obtained results show that there is an interrelation between energy consumption and economic growth. Besides that, the impact of energy consumption and economic growth is inversely related to the income level in the country. This means that efficient energy use is as important as energy consumption. This is considered to be an important indicator of economic growth. For evaluating the feasible energy-saving purpose with the current level of product output, Haider et al., (2019) found that firm size, age and financial performance are very important factors that impact the efficiency of energy use. Bordbari et al. (2019) performed the analysis of the energy efficiency for minimizing the energy consumption of buildings by developing the best structural parameters; they proposed a probabilistic multi-purpose optimization method based on statistical methods, i.e. rule of thumb and two-point method for analyzing the efficiency of energy use by buildings. Ming-Jia et al. 2017) propose new methods for short-term forecasting of the energy efficiency that include the model of generalized autoregressive conditional heteroskedasticity (SFA-GARCH) and radial basis function network model (RBFN). Studying the technique of the evaluating the current state of energy supply by the multi-faceted energy system is an important and current task of the country leaders.

The methods of integrated evaluation of national economy energy security proposed by Pysar (2019) can be continued by studying the impact of GDP energy intensity level on the indices of evaluation of national economy energy security. The efficiency of energy end use is a decisive measure used for reducing the energy intensity and production expenses. In their articles Soepardi et al. (2018) researched the interrelation between the following factors in terms of issues of increasing the energy efficiency: state policy, financial and economic factor, managerial and organizational factor, technological factor, workforce, quality and type of the used raw materials and fuel. The researchers found that all factors moderately influence the energy efficiency level, but the managerial and organizational factor has the most impact. The goal of researches by Tallini and Cedola, (2016) is to find the possible correlation between the indicators of energy efficiency and energy production, operation and consumption factors. An energy audit was performed for profiling the energy company, rationalization of energy consumption for improving the energy efficiency, evaluation of the energy-saving potential and reducing the environmental effect. Tkachuk et al. (2016) found that the energy-saving strategy of domestic enterprises needs to be transferred to energy-saving technologies, so there is a need to implement strategic management in terms of energy-saving on corporate and business level. The authors of the article proved that energy efficiency and energy saving are the most promising spheres of national strategic development.

The above-listed scientific works are considered to be the methodological basis of analyzing the level of energy-efficiency of the model of researching the most important factors that influence its level. The goal of this article is to study the actual GDP energy intensity as a criterion of national economy energy security, analyze the factors that influence it and find the dependencies between them. So studying threats to the energy security in terms of minimizing the energy consumption needs further expansion of the scientific thought and search for new criteria of evaluating the energy efficiency level within economic development. Determining the measures that influence the threat of the national energy security and scientific views on searching for sources of making the GDP more energy efficient is a very current issue and it needs expansion and continuation of scientific research in this sphere as evaluation of national economy energy security in terms of studying its actual GDP energy intensity is rather neglected.

3. METHODOLOGY

Production approach was applied for calculation. It revealed that GDP has two components such as production volume and the added value of the product. Definitely, the cost of the product depends on the fuel and energy consumption (and price) for its production. So we've analyzed the influence of the fuel price and expenditures on the actual GDP. Another reason of decreased actual GDP in Ukraine is that it had lost a big share of industrial potential in Luhansk, Donetsk regions so as in Autonomous Republic of Crimea. Based on expert estimates, their volume is approximately 20% of GDP[1]. Underproduction is the main economical drawback of industry decline. When the country cannot create a favorable investment environment for those who can work and wish to do so, the potential production is inalterably lost. Such lost products in form of GDP gap value is defined in macroeconomics as the difference between the actual and potential GDP. We can determine the influence of the dynamics of consuming fuel and energy resources on the dynamics of the actual GDP that can be compared:

$$\frac{Y_1 - Y_0}{Y_0} = 3 - 2\left(u_1 - u_0\right) \quad (1)$$

where Y_1 – is the actual production volume in the current year;

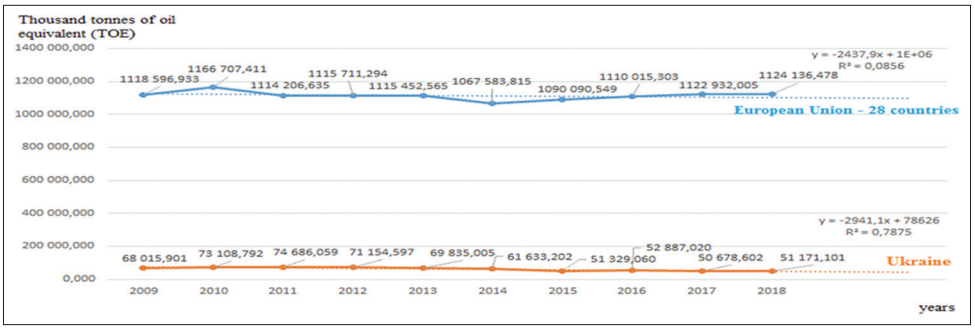
Y_0 – actual production volume in the previous year; u_1 – fuel and energy resources consumption volume in the current year; u_0 – fuel and energy resources consumption volume in the previous year.

