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Review

Defining the Perception of Energy Security: An Overview

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Abstract: Energy security is recognized as a key element for the successful functioning of an entire energy system. However, the perception of energy security is contextual and there is no universally accepted definition of the concept. The current global concerns about climate change, human welfare and energy market challenges due to the COVID-19 pandemic, military conflicts, various geopolitical issues and scarcity of energy resources have affected the perception of the energy security concept as well. The research aims to define how energy security is perceived amid current global concerns and to identify the essential components. The four-tiered research methodology was developed and applied to determine the current perception of energy security. While the systematic literature review was conducted according to the SALSA (Search, Appraisal, Synthesis and Analysis) framework, it was found that the current perception of energy security consists of seven main components, these are: Availability, Affordability, Environmental Impact, Social Impact, Geopolitical Relationships, Government Effectiveness and Technological Development. The paper contributes to discourse development and clarification of perception of energy security and will be useful for further research, both dealing with the concept of energy security itself and developing composite indicators for energy security assessment.

Keywords: energy security; energy policy; climate change; geopolitical relations; literature review

Citation: Siksnelyte-Butkiene, Indre. 2023. Defining the Perception of Energy Security: An Overview. *Economies* 11: 174. https://doi.org/10.3390/economies11070174

Academic Editor: António C. Marques

Received: 14 April 2023
Revised: 14 June 2023
Accepted: 21 June 2023
Published: 25 June 2023

1. Introduction

Energy is a critical component for the development and growth of the economy of a country, as many production and consumption activities require energy as a basic source. The usage of energy encourages productivity and growth of industry, as it is primary factor for the functioning of any country modern economy. The well-being of people, the competitiveness of industry and the general functioning of society depend on secure, sustainable and affordable energy. For example, in the EU, the energy sector, which encompasses extraction, generation and distribution, directly employs around 1.6 million people and generates an added value of 250 billion EUR, representing 4% of the value added of the EU's non-financial corporate economy (European Commission 2023).

The global concerns and uncertainties regarding the economic aspects, the global pandemic, geopolitical relations, and climate change present the energy sector with extremely big challenges in recent years (Jonek-Kowalska 2022; Costantini et al. 2022; Ghosh et al. 2022). Although energy security issues have been always considered as important, their relevance has become particularly evident in the context of recent challenges and to ensure energy security has become at to the top agenda both at the national and regional levels in different countries of the world. The necessity to strengthening the level of energy security under the global geopolitical challenges can be associated with military conflicts as the war in Ukraine, especially for European countries (Osička and Černoch 2022; Kuzemko et al. 2022), economic- and social-related problems for the energy consumers and the whole energy sector due to consequences of the COVID-19 pandemic, the scarcity of energy resources, and the global concerns regarding climate change and the well-being of people.

The example of the war in Ukraine, which was also followed by energy supply and affordability problems in European countries, aptly demonstrated the importance of energy

security. The recent energy-related issues proved that it requires particularly high attention from the government of a country to ensure independency and the well-being of people. At the same time, the COVID-19 pandemic (Siksnelyte-Butkiene 2021), the challenges regarding climate change, the growing demand of energy and concerns regarding limited energy resources (Mara et al. 2022) have revealed the importance to boost renewable energy and increase energy efficiency both at the level of the entire country and at the level of households, thus increasing the independence of energy consumers and reducing the risk to suffer energy poverty (Siksnelyte-Butkiene 2022).

Energy security can be recognized as a main core of a country's energy system and one of the main elements in international relations (Marhold 2021). Despite that, the perception of the concept is uncertain and context dependent. As a consequence, there is no one widely accepted definition and what it contains. The traditional understanding of energy security is mainly associated with energy availability and includes such issues as security of supply, self-sufficiency, energy diversification, and affordability. The well-known "4As" (availability, affordability, accessibility and acceptability) approach can also be attributed to the traditional perception (APERC 2007), if the acceptability dimension is understandable only as the amount of greenhouse gas (GHG) emissions or the renewable fraction.

In recent years, the perception of energy security shifted away from a traditional comprehension to an interdisciplinary approach. The global concerns regarding the climate change, well-being of people and uncertainties and changes in the market due to the pandemic, military conflicts, scarcity of energy resources have also changed the perception of the concept. Many scientists argue that current global concerns should be addressed when the concept of energy security is defined (e.g., Rodriguez-Fernandez et al. 2022; Cervan et al. 2022).

This paper tries to fill this gap and contributes to the clarification and discourse development of the perception of the energy security concept under the current global concerns and uncertainties. Thus, the goal of this study is to determine how energy security is perceived under current global concerns and uncertainties, and of what dimensions it is contained. To reach the goal of the study, the main tasks have been raised, which are:

- To identify the main global aspects affecting the energy security of a country;
- to overview recent concerns regarding energy security in the scientific literature;
- to analyze the composition of the latest energy security indicators;
- to single out the dimensions of the current perception of energy security and to provide insights regarding the perception of the concept;
- to discuss the significance of the perception of energy security for energy policy development.

The systematic literature review of recent developed composite indicators to measure energy security was carried out in order to identify the current perception of energy security. This study will serve for further research, both analyzing the concept of energy security itself, and developing indicator sets to measure energy security.

Section 2 of the paper presents a methodology that was followed for this research. The recent concerns and their reflection in the scientific literature are presented in Section 3 of the paper. Section 4 reviews the latest indicators developed to assess energy security, identifies the essential components and provides insights regarding the perception of the concept. Discussion and practical implications are presented in Section 5 of the paper. Finally, conclusions are provided in the Section 6.

2. Methodology

In order to examine the perception of the changing and context-dependent concept of energy security in the face of recent global uncertainties, the research methodology can be divided into several main parts, as presented in Figure 1. Firstly, it is necessary to clearly identify the most influencing global aspects, which may affect the extent of energy security of a country or region. Then, the recent concerns and their reflection in the scientific literature during the systematic literature review was determined. The main concerns and

its perception is reflected though indicators to measure the level of energy security of a country. Therefore, the latest composite indicators (developed during the last three years) to assess energy security were reviewed, and input data were distinguished. This provided a possibility to identify and compare changes in the perception of energy security in the context of recent global uncertainties.

Figure 1. Logical structure of the research. Source: produced by the author.

The systematic literature review was performed in the Web of Science Core collection database on two combinations of topics which are: "energy security" + "index" and "energy security" + "indicator". These keywords have been selected because they are often used as the main terms in studies dealing with energy security measurement, which allows for a targeted selection of relevant studies. The literature review was carried out following the SALSA (Search, Appraisal, Synthesis and Analysis) framework (Amo et al. 2018), which is one of the most popular tools to perform this kind of research in a scientifically recognized manner, and allows to select studies related with the problem which is analyzed and to minimize subjectivity.

