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Geo-economic approach to energy security measurement – principal component analysis

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ABSTRACT

Currently, there is no single accepted methodology for measuring energy security, while the prevailing scientific attitude is that energy security should be defined and quantified in a way to be able to follow rapid developments on the global economic and geopolitical scene. Considering the fact that the national economies represent an integral part of a dynamic international economy where external shocks (global financial and economic crisis, political conflicts, war, etc.) have the impact on energy prices and energy security in general, the paper proposes a new geo-economic concept of energy security. The new approach differs from the existing ones as regards the fact that, in addition to basic indicators, it takes into account sovereign *credit rating* as a measure of economic, financial and political stability - as one of the decisive factors which determines global energy trade and the ability of national economies to be stable and secure when it comes to energy. Determination and testing of *Geo-economic Index of Energy Security* was conducted by using the *Principal Component Analysis* in the European Union and in the selected countries of the world, over a period of ten years (2004–2013). The measured values of a newly proposed *Geo-economic Index of Energy Security* demonstrate significant deviations from the data obtained by using usual indicators of energy security. Observed individually, GDP per capita has the greatest impact on the change in final value of *Geo-economic Index of Energy Security*, while the impact of *sovereign credit rating* is slightly less. The study has shown that the least impact on energy security is exerted by energy dependence (which is traditionally used as a proxy indicator of energy security) and production of energy from renewable sources (which is defined by the EU policy as one of the methods for the improvement of energy security). Due to the results obtained, it is necessary to conduct further analysis of *sovereign credit rating* and to review the type and significance of the impact of *Energy Dependence* indicator as a measure of energy security in general.

1. Introduction

Energy security is today one of the most important geopolitical issues worldwide, largely affected by the economic crisis, and vice versa [1]. The "continuing financial crisis similar to the 2008–2009 recession including significant debt defaults" is expected in the future [2]. It is believed that the new wave of the financial crisis will be largely determined by the developments in energy market and will be even sharper than the initial crisis recorded in the period 2008–2010 [3]. The energy security issue has been greatly enhanced with the appearance of the emerging countries that have become major energy consumers. Therefore, significant changes occurred and will continue to occur on geopolitical scene [4]. Accordingly, significant changes occur in macroeconomic policy and financial stability, particularly in the countries and regions that are large energy consumers [5].

Energy profile of European Union (EU) is characterized by several specifics and characteristics resulting from changes in global economic and political environment [6]. The EU as a region is, on the one hand, large energy consumer and, on the other hand, faced with numerous problems concerning internal organization and priorities of its 28 member states (EU-28). Specifically, while the EU has a common energy policy on paper, its implementation has remained weak. EU energy security has been undermined by an internal challenge: a patchwork of national mini-markets, and a lack of political cohesion and solidarity. In addition, *Energy Union* strategy largely relies on changes in the field of electricity, since the EU is able to produce enough electricity for its own needs, and it strives for progressive electrification of its economy and for decarburization. The EU imports

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more than half of all the energy it consumes [7]. Its import dependency is particularly high for crude oil (more than 90%) and natural gas (66%). The total import bill is more than €1 billion per day [8]. There is a complete consensus about the fact that high energy dependence directly threatens energy security, as well as the security of each member country as well as a whole EU [9]. Economic development of any country may decelerate in the case of any disruption on global energy market [10]. For now, energy dependence can be considered the most important indicator of energy security [11].

As priorities of its energy policy EU states reducing energy intensity and greenhouse gas emissions, which will be considered in this paper as one of the factors of energy security. The data show gradual but continuous reduction in energy intensity in all countries, which consequently leads to reduced energy imports and has a positive effect on energy security in the long term [12]. Greenhouse gas emissions are also reduced in all the EU countries, although the reduction is uneven in different member states. Although there is a consensus on the need to reduce pollution, the relationship between economic growth, energy and environmental policies in EU is still a major issue of the future development of EU-28 [13]. This paper will also deal with residential electricity prices as a special factor of energy security, since the EU electricity market is largely liberalized and different electricity prices reflect, inter alia, different share of taxes and fees that further reflect the attitude towards environmental and energy policy. Thus, the final price also includes a number of incentives to increase the share of electricity generated from renewable sources, thereby gradually reducing import dependence and greenhouse gas emissions.

Due to said problems in the very approach and understanding of energy security, defining of energy security management method still remains a subject of study. Studying of energy security is very complex, because the "twenty-first century access to energy sources depends on a complex system of global markets, vast cross-border infrastructure networks, a small group of primary energy suppliers, and interdependencies with financial markets and technology" [14]. In fact, energy security is affected by many factors that are often impossible to accurately measure. Moreover, there are certain relations between the factors affecting energy security, and such relations are sometimes ambiguous, variable in their direction and intensity and differently manifested in different countries, regions and periods. Due to all the above, measuring the level of energy security still remains a particular challenge. It is necessary to focus on "three distinct perspectives on energy security: the 'sovereignty' perspective with its roots in political science; the 'robustness' perspective with its roots in natural science and engineering; and the 'resilience' perspective with its roots in economics and complex systems analysis." [15]

Currently, 11 most commonly used approaches to measuring energy security have been defined, all of which can be divided into two major groups: measurement based on security of supply and measurement based on aggregation of different indicators [16]. Each of these approaches has its advantages and disadvantages, which make it more or less suitable for measurement in this field. However, given the current trends, it is necessary to adopt the position that the measurement methods must be constantly reviewed and modified in accordance with the specifics on the world stage. The change in geopolitical relations is a dynamic process that takes place in the modern world, far more quickly than in the past [17]. Therefore, a detailed monitoring of all factors that affect changes in this field is of prime importance, as well as is the involvement of "governments, companies, military, environmental, law and intelligence agencies" to a much greater extent than before [18].

