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Energy Security: Theoretical Interpretations and Quantitative Evaluation

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ABSTRACT

Although the question of energy security is regarded as an integral part of the contemporary political agenda, there is no single definition that has been agreed among the international community. The term itself has been evolving for more than 40 years of use. This article reviewes and compares existing definitions of the concept at global, regional, and national levels as well as from scientific point of view. It is commonly accepted that security is related to risk. Identifying and measuring energy security risks is a difficult task as the term contains elements whose meaning often depends on the context. Since the energy system cannot be fully protected, it is appropriate to consider energy security as a risk management problem. This article analyses existing energy security assessment literature and proposes a complemented approach for measuring and evaluating national energy security.

Keywords: Energy Security, Energy Policy, Energy System, Risk, Uncertainty, Indicators, Assessment Framework
JEL Classifications: Q2, Q3, Q4

1. INTRODUCTION

Even though energy security is an integral part of the contemporary political agenda, it was raised only at the beginning of the 20th Century due to disruptions of oil supply to the army. There are many well-known examples in history that demonstrate how access to energy resources (initially, most of all, oil) was crucial to the economies or in some cases even for the existence of some states.

There is a significant change from the past to the contemporary threats to energy security. If before the 80s energy security has been considered mainly in terms of ensuring the supply of cheap oil under the threat of embargo and price manipulation by exporter countries (Colglazier and Deese, 1983), new energy security challenges go beyond oil supplies and generate new weaknesses, and they are closely related to other energy policy issues, such as ensuring equal access to alternative energy sources, climate change concerns and terrorist attacs to energy infrastructure. In addition to the classic vulnerabilities, it is likely that new ones appear - such as the vast installation of intelligent networks throughout the world over the next decades, which would require new responses, namely ensuring network security and data protection (Wueest, 2014).

Currently representing a set of various questions and problems, it is reasonable to expand the discussion on the definition of energy security to include ensuring security of the energy supply chain as a whole (Goldthau, 2010).

2. CONCEPT AND DEFINITION OF ENERGY SECURITY

Energy security as a problem emerged in early 20th Century. However, the use of the term energy security dates to the two oil crises during the 70's (although the term has been used in some literature even prior to that - for example, Lubell, 1961). For more than 40 years, the international community did not manage to determine a uniform definition of the term, and the term itself has constantly been changing its meaning during that time period. Even though there is a plenty of literature available and many discussions have been held on the content of the concept of energy security, scientists did not manage to come to a consensus on its uniform interpretation.

The existence of different interpretations of the concept does not mean that the concept itself has different substances. The fact that energy security reflects different notions that arise in different situations and countries has a natural rationale - each country has its own characteristics of its energy system, which leads to differences in the definition of the energy security problems (Cherp and Jewell, 2014). However, since the term has not been fully defined, it is rather difficult to measure it and balance it with other political goals pursued by a country.

The most noticeable difference in the concept of energy security is the one between energy resources producing and consuming countries (Energy Charter Secretariat, 2015). Despite the fact that there is no clear distinction between producing and consuming countries (simply because most countries both produce and consume energy resources in different proportions and volumes), priorities of energy importing countries for energy security differ from those of energy exporting countries. While importing countries need security of supply and low prices (mainly in the developed industrial countries), exporters seek to ensure security of demand and guarantee that their production will be acquired at an adequate price in the long term (securing a profitable rate for the invested capital). Energy security for transit countries is closely related to their interest in maximizing the profits from the proposed transit services, including the transportation of energy resources through their territories (Zhiznin, 2010).

Since from the very beginning of the use of the term energy security no global framework for considering all aspects of energy security has been established, some countries or groups of countries unilaterally decided to define their understanding of energy security, specific to their level of development and position in the international energy market. Despite the fact that the states in most cases refer to the importance of the development of the energy system, so far, no consensus has been reached on what exactly this concept means. As a result, there are a number of interpretations of the concept.

A number of conceptual ideas have been developed globally (IEA, World Energy Council, OPEC), at regional (EU, NAFTA, APEC), as well as national and scientific levels. Further will be reviewed some of the definitions at these levels.

The Copenhagen School defines the term "security" as "a real threat to a particular object" (Buzan et al., 1998). Within the framework of energy securitization, energy supplies are usually the designated object, while the real threat is the rejection of such supplies. This approach is reflected in the often-cited definition of energy security proposed by the International Energy Agency, namely: "Uninterrupted availability of energy sources at an affordable price" (IEA 2014b). IEA defines two types of energy security: long-term energy security, aimed mainly at making urgent investments in energy supply, along with economic development and sustainable environmental needs. The activities for the short-term energy security are focused on the ability of the energy system to respond quickly to sudden changes occurring at the level of the supply-demand balance (IEA, 2014a).

In this definition, energy security is a customer-centric concept. IEA identifies the following distinguishing features of energy security: Reliability (continuity), affordability (competitiveness) and physical availability of supplies (IEA, 2014a). As further analysis will show, these main elements can be found in many existing definitions of energy security (at least 45, as determined in Sovakool (ed.) (2011). However, these concepts are not very clear and contain certain ambiguities that can be broadly interpreted (Labandeira and Manzano, 2012).