All of the papers identified in the Search step were filtered based on inclusion and exclusion criteria defined for this literature review in the Appraisal step. The papers were included for further analysis if they met the inclusion criteria listed below: the main keyword of the search "energy security" should be in the title of the paper; the second keyword should be in the title, abstract, or keywords section; the document type should be identified as "article"; the paper should be published in one of the selected categories, which are Energy and Fuels or Economics. Then, the process of studies selection was followed by the application of exclusion criteria, which are: non-English papers, duplicates, not primary research papers, papers with errors in methodology (confusing methodological basis) and papers, that do not reflect the problem analyzed.

The Synthesis step is dedicated for required category identification, data extraction and classification. Two groups of categories (general and specific) are used for this research, in order to perform a systematic literature review of the latest energy security indicators and analyze the perception of the concepts under current global uncertainties. General characteristics can be assigned with such information as: year of the paper, source, name of indicator proposed, number of indicators included, case study applied. The specific data categories important for this research are as follows: input data used; the main outcomes of the paper and contribution to the field; methodological aspects, such as participation of experts, process of criteria selection, and way of weighting.

The full content analysis of selected studies is carried out in the Analysis step. It will answer key questions of the research and achieve the goal of the current study. In order to provide insights regarding the perception of energy security in the face of current global uncertainties, the detailed analysis of the developed indicators cover the last three years.

3. Growing Concerns and Its Reflection in the Scientific Literature

The analysis of the main characteristics of the studies identified in the search stage of the systematic literature review, enabled us to determine the extent of the problem. Figure 2 shows the number of scientific articles via the combination of keywords "energy security" and "indicator" or "index" in the Energy and Fuels, and Economics categories in the Web of Science database. The significant increase of studies is shown in the last three years (2020–2022). Studies in these last three years account for more than half of all search results. And although the issues of energy security have always been important for many countries of the world and these issues have been analyzed in the scientific literature; the global

events of recent years highlighted the extent of the problem and it is reflected both in the scientific literature and in the political documents of various countries.

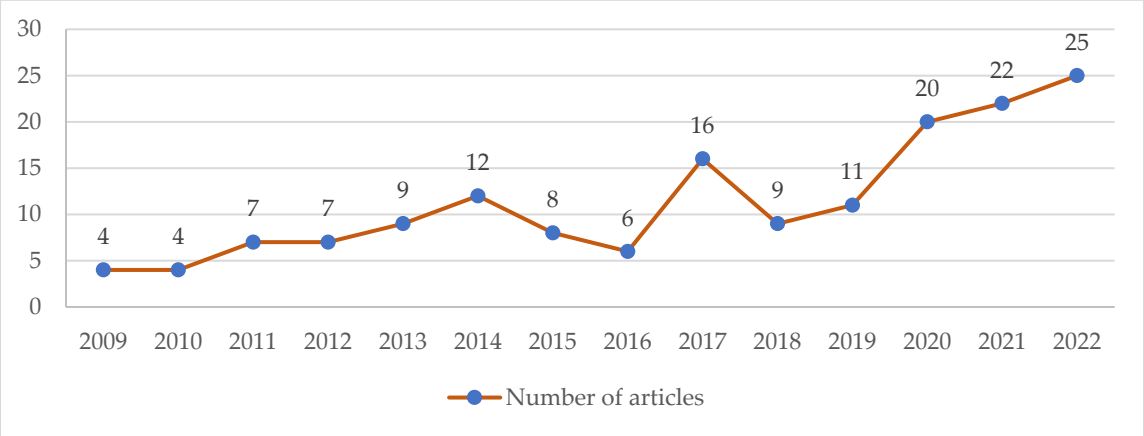

Figure 2. Number of articles via the combination of keywords "energy security" and "indicator" or "index" in the Energy and Fuels, and Economics categories. Source: produced based on Web of Science Core Collection database, 5 February 2023).

Evaluation systems dedicated to energy security measurement have been developed by researchers from more than sixty countries, but the leading ones can be singled out (Figure 3), which are: China, the United States, Poland and the United Kingdom. However, it is also important to consider the country's population, which has a direct impact on the amount of scientific studies carried out in that country. Here, Lithuania and Denmark can be singled out, which makes a significant contribution to the studies in this field, and where energy security issues have been relevant for many years and are being solved by the country's scientists. In this case, Denmark is one of the leading countries in the transition to a sustainable energy sector. Meanwhile, Lithuania is characterized by having very low-energy security indicators, such as a higher energy dependence on imported energy or still being connected to electricity transmission networks from Russia in the BRELL ring.

After the content analysis of the studies obtained during the systematic literature review, certain general research directions have been shown up among energy security studies. All the studies, which developed or used various composite indicators or indicator sets can be categorized into several research directions based on the main purpose of the study. Overall, six categories have been singled out; these research directions are provided in Figure 4.

The biggest part of the articles proposed a new composite indicator (index) or indicator set to measure the level of energy security for a specific country or on a global level. The analysis of such newly created composite indicators can reveal how energy security is perceived in the context of global and specific country concerns. The detailed analysis of the latest composite indicators which have been developed, are carried out in Section 4.

Another part of the research is focused on presenting new methodologies for energy security assessment. For example, a study performed by Yang et al. (2022) where the approach based on the Driving Forces-Pressures-State-Impacts-Responses (DPSIR) model, for the assessment of energy security in China, was presented, and interrelated links and impacts were examined. In order to assess energy trade and security dynamics at a global scale, Berdysheva and Ikonnikova (2021) introduced two indices, measuring the security of energy consumption and security of energy production. Wang et al. (2021) presented an evaluation tool to measure energy economic security, which considers four dimensions as follows: development of energy industry, level of energy utilization, capacity of energy supply, and impact on the environment.