From the EU perspective, the best method to improve energy security is the pressure on the banking and financial sectors of the Russian Federation, which is evident from a sharp drop in crude oil prices during 2015 and further on in 2016. In addition, the EU can use all the first-class banking instruments, but there is evidence that these are not always based on real indicators. One of the ways to put a country in favorable or unfavorable position in terms of access to global banking market and energy trade (as well as in other fields), is certainly to define its credit rating in a speculative manner [19]. There is evidence that the three major credit rating agencies (Standard & Poor's, Moody's and Fitch Ratings) failed to properly assess the situation in certain countries of the EU during and after the financial crisis of 2008, whereby these countries were assigned more favorable credit ratings and thus more privileged positions [20]. Higher sovereign credit rating of a particular country largely affects the increase in corporate credit rating of the companies operating in the given country and in the global energy market, thus becoming artificially stronger [21]. Given the geopolitical turmoils and dynamic changes in the global economic environment where a new wave of financial crisis emerges, whereby all of which certainly jointly reflects on energy security, quantitative assessment of energy security should take into account economic and political aspects. In regard to political aspects there is one major constraint given that these are difficult to measure quantitatively, and there is a general problem of high-quality data on political dimensions. In an effort to identify a sufficiently comprehensive indicator to include both of these aspects [22], *Sovereign Credit Rating* is used in this paper as an indicator for the calculation of energy security.

The main contribution of this study is the introduction of *Sovereign Credit Rating* in the procedure for measuring of energy security, noting that similar studies are unknown, whereby the comparison of the degree of *Sovereign Credit Rating* significance against other components of energy security, which are the subject of previous studies, is certainly most important. It should be borne in mind that measuring of energy security by the method proposed in this study can neither be considered universal nor acceptable in all cases, but that it represents a contribution in finding ways to measure energy security. Instead of defining a unique solution, "experts are guided toward identifying key energy security components, including indicators and policies, and in making these components consistent, focused, and customized for a particular country" [23]. International Energy Agency points to the fact that the methodology developed by them for determining energy security "can serve as a starting point for studies of national energy security by providing a systematic, generic assessment framework that can be complemented by nationally relevant indicators and considerations" [24].

2. Theory/calculation

Sovereign Credit Rating as a measure of the creditworthiness of a sovereign government takes into account a range of indicators the processing of which results in the "assessment of the political and economic strength of a government, as well as the ability of its economy to withstand financial and political shocks". It should be noted that the indicators used to assess *Sovereign Credit Rating* have different impact. Studies have shown that Gross Domestic Product (GDP) related indicators have only a short-term impact on *Sovereign Credit Rating* of a particular country. External debt, foreign reserves and government effectiveness have much larger and longer-term impact. The importance of certain indicators changes over time depending on a change in macroeconomic environment. During the European debt crisis, the financial balance, the economic development and the external debt indicators became more important after 2009 [25]. Several studies were conducted during the European debt crisis and showed empirical evidence of the impact of ratings and rating changes on fiscal discipline [26] and on banking sector and its regulation [27,28]. Changes in rating have impact on the bond and stock market, as well as on the firms' borrowing costs [29]. Generally, during the European financial crisis a strong interconnection between sovereign spreads, sovereign ratings and bank ratings was empirically recorded [30].

Estimates of *Sovereign Credit Rating* are made by the three largest credit rating agencies (Standard & Poor's, Moody's and Fitch Ratings) and are based on a defined methodology, with certain differences in interpretation of the results [31]. Although there are also new credit rating agencies which are commencing their work, the estimates made by said three agencies are currently present on the global stage and are most commonly used. The work of credit agencies was questioned during the sub-prime mortgage crisis in the United States. This is supported by evidence consistent with information leakage [32], followed by revised Code of Conduct Fundamentals for credit rating agencies aiming to address issues of independence, conflict of interest, transparency and competition. In EU, regulation on credit rating agencies entered into force at the end of 2009 and responsibility for registration and regulation of credit rating agencies was handed to the *European Securities and Markets Authority* in 2011.

The empirical evidence showed that ratings published by the agencies for certain countries have often proved to be calculating, bad or pretentious [33]. A large number of studies call into question the reality of *Sovereign Credit Rating* estimates [34,35] as well as suggestions for improving credit rating methods [36], indicating the possibility that estimates made by the credit rating agencies may even create or deepen the crisis in certain countries and regions [37,38].

In addition to impact of *Sovereign Credit Rating* estimates on the national economy, the existence of a clear link between the rating assigned to a certain national economy and the ratings assigned to companies and banks operating in the given country, has undoubtedly been proved [39]. Some studies show that "credit rating agencies have a pervasive and potentially devastating influence on the financial well-being of the public" [40]. In addition, it has also been proved that the collision exists between the methods used for estimates by some credit rating agencies [41], as well as the inconsistent impact of estimates made by certain agencies regarding the future economic developments in the observed country. All critics of the methodology of work and role of credit rating agencies agree that "when these rating agencies did make mistakes, these mistakes would have serious consequences for the financial sector", and therefore for energy trade and energy security in general [42].

Currently, the EU is considered a region with stable and proportionately high *Sovereign Credit Rating*, although it is highly energy-dependent [43]. The long-term objective of the EU is further expansion and centralization of its financial market, which will greatly affect the ability of the EU to reach and maintain the desired stability and independence regarding energy supply [44]. Relationship between *Sovereign Credit Rating* and energy security is complex and bidirectional. The reason for said rests with methodology for determining *Sovereign Credit Rating* (with possible errors and speculative determination) and the importance of financial stability of countries in terms of the possibility to import energy and thus ensure energy security.

The country's ability to import enough energy for its own needs depends on financial stability, which is monitored through a number of indicators that are, inter alia, included in *Sovereign Credit Rating*. Import of energy has a negative impact on the state of trade balance. As trade balance is portion of the current account, which must always be balanced, the country has several ways to make up the deficit. The easiest solution to cover trade balance deficit is over revenues from exports of other goods and services. However, if this is not possible (for example, due to lack of competitiveness of the economy), balance of current account can be achieved by attracting foreign direct investments and portfolio investments, through borrowing, etc. Therefore, trade balance deficit based on energy imports always reflects on financial stability of a country, while the possibilities for its coverage through investments and borrowing depend on *Sovereign Credit Rating* monitored by investors and loan borrowers [45]. *Sovereign Credit Rating* also takes into account the level of foreign exchange reserves that demonstrate the ability of a country to provide import of goods and services in case of reduced inflow of foreign capital over a certain period of time, which also affects energy security level.

The equity market is a common and consistent source of risk for all the oil related sectors and the bond/interest rate options markets [46]. Credit swaps default market and the crude oil futures market is also related to credit rating. Specifically, negative jumps of oil futures have an increasing importance as the credit rating deteriorates during the crisis period, while the results for positive jumps and volatility futures are mixed. Overall, the relation between the credit swap default market and the futures market is stronger during volatile periods and strengthened after the global financial crisis [47]. Also, oil price uncertainty can predict credit default swap returns [48].

