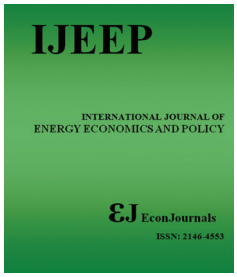

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Energy Security Faces Critical Global Attention

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ABSTRACT

Ensuring a stable and sustainable supply of energy has emerged as a critical global concern in the face of increasing energy demand, environmental degradation and geopolitical uncertainty. As all countries rely heavily on energy to drive economic growth and technological progress, ensuring a stable and accessible supply of energy has become a paramount imperative. This study aims to explore the multifaceted concept of energy security and its derivative topics for follow-up development in the future. The research approach combines bibliometric analysis and the analytical hierarchy process which was developed to analyze the derivatives of the concept of energy security. Data sourced from scientific literature collected from journal publications published from 2018-2022. The results of the study found three priority topics that have the potential to have novelty in the development of energy security in the future, including clean energy, energy harvesting and energy equity. This priority topic underscores the importance of a transition towards sustainable energy system that not only guarantees a reliable supply of energy but also promotes environmental stewardship and people's well-being.

Keywords: Energy Security, Clean Energy, Energy Harvesting, Energy Equity, Energy Sustainability
JEL Classifications: K32, P48, Q42, Q48

1. INTRODUCTION

Studies related to energy security in various countries are serious concern to experts so that their elaboration is more specific in the last 5 years, which generally focus on studying renewable energy at an advanced level. National energy security is perceived as part of the state's ability to ensure the availability of energy that is able to meet energy needs in a sustainable and affordable way for citizens (Sanchez et al., 2023). As an example for the application of this concept which states that energy security is an important reference and a major concern for environmental sustainability and development in economic sector (Alola et al., 2023). Renewable energy policies are formed due to potential threats to energy security and achieving energy security at an optimal level is the main support for achieving renewable energy (Sattich et al., 2022). Energy security has a close relationship with the needs of human life and the level of productivity where many extreme natural events have occurred over the last few decades, besides that this concept has also become a trigger for international conflicts (Qiu et al., 2023).

In general, studies related to energy security cover three main aspects including the availability of energy sources, the affordability of energy supply, and the continued development of renewable energy. However, even though research into energy security has been widely studied in terms of various elements, there are still many problems regarding energy security that are of particular concern to academics and researchers in various countries. Some of the problems that arise include the many concerns that are closely related to energy security which can affect energy preferences for the public by criticizing that the ability to provide renewable energy can threaten energy security (Arndt, 2023). Other problems arise in pushing the main vision of energy security due to being in a global energy transition and the existence of energy dependence on Russia which triggers world tensions to focus more on efforts to ensure future energy security arrangements and efforts to succeed in energy transitions that are able to create energy security (Höysniemi, 2022). In addition, the energy problem has also intensified with efforts to reduce natural gas consumption during the winter

due to the energy crisis as a result of the conflict (Mišík and Nosko, 2023).

Solutions to strengthen energy security have been pursued through various studies including efforts to encourage energy security which are implemented through environmental regulatory arrangements despite having regional differences and spatial dependencies (Zhao et al., 2023), and it is also necessary to consider three new perspectives that can be applied in developing the concept of energy security including sovereignty, robustness and resilience (Rodríguez-Fernández et al., 2022). In addition, the increasing complexity of the economy in various countries encourages increased energy efficiency through optimizing energy intensity and lower carbon intensity which has an effect on increasing energy security risks in strengthening energy intensity with varying impacts on carbon intensity (Payne et al., 2023). Other solutions to improve performance in improving energy security indicators can be carried out through several actions such as improving energy governance, increasing generation capacity with priority on renewable energy sources, increasing energy efficiency, increasing power system capacity and encouraging research and development, as well as trying to pay more attention to problems environment (Tete et al., 2023). Environmentally friendly behaviour leads to increased performance in creating energy security thereby influencing technical configurations and being able to contribute to the affordability of collective energy security acceptance (Fouladvand, 2022), and energy security risks have a positive effect on the development of renewable energy, but for middle-income countries where the impact of energy security risks on renewable energy takes place in unstable conditions (Chu et al., 2023).