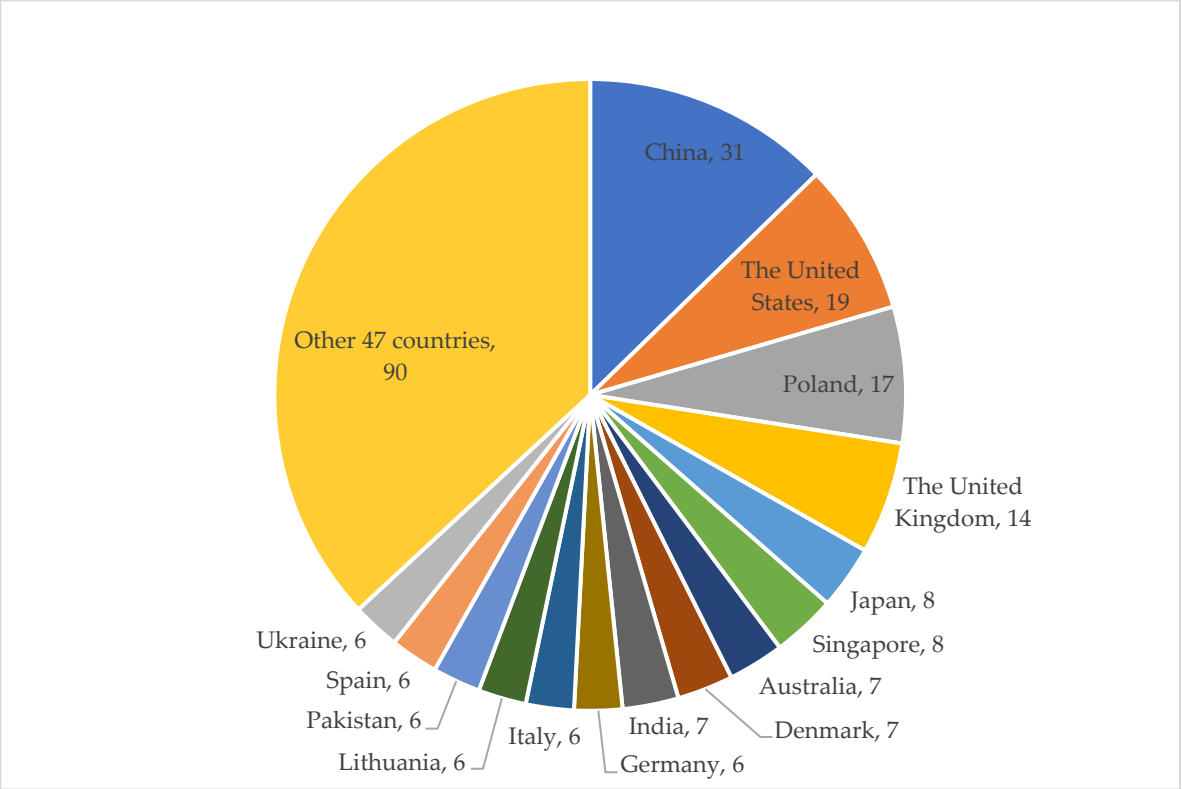

Figure 3. Distribution of articles by countries. Source: produced based on Web of Science Core Collection database, 5 February 2023).

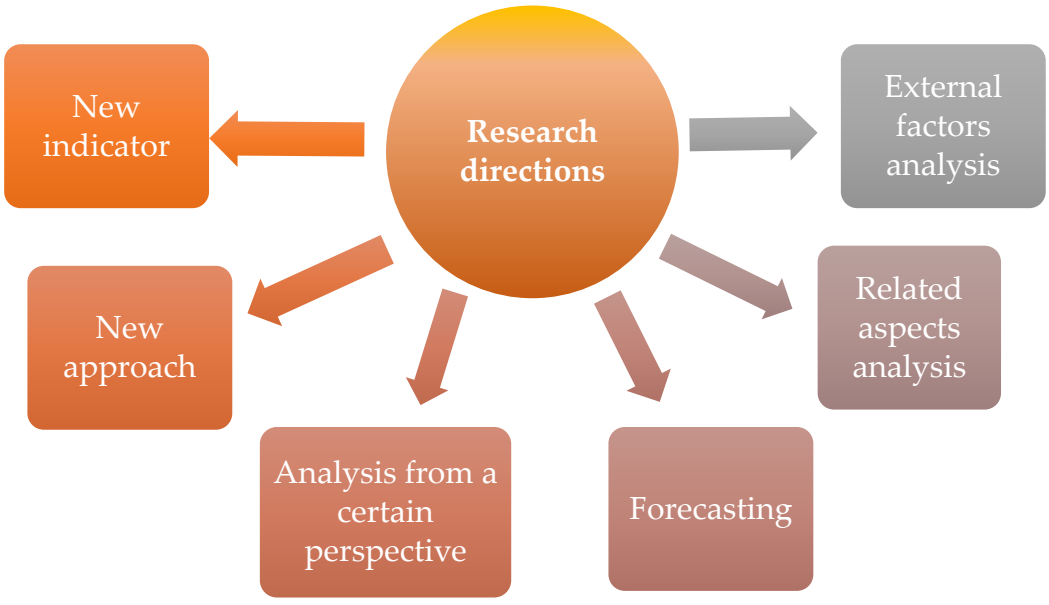

Figure 4. Research directions in energy security studies. Source: produced by the author.

Also, a part of these studies was focused on the energy security assessment from a certain perspective and can be classified as partial assessments. For example, the composite indicator presented by Kosai and Unesaki (2020) is designed to assess the security of nuclear energy supply in the United States. The Power System Security Index introduced by Fuentes et al. (2020) is dedicated to measure the level of electricity supply security and was thus applied for a case study of Argentina. The proposed approach emphasizes the importance to measure energy security of different energy systems in order to identify

policy improvements. Rodriguez-Fernandez et al. (2020) introduced the Weighted Energy Security Index to measure for gas supply security; the proposed index was applied for a case study of 27 EU member states.

Attempts to forecast the level of energy security can also be found in the literature. Some authors used well known and widely used indices; e.g., Ziemba (2022) forecasted the level of energy security by the application of the International Energy Security Risk Index, which was created by the Global Energy Institute more than ten years ago (in 2012). Other authors developed unique composite indicators in order to forecast the level of energy security; e.g., Li and Zhang (2018) created the Energy Supply Security Index and performed short-term forecasting in China.

Various relationships between energy security and other aspects are also of interest among scientists. The linkages between energy security and such issues as monetary policy (Wang et al. 2022), macroeconomic stability (Filipović et al. 2018), prediction of energy stock returns (Iyke et al. 2021), income inequality (Lee et al. 2022), energy poverty (Taghizadeh-Hesary et al. 2022; Nasir et al. 2022), food security (Zakari et al. 2022; Guo and Tanaka 2022), participation in global value chains (Ha and Thanh 2022) were proved.

External factors that can have a direct impact on the level of energy security are also analyzed in the recent scientific papers. It was determined that such issues as climate change (Gyeltshen 2022), interruption in resource supplies (Mróz 2022), inappropriate political actions (Dobrowolski 2021) and a lack of the appropriate organization of the energy market and a low flexibility of energy infrastructure (Sutrisno et al. 2021) may negatively affect the level of energy security of a country.

Many studies stress the importance to ensure energy security of a country or region under the current global concerns, such as: climate change, military conflicts (e.g., war in Ukraine), scarcity of energy resources, consequences of the global COVID-19 pandemic (e.g., supply problems, increase in the level of energy poverty), and the well-being of people.