Particular interest lies in changes that take place in BRIC countries with a strong impact on geopolitical developments in the world. These countries have significant resources and potentials in every respect. Implementation of macro-finance models can provide a useful framework for exploring the link between sharp changes of political and economic regime, as well as financial crises [49]. Therefore, the assessment of economic, political and country risk rating is of a particular importance in the global sense, especially for investors, traders and policy-makers. Studies have shown that the financial rating is more sensitive than economic and political rating. In addition, only the Chinese stock market is sensitive to all the factors. Among the five BRICS, Brazil shows special sensitivity to economic and financial risks, Russia and China hold strong sensitivity to political risk, while India demonstrates special sensitivity to higher oil prices. Among the global factors, oil price is more sensitive to economic than to financial risk [50].

Finally, China is a good example of a country which invests in energy-related products abroad based on balance of payments surplus, whereby it does not only solves the problem of balance of payments surplus but also provides a certain amount of energy for its own needs. The Chinese government has encouraged China's National Oil Companies to expand their investments around the world. Some of the high-profile cases of state support for these international deals have taken the form of "loan-for-oil" agreements [51]. Specifically, in order to improve its own energy security and the stability of its own balance of payments, China places its investments in the production of coal, oil, gas, [52] and renewable energy in the EU [53].

Sovereign Wealth Fund operates in Norway since 1990. Through the Fund, surpluses are invested from oil and gas industry, thus providing continuous secondary income and enabling it to endure the consequences of large fluctuations on the global market of energy products [54]. A similar situation is observed in energy-rich countries, which have had significant credit expansion. Sovereign wealth funds that were established in a majority of energy rich emerging economies may enable the selection of winners in specific economic sectors [55], but investment in clean technologies currently consumes the most capital and yields the lowest returns [56].

The following are of great importance for the stability of power investments: contingency equity support, standby credit guarantee, subordinated debt mechanism, financing with political risk insurance, escrow account, and standby letter of credit [57].

3. Results and discussion

Defining of a research sample and data processing methodology is conducted in accordance with the aim of the study (testing of significance of *Sovereign Credit Rating* variable in the assessment of energy security), as well as with the recommendations existing in this field. Specifically, the results of previous studies show that the most suitable methods for the respective research may be the methods of panel data analysis, co-integration models and autoregressive distributed tests, with due consideration for the inclusion of new variables, noting that there is no single methodology and that such methodology will likely never be developed [58]. Also, one of the conclusions of the previous studies is that the analyses have to be done in a large sample

Table 1
Indicators used for constructing of Geo-economic Index of Energy Security.

Indicator	Source
Energy Intensity	Eurostat, database
Energy Dependence	Eurostat, database
Gross Domestic Product per capita	Eurostat, database
Final Energy Consumption per capita	Eurostat, database
Carbon Intensity	Eurostat, database
Electricity Prices	Eurostat, database
Electricity Consumption per capita	Eurostat, database
Production of energy from renewable sources	Eurostat, database
Sovereign Credit Rating	*Fitch Ratings* - Report

of countries [59], whereby it is most appropriate to research energy security, as well as the impact of all studies related thereto, at the national level [60]. Although there is no precise list of indicators that can and should be used for these purposes, their selection and number have to be adequate and the selected indicators have to show relevant characteristics of the system [61].

The research was conducted in four phases. The first phase included determination of Geo-economic Index of Energy Security in the EU-28 for the period from 2004 to 2013. Thereafter, the 2013 country ranking was defined based on the previously obtained results. In the third phase of research a ten-year trend of energy security in each individual country of EU-28 region was established. In the last, fourth phase of the study, the influence of individual nine variables on *Geo-economic Index of Energy Security* was studied.

For the purpose of this research, *Geo-economic Index of Energy Security* has been defined based on the aggregation of nine indicators, as shown in Table 1:

Data processing was done by using *Principal Component Analysis*. This method is chosen because it evaluates the impact of changes in the values of certain variable on final result. It is the most used for explanatory data analysis and as a method of projections, whereby it enables revealing of data structure and explains the variations [62]. According to available data, the method is not often used in quantification of energy security, but its use in the analysis of the phenomena affected by a larger number of variables has proved to be acceptable [63].

Before application of *Principal Component Analysis*, *mean normalization* (Eq. (1)) was used. First, it was determined the average value of each set of variables and then, from obtained values for each variable was subtracted the mean value. In this research, all variables have different scales, so after scaling, all have a comparable range of values and all values have an average about 0.

$$x_j^i = \frac{x_j - \mu_j}{s_j} \tag{1}$$

x_j^i - Value of each variable in each variable set
μ_j- Mean of each variable set
s_j - Standard deviation of each variable set

Principal Component Analysis was used for the determination of results, by assigning weights to each of variables included in the formation of the index. The first principal component is the best representative of values of the given variables – that is the value of the newly established index. The resulting weights represent the degree of correlation between a given variable and formed index, based on which it can be concluded which variables have a key role in explanation of the index itself. Because of standardization, all principal components will have mean 0. The standard deviation for each of the components is the square root of the eigenvalue.

Principal Component Analysis involves two stages: identifying and interpreting the factors. The first stage consists of identifying the factors with the lowest correlation pairwise and determining of the total variance of the variable they account for. The objective is to extract the factors that account for the highest portion of the variation in the original variables. The first factor explains the largest percentage of the total variation. Afterwards, the second factor is extracted, explaining the largest share of the remaining unexplained variance but with no correlation to the first factor, and so on until the number of identified components equals the number of original variables. Thereafter, it is possible to extract the components which explain a share of variance above a certain threshold, expressed in terms of the amount of variance in the original variables explained by each component (or eigenvalue). This threshold is usually set at one [64].

First Principal Component (PCA1): Y1

The first principal component is the linear combination of x-variables that has maximum variance (among all linear combinations), so it accounts for as much variation in the data as possible.