The World Energy Council (WEC) suggests minor variations of IEA concept and emphasizes that the concept of energy security is one of the dimensions of the so-called Energy Trilemma (the World Energy Council's definition of energy sustainability is based on three core dimensions – energy security, energy equity, and environmental sustainability. These three goals constitute the "energy trilemma"). According to the agency, energy security is the effective management of primary energy supplies from internal and external sources, the reliability of the energy infrastructure, and the ability of energy supplying organizations to meet current and future demand (World Energy Council, 2014). However, it should be noted that this definition does not contain the notion of affordability, as the Agency transferred this feature to the alternative dimention of the energy trilemma - namely, to the equitable distribution of energy resources (physical availability and affordability of energy resources among the population).

These two organizations (IEA and WEC), generally represent the point of view of energy-importing countries. At the global level, there is a more holistic approach to the concept of energy security, which is guided by the World Bank. In the 2005 Energy Security Issues Briefing paper (The World Bank Group, 2005), the mening of energy security is ensuring that countries can sustainably produce and use energy at reasonable cost in order to facilitate economic growth and, through this, poverty reduction, and directly improve the quality of peoples' lives by broadening access to modern energy services. In fact, the World Bank confirms that the exact meaning of energy security (as well as the priorities in this area) will vary by country, and therefore suggests a classification of five overlapping groups of countrie based on three main criteria: (a) level of economic development, (b) endowment of energy resources, and (c) potential impact on global energy demand.

It is interesting to note that, despite its role in the international energy market, OPEC does not have its own definition of energy security. Based on statements by high representatives of the Organization (Barkindo, 2003), it may be concluded, that the meaning of this term according to OPEC is that the ensuring energy security is part of universal responsibility within the global community, and guaranteeing supply and demand, in turn, are complementary issues that require similar acceptable and balanced solutions.

It is worth to note also several approaches to the concept of energy security at regional and national levels. Detailed comparative analyzes between the approaches of Russia, the EU and the USA in terms of energy security definition could be found in the works of Seliverstov (2007) and Golovina (2015).

Russia's understanding of energy security has been initially stated in the 2020 Energy strategy of the Russian Federation 2020 (Energeticheskaya strategia Rossii na period do 2020 goda, 2003), namely as the state of protection of the country, its citizens, society, and the state serving their economy from threats to reliable fuel and energy supply. At first glance, such definition differs from the IEA definition of energy security. However, upon further reading of the Energy Strategy, among its priorities are full and reliable provision of the population and the economy of the country with energy resources at affordable but at the same time stimulating energy savings prices, reducing risks and preventing the development of crisis situations in the country's energy supply. Hence, we see certain similarity with the understanding of the concept of the IEA which means to ensure security of energy supplies, including physical accessibility and price.

In the framework of the new international economic and geopolitical realities, a new Doctrine of Russia's energy security has been approved by the President of the Russian Federation on May 13, 2019. The conceptual statements of the draft Doctrine from the end of November 2018 contained a distinction of 6 types of energy security levels (global, national, systematic, regional, objective [corporate], local [individual]) as the national energy security (in a broad sense) was considered part of the state's national security, which depends on the energy factor, ensuring the quantity (volume), quality (efficiency and reliability) and constructiveness (organization) of energy supply to consumers. These definitions are not included in the final version of the Doctrine of May 2019. However, a definition of energy security is present in the final document – *the state of protection of country's economy and population from national security threats in the field of energy, where the requirements for fuel and energy supply to consumers provided by the legislation of the Russian Federation are being fulfilled and the contracts for export and the international obligations of the Russian Federation are being executed* (Doctrine for the Energy security of the Russian Federation, 2019).

This definition comprises the element of energy supply/physical (accessibility) but further in the text the Doctrine adds also the price elemet as it identifies *price increases (tariffs) for the products of organizations of the fuel and energy complex and energy services as a consequence of the realization of threats to energy security*. So far the definition resembles the importing states understanding. Further on, it contains the novel notion of the requirement for executing export contracts (specific for exporting countries) and international obligations of Russia. The 2006 G8 Summit held in St. Petersburg adopted the Global Energy Security document which has been developed by Russian and international experts. This document was in fact one of the first practical instruments based on the provisions of the energy security concepts of both importing and exporting countries. Following the summit in St. Petersburg, a draft convention on ensuring international energy security has been developed by Russian experts in 2010. Although the document had certain recognition among the international energy community, it has not been further developed. In the recent years, Russian experts continued to study political, ecological and technological aspects of the concept of energy security. Important theoretical statements about political risks for the energy securirity in the Russia – EU relationship were presented in scientific papers of two Russian experts (Simonija and Torkunov, 2014 and Simonija and Torkunov, 2016). The impact of energy on sustainable development particularly connected with different ecological problems is presented in some conseptual approaches. Specific analytical work can be found in Zhiznin and Timokhov, 2017 and Zhiznin and Timokhov, 2018. Another important issue in the theoretical conceptual interpretations of energy security deals with prospects of alternative energy in connections with the UN approved programme of sustainable development. It is worth mentioning the development of different ways of practical use of hydrogen energy including technological projects dealing with use of Secondary Renewable Energy Sources for producing hydrogen for different purposes instead of organic fuels. The conceptual approach is presented in a paper of Russian and Bulgarian scientists published in the International Journal of Hydrogen Energy (Zhiznin et al., 2019).