The multi-directional analysis of energy security, the strongly increased number various composite indicators and analytical methodologies, and their application in different countries of the world reveal the extent of the problem in the context of the global challenges of recent years. It can be assumed that concerns of recent years have undoubtedly changed the perception of the concept of energy security. The main changes can be identified by analyzing the indicators that are used in the latest energy security assessment systems.

4. Review of the Latest Indicators to Assess Energy Security and Insights Regarding Perception of the Concept

Twenty-one composite indicators created in the last three years have been found with the aim to measure the energy security of a country or region, or perform a global level assessment. A variety of composite indicators and sets developed in recent years to measure the level of energy security, are presented in Table 1.

Table 1. Variety of composite indicators developed in recent years to measure the level of energy security. Source: produced by the author.

Name of Composite Indicator	Source	Number of Indicators Included	Case Study	Input Data	Experts Engagement	Criteria Selection Process	Way of Weighting	Main Outcomes and Contribution to the Field
Provincial Energy Security Index	Li et al. (2020)	12	China	Energy consumption, production, diversity, storage, renewable fraction, infrastructure (transportation maturity), intensity, air pollution, sewage ratio, affordability, subsidies, investments	Yes	Own selection	Entropy method, order relation method (experts)	The Provincial energy security index for China was introduced and applied in practice.
Energy Security Level	Augutis et al. (2020)	24 compound indicators	The Baltic States (Lithuania, Latvia, Estonia)	Installed capacity, energy production, consumption, renewable fraction, reserves, affordability, market competition, energy dependency, diversification, political risk, energy expenses of households,	Yes	Literature, own selection	Experts survey	The approach to measure the energy security level is proposed and applied for three Baltic States countries
Energy Security Index of Pakistan	Bin Abdullah et al. (2020b)	22	Pakistan	Energy production, consumption, diversification, air pollution, access, efficiency, import dependency, renewable fraction,	Yes	Literature, experts survey	Principal component analysis	The index for the energy security in Pakistan was proposed and applied to evaluate the performance in the period of 2000–2018
Energy Security Index for Cape Verde	Coutinho et al. (2020)	20	Carpe Verde	Energy import dependency, diversification, access, self sufficiency, geographic dispersion of energy facilities, affordability, intensity, innovations, capacity margins, direct employment, government investment, access to information, air pollution	Yes	Literature, Delphi survey	Delphi survey	The energy security index for Cape Verde was presented and applied in practice.
Dynamic Energy Security Index	Wang et al. (2020)	17	China	Import dependency, concentration, energy reserves, self sufficiency, intensity, energy mix, affordability, investments, efficiency, air pollution	No	Literature	Own estimation—equal weights	The Dynamic Energy Security Index based on functional data analysis was introduced and applied for a case study of China.
-	Wu et al. (2021)	18	Applied at global level (125 countries)	Energy production, consumption, diversification, import, self sufficiency, reserves, GDP, access, supply diversification, affordability, renewable fraction, air pollution, intensity, efficiency, government effectiveness and expenditure, political stability	No	Literature, own selection	Principal component analysis	Indicators for global level analysis were selected and an innovative approach to measure energy security was applied for global level assessment.
-	Kharazishvili et al. (2021)	42	Ukraine	GDP, energy consumption, production, intensity, air pollution, import, involvement in foreign markets, energy mix, renewable fraction, infrastructure, self sufficiency, energy suppliers, technological dependence, energy reserves, reliability, legislation, regulatory and policy stability, investments, wages in energy sector, affordability, public policy quality, quality of energy services and staff.	No	Literature, own selection	Principal component analysis	An innovative approach for the energy security analysis and strategic management is proposed and applied for a case study of Ukraine.
-	Zhang et al. (2021)	28	China	Energy production, efficiency, diversification, self sufficiency, affordability, households expenditure for energy needs, heated area per household, energy access, infrastructure, reliability, intensity, investments, expenditures on environmental protection, air pollution	Yes	Literature, own selection	Fuzzy AHP, pairwise comparisons	A new innovative approach to measure regional energy security was proposed and applied for a case study. The study can serve as a guide for further research, because of advanced methodology.
-	B. Huang et al. (2021)	10	China	Energy reserves, consumption, investments, diversification, GDP, air pollution, expenditures on pollution treatment, expenditures on research and development, labor input in research and development,	Yes	Own selection	Fuzzy BWM	An innovative approach to measure energy security was proposed; indicator set developed and applied in practice.

Table 1. *Cont.*

Name of Composite Indicator	Source	Number of Indicators Included	Case Study	Input Data	Experts Engagement	Criteria Selection Process	Way of Weighting	Main Outcomes and Contribution to the Field
Energy Economic Security Index	Wang et al. (2021)	24	China	Energy investments; employment; energy industry benefit; changes in energy price; energy production, consumption, efficiency, elasticity, import, air pollution, energy mix	No	Literature, own selection	Principal component analysis	The index to measure energy economic security at a regional level was proposed and applied for the assessment of 30 regions in China.
Energy Security Index	Stavytskyy et al. (2021)	29	Applied at global level (45 countries of Europe and Western Asia)	Energy consumption, import, export, depletion, intensity, efficiency, renewable fraction, air pollution	No	Own selection	Own estimation—equal weights	The energy security index to measure energy security on an international scale was proposed and applied for the a analysis of 45 countries, and to identify changes in the last two decades.
-	Sotnyk et al. (2021)	15	Ukraine	Energy production, consumption, import dependency, Depreciation of fixed assets, investments, energy reserves, renewable fraction, efficiency, energy poverty, renewable energy financial burden, capacity development, energy fluctuations	No	Literature, own selection	-	The improved indicators set for the measurement of energy security in Ukraine was proposed. Additional composite indicators were justified in the context of global and national threats.
Energy Security Performance framework	S. Huang et al. (2021)	20	Applied at global level (34 OECD countries)	Energy consumption, production, renewable fraction, import dependency, national reserve, efficiency, air pollution, forest area, political stability, research and development expenditure, corruption perception, affordability, time to get electricity	No	Literature	Principal component analysis	The indicators set to measure energy security was proposed and applied for 34 OECD countries. The proposed system allows to repeat the research and monitor the progress achieved.
Energy Security Index of Pakistan	Bin Abdullah et al. (2020a)	39	Pakistan	Energy consumption, production, renewable share, affordability, energy import, intensity, efficiency, corruption, governance effectiveness, oil stock, air pollution, forest area	No	Literature	Principal component analysis	The index for the energy security in Pakistan was proposed and applied to evaluate the performance for the last three decades and to measure possible performance in the future.
China's Energy Security Index	Gong et al. (2021)	13	China	Energy production, consumption, air pollution, investments, affordability, GDP	No	Literature	Entropy weight method	The index to measure energy security in China at regional level was proposed and applied in practice.
-	Yang et al. (2022)	20	China	Population, economic output, industrialization and urbanization, GDP, energy consumption, intensity, air pollution, investments	No	Literature, own selection	Entropy weight method	The new approach to analyze energy security was presented. The Driving Forces-Pressures-State-Impacts-Responses model was applied to assess the level of energy security and interrelations among dimensions.