Energy security plays an important role in the sustainability and economic, social and political stability of a country. Energy security includes efforts to ensure a reliable, affordable and sustainable supply of energy for the needs of society and industry. Energy is the backbone of economic growth. Energy security ensures that energy supply is stable and reliable to support economic activities, avoiding disruptions in energy production and distribution that can have a negative impact on economic stability. Energy security encourages the country to move towards energy independence by relying on domestic energy resources and reducing dependence on energy imports. This helps reduce risks to fluctuations in energy prices on international markets and enhances economic security. In addition, energy security focuses on the security of energy supply to prevent supply shortages that can cause major disruptions in daily life and industry. This involves diversifying energy sources, developing a reliable energy infrastructure, and mitigating risks from natural or political disturbances. Energy security is also related to climate change mitigation. Shifting towards sustainable energy sources such as renewable energy can help reduce greenhouse gas emissions and help protect the environment and society from the effects of climate change. The focus on energy security encourages the development and application of innovative technologies in the energy sector such as energy storage, smart grids and electric vehicles that can improve energy efficiency and sustainability.

However, several solutions that have been expressed by experts in various study areas still tend to be partially investigated. Paying attention to the various solutions offered from previous studies where each has its own uniqueness. However, the concept of energy security needs to be addressed by implementing a new strategy. Furthermore, almost all countries in the world have problems related to how to maintain energy security capabilities to ensure the continuity of citizens' lives. Therefore, it is important to increase energy security capabilities, one of which can be done by finding new theories and constructs as part of the derivatives of the energy security concept to be further developed in the future. This study aims to find several new theories and constructs from energy security derivatives to support the development of energy diversification in the future. Knowledge development is emphasized through the dissemination of scientific journals (Sarjana et al., 2022).

2. METHODS

Method is applied through an approach that combines qualitative aspects and bibliometric analysis as a unique approach because it combines the characteristics of qualitative research that are more in-depth in understanding meaning and context in exploring patterns and trends in scientific literature. Qualitative data were analyzed using VOSviewer sourced from scientific journal publications (Pranita et al., 2023). The analysis of scientific journals is studied through a qualitative approach (Sarjana, 2022). First step is carried out by collecting bibliometric data in the form of scientific publications that are relevant to the concept of energy security. The data collected includes data on article titles, authors, published journals, year of publication, citations, and other relevant information. Timeframe for collecting scientific journals starts from 2018 to 2022 or applies for the last 5 years obtained through searching journals on Google Scholar. The number of scientific articles that were collected was 4685 journals with a total number of citations of 138976. Bibliometric analysis is one of the studies that develops meta-analysis to analyze research topic (Raharjo and Sarjana, 2022). Bibliometric analysis was carried out to identify patterns and trends based on data collected using software VOSviewer to visualize citation networks, analyze collaboration between authors, identify key words that that appear most often, identify the most influential topics and find topics that rarely appear that have the potential to obtain novelty from the derivative concepts studied. After carrying out a bibliometric analysis through the integration of the findings from the analysis carried out which was able to identify emerging patterns and explain how the patterns formed are connected to the qualitative findings. The integration of findings has the potential to provide a deeper understanding of topic derivatives based on the results of the study. Bibliometric analysis provides rich insights into research developments in the field of energy security, relationships between researchers, and trends in the scientific literature. This approach can also help identify research gaps and future research directions in the field under study.

In addition, the next step of study is carried out through an analytical hierarchy process (AHP) for decision making that is used to address complex problems involving several criteria and

alternatives. AHP is applied in various fields including in the analysis of energy security concepts in order to obtain priority from existing alternatives. The main goal in this analysis is directed at finding topic derivatives that have the potential to have novelty in the concept of energy security. This analysis utilizes several criteria including availability, affordability, efficiency, acceptability and accessibility. While the alternatives applied in the analysis include energy harvesting, energy independence, energy equity, energy trilemma, energy sustainability, clean energy and energy hub. Furthermore, it is necessary to make a hierarchy of criteria and alternatives that have been identified which shows the structure of the relationship between each criterion and alternative which refers to the upper level being the main goal and the lower level contributing to achieving the goal. Pairwise comparison matrices are developed to apply to each hierarchical level. AHP measurement needs to be calculated using pairwise comparisons (Sarjana and Raharjo, 2023). In this matrix, the comparison value of each criterion or alternative is determined based on the level of importance of the other criteria or alternatives. The relative weight calculation for each criterion is carried out using this method which reflects the level of importance in achieving energy security goals. The analysis of results for assessment is directed at identifying the alternatives that best support the achievement of energy security goals. The alternative with the highest score is one that best suits the needs directed to priority for decided. The use of AHP in energy security analysis can assist with accuracy in policy making to understand and address complex issues related to energy security and availability. This method helps to identify the key factors that contribute to energy security and provides guidance in developing strategies and policies that are effective in dealing with the energy challenges faced by countries.