Energy efficiency and energy intensity indicators were also calculated for evaluating the energy-saving potential in Ukraine. Development of collection of data on end use of fuel and energy resources and energy efficiency values became the energy efficiency monitoring tools.

Comparison of the level of actual GDP in Ukraine and EU countries was made through the ratio between the values according to data of Statistical Office of the European

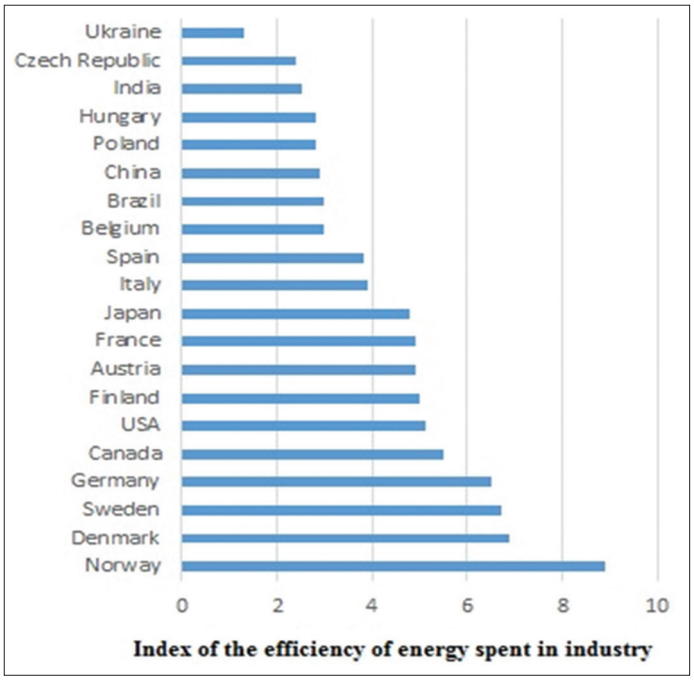
1 Ukraine lost $ 50 billion to $ 150 billion as a result of Russian aggression (2019).

Figure 1: End energy consumption



Source: Eurostat, 2019; State Statistics Committee of Ukraine, 2019

Figure 2: Funds efficiency index, 2018



Source: Eurostat, 2019; State Statistics Committee of Ukraine, 2019

Communities for 2018. Index of efficiency of funds spent on industrial energy carriers was calculated for studying the costs on energy resources for creating 1 UAH of added value in the Ukrainian industry in EUR: Added value volume received for 1 UAH of costs on energy carriers. The following approaches were used for GDP calculation: production approach (based on the added value); income approach (based on distribution); consumption approach (based on end use). GDP energy intensity was determined as the ratio of energy consumption in tons of oil equivalent on the GDP level in the current year determined according to the parity of purchasing power with European countries determined in EUR. We have found what energy volume is used for making one product unit. The ratio value is inversely related to the energy efficiency level, i.e. less energy is used for making one product unit.

Calculation of multiple correlation regression model of dependency of the actual GDP of Ukraine on total volume of fuel consumption was made using the least-squares procedure.

4. RESULTS AND DISCUSSION

The main task of economics and energetics of the country determined by the Energy strategy of Ukraine by 2030 is to reduce the GDP energy intensity by implementing industry-specific and cross-sectoral energy-saving programs practically in all sphere of economy, first of all, in industrial and utilities sphere where the consumption volume exceeds 40% of the total end consumption of energy resources in Ukraine, according to the energy balance data. Costs on energy resources for creating 1 UAH of added value in the Ukrainian industry are the highest among leading EU countries and exceed the average level more than 3 times (Table 1).

Costs on primary energy resources (coal, peat, crude oil, natural gas etc.) fall on almost 60% of costs on energy resources spent by Ukrainian industry. The following countries have the same or higher share: Poland – 64%; Denmark – 66%; Norway – 69%; USA – 69%; Canada – 70%[2].