Table 1. *Cont.*

Name of Composite Indicator	Source	Number of Indicators Included	Case Study	Input Data	Experts Engagement	Criteria Selection Process	Way of Weighting	Main Outcomes and Contribution to the Field
-	Tutak and Brodny (2022)	17	12 EU countries (Austria, Bulgaria, the Czech Republic, Croatia, Estonia, Hungary, Lithuania, Latvia, Poland, Romania, Slovakia, Slovenia)	Energy supply, consumption, efficiency, intensity, import dependency, diversification, renewable fraction, net trade, GDP, GHG intensity, affordability, households income	No	Literature	Entropy weight method.	The indicators set reflecting the EU energy policy priorities was developed and applied for a case study of 12 EU countries. The proposed set can be easily adapted for a case study of all EU member states.
Pakistan's Multi-dimensional Energy Security Index	Bin Abdullah et al. (2022)	27	Pakistan	Energy consumption, import, access, intensity, efficiency, affordability, corruption, governance effectiveness, air pollution, renewable fraction, forest area	Yes	Own selection, Experts survey	Principal Component Analysis	The index to measure energy security in Pakistan was proposed and applied to measure situation for the last three decades as a whole and across different dimensions. The methodology used to measure situation across dimensions is useful for further research and can serve as a guide.
Energy Security Index	Cervan et al. (2022)	15	9 South American countries (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Peru, Paraguay and Uruguay)	Energy access, quality, affordability, supply, diversity, consumption, energy intensity, air pollution, renewable fraction	No	Literature	n/a	The new index is proposed, reflecting different dimensions of energy security and applied for a case study of 9 countries and its comparison.
Energy Security Performance	Ha and Thanh (2022)	7	Applied at global level (85 countries)	Energy consumption, intensity, air pollution, CO2 intensity, renewable fraction, GDP, foreign investments, industrialization level, effectiveness of government	No	Own selection, Literature	n/a	The nonlinear relationship between participation in global value chains and performance of a country energy security has been proved.
Bangladesh Energy Security Framework	Khan and Dhakal (2022)	23	Bangladesh	Energy supply and production security, diversity, import dependency, affordability, infrastructure, subsidies, decentralization, international geopolitics, institutions and governance, economic acceptability, technology adaptability, efficiency, environmental acceptability, safety and reliability, resilience.	Yes	Literature, Delphi method, Experts/interviews/survey	n/a	The study provides a set of indicators to address issues of energy security in Bangladesh. The study reveals that there are significant differences in the perception of the concept among energy experts and stakeholders.

Seven composite indicators have been created in the past three years to measure energy security in China or its provinces. Li et al. (2020) presented the Provincial Energy Security Index, which is constructed from 12 indicators. The authors singled out three dimensions, which are: Availability and stability of energy supply structure, Sustainability and acceptability of energy use, and External influences of policies and market. In addition to the commonly used indicators for measuring energy security, the authors also include others, such as: Sewage ratio, Energy policy, Investment in the energy industry. In order to develop the Dynamic Energy Security Index to measure energy security in China, B. Huang et al. (2021) selected 10 indicators for energy security assessment in China's provinces. The authors singled out eight dimensions and grouped indicators into two categories: input and output. Although, most dimensions have only one indicator arranged, the dimensions singled out are as follows: the "4As" plus energy, investment, governance, and technology. The interdisciplinarity of the approach followed in this research is expressed with such indicators as: R&D personnel, R&D expenditure, expenditure on pollution treatment, and investment in the energy sector. Gong et al. (2021) developed China's Energy Security Index for regional level analysis. The index is constructed from 13 indicators and four dimensions, which represent Supply, Use, Environment, and Economic security issues. The interdisciplinarity of the approach is expressed through indicators representing investments in the energy industry and controlling environmental pollution. Zhang et al. (2021) selected 28 indicators to measure energy security in a Chinese province. The selected indicators are categorized into seven dimensions, which are: Availability and diversity, Affordability, Sociality and equality, Energy infrastructure, Technology and efficiency, Environmental sustainability, and Governance. Some of selected indicators show the interdisciplinarity of the approach, as examples can be indicators related to social living standards, efficiency of government, management of the environment, etc. Wang et al. (2021) developed the Energy Economic Security Index for the regional level assessment of China's provinces. The index is constructed from 24 indicators and four dimensions, which are: Energy industry development, Energy supply capacity, Energy utilization level, and Energy environmental impact. The interdisciplinarity of the approach is expressed with social and efficiency indicators, such as: employment in the energy sector and Industrial added-value. Wang et al. (2020) selected 17 indicators, representing Energy supply, Consumption and Environmental dimensions to construct the Dynamic Energy Security Index and applied it for a case study of China. In addition to the traditionally used indicators, the authors included the fixed share of investments of the energy industry. Yang et al. (2022) introduced an innovative approach based on the Driving Forces-Pressures-State-Impacts-Responses model and applied it to analyze energy security in China. The authors selected 20 indicators to express energy security and arranged them according to the criteria of the model. Additional to the traditional indicators, indicators regarding the investments in pollution control and R&D expenditures were included.

The other authors developed composite indicators to evaluate energy security at a global level. Wu et al. (2021) sought to measure energy security performance and created a set of 18 indicators, which can be arranged into six dimensions and can be described as the "4As" plus Efficiency and Governance. The developed set of indicators was applied to measure the energy security of 125 countries. The interdisciplinarity of the set is expressed mainly through Governance indicators, such as: effectiveness of the governance, government spending, and political stability. Stavytskyy et al. (2021) developed the Energy Security Index for global level assessment and applied it for a case study of 45 countries. The index is constructed from 29 indicators and arranged into six groups: consumption, depletion; efficient use; attraction of new resources; pollution, and access. It should be noted that despite the variety of traditional indicators included, the authors paid quite a lot of attention to environmental indicators. The Energy Security Performance framework is presented by S. Huang et al. (2021) and applied for the analysis of 34 OECD countries. The composite indicator proposed consists of 20 indicators and five dimensions, which are: Energy reliability, Energy efficiency, Environmental sustainability, Governance innovation,

and Social welfare. The interdisciplinarity shows indicators assigned to the Governance innovation dimension, such as: Political stability index, Corruption perceptions index, and R&D expenditure. Ha and Thanh (2022) sought to evaluate how participation in global value chains affects the energy security performance of a country. The authors performed global level analysis (85 countries) and selected seven indicators to reflect energy security; these indicators were arranged into four dimensions, which are: Availability, Acceptability, Develop-ability, and Sustainability.