To some extent, the EU approach is similar to the definition of the IEA. Namely, energy security is usually understood as security of supply. Even though there is no explicit definition in the 2014 European Energy Security Strategy (Communication from the Commission to the European Parliament and the Council, 2014), such definition can be found in other EU documents. Security of energy supply is associated with ensuring social and economic security, which is reflected in the 2011 Green Paper (Luxembourg, Office for Official publications of the European Communities, 2001): Ensuring, for the good of the general public and the smooth functioning of the economy, the uninterrupted physical availability on the market of energy products at prices for all consumers, in the framework of the objective of sustainable development. It should be noted that the 2001 EU Green Paper contains also the notion of environmental protection, which is a relatively recent modification of the concept of energy security.

Despite the fact that the United States is considered the birthplace of energy security, it is quite difficult to find a definition of this concept in official documents. For decades, the concept of energy security in America has been equated with the concept of energy independence. According to Skalamera, 2015, since the 1973 Arab oil embargo, the concept of energy independence prevails in official US policy documents. This position began to change (albeit rather slowly) with recent technological developments of shale gas and tight oil, which suddenly turned the United States into a state with its own gas resources and less dependent on foreign oil suppliers. However, neither the 2007 Law on Energy Independence and Security (Energy Independence and Security Act of, 2007), nor the 2005 Law on Energy Policy (Energy Policy Act of. 2005), fixed the precise definition of energy security. According to a high representative of the Department of Energy (Harbert, 2006), energy security is linked to the economic prosperity and national security of the state, and access to guaranteed, reliable and affordable energy sources is fundamental for ensuring national economic security. Moreover, each year, the US Chamber of Commerce issues an Energy Security Risk Index (International Energy Security Risk Index Report, 2016. It presents energy and security indicators which together create an indicator of enegy security risks. Despite the subjectivity of such indicators, it is possible to generalise the American approach to the issue of energy security from the point of view of types of indicators. They contain the following elements corresponding to those proposed by the IEA: Reliability (continuity), affordability (competitiveness) and availability of (access to) supply.

Despite that it may be concluded by the analysis presented above, that the three national approaches to the definition of energy security contain certain similar elements, it should be noted that, in the case of the EU and the USA, these elements are undoubtedly important from the point of view of not only domestic resources, but also of imported.

It is important to mention that despite that the notion of Environmental protection is a relatively recent refinement of the concept of energy security, it has already been included in some important documents, such as the 2000 European Commission's Green Paper on the security of energy supply (Luxembourg, Office for Official publications of the European Communities, 2001).

3. EXISTING APPROACHES TO QUANTIFYING ENERGY SECURITY

The emerging energy security problems evolved from concerns regarding oil supplies to the industrialized countries before the end of the Cold War to matters covering new factors and threats, such as information security of and terrorist threats to energy infrastructure. While the concept of energy security is in constant development, its importance and potential threats become visible (Vivoda, 2016).

Despite the fact that the international community has not been able to come to a consensus on the definition of energy security, it is commonly agreed that security is related to risk. Since the energy system cannot be fully protected, it is practical to consider energy security as a risk management problem (OECD/IEA, 2007).

The concept of risk itself is complex and there are various approaches to its examination. For example, ISO 31000:2018 provides a set of principles, a framework and a process for risk management, and also defines the concept of risk as "the effect of uncertainty on objectives" (Risk management — Guidelines, 2018), since impact is a deviation from the expected, either positive or negative. However, risk is more often associated with the negative effect of various factors (Ivanov and Shaidullina, [2008]).

Regardless of the nature of the consequences of the risk (positive or negative), the risk management process is the same. Figure 1 below shows a generally accepted and widely used scheme of activities aimed at implementing the process of risk management.

However, attempts to identify and measure energy security risks is a difficult task. The term energy security is widespread, but as discussed above, also contains elements whose meaning depends on the context. The simplest definition of energy security (the necessary level of supply at an affordable price) demonstrates how difficult any attempt to assess it is: from the assessment of the "necessary level" of supplies to the assessment of the "affordability" of the cost of energy supplies.

Thus, even the very idea of trying to measure the concept of energy security for further measures undertaken by the policy makers seems rather complicated. The politicization of the issue also complicates the situation and leads to neglecting of the economic aspects of energy security (Kaveshnikov, 2011).

At the same time, each country interprets the concept in its own way and, based on this interpretation, develops a national system of indicators, and carries out a quantitative assessment and analysis of the current and future level of the country's energy security (Vasikov et al., 2010).