3. RESULTS AND DISCUSSION

Collection of bibliometric data relevant to energy security in article titles, authors, journals, year of publication and citations, the next step is preprocessing the data to tidy up the data obtained, including checking duplicate data and deleting irrelevant data. Processed data import into VOSviewer is used to perform analysis in the form of network visualization of quotes and author analysis or visualization of keywords that often appear in scientific articles on energy security. By using the analysis features of VOSviewer, identify the main themes in literature on energy security in order to find patterns of collaboration between authors or research groups that are active in studying this concept. Analysis of the results of VOSviewer visualization and interpretation of findings relevant to energy security are carried out which identify research developments, trends and latest needs in the concept of energy security.

Citation metrics on journal publications refer to a way to measure how often a scientific journal is cited by articles or other journals. Citation metrics help in assessing how influential and relevant a scientific paper is. It is important to note that the citation metric is an evaluation tool and should not be the only factor in assessing the quality of a scientific paper. The keywords used in the search process for journal articles on the concept of energy security were studied within the span of publication in the last 5 years as presented in Table 1. The number of papers that were successfully submitted on the concepts studied varied according to the scientific journal data collected. In addition, it also explains the number of citations per year, average citations per paper, per year and per author. It is known that scientific journals published with a longer time span have a relatively higher number of citations compared to newer publications. However, in studying this topic, it is clear that the trend in the number of authors per paper has increased from previous years. To determine the quality of journal publications, it can be determined by the value of the h-index, g-index, or hA-index where this assessment refers to the number of citations and the number of publications produced so that the greater the index value obtained, the better the value of the journal publication. The h-index is used to measure the productivity of scientific work produced by researchers through the number of citations obtained in publications, while the g-index is the average value of citations obtained as a whole, and the hA-index is an index that measures the impact produced by researchers.

Citation trends play an important role in scientific publications and have a significant impact on research and especially for researchers. Citation trends are the main indicator of the impact and relevance of a scientific work where the more an article is cited by other articles, the greater its impact in the academic community. Articles that are frequently cited tend to be regarded as significant and valuable works. Citation trends as a tool to measure prestige for researchers or journals. Researchers who have many citations in their work are considered influential researchers in their field. Likewise, journals that are frequently cited tend to have a higher reputation among academics. Citation trends help spread research and thinking. When an article is cited, it means that the research is acknowledged and used as a reference by other works where the

Table 1: Journal publication period metrics on the concept of energy security

Citation metric	2018	2019	2020	2021	2022
Papers	740	991	993	982	979
Citations	32203	42681	35152	21150	7790
Cites/year	6440.60	10670.25	11717.33	10575.00	7790.00
Cites/paper	43.52	43.07	35.40	21.54	7.96
Cites/author	12940.01	15809.76	12322.79	7301.86	2836.95
Papers/author	366.88	440.11	446.94	408.18	418.15
Authors/paper	2.79	3.04	3.05	3.24	3.23
h-index	89	98	92	68	35
g-index	148	161	138	95	51
hA-index	34	43	44	42	35