Several composite indicators have been found for analysis and comparison of selected countries in a region. Augutis et al. (2020) developed Energy Security Index from 24 compound indicators to measure the level of energy security in the Baltic States. The proposed index is constructed from three blocks, which represents technical, economic and sociopolitical indicators. Technical indicators include energy availability and market indicators; indicators allocated to the economic block are related to the availability and affordability issues, while indicators allocated to sociopolitical block include indicators related to political risk and the implementation of priorities regarding climate change. Tutak and Brodny (2022) selected 17 indicators and singled out four dimensions (energy, environmental, economic, and social) in order to measure the level of energy security in twelve EU countries. Additionally to the traditional indicators, indicators expressing energy poverty of households were selected. Cervan et al. (2022) sought to measure the level of energy security in nine South American countries. The authors developed the Energy Security Index from 15 indicators and three dimensions, which reflect Energy supply, Energy access and affordability, and Environmental sustainability issues.

Two indicator sets have been found in the studies addressing the current energy security issues in Ukraine. Kharazishvili et al. (2021) analyzed energy security in Ukraine using 42 indicators. The authors categorized the indicators in a slightly different way, dividing them into components as follows: Integral system, System's elements and links, Functions and roles, Processes, System's material. However, despite this, it is possible to single out indicators that define an interdisciplinarity of the perception of energy security, such as: predictability and sequence of policy and regulatory changes, quality of legislation, level of investment, level of wages, quality of public policy, quality of services, staff quality, etc. Sotnyk et al. (2021) presented an improved indicator set to evaluate the energy security in Ukraine. In addition to the indicators representing the traditional understanding of energy security, the authors proposed to include indicators representing the financial burden of renewables on the state budget, decoupling index of energy efficiency, an indicator showing the energy poverty of households, energy balancing, and fluctuation indicators.

Three studies introducing composite indicators to measure the level of energy security in Pakistan have been found during the systematic literature review (Bin Abdullah et al. 2020a, 2020b, 2022). Although the proposed indices differ in the number of indicators selected, they are similar at its core and at the dimensions singled out. In one of the first attempts by the authors (Bin Abdullah et al. 2020b), 39 indicators were selected as potential indicators to reflect energy security of Pakistan; these indicators represent Availability, Affordability, Governance and Regulation, Technology and Efficiency, and Environment and Sustainability dimensions. As can be seen, the dimensions singled out are almost completely the same as those introduced by Sovacool and Mukherjee (2011). Indicators such as land use, water, governance, trade and regional connectivity, knowledge and access to information, investments and literacy can be singled out as demonstrating the interdisciplinarity of the approach. In the other study (Bin Abdullah et al. 2020b), the authors selected 22 indicators from those previously mentioned, which represent a narrower meaning of the concept. However, according to the authors, the indicators selected reflect Availability, Affordability, Technology, Governance, and Environment dimensions. In the last study of the authors (Bin Abdullah et al. 2022), 27 indicators to construct Pakistan's Multidimensional Energy Security Index were selected.

Coutinho et al. (2020) developed the Energy Security Index for Cape Verde based on an indicator list created by Sovacool and Mukherjee (2011). Sovacool and Mukherjee

(2011) singled out 372 indicators to measure and analyze energy security. In this research five dimensions of energy security were singled out, which are: Availability, Affordability, Technology development and efficiency, Regulation and governance, Environmental and social sustainability dimensions. Coutinho et al. (2020) selected 20 indicators, reflecting the same dimensions presented by the previous study by Sovacool and Mukherjee (2011). The interdisciplinarity of the approach is expressed with indicators, such as: direct employment in the energy sector, electric sector governance, periodic publication of energy balance sheet by the energy companies, innovation in the energy sector. Cervan et al. (2022) sought to measure the level of energy security in nine South American countries. The authors developed the Energy Security Index from 15 indicators and three dimensions, which reflect: Energy supply, Energy access and affordability, and Environmental sustainability issues.

Khan and Dhakal (2022) developed the Bangladesh Energy Security Framework from 23 indicators and five dimensions, which are the "4As" plus Adaptability. Among traditionally used indicators, the authors also selected an indicator reflecting political stability in a country.

A variety of energy security dimensions in recent composite indicators are presented in Table 2.

However, it should be noted that the dimensions singled out are interrelated. Different authors name the dimensions differently, therefore, the dividing is conditional. For example, mostly the Availability dimension includes indicators reflecting infrastructure and energy supply, while some authors identify them as separate dimensions. Also, the indicators related to resource depletion or the development of new resources are usually included in the Availability dimension, while some authors singled them out as individual dimensions. A similar situation is with the Acceptability dimension, where indicators related to climate emissions or renewable fractions are included, while other authors singled out these indicators into a separate group. However, a clear tendency to add more indicators related to the impact on the environment can be seen in recent years. In any case, certain trends and changes in the current understanding of the concept of energy security can be distinguished. Figure 5 presents the current perception of energy security, expressed through the dimensions covered.