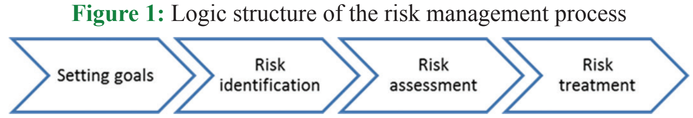
Recent academic studies have encountered the difficulty of conceptualizing energy security, identifying about 20 possible dimensions within the concept of energy security, which undergo a comprehensive assessment of 372 indicators (Lilliestam and Patt, 2012).

Most of the existing works on measuring energy security approach the issue indirectly through geopolitical analysis, or, in most cases, using indicators.

Although the UN and other multilateral groups have put a lot of efforts on the development of composite indicators for transport productivity, environmental quality and industrial productivity, developing both standard metrics for assessing energy security and a comprehensive set of energy security indicators are still subject to discussion (Sovacool and Mukherjee, 2011).

In fact, it is widely accepted that there is no single metric applicable to all goals and situations for measuring energy security, as well as that that any quantitative indicators of energy security require certain methodological choices or established boundaries of research. Thus, it is necessary to consider the extent to which aspects of energy security can be measured

Figure 1: Logic structure of the risk management process



Source: Compiled by the author based on ISO 31000:2018 and what tools can be used to contribute to the exploration of this issue.

4. METHODOLOGY FOR ASSESSING NATIONAL ENERGY SECURITY

An approach which stands out among the analyzed existing works on the problem of energy security is the one proposed by Cherp and Jewell (2011) and would be used as a basis for the proposed methodology for assessing national energy security.

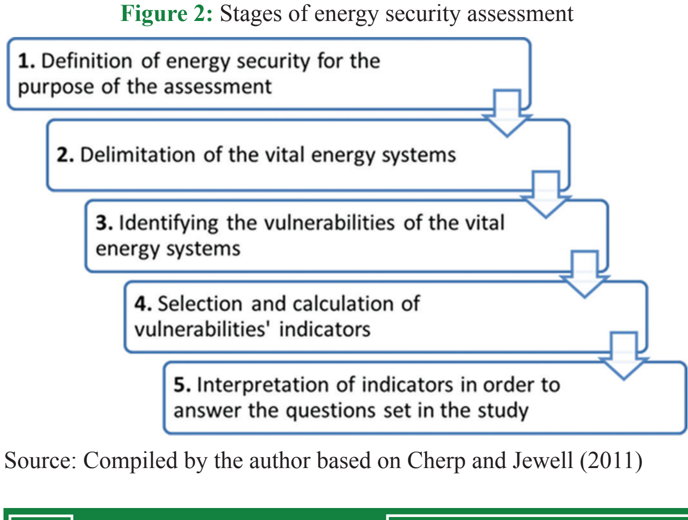
The proposed methodology includes five stages (Figure 2), which will be discussed further down.

A main point of the proposed approach is to measure energy security within the following evaluation framework:
- Sufficient systematicity to ensure scientific clarity and flexibility to take into account specific circumstances and prospects for development
- Sufficient specificity to reflect context-specific questions, in the presence of universality for a broader comparison.

Thus, when analyzing energy security, two basic choices need to be made. The first choice is to determine what are the particular challenges which understanding the phenomenon of energy security faces, and whether these challenges are factual, or are a matter of subjective perception. Focusing on facts makes it easier to carry out quantitative analysis and comparison; however, sometimes facts cannot explain priorities which are formed under the influence of history, culture, politics and psychology. On the other hand, subjective perceptions may be useful only when they come from a certain group of stakeholders and are aimed at setting priorities among different challenges.

The second choice is between more general and more specific scope of study, focus and assessment tools. Cherp and Jewell (2014) recommend relying more on a more general assessment methodology in cases where there is a difference in the comprised energy systems, which is the case when analising several countries. The number of questions raised may be broader, the indicators - more universal, and their interpretation may include more elements of the qualitative analysis (Sovacool [ed.], 2011).

Figure 2: Stages of energy security assessment



Source: Compiled by the author based on Cherp and Jewell (2011)

In order to perform an appropriate energy security risk analysis, it is important to make a well-considered classification of potential risks and vulnerabilities.

Any object is simultaneously affected by many and heterogeneous risks, and a classification is needed to simplify the process of identifying risks and would allow to select quickly the methods for working with risks (Bogoyavlenskii, 2010). Since risk is versatile, there are many and various classification criteria. As noted in Bogoyavlensky (2010), common approaches to this question have not been agreed yet. In regard to the characteristics of the energy systems that reflect the concept of their security, various scientific works suggest the existence of different dimensions of energy security and associated risks.

According to the Global Energy Resource Assessment report (GEA, 2012), the simplest approach uses two dimensions of energy security: physical and economic (like Gupta, 2008). Another option is comparison between long-term and short-term approaches to the analysis of energy security (IEA).

