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Energy security measurement – A sustainable approach

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ABSTRACT

The main objective of this paper is to define a new energy security indicator with the long-term sustainability and to test it in a sample of 28 European Union countries for the period 1990–2012, as well as to determine the level of impact of six different indicators on energy security. The previous methodologies for measuring of energy security have been mainly focused on security of supply, while not taking into account environmental indicators and the social component. The newly proposed indicator, *Energy Security Index*, differs from the existing measuring methods precisely in a way that it includes environmental and social aspects. *Energy Security Index* recorded a decline in values in most countries in the period 1990–2000. In the period 2000–2008, the values became positive, and after 2008 some countries reported again gradual deterioration. The Index value varies by year, and the biggest positive changes were recorded in the case of the Netherlands, Slovenia and Spain. The four economically strongest EU countries (the United Kingdom, France, Germany and Italy) recorded significantly less fluctuations in energy security over 23 years, compared to other countries. The data for France and Denmark show that an increased share of energy from nuclear and renewable sources can compensate even increased energy import dependence. The assessment of impact of individual indicators on Energy Security Index was conducted by using *Principal Component Analysis* and showed that *Energy Intensity*, *GDP per capita* and *Carbon Intensity* have the greatest impact. The countries of the former Eastern Bloc are facing particular challenges of energy security, which is primarily related to the rapid economic growth and, at the same time, a high degree of dependence on import of energy generating products. In terms of energy security, the most stable transition was reported in Hungary and Poland.

Contents

1. Introduction

Energy security is one of the key parameters used to determine the current position and orientation of the development of all countries and regions in the future [1]. Energy resources are limited and unevenly distributed, the demand for energy is increasing, and the countries undergoing rapid development are facing huge energy needs – all of which suggests that energy security is

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one of the priority issues of each country's development [2]. Complex geopolitical changes indicate that energy security is part of national security and must be considered an integral part thereof [3]. Dyer and Trombetta [4] implicitly state that "energy security is in association with national security and defines the continuous availability of energy in varied forms, in sufficient quantities and at affordable prices."

International Energy Agency (2014) has developed short-term and long-term approach to energy security, which defines energy security as "an interrupted availability of energy sources at an affordable price". Short-term approach considers energy security as the system's ability to meet the particular country's energy needs, whereby the absolute focus is on the security of supply [6,7]. New approaches to energy security highlight the need to take into further consideration the environmental and social aspects as well [44,8].

Further studies in the field of defining a methodology for measuring energy security have to shift their focus from strictly scientific to practical application [39]. Energy security is a specific parameter influenced by numerous factors, thus the position of a certain part of scientific and expert public, according to which the defining of a unique methodology for measuring energy security is not possible, but is neither essentially necessary, becomes more pronounced. Each country has its own peculiarities and own approach to development, which change over time, so the defining of the method for determining energy security at the level of each country individually, can be considered more meaningful [11,12]. It should also be borne in mind that it is not possible to develop a unique methodology that will be applicative to all countries, because each country has different wealth of energy resources, different economic growth, climate conditions, demographic indicators, priorities, geopolitical position and the like. Thus, this paper is a contribution to the efforts to better interpret the factors affecting energy security, as well as a contribution to efforts to improve the methodology for measuring energy security. The definition of energy security alone is connected with a number of challenges, so the changes and corrections in the field of defining the methodology for measuring energy security are constant and entirely expected in the future [13].

There are currently several important obstacles hindering a unique and simple definition of energy security. First of all, the countries have different energy resources, whereby the use of energy resources differs in type and intensity at different points of development [14]. Given the different historical, political and social specificities, each country develops its own plans for the future and defines different priorities [15]. It is therefore most real to argue that the methodology for measuring energy security in a certain country can be considered applicable only at a given moment. Along with the change in strategic priorities, the methodology of measurement must be changed consequently [16]. Furthermore, the practice has shown that energy prices have an impact on energy consumption and economic development, and thus on energy security as well. With the increase in energy prices the consumption does not decline, but with the decrease in energy prices energy consumption increases significantly [17].