First stage involves definition of coefficients e11, e12, ..., e1p for that component in such a way that its variance is maximized, subject to the constraint that the sum of the squared coefficients is equal to one. This constraint is required so that a unique answer may be obtained. More formally, select e11, e12, ..., e1p that maximizes:

$$\mathrm{var(Y1)} = \sum \mathrm{k = 1p} \sum \mathrm{l = 1pe1ke1l\sigma kl} = e'1\Sigma \mathrm{e1} \tag{2}$$

Subject to the constraint that:

$$\mathrm{e'1e1} = \sum \mathrm{j = 1pe21j = 1} \tag{3}$$

Second Principal Component (PCA2): Y2

The second principal component is the linear combination of x-variables that accounts for as much of the remaining variation as possible, with the constraint that the correlation between the first and second component is 0. Select e21, e22, ..., e2p that maximizes the variance of this new component.

$$\mathrm{var(Y2)} = \sum \mathrm{k = 1p} \sum \mathrm{l = 1pe2ke2l\sigma kl} = e'2\Sigma \mathrm{e2} \tag{4}$$

subject to the constraint that the sums of squared coefficients add up to one,

$$\mathrm{e'2e2} = \sum \mathrm{j = 1pe22j = 1} \tag{5}$$

along with the additional constraint that these two components will be uncorrelated with one another.

$$\mathrm{cov(Y1,\ Y2)} = \sum \mathrm{k = 1p} \sum \mathrm{l = 1pe1ke2l\sigma kl} = e'1\Sigma \mathrm{e2} = 0 \tag{6}$$

All subsequent principal components have the same property – they are linear combinations that account for as much of the remaining variation as possible and they are not correlated with the other principal components. The procedure is the same for each additional component.

The research was conducted in a sample of 28 countries of the EU for a period of 10 years (2004–2013).

a) Determination of Geo-economic Index of Energy Security

Aggregation of values of individual indicators was performed in the first phase of the research. Final value of *Geo-economic Index of Energy Security* is presented in Table 2.

The highest Index value is recorded in Luxembourg, which is followed by Sweden, Finland, Denmark, Germany and Austria. Said results primarily arise from continuous investment in responsible energy policy and financial stability of those countries. The lowest values are recorded in Bulgaria, Estonia, Poland, Latvia, Lithuania, Hungary, Croatia, Slovakia and Greece. In the same time, in most of these countries, values remain negative. These are the former Eastern Bloc countries that underwent, or are undergoing, the process of transition, that are highly dependent on energy imports and that

Table 2
Geo-economic Index of Energy Security in EU-28 (2004–2013).
Source: authors' calculation.

Country	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria	1.65	1.75	1.76	1.99	1.84	2.13	2.02	1.92	1.86	1.85
Belgium	1.06	1.39	1.31	1.36	1.56	1.60	1.65	1.56	1.61	1.60
Bulgaria	-4.28	-4.44	-4.56	-4.62	**-4.68**	-4.46	-4.41	-4.50	-4.40	-4.22
Croatia	-2.15	-1.64	-1.68	-1.82	-1.72	-1.66	-1.61	-1.60	-1.37	-1.54
Cyprus	0.31	-0.18	-0.13	-0.15	0.21	0.24	0.41	0.43	0.43	0.18
Czech Republic	-1.17	-1.36	-1.34	-1.56	-1.47	-1.73	-1.64	-1.48	-1.80	-1.67
Denmark	1.46	2.41	2.34	2.41	2.30	2.31	2.36	2.18	2.16	2.11
Estonia	-2.03	-2.51	-2.31	-2.54	-2.77	-2.97	-3.07	-2.73	-2.64	-2.64
Finland	2.69	2.45	2.50	2.51	2.47	2.38	2.38	2.49	2.52	2.55
France	1.36	1.27	1.15	1.06	0.95	1.06	1.07	0.85	0.77	0.84
Germany	1.27	1.62	1.55	1.70	1.52	1.87	1.91	1.71	1.67	1.91
Greece	-0.06	-0.81	-0.85	-0.78	-0.76	-0.91	-1.14	-1.55	-1.28	-1.82
Hungary	-1.01	-1.23	-1.51	-1.41	-1.41	-1.09	-1.47	-1.43	-1.43	-1.58
Ireland	1.85	1.96	1.95	2.16	1.97	1.55	1.04	1.13	1.22	1.43
Italy	0.81	1.07	0.87	0.26	0.68	0.83	0.72	0.75	0.77	0.54
Latvia	-1.52	-1.84	-1.83	-1.61	-1.84	-2.03	-2.36	-1.65	-1.47	-1.40
Lithuania	-1.99	-2.22	-2.30	-2.31	-2.12	-2.46	-1.81	-1.63	-1.43	-1.33
Luxembourg	4.87	4.90	5.03	5.05	4.97	**5.22**	5.09	5.04	4.92	4.99
Malta	-0.63	-1.08	-1.01	-1.32	-0.85	-0.59	-0.37	-0.29	-0.36	-0.46
Netherlands	1.46	1.98	1.97	1.68	1.56	1.80	1.52	1.30	1.53	1.26
Poland	-2.21	-2.22	-2.33	-2.17	-2.25	-2.28	-2.03	-2.12	-2.25	-2.06
Portugal	-0.19	-0.10	-0.13	-0.07	-0.15	-0.16	-0.29	-0.26	-0.31	-0.43
Romania	-4.24	-3.50	-3.05	-2.83	-2.99	-3.39	-3.07	-2.88	-3.29	-2.57
Slovakia	-1.91	-1.82	-1.77	-1.64	-1.51	-1.22	-1.11	-1.03	-1.04	-1.15
Slovenia	-0.17	-0.32	-0.23	-0.25	0.05	-0.23	-0.19	-0.27	-0.39	-0.45
Spain	0.90	0.76	0.72	0.80	0.78	0.79	0.70	0.65	0.35	0.36
Sweden	2.58	2.64	2.77	2.84	2.65	2.54	2.87	2.80	2.78	2.85
United Kingdom	1.31	1.07	1.11	1.25	0.98	0.83	0.81	0.63	0.89	0.86

record high greenhouse gas emissions. Financial stability of these countries differs, but their *Sovereign Credit Rating* is lower than in other countries in the research sample.

Depending on the level of changes observed over ten years, categorization of countries into three groups may be implemented.