Bogoyavlensky (2010) distinguishes between two groups of criteria, on the basis of which a risk classification system can be created:
- In terms of characteristics of the causes of risk
- In terms of characteristics of the consequences of risk realisation.

Further complication of this framework is proposed by Kondrakov and Lapshin (2014) and establishes the following additional features:
- Type of source
- Time of occurrence
- Major factors of occurrence
- Nature of accounting
- Nature of consequences
- Sphere of origin.

The widely used classification of energy security risks named 4A's ("availability", "accessibility", "affordability," and "acceptability") includes 4 basic concepts: Availability of energy resources, accessibility, affordability and environmental acceptability (Kruyt, 2009). Another common approach (Sendrov, 2013) is to structure the following groups of conditions and factors that create risks for energy security: national economic, socio-political, technological, natural, related to foreign policy and international economics. Other classifications include economic, environmental, social, foreign policy, technical, and security dimensions (Alhajii, 2007), as well as technological, environmental, socio-cultural and military security dimensions (von Hippel, et al. [2011]), accessibility, price acceptability, efficiency, and rational use of natural resources (Sovacool and Brown, 2010), domestic policy, geopolitical, as well as security policy measures (Baumann, 2008).

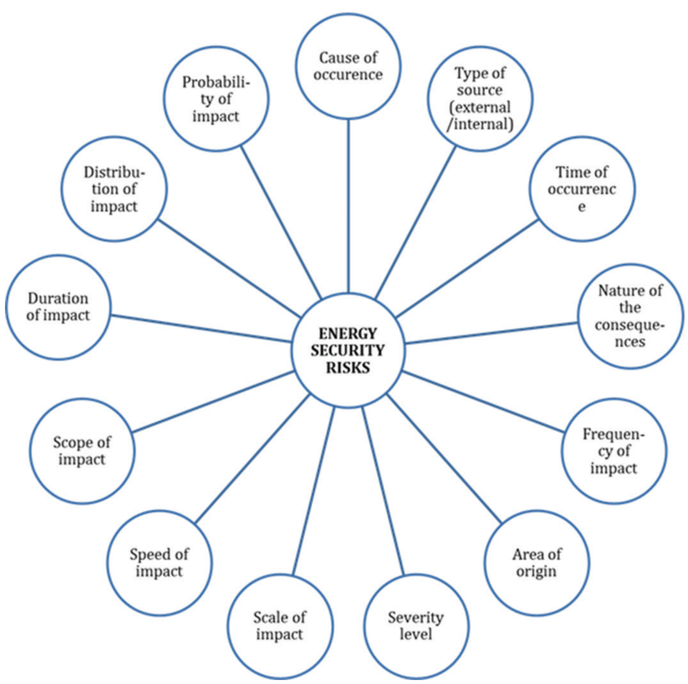
Due to the difficult process of measuring all threats at the same time, it is more practical to choose the conceptual boundaries of the concept of energy security. In Winzer (2011) about 40 definitions of the concept have been analyzed in order to group them into three groups, according to the method of limiting the concept of energy security:

1. The first group of authors defines energy security as the continuity of the supply of energy products (gas, oil, coal and electricity) - this view is shared by most definitions (Scheepers et al. [2007], Ölz et al. [2007], etc.)
2. The second group of authors proposes in addition a subjective "level of severity filter" to draw the line between safe and not safe levels of continuity. Such filters are characteristics or criteria of energy security risks. They determine which threats are relevant to the current analysis. Although there are many possibly applicable severity filters, Winzer (2011) establishes the following filters: speed, size, duration of exposure, distribution of exposure, frequency and probability of exposure. Such approach is applied also by Le Coq and Paltseva (2009) and Vicini et al. (2005)
3. The third group of authors includes the scale of impact in the definition of energy security. Instead of measuring cost and continuity of supply, the authors measure cost and continuity of services, impact on the economy and further impact on the environment and society. These authors include Bohi et al. (1996), and Noel and Findlater (2010).

It is more convenient to visually present energy security dimensions. Figure 3 below represents a generalized scheme of possible risk classifications, as well as dimensions of energy security, which are based on available scientific works on data systematization research, including the works presented above.

According to Winzer (2011), the sources of risk and the magnitude of the impact describe the limits of the system to be analyzed. The remaining dimensions describe severity filters and are used to determine which threats are relevant to the analysis. The list of criteria is not exhaustive. The severity of the threat rises by increasing speed, size, duration and spread of impact, and at the same time falls by increasing frequency and likelihood of impact.