Regardless of methodological difficulties, the practice shows that all countries are trying to improve their energy security by increasing energy efficiency, improving the stability of energy system, reducing energy system vulnerability [18,29], increasing of resistance and self-sufficiency [19]. "All aforementioned leads to conclusion that the stability in the field of energy security is a lot more important than estimated figures, as well as the economic and environmental costs related to it" [20].

2. Material and methods

Different approaches to measuring energy security have been developed thus far. Ten methodologies have been most commonly used, whereby standard methods are applied that may be considered appropriate for this kind of research, as well as new methods developed specifically for this purpose [21]: Herfindahl – Hirschmann Index, Supply/Demand Index for long-term security of supply, Oil Vulnerability Index, Vulnerability index, Risky External Energy Supply, Socio-economic Energy Risk, The US Energy Security Risk Index, MOSES – The IEA Model of Short-term Energy Security, Energy Security Index developed by EU Joint Research Center in Italy and Global Energy Architecture Performance Index, proposed by World Economic Forum.

Herfindahl – Hirschmann Index determines the degree of a certain country's dependence on a certain supplier [22] and can be used as an indicator that indirectly points to energy security of a country. It is completely supply-oriented, is sum of the squares of the market shares of the countries of import for any given country. The survey conducted by the International Energy Agency [23,5] showed that Estonia, Finland, Sweden, Slovakia and Ireland are at maximum risk (value 1.0). Poland and Czech Republic reported the risk of 0.8. Medium risk (0.55) was recorded in Hungary and Switzerland. The values between 0.3 and 0.4 were reported by Portugal, Greece, Austria, Luxembourg and Germany. The lowest risk was recorded in Belgium, Italy, Spain and France. Of the countries of Eastern Bloc, the research included only Estonia, but, given the total dependence on gas imports all the other countries in the region can be considered to be in a high-risk zone.

Supply/Demand Index for long-term security of supply (S/D Index) is a composite indicator that comprises 30 individual indicators and considers the characteristics of demand, supply and transport [24]. The research conducted in the sample of eight EU member states indicates that the value of this index, thus energy security, is the highest in Denmark, which is followed by the United Kingdom, Ireland, the Netherlands, Poland, Estonia and Italy. The same research showed that the value of this index is expected to decline by 2020 in the United Kingdom and Ireland, whilst in other countries it will remain at a similar level [25].

Oil Vulnerability Index is, to some extent, more comprehensive composite index that takes into account certain economic indicators, import dependence and political stability, the range of values between 1 and 100 [26]. Measuring energy security by using this index [27] showed that the highest level of energy security was recorded in Sweden (0.37). Values between 0.40 and 0.50 were recorded in Germany, France, Austria, Switzerland and Ireland. These countries are further followed by a group of countries where the value of the index stands between 0.51 and 0.60, i.e. the Netherlands, Finland and Italy. The values between 0.61 and 0.70 are reported by Belgium and Hungary. Spain and Slovakia are vulnerable countries (0.71 to 0.80), while the group of most vulnerable ones includes Poland, Portugal, Czech Republic and Greece, with values ranging between 0.81 and 0.89.

"Vulnerability index is a composite index which considers five different indicators: energy intensity, energy import dependency, ratio of energy-related carbon emissions to TPES, electricity supply vulnerability and non diversity in transport fuels" with the range of values between 1 and 100 [28]. This index, unlike the previous ones, considers carbon emission as an environmental indicator. The available data of the research [18,29] conducted for 2003 show that the greatest value of index, thus the greatest level of vulnerability, is reported by Cyprus (0.75). Luxembourg and Estonia reported the value of 0.70, and are followed by Ireland and Portugal with 0.65. The values between 0.60 and 0.50 are reported by Belgium, Spain, Romania, Germany, the Netherlands, Slovenia, Austria and Finland. The group of countries with lower index values (between 12.49 and 12.40) includes the United Kingdom and Slovakia.

Risky External Energy Supply is entirely supply-oriented because it considers solely the level of diversification, with particular emphasis on the assessment of transport safety of energy generating products [30]. A specific study of this indicator for crude

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