The first group consists of countries where a minimum changes of the value of *Geo-economic Index of Energy Security* has been recorded (level of change is < 0.5). This group includes 11 countries: Latvia, Luxemburg, Malta, Netherlands, Austria, Poland, Portugal, Slovenia, Finland, Sweden and United Kingdom.

The second group consists of 15 countries in which changes between 0.5 and 1 index points were recorded. Countries in this group are: Belgium, Denmark, Czech Republic, Germany, Estonia, Spain, Slovakia, France, Croatia, Lithuania, Hungary, Bulgaria, Ireland, Italy and Cyprus.

The third group consists of 2 countries in which the highest level of change is registered (> 1): Greece and Romania. In case of Greece, indicated change was negative. This is mainly the result of prolonged economic crisis in this country, which resulted in reduced GDP and GDP-related measures.

In most countries, changes were positive, but in case of six countries, energy security measured by newly proposed indicator showed negative trend: Czech Republic, Estonia, Ireland, Spain, France, Hungary, Portugal, Slovenia, United Kingdom and slightly in Finland and Netherlands. The data show that the biggest drop in the value of *Geo-economic Index of Energy Security* is recorded in 2009 and 2010, as a result of the 2008 economic crisis. During the observed period, the lowest level of change has been recorded in Luxembourg (from 4.87 to 4.99), while the highest level of change has been evident in the case of Romania (from − 4.24 to − 2.57). The reason for the above certainly rests with the fact that Luxembourg is a small country with low energy consumption in absolute terms, and that it is characterized by exceptional financial stability. On the other hand, Romania is a country that successfully implemented economic reforms over the period of ten years and recorded improvement in other areas, particularly in the area of reduction in greenhouse gas emissions.

a) Determination of trend of *Geo-economic Index of Energy Security*

The review of a trend in measured values of *Geo-economic Index of Energy Security* is given in Fig. 1.

Trend display indicates the existence of two groups of countries - countries where the trend recorded positive values and the countries in which the values were negative. Namely, negative values of *Geo-economic Index of Energy Security* showed that the reporting countries recorded higher values of variables with negative impact on energy security (*Carbon Intensity* and *Energy Intensity*), and these were mostly countries of the former Eastern Bloc. In these countries, economic development over decades has been based on the use of energy-intensive technologies and intensive use of (mainly fossil) energy resources without paying attention to energy efficiency and savings, as well as environmental protection. In addition, the price of energy for end user represented (and in some places still represents) a social, not market value, so there is no opportunity to acquire real profit and invest in advanced technology. Energy reforms in indicated countries were extremely slow, connected with monopoly status of energy producers and poorly developed institutions. Even after accession to the EU, these countries are still highly dependent on energy import, with outdated energy infrastructure and general economic difficulties. Energy prices are disproportionately low with the main purpose of preserving social standard, a free energy market exists but access to it is difficult, investment in renewable energy sources and environmentally friendly and energy efficient technologies are slow and insufficient.

Generally, the changes are more pronounced in countries with lower values of *Geo-economic Index of Energy Security*, which primarily witnesses about their instability and the need for further efforts to acquire a stable and long-term sustainable position.

a) *Geo-economic index of energy security* in 2013

Ranking by value was carried out for the year 2013, as the final year of the research, and the results thereof are presented in Table 3:

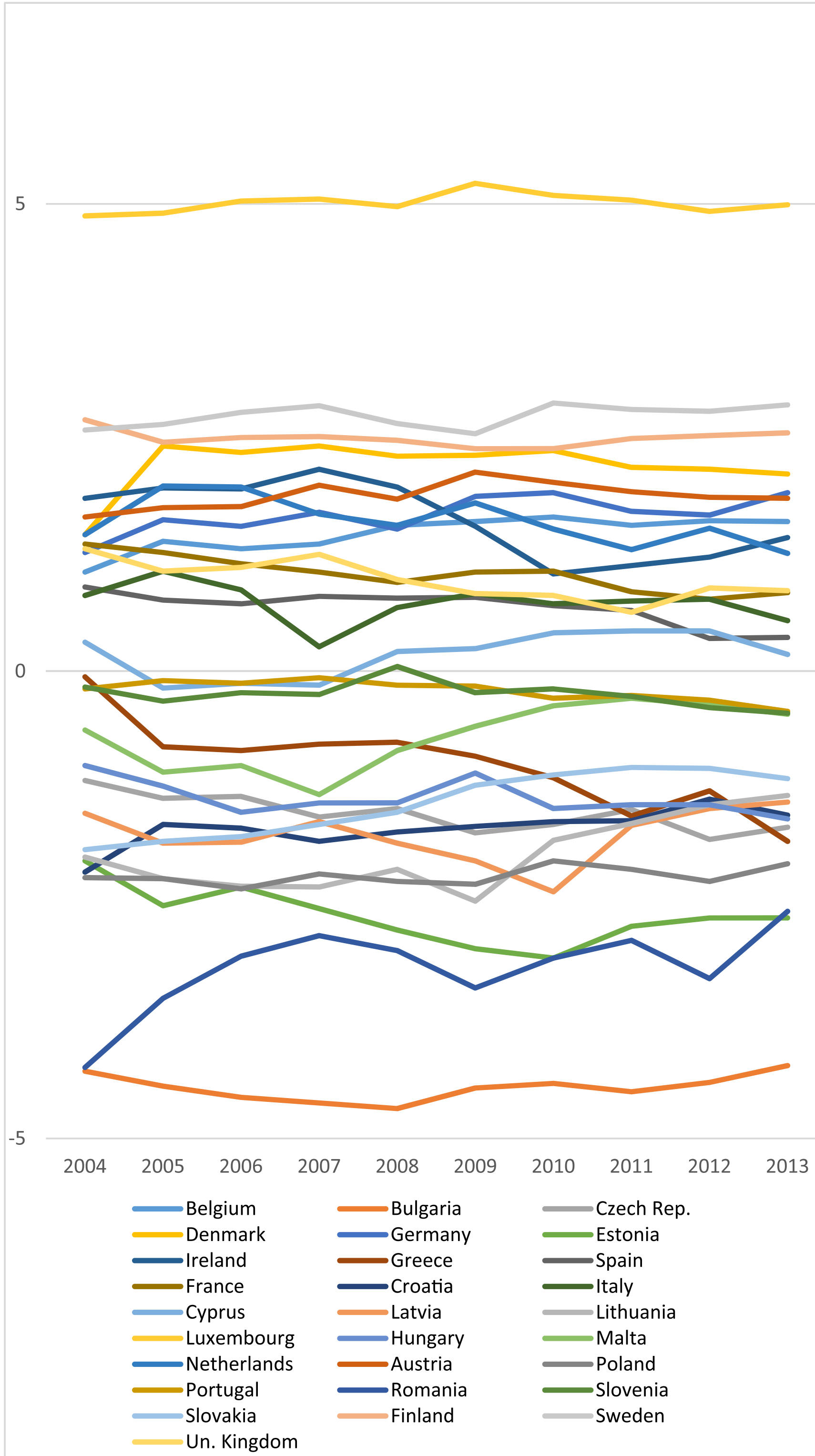

Fig. 1. *Geo-economic Index of Energy Security* in EU28 (2004–2013) – trend. Authors' calculation.