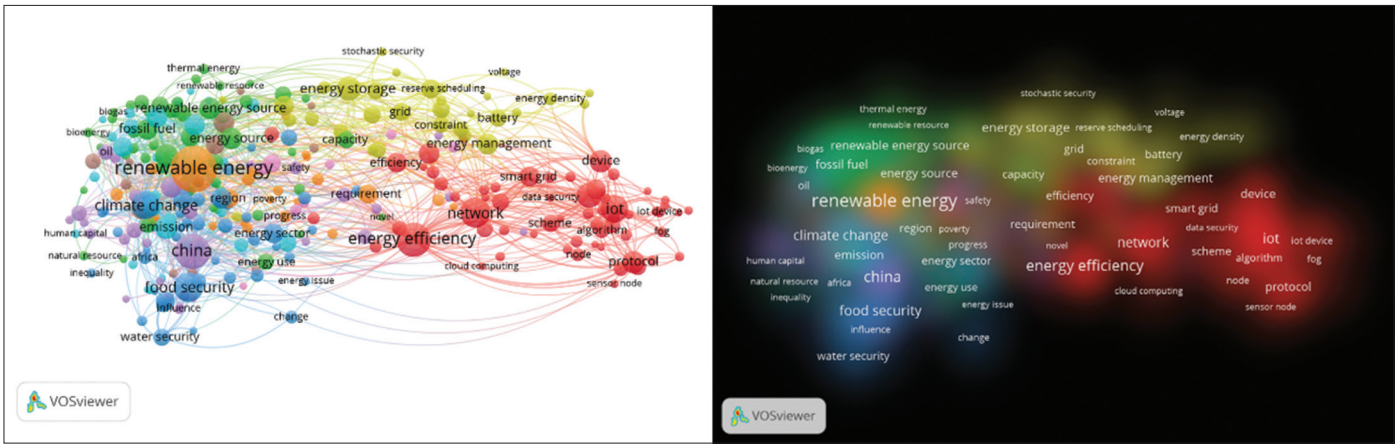
citation helps disseminate information and scientific thought and expands the impact of research in various fields. Citation trends help in assessing the quality of research because articles that are frequently cited tend to have passed peer review and validation and are considered to have made an important contribution to knowledge. Citation trends help in finding relevant research. When reading an article, the citations included can direct the reader to other relevant sources and enrich understanding of a particular topic. Citation trends can reward researchers for their contributions so as to increase motivation and enthusiasm in conducting further research. In addition, citations create opportunities for collaboration between researchers who are interested in the same topic. It is important to note that citation trends can be influenced by other factors such as social media popularity, active promotion or the presence of a strong collaboration network. Therefore, when using citation trends as an indicator, it is important to consider the context and other factors that may influence them. In Table 2 it can be seen that the trend of citations cited by other articles in the highest number in the last 5 years are articles published in well-known journals and owned by reputable publishers. To publish good quality articles, publication in well-known scientific journals is needed and is in a publisher that has a globally reputable index.

Network visualization using VOSviewer is a useful way to analyze the relationship between various elements in a particular concept, such as energy security. Network visualization on energy security can provide a clearer picture of the relationships and interactions between various topics that are relevant in the context of energy security. With network visualization on energy security, the studies carried out can better understand the structure and dynamics of the relationship between the elements in the concept under study. This can assist in identifying challenges and opportunities in energy security as well as gaining new insights that may not be apparent from traditional data analysis. After the data is imported and the network is configured, VOSviewer will produce different network visualizations in the form of node maps and cluster maps shown in Figure 1. The network visualization is able to explore the map to see how different topics are connected to each other. Derivatives of the topics studied through network visualization found that several topics have been widely published including renewable energy,

Table 2: Citation trends in journal publications

TC	Authors (Year)	Title	Source Journal	Publisher
1505	(Abe et al., 2019)	Hydrogen energy, economy and storage: Review and recommendation	International Journal of Hydrogen Energy	Elsevier
1293	(Li et al., 2018)	5G Internet of Things: A survey	Journal of Industrial Information Integration	Elsevier
1103	(Dawood et al., 2020)	Hydrogen production for energy: An overview	International Journal of Hydrogen Energy	Elsevier
881	(Chettri and Bera, 2020)	A comprehensive survey on Internet of Things (IoT) toward 5G wireless systems	IEEE Internet of Things Journal	IEEE
703	(Pata, 2018)	Renewable energy consumption, urbanization, financial development, income and CO_2 emissions in Turkey: testing EKC hypothesis with structural breaks	Journal of cleaner production	Elsevier
673	(Chowdhury et al., 2020)	6G wireless communication systems: Applications, requirements, technologies, challenges, and research directions	IEEE Open Journal of the Communications Society	IEEE
624	(Wu et al., 2018)	A survey of physical layer security techniques for 5G wireless networks and challenges ahead	IEEE Journal on Selected Areas in Communications	IEEE
593	(Ferrag et al., 2019)	Blockchain technologies for the internet of things: Research issues and challenges	IEEE Internet of Things Journal	IEEE
526	(Sengupta et al., 2020)	A comprehensive survey on attacks, security issues and blockchain solutions for IoT and IIoT	Journal of Network and Computer Applications	Elsevier
516	(Gai et al., 2018)	A survey on FinTech	Journal of Network and Computer Applications	Elsevier

Figure 1: Network visualization in 2018-2022



energy efficiency, food security, climate change, water security and smart grids. However, there are several topics that have the potential to be new because they are rarely published, including energy harvesting, energy independence, energy equity, energy trilemma, energy sustainability, clean energy and energy hub.