The energy intensity of Ukrainian GDP is 2.5 times higher than the average energy intensity of the GDP of other countries (Figures 1 and 2) due to lack of a certain strategy of developing the energy market in Ukraine and the mechanism of making the domestic industry more energy-efficient for stimulating the energy-saving measures, controlling the measures of its implementation, improving the system of the tariff policy on the Ukrainian energy market. Currently the energy sphere of Ukraine has a big potential of developing the energetic independence of Ukraine as it has a stock of fuel and energy resources thus can satisfy the demand for energy resources in Ukraine considering the development of alternative sources of energy: Bio-energetics, wind power, small hydropower and alternative gases. Ukraine can reveal its high export potential as it owns a powerful infrastructure for energy transportation, storage and generation, but it should be modernized. So investments are required.

High GDP energy intensity in Ukraine is determined mostly by significant technological inferiority in most spheres of economy caused by old-fashioned energy-intense technologies and

2 National accounts (including GDP and regional accounts), 2018; Energy Efficiency, 2019.

Table 1: Calculation of energy efficiency, TOE

European countries/ Indicators evaluation	Final energy consumption, TOE, 2018	Gross domestic product at market prices, million euro, 2018	Energy consumption, TOE/%, 2018 (the first approach)	Population, 2018	Total energy consumption by a person, TOE, 2018	GDP per capita, million Euro, 2018	Energy consumption, TOE, %, 2018 (the second approach)
Belgium	36,333.730	459,819.8	0.08	11,398,589	0.003187564	0.040340063	0.079017324
Bulgaria	9,913.209	56,086.9	0.18	7,050,034	0.001406122	0.00795555	0.176747315
Czech Republic	25,318.470	207,570.3	0.12	10,610,055	0.002386271	0.019563546	0.121975398
Denmark	14,961.941	301,340.9	0.05	5,781,190	0.002588038	0.052124372	0.049651212
Germany	215,370.766	3,344,370.0	0.06	82,792,351	0.002601337	0.040394674	0.064398008
Estonia	2,958.781	26,035.9	0.11	1,319,133	0.002242974	0.01973713	0.113642355
Ireland	12,271.282	324,038.2	0.04	4,830,392	0.002540432	0.06708321	0.037869862
Greece	15,952.554	184,713.6	0.09	10,741,165	0.001485179	0.017196794	0.086363722
Spain	86,839.277	1,202,193.0	0.07	46,658,447	0.001861169	0.025765817	0.072234056
France	146,608.733	2,353,090.0	0.06	66,918,941	0.002190841	0.035163288	0.062304771
Croatia	6,851.605	51,625.1	0.13	4,105,493	0.001668887	0.012574641	0.132718484
Italy	116,465.878	1,765,421.4	0.07	60,483,973	0.001925566	0.029188251	0.065970582
Cyprus	1,859.845	21,137.8	0.09	864,236	0.002152011	0.024458366	0.087986687
Latvia	4,177.016	29,151.0	0.14	1,934,379	0.002159358	0.015069953	0.143288944
Lithuania	5,547.741	45,264.4	0.12	2,808,901	0.001975058	0.01611463	0.122563008
Luxembourg	4,346.126	60,053.1	0.07	602,005	0.007219418	0.099755152	0.072371385
Hungary	18,542.887	133,782.2	0.14	9,778,371	0.001896317	0.01368144	0.138605039
Malta	660.228	12,378.8	0.05	475,701	0.001387905	0.026022228	0.05333538
Netherlands	50,270.484	774,039.0	0.06	17,181,084	0.00292592	0.045051814	0.064945673
Austria	27,911.053	385,711.9	0.07	8,822,267	0.003163705	0.043720271	0.072362437
Poland	71,933.470	496,360.9	0.14	37,976,687	0.001894148	0.013070147	0.144921709
Portugal	16,907.373	203,896.2	0.08	10,291,027	0.001642924	0.019813008	0.082921472
Romania	23,534.647	204,640.5	0.12	19,530,631	0.001205012	0.010477926	0.115004835
Slovenia	4,975.850	45,754.8	0.11	2,066,880	0.002407421	0.022137134	0.108750339
Slovakia	11,113.079	89,721.0	0.12	5,443,120	0.002041674	0.016483377	0.12386263
Finland	25,837.002	234,370.0	0.11	5,513,130	0.004686449	0.042511241	0.110240227
Sweden	32,001.936	471,207.9	0.07	10,120,242	0.003162171	0.046560932	0.067914685
United Kingdom	134,671.515	2,423,736.6	0.06	66,273,576	0.002032054	0.036571689	0.055563593
Iceland	3,622.789	21,987.7	0.16	348,450	0.010396869	0.063101449	0.164764346
Norway	19,019.829	367,893.7	0.05	5,295,619	0.003591616	0.069471331	0.051699252
Montenegro	753.435	4,663.1	0.16	622,359	0.001210612	0.007492621	0.161573846
North Macedonia	1,853.458	10,698.1	0.17	2,075,301	0.000893103	0.005154963	0.173251138
Albania	2,125.412	12,782.4	0.17	2,870,324	0.000740478	0.004453295	0.166276443
Serbia	8,998.969	42,855.5	0.21	7,001,444	0.001285302	0.006120952	0.209983993
Turkey	101,727.621	652,519.9	0.16	80,810,525	0.001258841	0.00807469	0.155899645
Ukraine	51,171.101	118,623.5	0.43	42,216,766	0.001212104	0.002809867	0.431374062