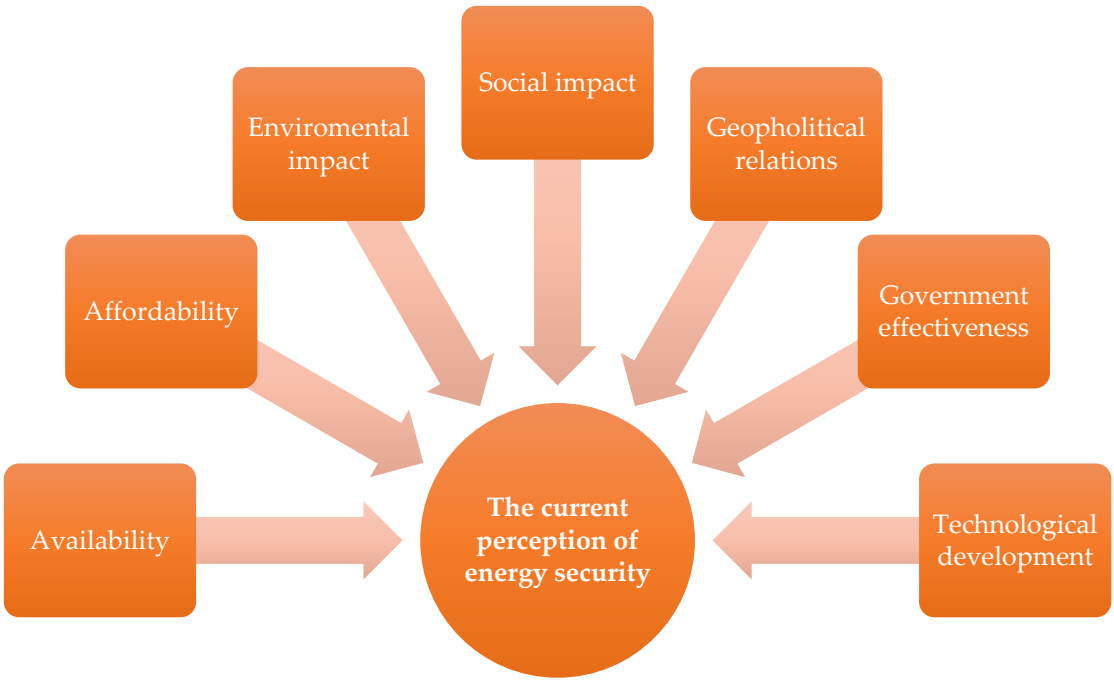

Figure 5. The current perception of energy security expressed through the dimensions covered. Source: produced by the author.

Table 2. A variety of energy security dimensions in recent composite indicators. Source: produced by the author.

Dimensions	Reference
Availability	Li et al. (2020); Bin Abdullah et al. (2020a, 2020b, 2022); Coutinho et al. (2020); Wu et al. (2021); Zhang et al. (2021); B. Huang et al. (2021); Ha and Thanh (2022); Khan and Dhakal (2022)
Affordability	Bin Abdullah et al. (2020a, 2020b, 2022); Coutinho et al. (2020); Wu et al. (2021); Zhang et al. (2021); B. Huang et al. (2021); Cervan et al. (2022); Khan and Dhakal (2022)
Accessibility	Wu et al. (2021); B. Huang et al. (2021); Stavytskyy et al. (2021); Cervan et al. (2022); Khan and Dhakal (2022)
Acceptability	Li et al. (2020); Wu et al. (2021); B. Huang et al. (2021); Ha and Thanh (2022); Khan and Dhakal (2022)
Technology	Augutis et al. (2020); Bin Abdullah et al. (2020a, 2020b, 2022); Coutinho et al. (2020); Zhang et al. (2021); B. Huang et al. (2021)
Efficiency, Develop-ability	Bin Abdullah et al. (2020b, 2022); Coutinho et al. (2020); Wu et al. (2021); Zhang et al. (2021); Stavytskyy et al. (2021); S. Huang et al. (2021); Ha and Thanh (2022)
Governance	Bin Abdullah et al. (2020a, 2020b, 2022); Coutinho et al. (2020); Wu et al. (2021); Zhang et al. (2021); B. Huang et al. (2021); S. Huang et al. (2021)
Regulation	Bin Abdullah et al. (2020b, 2022); Coutinho et al. (2020)
Environment	Bin Abdullah et al. (2020a, 2020b, 2022); Coutinho et al. (2020); Wang et al. (2020); Zhang et al. (2021); Wang et al. (2021); Stavytskyy et al. (2021); S. Huang et al. (2021); Gong et al. (2021); Tutak and Brodny (2022); Cervan et al. (2022)
Sustainability	Li et al. (2020); Bin Abdullah et al. (2020b); Coutinho et al. (2020); Ha and Thanh (2022)
Social sustainability	Coutinho et al. (2020); Zhang et al. (2021); S. Huang et al. (2021); Tutak and Brodny (2022)
Consumption	Wang et al. (2020); Wang et al. (2021); Stavytskyy et al. (2021); Gong et al. (2021)
Energy supply	Li et al. (2020); S. Huang et al. (2021); Gong et al. (2021); Wang et al. (2020); Wang et al. (2021); Cervan et al. (2022)
Infrastructure	Zhang et al. (2021)
Depletion	Stavytskyy et al. (2021)
New resources	Stavytskyy et al. (2021)
External influences of policies and market	Li et al. (2020)
Adaptability	Khan and Dhakal (2022)
Economic	Augutis et al. (2020); Gong et al. (2021)
Sociopolitical	Augutis et al. (2020)
Investment	B. Huang et al. (2021)
Energy, Energy industry development	B. Huang et al. (2021); Wang et al. (2021); Tutak and Brodny (2022)

The review of composite indicators and their input data allowed to identify the main aspects regarding the perception of the current energy security concept. Seven aspects or dimensions, having influence on the perception of the concept, are singled out, which are as follows: availability of energy resources, energy affordability, impact on the environment, social impact, geopolitical relations of a country, effectiveness of government, and technological development. The dimensions of accessibility and affordability, as in the traditional concept, continue to be important aspects in the perception of energy security. However, the traditional dimension of acceptability is being replaced by the dimensions of impact on the environment and social impact. With increasing concern regarding climate

change and the growing pursuit of people's well-being, the acceptability dimension has been expanded and now different indicators reflecting environmental and social impact are used. Recent military conflicts, geopolitical competition and various disagreements between countries have highlighted the importance of geopolitical relations for ensuring the country's energy security. Also, in recent studies, great attention is paid to indicators related to the effectiveness of the government, such as the level of corruption in the country. And finally, as a separate dimension, indicators related to the development of new effective technologies, investments in research and increasing efficiency can be distinguished.

5. Discussion and Practical Implications

Various concerns regarding energy security are very important for many countries in different regions. The rising amount of studies dealing with energy security assessment proposed different composite indicators and assessment frameworks, which reveal the multifaceted nature of the problem. It is necessary to mention that energy security also has clear connections with many other issues, such as resource efficiency, economic growth, energy poverty, environmental, economic, social and foreign policy, etc. The systematic literature review stated that indicators started to be more complex, have broader, applicable extensions, and aims to provide directions for future energy policy decision-making.

The concept of energy security has close linkages with the concept of the sustainable development paradigm and is far from the traditional "4As" understanding of energy security. The energy security approach with the social, economic, technological, geopolitical and environmental dimensions of the sustainable development perspective becomes consistent with broad and long-term considerations of sustainable energy development. Therefore, it is very important that this broader approach is reflected and put into practice as soon as possible in the development of national or regional energy policies.

The linkages with the indicators reflecting environmental and social impact can be found in the previously and widely used "4As" approach, where such indicators as the level of GHG emissions or renewable fraction were used. Today, this understanding has expanded to include health, job creation, service quality, and other indicators that represent these dimensions. However, it necessary to highlight that indicators for measuring energy security must be selected very thoughtfully and guided, not only by the popularity of the indicators and the representation of national or regional goals, but also by assessing the possible risks to the level of energy security of a country. As an example, renewable energy indicators can be provided, which are often included as reflecting environmental, social or availability dimensions. However, the stability of equipment supply chains, timely servicing of equipment or energy system flexibility issues are usually not considered.