The second phase of the research included evaluation of the degree of impact of the selected variables on final value of Geo-*economic Index of Energy Security*. The results of the impact of certain variables are presented in Table 3 and Fig. 2.

The highest values of *Geo-economic Index of Energy Security* were recorded in Luxembourg, Sweden, Finland, Denmark and Germany – the countries with high *Sovereign Credit Rating*, low level of energy and carbon intensity and high GDP. The lowest values were reported in Poland, Romania, Estonia and Bulgaria, which recorded lower *Sovereign Credit Rating*, high levels of energy and carbon intensity and low share of energy generated from renewable sources.

Significant differences in the value of *Geo-economic index of energy security* in 2013 result from the operation of a number of factors, while disparities contribute to different priorities of individual EU countries in a given moment. Certainly, economically richer countries with high Sovereign *Credit Rating* are able to implement a series of measures in

Table 3
Ranking of EU-28 countries based on the value of Geo-economic index of energy security in 2013.
Source: authors' calculation.

Country	Geo-economic Index of Energy Security (2013)	Country	Geo-economic Index of Energy Security (2013)
Luxembourg	4.99	Portugal	−0.43
Sweden	2.85	Slovenia	−0.45
Finland	2.55	Malta	−0.46
Denmark	2.11	Slovakia	−1.15
Germany	1.91	Lithuania	−1.33
Austria	1.85	Latvia	−1.40
Belgium	1.60	Croatia	−1.54
Ireland	1.43	Hungary	−1.58
Netherlands	1.26	Czech Republic	−1.67
United Kingdom	0.86	Greece	−1.82
France	0.84	Poland	−2.06
Italy	0.54	Romania	−2.57
Spain	0.36	Estonia	−2.64
Cyprus	0.18	Bulgaria	−4.22

the field of energy efficiency improvement, and above all to invest in energy-efficient technologies. On the other hand, countries at a lower level of economic development and with lower *Sovereign Credit Rating* do not have said possibilities and continue to consume energy inefficiently, and therefore they are positioned high in the list of energy insecurity. The situation is further complicated by the fact that a large number of EU countries are dependent on energy import from one or two sources. Creation of Energy Union (2015), which provides for greater solidarity among the EU countries, can certainly contribute to establishing of a better balance in the level of energy security among countries so that they will not be forced to provide their energy policy (and thus energy security) through individual contracts with energy suppliers.

a) Impact of individual variables on *Geo-economic Index of Energy Security*

In the third stage of research, the impact of individual variables on final value of *Geo-economic Index of Energy Security* was tested. In this way it is possible to provide clearer insight into the intensity of their individual impact on trend over time. The results of this part of the research are shown in Table 4.

Interpretation of the principal components is based on a finding regarding the countries with the strongest correlation to each component, i.e. the numbers which are large in magnitude, the farthest from zero in either positive or negative direction. A decision on the numbers we consider large or small is, of course, subjective – in this study, correlation value above 0.35 is deemed important. Accordingly, it is evident that, according to the degree of impact on end result, the eight selected indicator can be clearly divided into two groups. The first group comprises indicators with greatest impact on *Geo-economic Index of Energy Security, namely: Energy Intensity, GDP per capita, Final energy consumption per capita, Carbon intensity, Sovereign Credit Rating* and *Electricity consumption per capita*.