Figure 3: Illustration of energy security dimensions and associated risks. The list of criteria is not exhaustive



Source: Compiled by the author based on data from literature sources devoted to risk analysis

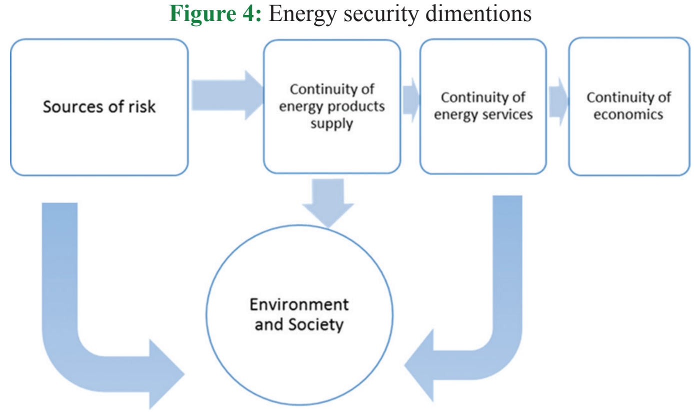
Most risks that have an impact on the supply chain, in turn, affect the continuity of the supply of energy products by amanding availability or price of energy products such as oil, gas, coal or electricity. Depending on the robustness of end-use appliances to interruptions in the supply of the consumed energy products, changes in the availability and price of these products may affect the continuity of the provision of energy services such as heating, lighting, communications or transportation. Depending on the severity of gaps in the provision of energy services and their reflection on the economy, changes in the availability and cost of energy services, in the end, can affect the continuity of the national economy. In addition to these effects, the provision and consumption of energy products can also affect the safety of citizens and the environmental sustainability. All these casual relationships are illustrated in Figure 4.

Winzer (2011) proposes to distinguish between threats that have an impact on the supply chain, and the impact of the supply chain on the environment. The paper proposes to limit the concept of energy security to the impact on the continuity of supply and provision of services, and, as a consequence, the impact on the continuity of economic development, while the effects on the safety of citizens and the environment are highlighted in separate concepts.

As brought out hereinabove, energy security is traditionally associated with the features of reliability and price stability. To date, a new fundamental principle has been added to the above features, namely the so-called environmental security. In the past, the notion of environmental sustainability has not been included in the definitions of energy security, but at present it is an integral part of the indicators defining the concept.

However, concerns about the climate change accelerated the expansion of the concept, which influenced the establishment of the so-called energy triangle (Energy Trilemma – World Energy Council), (Umbach, 2012) which includes security of energy supply, economic competitiveness and environmental/climate sustainability. Very often, it is underestimated that these three requirements contradict each other in practice (Carbon Brief, Climate rhetoric: What's an energy trilemma, 2013)

Figure 4: Energy security dimentions



Source: Compiled by the author based on data from Winzer (2011)

Answering the question *"what exactly needs to be protected?,"* it is impossible to focus on the abstract concept of "energy," but on ensuring the safety of energy systems that are critical for society - vital energy systems (Cherp and Jewell, 2011). As it is reasonably argued, energy security is usually considered a protection against failures of the critical energy systems. "Critical" is developing in the course of history from oil supplies for military purposes and covers various energy sources, infrastructure and end-use sectors. The idea of "protection against disruptions" has also evolved from ensuring military and political control over energy resources to the establishment of comprehensive policies and measures for strategically managed risks that affect all elements of energy systems. Such vital energy systems are subject to examination at national, regional or global levels. It is also necessary to clarify which sectors of the energy system will be analyzed and is it necessary to examine them together or separately.

The vulnerabilities of the energy system are a combination of risk and robustness, or the ability to respond to system disorders. More often, the existing approaches to the assessment of energy security is studied from the point of view of risks. However, there are authors who consider the question from the point of view of robustness/flexibility.

Instead of classifying vulnerabilities (or risks) according to the various areas of study (economic, political, technical, etc.), three distinctive perspectives of energy security could be identified (Cherp and Jewell, 2011). Each of these three perspectives is guided by its own philosophy, based on a separate academic discipline, and each of them focuses on a specific set of threats, reactions and robustness strategies.

- The "sovereignty perspective" has been historically shaped by the problems caused by oil security and has its roots in security studies, theories of international relations and political science. It focuses on the risks arising from external control over vital energy systems and analyzes these risks in terms of configuration of interests, influence, alliances and space for maneuver (for example, the ability to switch between suppliers or sources of energy) of the participants. Strategies to minimize risks according the sovereignty perspective include switching to a more trustworthy supplier or weakening the single supplier factor through diversification, replacing imported resources with domestic ones, as well as military, political and/or economic control over energy systems
- The development of the "robustness perspective" is rooted in the technical and natural sciences. According to this perspective, threats to energy security are considered as "objective" and mainly quantitative factors, such as increased demand, resource scarcity, mechanical aging of infrastructure, technical failures, or natural disasters. Minimizing the risks of such disruptions within this perspective involves upgrading the infrastructure, switching to more saturated energy sources, introducing safer technologies, and managing demand growth (Cherp and Jewell, 2011)
- The "resilience" or the "flexibility" perspective" considers a source of risk the increasing complexity and uncertainty in technological, social and economic factors affecting energy systems. This perspective recognizes the fact that many failures and risks cannot be predicted with 100% accuracy (regulatory changes, unpredictable economic crisis, political regime change, revolutionary technologies, climate change). Instead of identifying and managing risk, this perspective offers the examination of more general characteristics of energy systems (flexibility, adaptation, diversity), that provide protection against threats through risk allocation (both known and unknown), as well as preparation for unforeseen circumstances.