Bibliometric data-based visualization and network analysis enables visual analysis of co-authors in scientific publications. The results of the network visualization display nodes indicating authors and edges describing relationships between authors which are presented in Figure 2. Interpretation of the results is done by examining patterns and connections between authors in the network formed which can help understand trends in research collaboration and the influence of authors on the topic of energy security. Some of the main authors who disseminate studies on the concept of energy security include Liu X, Zhang I, Wang Y, Li X, Wang Q, Yang Y, Zhang J and Wang Z where the publications of these authors are widely referred to by other researchers with more in-depth studies as follow-up in diversified studies. Based on the author's name that appears from the results of this network visualization, it can be seen that the dominance of the author's country comes from a certain country and the studies carried out have not been carried out evenly globally. For this reason, it is necessary to study a wider scope in various regions in studying energy security in order to ensure energy sustainability and energy security in their respective countries.

Figure 3 illustrates AHP method used in this study to make complex decisions by solving problems into hierarchical structure of various criteria and alternatives. In the context of energy security, this method can be used to prioritize factors that contribute to energy security based on the importance of each factor involved. The main objective to be achieved in the designed hierarchical structure is to find three main alternatives to be followed up as priority topics in the development of energy security. The several criteria applied to properly and fairly assess energy security include availability, affordability, efficiency, acceptability and accessibility. Meanwhile, the alternative options provided to obtain an accurate assessment include energy harvesting, energy independence, energy equity, energy trilemma, energy sustainability, clean energy and energy hub. Utilization of several alternative options presented as part of the selected concept derivatives is a priority topic that can be developed appropriately to leverage energy security more effectively and efficiently.

Performance sensitivity in energy security studies refers to the ability of an energy system or energy infrastructure to respond and adapt to changing conditions that may affect the security of energy supply, distribution and use. In this context, performance sensitivity reflects the extent to which the system can maintain its main performance and function in the face of various risks and changes. The priority assessment is based on the seven criteria used in measuring the five alternatives in the hierarchical structure shown in Figure 4 resulting in three main priorities in selecting

Figure 2: Network visualization in 2018-2022

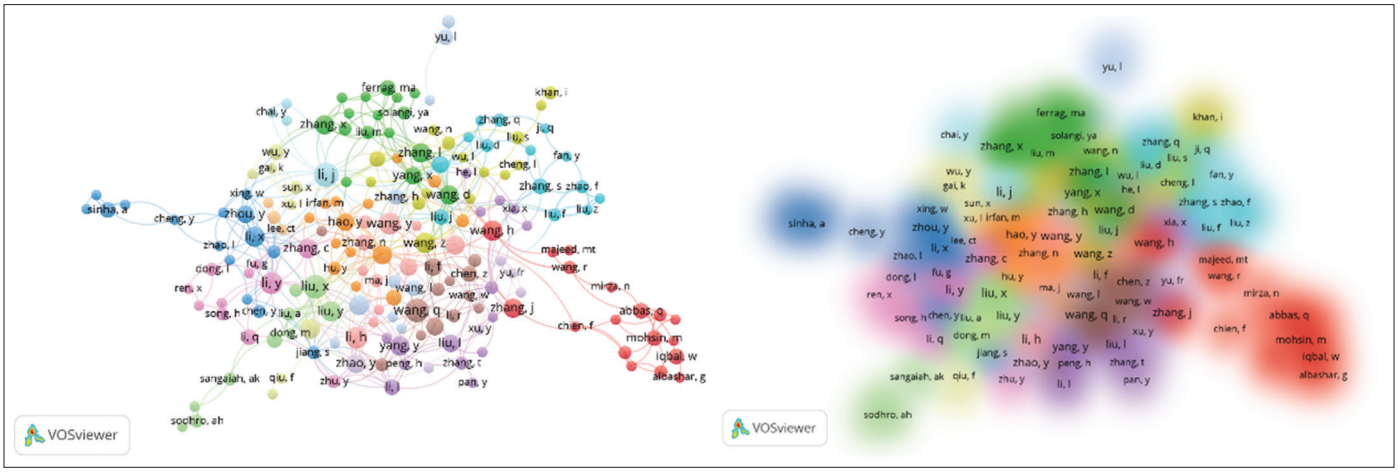
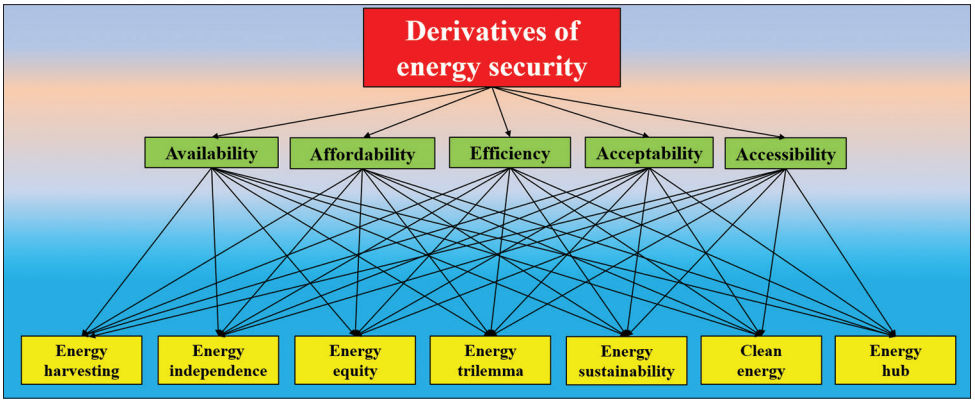