The second group comprises indicators with lower impact on *Geo-*

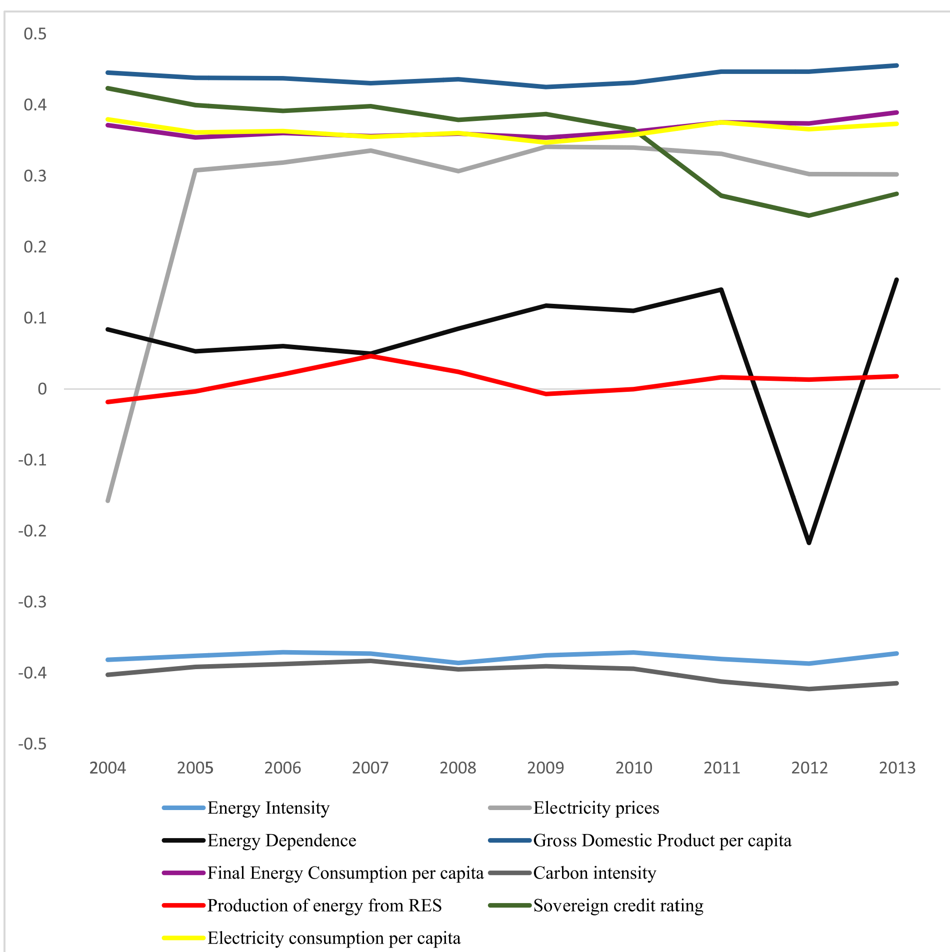

Fig. 2. Impact of selected variables on *Geo-economic Index of Energy Security* in EU28 (2004–2013) – trend. Authors' calculation.

Table 4
Impact of individual variables on Geo-economic Index of Energy Security in EU-28 (2004–2013).
Source: authors' calculation.

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Energy Intensity	**−0.3815**	**−0.3758**	**−0.3709**	**−0.3727**	**−0.3859**	**−0.3752**	**−0.3712**	**−0.3804**	**−0.3868**	**−0.3725**
Electricity prices	−0.1576	0.3079	0.3188	0.3357	0.3067	0.3411	0.3401	0.3312	0.3026	0.3022
Energy Dependence	0.0839	0.0530	0.0603	0.0497	0.0850	0.1173	0.1100	0.1398	−0.2168	0.1539
GDP per capita	**0.4456**	**0.4382**	**0.4376**	**0.4307**	**0.4362**	**0.4252**	**0.4314**	**0.4469**	**0.4469**	**0.4556**
Final Energy Consumption per capita	**0.3716**	**0.3542**	**0.3604**	**0.3562**	**0.3596**	**0.3541**	**0.3624**	**0.3756**	**0.3739**	**0.3894**
Carbon intensity	**−0.4025**	**−0.3914**	**−0.3874**	**−0.3830**	**−0.3950**	**−0.3906**	**−0.3941**	**−0.4121**	**−0.4226**	**−0.4145**
Production of energy from RES	−0.0183	−0.0035	0.0207	0.0462	0.0241	−0.0071	−0.0003	0.0164	0.0132	0.0179
Sovereign credit rating	**0.4235**	**0.3998**	**0.3916**	**0.3983**	**0.3790**	**0.3871**	**0.3654**	0.2723	0.2441	0.2749
Electricity consumption per capita	**0.3797**	**0.3614**	**0.3632**	**0.3551**	**0.3604**	0.3472	**0.3581**	**0.3755**	**0.3659**	**0.3734**

economic Index of Energy Security, namely: *Electricity prices, Energy dependence, Production of energy from RES* and *Electricity consumption per capita*.

In addition to the intensity of impact of certain indicators on a final Index, interpretation of the results of *Principal Component Analysis* also shows the direction of impact of certain indicators, which may be positive or negative. In this case, it is evident that *Energy intensity* and *Carbon intensity* have negative impact on Index value, which is certainly a result of the reverse relation of these two indicators for GDP. Due to the above, it is necessary to consider the appropriateness of the use of these two indicators in the estimates based on the aggregation of variables and estimates of their individual impact on end result. Specifically, in the case of inclusion thereof their relationship with other variables is observed. But this can lead to overlooking the impacts that some other variables may have. These two indicators should definitely be taken as a measure of progress in the field of energy consumption efficiency and reduction in carbon dioxide emissions.

Due to specificity of the very *Principal Component Analysis* it should be noted that, if the second set of variables is selected, it is possible to obtain different results. However, the values of obtained indicators are of secondary importance. It is of primary importance to observe the relationship between selected indicators and to consider the appropriateness of their use - with the aim of developing a set of energy security indicators that will be relevant to the maximum extent; it is also important to monitor changes in the degree of impact of each indicator over time, i.e. trend. A ten-year trend of impact of the selected variables on the measured value of *Geo-economic Index of Energy Security* is presented in Fig. 2.

It is evident that nine variables can be divided into three groups. The greatest impact on Index value is exerted by *Gross Domestic Product per capita* and, observed by year, this impact is stable. The above is certainly a result of EU policy of the sustainable economic growth in the observed period. Uniform intensity of GDP impact on energy security shows that, despite numerous challenges, GDP will remain the indicator for the time to come.

Sovereign Credit Rating has very similar, though slightly less impact on Index value, but its importance declined after the year 2010. Reduced impact of *Sovereign Credit Rating* on energy security after 2009 is certainly a result of the global economic crisis and the reduction in ratings value in come EU countries.

The research shows that the impact of *Final Energy Consumption per capita* and *Electricity Consumption per capita* is almost identical. On the whole, energy consumption (regardless of source) has great impact on energy security of all EU countries. Numerous measures which are defined by the common EU energy policy, and which refer to more efficient use of energy, show that the EU countries, as a whole, spent the same amount of energy during the period observed, but in a more efficient manner. The only exception (Table 2) refers to the former Eastern Bloc countries that continue largely to use energy-intensive and obsolete technology.

Electricity price recorded sharply increasing significance in 2005, and the impact thereof remained constantly high thereafter. In this respect, it is important to note that electricity prices are quite different in some EU countries, and that many governments (17 of the EU-28) still regulate or put caps on prices, either wholesale or retail or both [65]. This means that the electricity price is established in ways that do not reflect its market value, as well as that the price structure includes various taxes and fees with different share in the price structure in EU-28 (e.g. 5% in Great Britain and 69% and Denmark, source: Eurostat). In this respect, connection between electricity prices and generation of energy (electricity) from renewable sources should also be noted. Specifically, permitting of scarcity pricing reflects nothing but the available balance of supply and demand. A pure 'energy only' market, in which generators' only revenue comes from what they can sell in the market, is not possible as long as renewable generators get subsidies. Different degree of impact of *Electricity prices and Production of energy from renewable sources* on *Geo-economic Index of Energy Security* shows that these two indicators are definitely in conflict and that EU energy policy in this direction certainly requires some changes.