Currently, not only these problems intersect with each other, but also the need to integrate their solutions is increases. This sets the current energy security agenda and requires the creation of a new level of interaction between the three perspectives (Cherp and Jewell, 2011).

Indicators of energy security could be selected from those proposed in the extensive scientific literature or create them specifically for the purposes of a specific study. The choice should be based on how well the indicators represent certain risks or vulnerabilities. However, any given indicator is rarely a direct measure of risk or system resilience. Rather, it is a signal for the condition of a complex and dynamic system. In the case when there is no access to detailed information about several countries being analyzed, it is recommendable to use less detailed (more general), but various indicators (Cherp and Jewell, 2011).

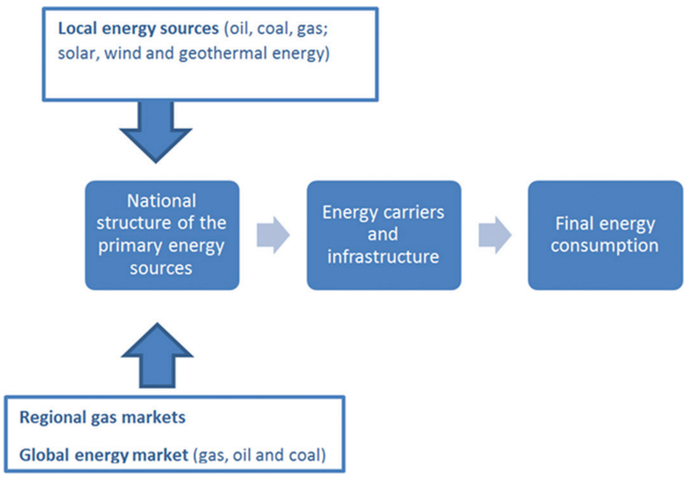
After the calculation of the selected indicators, it is necessary to explain and communicate thei meaning to the target audience of the study. Although some indicators directly provide answers (metrics already used in the policy making process), there are cases where the direct interpretation is not effective. This is the case when several indicators are necessary to demonstrate the complete picture, but this may cause difficulties for the politicians to understand them. Thus, the strategy in such cases could be to combine the indicators in the form of "parameters of energy security," but a balance should be kept between reducing the data and transmitting true information about the system and the vulnerabilities identified earlier (Cherp and Jewell, 2011).

Based on the energy security analysis methodology refered to above and the corresponding development of the five stages, as well as taking into account the complexity of the concept of the contemporary energy security, the necessary methodological choices for analyzing national energy security are be presented below - defining energy security for the needs of the assessment, determining the boundaries of the vital energy systems, identifying the vulnerabilities of the vital energy systems and selecting indicators for these vulnerabilities.

1. As a working definition of energy security, this work proposes the following interpretation, which includes the concept of the acceptable risk or the principle of optimization (ALARA – as low as reasonably achievable), used to ensure radiation safety: *"vulnerability of the vital energy systems as low reasonably achievable at an affordable price, while respecting environmental considerations"*
2. Determination of the vital energy systems: Regarding the geographic boundaries, it is suggested to primarily formulate

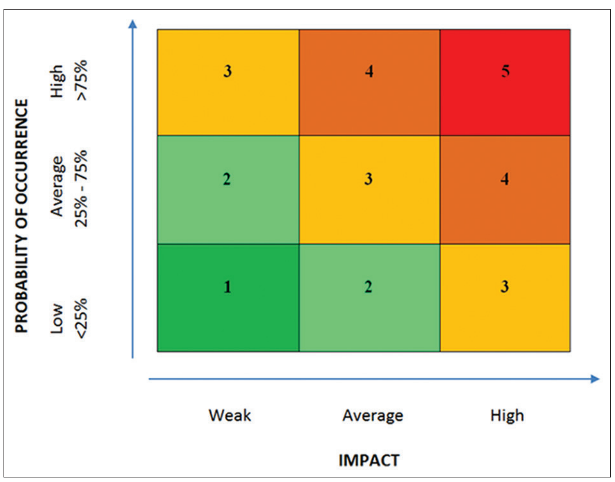
the challenges to energy security for the national level, since historically it has always been the state that was responsible for ensuring security. However, intraregional energy integration and trade are important factors for most regions, and therefore, an analysis of energy security at the regional level should also be considered. Regarding sectoral boundaries of the analysis, it is proposed to apply a separate analysis of the various primary energy sources, since it is assumed that energy sources cannot always replace each other and often have distinct vulnerabilities.