Figure 3: Hierarchy of energy security concept derivatives



alternatives which include clean energy, energy equity and energy harvesting. Performance sensitivity studies in energy security are important for identifying potential risks and vulnerabilities and designing appropriate mitigation strategies. It also involves a deep understanding of the impacts of climate change, fluctuations in global energy prices, new technologies and energy policies. By addressing sensitivities in various aspects of performance, energy systems can be more resilient and able to maintain energy supply security in the face of various challenges. For this reason, the three main alternatives chosen have an important role in further energy security studies to encourage energy sustainability.

Gradient sensitivity refers to changes in calculations or results in response to small changes in certain parameters. In the context of energy security, this can refer to how changes in several implemented criteria such as availability, affordability, efficiency, acceptability and accessibility can affect the level of security of energy supply. Gradient sensitivity measures the extent to which a system can adapt to changes and reduce their negative impact on energy security. It is important to measure gradient sensitivity in an energy security analysis in order to identify the critical elements presented in the form of criteria that can have a significant impact on the security of the energy supply. Furthermore, a more effective risk management strategy can be designed and anticipate potential changes that could endanger the security of energy supply. In Figure 5 it can be seen that the three main priorities are selected based on the alternatives disclosed in the development of energy security in the future. Even though there is a downward trend in clean energy in the assessment at the criterion level, it is still in first place because it has a high score since the initial criterion assessment. Energy harvesting has experienced an increasing trend based on the criteria assessment carried out so that it is in second position while energy equity has an assessment at a level below it due to a downward trend. Gradient sensitivity analysis is very important in designing risk mitigation strategies and developing effective energy policies. By understanding the extent to which the system responds to changes based on the criteria applied in selecting alternatives, policies can be designed to minimize the negative impacts of these changes and increase the resilience of the energy system to various risks.

Two-dimensional sensitivity in energy security studies refers to an analysis of the impact of changes in two different criteria on the performance or security of the energy system. In this case, two criteria that interact with each other and can have a complex impact on the security of energy supply, distribution and use include affordability and availability. Two-dimensional sensitivity analysis helps identify the combined impact of the criteria used in the selection of alternatives to the energy system and helps design a more holistic and effective strategy in maintaining energy supply