The second group comprises two variables with high (but negatively oriented) impact on *Geo-economic Index of Energy Security*, and these are *Carbon Intensity and Energy Intensity*. This is mainly due to the fact that these two indicators are related to GDP.

The third group comprises two indicators whose impact on Index measured values is significantly less than the impact of other indicators. These are *Energy Dependence*, as an indicator usually related to and often used for indirect assessment of energy security (primarily the security of supply) and *Production of energy from renewable sources* (which, in all official EU documents, is considered one of the most important methods for mitigating energy dependence). Both of these variables recorded proportionally small impact on energy security compared to other variables.

The given results reflect, to a certain extent, the situation in the EU energy policy and, indirectly, in economic and foreign policy as well. The EU is trying to improve its own energy security through a series of measures. Since 2008, the EU energy market became better integrated, the infrastructure in the field of gas supply improved, but the results achieved in improvement of energy security have been poor so far. The new members, i.e. the countries heading for the accession to the EU, are currently facing the specific problems and challenges regarding the acceptance of insufficiently successful European energy policy, and thus the principles of energy security. On the other hand, for Russia, whose gas the EU depends heavily on, the issue of energy security is the most important foreign policy issue and the basic element of national security in general. In addition, the Black Sea region as the main area of intersection of transit energy routes, as well as the region which represents alternative source to Russian gas, has reported manifestly increasing interest of the U.S. and NATO.

In order to succeed in said, energy-importing countries (and therefore the EU) are trying to envisage certain activities in the long run and to implement them in a planned manner in order to gradually reduce their energy-dependent position. The EU dependence on gas imports from the Russian Federation is a phenomenon that largely determines the global political scene. The effort to improve the EU position to a certain extent has so far yielded only partly good results, with a tendency to continue using energy as a political weapon. The Ukraine crisis has not led to rapprochement between the EU and Russia, but has created further lack of understanding and a potential flashpoint.

In addition to these results for individual EU countries and defining of the significance of impact of the selected factors, research has clearly shown the need for further improvement in terms of methodology. Apart from defining energy security it is necessary to clearly define the input and output signals that characterize energy security system, regardless of whether its boundaries are clearly known or not. In this regard, it is necessary to implement filtration to separate long-term trends from short-term changes and disturbances in the value of the factors observed. Filtration is absolutely necessary in order to eliminate noise, seasonal variations and changes, and its implementation will help get the answer to the question as to which extent filtration affects end result.

Since these are, most commonly, complex factors that define energy security, their interdependence must be clearly understood and quantified. It is particularly important to identify the cause and consequence in factors that are dependent on each other, which would allow obtaining relevance for certain selection of factors. The most common interdependences of certain factors are not stationary, but have adequate dynamics (for example, one factor changes due to the change in other factor, but with a certain delay), so certain dependences could be studied based on factor values in the previous time period. Said task is even more complex if one takes into consideration the fact that most factors represent complex functions of several variables, whereby several variables change simultaneously in a random manner.

The question arises as to whether the specific selection of factors adequately quantifies energy security and whether the selection of these factors is universal. In addition to the above, the increasing level of globalization and the existence of interdependence of not only close, but in distant countries as well, should also be considered. If energy security of a country (region) is described by a set of indicators, it is necessary to establish numerical criteria by which will be determined whether energy security is at the appropriate level.

4. Conclusions

The problem with definition and quantification of energy security is one of the most important research challenges faced today. High energy dependence of EU (and of many other countries and regions), rapidly changing geopolitical scene and a sharp drop in prices of crude oil definitely have, and will continue to have, major impact on future developments on geopolitical and economic scene. The resulting changes in the global financial sector necessitate the introduction of a large number of indicators from this group into the procedure for determining energy security, because the global energy market is closely related to operations of the stock exchange, banks and institutions that define global financial developments. In addition, there are parameters closely defining the political, financial and investment stability in the countries, companies and banks involved in energy trading.

One of the parameters with big impact on the developments in this complex field is Sovereign Credit Rating. The scientific contribution of this paper rests with the fact that this study represents the first study of a kind, aimed at determining whether and to what extent Sovereign Credit Rating affects energy security. The main contribution of the study is not reflected so much in presentation of a new methodology for quantifying energy security, but in a presentation of the degree of Sovereign Credit Rating impact on energy security in certain countries, compared to commonly used indicators of energy security. There are clear indications that *Sovereign Credit Rating* is not always a reflection of the real situation in the observed system and that the adjustment thereof greatly affects the creation and developments of the financial crises (thus energy security as an integral part thereof), so there are real grounds for reviewing the trend of *Sovereign Credit Rating* impact on energy security. *Geo-economic Index of Energy Security* has been defined in this respect. It includes the basic and most commonly used indicators of energy security, along with *Sovereign Credit Rating* as an indicator of political and financial stability of a particular country.

Results of the research show that the biggest impact on energy security is exerted by *Gross Domestic Product per capita,* and slightly less but still very high by *Sovereign Credit Rating*. In addition, large impact is exerted by *Electricity consumption* and *Final Energy Consumption per capita*. The impact of *Electricity prices* reported sharp increase after 2005 and has remained at a high level thereafter. On the other hand, the research has revealed a particularity - more precisely, it has shown that energy security measured in this way is under small influence of *Energy Dependence* and *Production of energy from renewable sources*. Specifically, *Energy Dependence* is traditionally considered a proxy indicator of energy security, but upon the introduction of *Sovereign Credit Rating* it proved to be an indicator of a minor importance. The foregoing leads to a conclusion that import dependence of a country does not imply insecure energy supplies of that country, as well as that import dependence can be compensated by strengthening of other elements of the system, such as strengthening of the financial position (based on real or calculating estimates). In addition, the research shows that *Production of energy from renewable sources* also has little significance for energy security in general, and this significance remains at the same low level during the observed period of ten years. Encouraging of the production of energy from renewable sources is regarded as one of the priorities of the EU's energy policy, and this research shows that it can be considered an activity contributing to reduction of pollution, but not the factor that will significantly improve energy security in the short run.

In order to obtain more precise results, it is necessary to include sectoral analysis of energy security and investment in energy-efficient solutions in future studies, as well as the assessment of the security of supply and energy infrastructure. Finally, this study emphasizes the need for development of more flexible and dynamic solutions for energy security measurement, according to the specificity of each country, which is in certain economic and political position in any given moment.

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