The dimension of geopolitical relations has also emerged only in recent years. Geopolitical relations have a crucial impact on both energy supply and energy prices, as well as the development of energy infrastructure and ensuring the maintenance of energy infrastructure. The example of European countries' dependence on Russian energy sources showed how important is to cooperate with reliable energy suppliers and how important it is to allocate the risk in order to avoid possible economic difficulties in the future (European Commission 2021; European Commission 2022). The global COVID-19 pandemic has highlighted the fragility of global supply chains (Goldthau and Hughes 2020; Emenike and Falcone 2020). With the rapid development of renewable energy infrastructure, it is crucial to assess and ensure the stability of supply chains. This must be taken into account by the policy makers when creating a policy that would ensure both the smooth development of the infrastructure and its maintenance. Also, it should not be forgotten that with the development of renewable energy, there are also other issues to be resolved, such as the utilization of old facilities or changes in the landscape (Siksnelyte-Butkiene et al. 2022), which already include the dimensions of environmental and social impact.

Government effectiveness issues are discussed in recent studies, not only when measuring energy security, but also other issues. For example, Syed et al. (2022) found that economic policy uncertainty negatively affects the performance of green bonds, which has

a clear relationship with the clean energy index and oil prices. Various indicators related to government efficiency determine how quickly, efficient and timely decisions are made, as well as being politically correct. Additionally, questions to how efficiently the government can respond in the case of challenges has arisen. For example, the study by Ekinci et al. (2022) showed that supply difficulties in disruptive events can be managed with effective, centralized decision-making. Therefore, the inclusion of indicators reflecting government effectiveness is very important in today's energy security studies for evaluating how effective emerging challenges are, and their appropriate response, in the context of global crises and geopolitical instabilities.

The dimension of technological development is usually associated with investments in energy infrastructure, the development of research and innovation, energy industry development, and the search for new, more efficient technologies and solutions. As stressed by Sachs et al. (2019), the implementation of the Sustainable Development Goals are dependent on green projects, where green financing plays a crucial role. Such instruments as green bonds, carbon market instruments, green banks, community-based green funds and others can provide environmental benefits and help to ensure the energy security of a country. Therefore, technological development helps to achieve environmental, social, affordability and availability issues, and shows the potential of the country to ensure these questions are responded to.

This research proved the statement that the perception of energy security is contextual and dynamic in its nature. The results of this research can be compared with the other studies analysing the perception of the concept of energy security. For example, Ang et al. (2015) analysed studies in the field from 2001 to 2014 and singled out seven dimensions defining the concept, which are: energy availability, energy infrastructure, energy prices, effects on the society, impact on the environment, governance, and energy efficiency. It should be noted that despite the authors identifying governance as a separate dimension, only two papers were found taking governance issues into account in the period under analysis. Azzuni and Breyer (2018) analysed definitions of energy security in the literature and identified 15 dimensions of the concept, which are: availability, diversity, cost, technology and efficiency, location, timeframe, resilience, environment, health, culture, literacy, employment, policy, military, and cyber security. Compared to the findings of the current study, the dimensions of geopolitical relations and government effectiveness have only emerged recently.

As previously mentioned, ensuring energy security is closely related to the sustainable development of energy and the pursuit of sustainable development goals. Also, a safe and reliable energy supply is a key factor for the growth and development of each modern country's economy, which plays a crucial role to all sectors of the economy, from production to the transport sector, and from various service sectors to private households. Therefore, it is very important that policy makers take into account all the components of the energy security concept when making decisions, thus developing a safe and sustainable sector for present and future generations.

6. Conclusions

The four stage research methodology was developed to identify the current perception of energy security. The first stage was the identification of the most influencing global aspects, which may have an impact on the extent of energy security in a country or region. In the second stage, the recent concerns regarding the issues of energy security in the scientific literature was analyzed. The perception of energy security was analyzed through composite indicators developed to measure the level of energy security in recent years. It allowed to identify and compare changes in the perception of energy security under recent global concerns and uncertainties. And finally, the insights regarding the perception of the current concept, based on the analysis of input data of the latest composite indicators, was presented.

Twenty-one composite indicators developed in the last three years have been selected for the review. Analyzing the application of the developed indicators to the case studies, we noticed several trends emerge. Firstly, one-third of the recent studies focus on measuring China's energy security at the national or regional scale. Secondly, the Russian–Ukrainian war has globally brought to light issues of energy security, especially in countries dependent on energy resources from Russia. Thirdly, due to geopolitical relations and the efficiency of government institutions, corruption indicators began to be actively included in composite indicators dedicated to measure energy security in many cases.

The recent studies dealing with the Issues of energy security highlight the necessity to ensure energy security of the energy system under current global concerns. Mainly, these global concerns can be associated with geopolitical challenges such as military conflicts, economic- and social-related issues due to the COVID-19 pandemic, the scarcity of energy resources, and global concerns regarding climate change and the well-being of people. As the concept of energy security is context dependent, the current concerns should be reflected when assessing energy security.

After a detailed analysis of the recent composite indicators that have been proposed, it was noticed that, despite a difference in the variety and number of indicators included or dimensions reflected, the interdisciplinary approach is followed. It should also be noted that experts are increasingly being involved in the selection of indicators or the determination of their weights. Such practice allows to develop composite indicators that are more comprehensive and to reduce the factor of subjectivity. Also, scientific methods are mostly used to determine the weights, while previously, the subjective weighting allocation prevailed. Here, principal-component analysis and the entropy-weight method are among the most popular.

The review of recent composite indicators and their input data allowed to identify the main aspects regarding the current perception of the energy security concept. Seven aspects regarding the perception of the concept were singled out, which are as follows: availability, affordability, environmental impact, social impact, geopolitical relations, government effectiveness, and technological development.

It is necessary to highlight that despite the concept of energy security changing over the time and being multidimensional and dependent on the context, it is very important, that decisions in the energy sector follow the current understanding and consider all the concerns. This is important because the issues of energy security of a country (and region) can considerably affect the well-being of people through the development of the economy, and economic growth as energy plays a key role in all sectors of the modern economy and society.

This study has also some limitations, as the systematic literature review was carried out on an exact combination of topics; therefore, some relevant literature sources may not be included in this research. Also, the future research is needed to select the most important indicators reflecting each dimension of energy security and the created set should also be applied in practice.

This paper contributes to the clarification and discourse development of the perception of the energy security concept under the current global concerns and uncertainties, and will be useful for further research, both analyzing the concept of energy security itself, and developing indicator sets to measure energy security.

Funding: This research received no external funding.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: Author is thankful for Reviewers comments and valuable suggestions for the improvement of this paper.

Conflicts of Interest: The author declares no conflict of interest.

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