Figure 4: Performance sensitivity in energy security

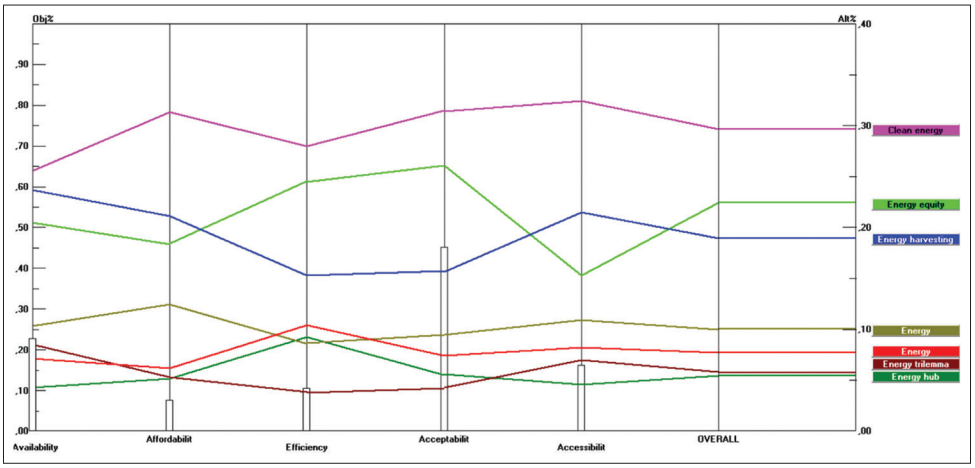


Figure 5: Gradient sensitivity in energy security

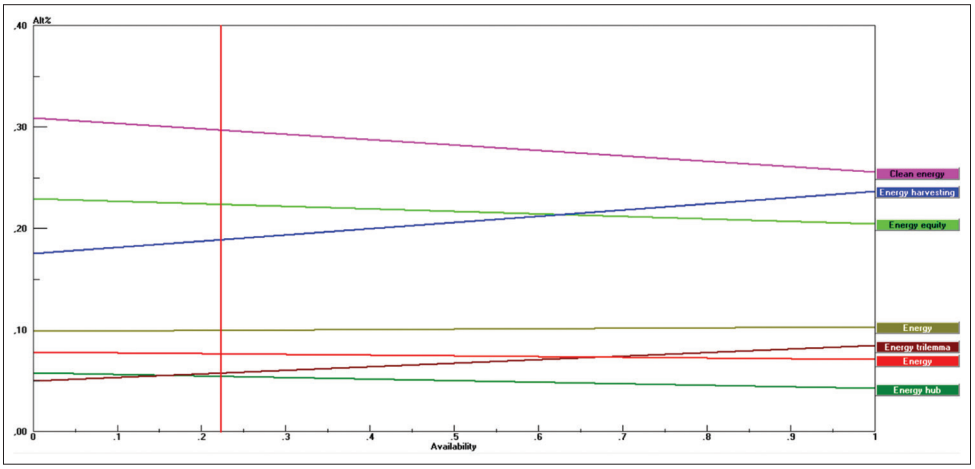


Figure 6: Two-dimensional sensitivity in energy security

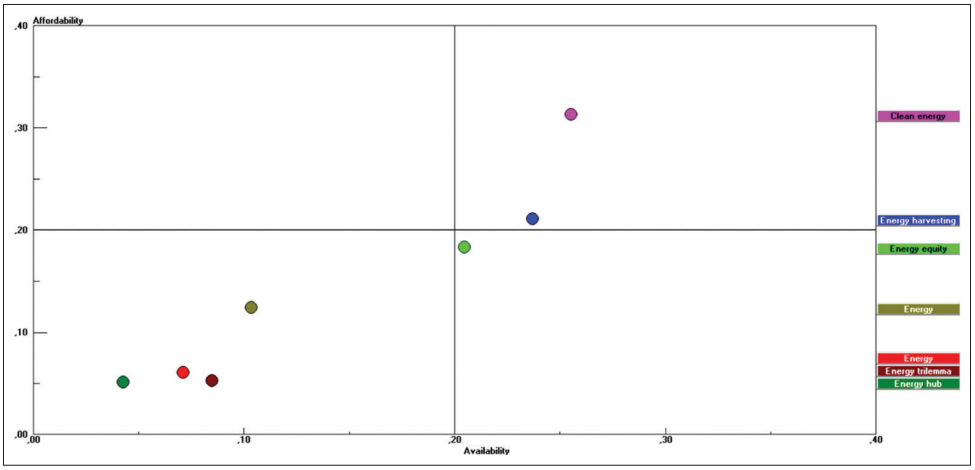
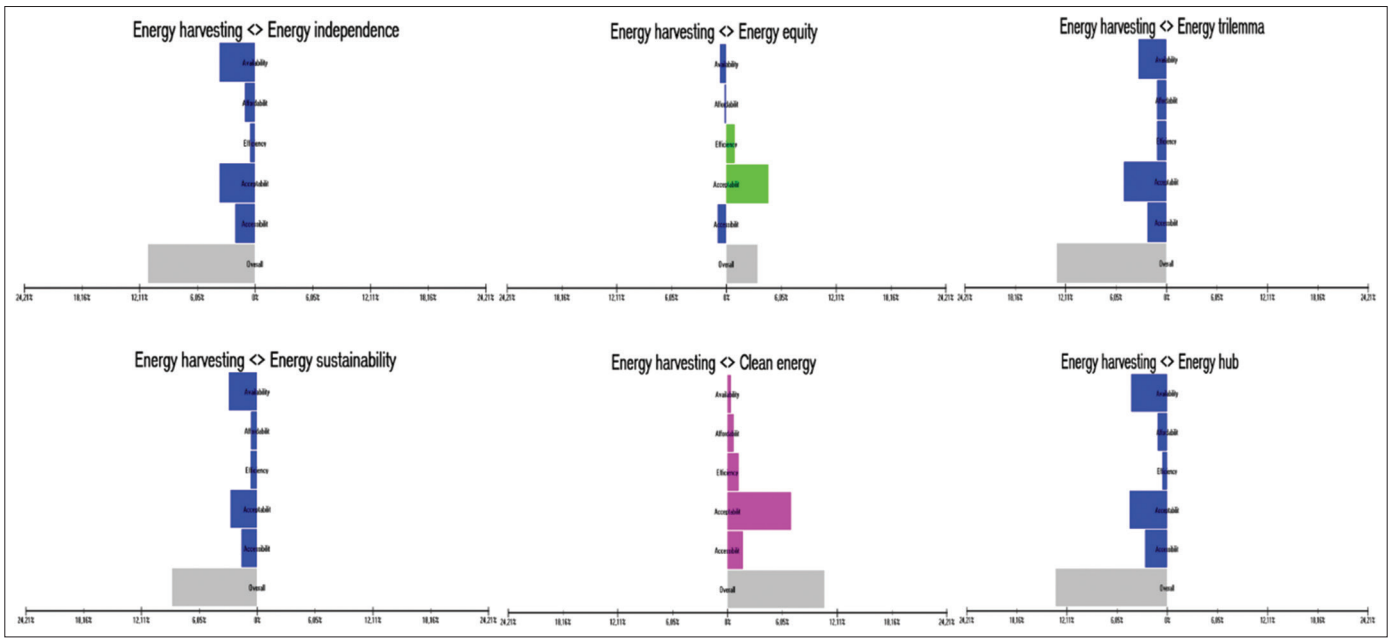