Source: Eurostat, 2019; State Statistics Committee of Ukraine, 2019

equipment so as inefficient consumption of energy resources for making a product unit in corresponding spheres of economy.

Thus, in the sphere of consuming fuel and energy resources in Ukraine 37.53% falls on natural gas, 31.06% on coal, 12.51% on oil and petroleum products, 16.50% on nuclear energy, 2.4% on electricity generated by HPP[3].

Mining and food industry, energetics and metallurgy are key industries with total contribution to gross added value more than 70%[4]. Costs on energy resources for creating 1 UAH of added value in the Ukrainian industry are the highest among leading countries. Costs on primary energy resources (coal, peat, crude oil, natural gas etc.) fall on almost 60% of costs on energy resources spent by Ukrainian industry. The following countries have the same or higher share: Poland – 64%; Denmark – 66%; Norway – 69%; USA – 69%; Canada – 70% (Figure 2). The efficiency of costs on the above-given types of energy resources is the lowest in Ukraine (Table 1) and costs on them per added value unit in industry are almost 2.6 times higher than the average value among EU countries and OECD[5].

It should be mentioned that recently the structure of industrial production has changed a lot. This can be explained not by structural changes, but by an overall decline. If compared with 2013 in the total structure mechanical engineering and mining industry decreased by 13.9%, mechanical engineering - minus 7%, consumer goods manufacturing - minus 2.3%. Industrial spheres are characterized by a high export share: metallurgy (63.6% of products are exported), mechanical engineering (51.9%), consumer goods manufacturing (46.3%), woodworking industry (35.8%). Other sectors export <30% of their output[6].

3 State Statistics Committee of Ukraine, 2018.
4 Global Analysis of Basic Macroeconomic Indicators of Ukraine, 2018.
5 Energy intensity level of primary energy, 2019.
6 Global Analysis of Basic Macroeconomic Indicators of Ukraine, 2018.

Table 2: Estimation of impact of actual Ukrainian GDP (mln UAH) on the dynamics of consuming fuel and energy resources, toe

Years	Nominal GDP of Ukraine, mln UAH	Deflator of GDP of Ukraine	Deflator changes in relation to the reference year	Actual GDP	Change of actual GDP before the previous year	Change of actual GDP in relation to the previous year, %	End energy consumption, thousands toe	Change of volumes of consuming fuel and energy resources, thousands toe	Change of volumes of consuming fuel and energy resources, %
2004	345,113.00	40.00	0.40	862,782.50					
2005	441,452.00	43.00	0.43	1,026,632.56	1.19	+19			
2006	544,153.00	49.40	0.49	1,101,524.29	1.07	+7			
2007	720,731.00	60.60	0.61	1,189,325.08	1.08	+8	856955.00		
2008	9486056.00	78.00	0.78	1,215,456.41	1.02	+2	83,283.00	−2,672.00	−3
2009	913,345.00	88.20	0.88	1,035,538.55	0.85	−15	67,555.00	−15,728.00	−19
2010	1,082,569.00	100.00	1.00	1,082,569.00	1.05	+5	74,004.00	6,449.00	10
2011	1,316,600.00	114.20	1.14	1,152,889.67	1.06	+5	75,852.00	1,848.00	2
2012	1,459,096.00	123.10	1.23	1,185,293.26	1.03	+4	73,107.00	−2,745.00	−4
2013	1,522,657.00	128.40	1.28	1,185,869.94	1.00	0	69,557.00	−3,550.00	−5
2014	1,586,915.00	148.90	1.49	1,065,758.90	0.90	−10	61,460.00	−8,097.00	−12
2015	1,988,544.00	206.70	2.07	962,043.54	0.90	−10	50,831.00	−10,629.00	−17
2016	2,385,367.00	242.20	2.42	984,874.90	1.02	+2	51,649.00	818.00	2
2017	2,983,882.00	295.60	2.96	1,009,432.34	1.02	+3	49,911.00	−1,738.00	−3
2018	3,560,596.00	341.10	3.41	1,043,856.93	1.03	+3	51,171.00	1,260.00	3