Figure 5: Structure of the energy system



Source: Compiled by the author based on data in Winzer, 2011

Figure 6: Risk matrix



Source: Compiled by the author based on Novozhilov (2015)

Table 1: Model table to present risks and a base for indicators of energy security (based on the Global Energy Assessment, 2012)

Energy system	Energy security risks		
	Robustness	Sovereignty	Resilience
1. Primary energy source			
1.1. Oil			
Global and regional level	a	b	c
National level	d	e	f
1.2. Coal			
Global and regional level	g	h	i
National level	j	k	l

Etc., primary energy source, energy carriers and the national energy system as a whole

Three main subsystems could be distinguished in the energy system: primary energy sources, energy carriers and infrastructure, as well as final consumption (Figure 5). These subsystems have (fully or partially) a national, regional and global dimension. In addition to the main sources of energy, it is proposed to also include energy carriers (electricity: electrical networks and power plants) in the analysis. The end-user sector (energy services: transport, industry, residential and commercial facilities) is outside the scope of this study.

After defining energy security and determining the boundaries of the vital energy systems for the purposes of the study, the next steps of the proposed methodology suggest further identification of the vulnerabilities of the vital energy systems and the selection of indicators to describe them.

For this purpose, a matrix in a tabular form could be used (Table 1), which contains, on the one hand, energy systems (primary energy sources, energy carriers and the national energy system as a whole), and on the other, three dimensions of energy security risks (in terms of sovereignty, robustness and resilence). To quantify national energy security, it is necessary, first, to analyze the energy sector of the particular country and identify the risks and their nature for each energy system, and then to identify indicators that reflect quantitatively these risks.

Based on a quantitative and a qualitative analysis, it will be possible to identify the main risks to energy security in the country. Since risk is most often perceived as a combination of the likelihood (or frequency) of an undesirable event and the impact of its consequences, a risk matrix can be used to display this combination (Figure 6), since it is considered the most convenient and visual tool used to support decision making in risk management systems. It represents a table of cells that displays a combination of the frequency of an undesirable event and the severity of its consequences, and allows, in a visual form, to give information about the risk levels for the event in question (Novozhilov, 2015).

5. CONCLUSION

This article reviewes the existing definitions of the concept of energy security at the global, regional, as well as national and scientific levels. The analysis of the three approaches of Russia, the EU and the United States to the definition shows that they contain certain similar elements, namely the notions of "availability," "reliability" and "affordability."

Identifying and measuring energy security risks are difficult tasks. The term energy security is widespread and contains elements whose meaning depends on the context. Even though the international community did not manage to come to a consensus on the definition of the concept of energy security, it is commonly agreed that security is related to risk. Since the energy system cannot be fully protected, it is appropriate to consider energy security as a risk management problem. Since risk is versatile notion, there are many and different classification criteria. Regarding the characteristics of energy systems that reflect the concept of their security, the existing scientific works propose various dimensions of energy security and the associated risks.

Based on a review of energy security assessment literature, the approach developed in Cherp and Jewell, 2011 has been proposed as a basis for assessing national energy security. The proposed methodology for assessing energy security includes five steps, namely, defining energy security, determining the boundaries of the vital energy systems, identifying the vulnerabilities of the vital energy systems, selecting and calculating indicators for these vulnerabilities and interpreting the indicators to answer the questions raised in the particular analysis.

Instead of classifying vulnerabilities (or risks) in different areas of study (economic, political, technical, etc.), it is proposed to identify three distinctive perspectives of energy security. Each of these perspectives is guided by its own philosophy based on a particular academic discipline, and each of them focuses on a specific set of threats, reactions and resilience strategies, namely threats associated with the sovereignty, robustness and resilience of energy systems.

As a working definition of energy security, this paper proposes the following interpretation, which includes the concept of the acceptable risk or the principle of optimization (ALARA – as low as reasonably achievable), used to ensure radiation safety: *"vulnerability of the vital energy systems as low reasonably achievable at an affordable price, while respecting environmental considerations."*

Regarding the geographic boundaries of the research, it is proposed to formulate the challenges to energy security, first of all, at the national level, since historically it has always been the state that was responsible for ensuring security. Nonetheless, intraregional energy integration and trade are also important factors for many regions, and therefore it is proposed to include an analysis of energy security at the regional level as well. Regarding the sectoral boundaries, it is recommended to review separately the various primary energy sources, since it is considered that they can not always replace each other and often have distinctive vulnerabilities.

Three main subsystems could be distinguished within the energy system: primary energy sources, energy carriers and infrastructure, and final consumption. These subsystems have (fully or partially) national, regional and global dimensions. In addition to the main sources of energy, it is also necessary to include energy sources in the analysis (electricity: electrical networks and power plants). The final consumption sector (energy services: transport, industry, residential and commercial facilities) is outside the scope of this study but could be additionaly analysed.

Since risk is most often perceived as a combination of the likelihood (or frequency) of an undesirable event and the impact of its consequences, a risk matrix can be used to display this combination. It may contain, on the one hand, energy systems (primary energy sources, energy carriers and the national energy system as a whole), and on the other, the three dimensions of energy security risks (in terms of sovereignty, robustness and resilience).

To quantify the national energy security, it is necessary, first, to analyze the energy sector of a particular country and identify risks and their nature for each energy system, and then to identify indicators that reflect these risks quantitatively.

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