Figure 7: Head-to-head sensitivity in energy security



security. In some cases, this analysis involves complex modelling to understand the interactions between criteria. The positioning nodes presented in Figure 6 show that there are three nodes that represent the main alternative choices, namely clean energy, energy harvesting and energy equity which are at the highest level based on affordability and availability criteria.

Head-to-head sensitivity in the study of energy security refers to a direct comparison analysis or side-by-side comparison of two or more different alternatives in the context of energy security. The main objective of this analysis is to understand how changes in certain parameters or alternatives can affect the security of energy supply, distribution and use in two or more scenarios being compared. Figure 7 shows head-to-head sensitivity comparing energy harvesting with other alternatives including energy independence, energy equity, energy trilemma, energy sustainability, clean energy and energy hub. Energy harvesting looks more dominant and has a better ratio of values when compared to energy independence, energy trilemma, energy sustainability and energy hub. Meanwhile, energy harvesting has a lower value when compared to energy equity and clean energy. Head-to-head sensitivity approach helps decision makers to understand the practical implications of choices in the context of energy security. By directly comparing alternatives to gain deeper insight into how decisions affect the stability and resilience of energy systems.

4. CONCLUSION

The high level of interest in studying the concept of energy security needs to be more seriously enhanced in various regions in order to ensure the continuity of national energy availability. The results of the study found three main alternatives as priority choices referring to the derivatives of the energy security concept including clean energy, energy harvesting and energy equity. The selected alternative priority is an important novelty topic to be studied further by various parties, both researchers, academics and the government in order to encourage the development of sustainable energy and renewable energy. Clean energy, energy

harvesting and energy equity play an important role in encouraging the strengthening of energy security in a sustainable, efficient and inclusive way. The use of clean energy such as renewable energy including solar, wind, hydro, sustainable biomass can help reduce greenhouse gas emissions and air pollution that contribute to climate change and health problems so that the energy system becomes more sustainable in the long term and more resilient to price fluctuations. Energy harvesting technology can assist in the development of decentralized energy resources such as sensors that use energy from the surrounding environment thereby reducing dependence on external energy supplies. Building energy equity means ensuring that all people have equal opportunities to benefit from existing energy sources and services whereby efforts to create energy equity mean that more vulnerable communities will not be left behind and are better able to deal with changes in energy supply or prices. The combination of these three concepts has a positive impact in encouraging the strengthening of energy security. The use of clean energy helps reduce supply risks associated with fluctuations in fossil fuel prices and environmental risks while supporting long-term sustainability. Energy harvesting can provide a sustainable and decentralized solution, reduce dependence on external sources of energy, and increase resilience to supply disruptions. Achieving energy equity involves wider societal inclusion in access to and benefits from energy sources, which in turn can enhance social and economic stability and reduce the risk of energy-related conflicts. In combination, these three concepts help build a more resilient, sustainable and equitable energy system, ultimately contributing to strengthening overall energy security.

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