Source: Eurostat, 2019; State Statistics Committee of Ukraine, 2019; National Bank of Ukraine, 2019

The main task of economics and energetics of the country determined by the Energy strategy of Ukraine by 2030 is to reduce the GDP energy intensity by implementing industry-specific and cross-sectoral energy-saving programs practically in all sphere of economics; firstly, in Ukrainian industrial and utilities sphere where the consumption volume exceeds 40% of the total end consumption of energy resources and the consumption of fuel and energy resources is the highest when generating electricity and heat energy by TPP and HES (20.42%), pig iron (12.47%), heat energy generated and supplied by boiler houses (12.02%) and heat energy supplied by industrial power plants (4.95%).

The built correlation model of dependency of the actual GDP of Ukraine on total fuel consumption volumes by Ukrainian industry, industrial production volume, degree of wear of fixed production assets, number of enterprises using advanced production technologies shows that the two last factors significantly influence the fuel consumption by Ukrainian industry (−0.482 and 0.521 correspondingly). The volume of industrial production has a proportional influence on the volume of consuming fuel and energy resources, so all factors were considered in the regression model. So the following best dependency under $K_{det} = 0.97$ was calculated:

$$y = 168.48x_1^{-0.521}x_2^{0.958}x_3^{0.524}x_4^{0.85} \quad (2)$$

The parameters of the power law model are elasticity coefficients, so when the number of enterprises with advanced production technologies increases by 1%, the volume of consumed fuel and energy resources is reduced by 0.521% providing that other factors included into the model also influence this, but do not change it; when the degree of wear of fixed production assets increases by 1%, the volume of consumed fuel and energy resources increases by 0.958%; increase of industrial production by 1% is accompanied by the increase of volume of consuming fuel and energy resources by 0.524%; increase of total GDP volume by 1% increases the consumption of fuel and energy resources by 0.85%. Multi-faceted correlation regression model of the volume of consuming fuel and energy resources is sound. The determination coefficient shows that 97% of variation of the volume of consuming fuel and energy resources is determined by the change of the factors considered in the model and 3% is determined by the factors that have not been considered. Using a correlation model, the economic losses of the Ukrainian economy caused by inefficient use of fuel and energy resources (Table 2) were calculated where the pace of GDP increase was calculated and the transfer from separate values to determinants was made by index method while studying the functional dependency of the criterion of national economy energy efficiency on the actual Ukrainian GDP energy intensity level.

The real Ukrainian economy in 2014-2015 suffered significant losses during the war in Eastern Ukraine that has led to destruction of facilities of coal, metallurgy, machine engineering, chemical industry that formed a significant share of the domestic industrial production and export. The differential evaluation of economic losses of the Ukrainian GDP due to economic transformation and hybrid war can serve as a basis for developing a public management strategy and evaluation of the level of Ukrainian energy security.

5. CONCLUSION

From the research we have concluded that the high energy intensity of actual GDP threatens the national energy security of Ukraine. Thus, during 2011-2018 the actual GDP of Ukraine reduced twice if compared with the value of 2010 and GDP energy intensity did not decrease during all these years. This can have the following reasons: high level of the volume of fuel consumption by Ukrainian industry, low industrial production volume, high degree of wear of fixed production assets in the Ukrainian industry, reduction

of the number of industrial enterprises in the national economy, low level of implementing advanced energy-saving production technologies (11.86% in 2018) and this share grows too slowly due to underinvestment into developing industrial and scientific innovations, low performance level and old-fashioned technological paradigm in the national economy if the actual Ukrainian GDP are compared with the one in European countries, low added value percentage in the production structure as Ukraine mostly exports raw materials and semi-finished goods, but not end products. For checking the actual impact of the energy efficiency policy the following is required: continuous monitoring of achievements and measure efficiency; evaluation of energy efficiency measures, promotion and use of standardized procedures for measuring the energy-saving level; development of energetics management system; development of regular mandatory energy audit.

So, complex study of the influence of several factors on the GDP energy intensity as the criterion of evaluating the energy security of national economy can be useful for making the best managerial decisions on the state level and during the preparation of the state economic development.

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