Energy Strategy Reviews 52 (2024) 101345

Contents lists available at ScienceDirect

Energy Strategy Reviews

journal homepage: www.elsevier.com/locate/esr

An energy security strategic causality model using text mining for world region comparisons

Tat-Dat Bui [a], Hien Minh Ha [b], Thi Phuong Thuy Tran [b], Ming K. Lim [c,f], Ming-Lang Tseng [d,e,f,g,*]

[a] Department of Shipping and Transportation Management, National Taiwan Ocean University, Taiwan
[b] Foreign Trade University, Ho Chi Minh City Campus, Viet Nam
[c] Adam Smith Business School, University of Glasgow, Glasgow, United Kingdom
[d] Institute of Innovation and Circular Economy, Asia University, Taichung, Taiwan
[e] Department of Medical Research, China Medical University Hospital, China Medical University, Taichung, Taiwan
[f] UKM-Graduate School of Business, Universiti Kebangsaan Malaysia, 43000 Bangi, Selangor, Malaysia
[g] Department of Industrial Engineering, Khon Kaen University, 40002, Thailand

A R T I C L E I N F O

Handling Editor: Dr. Mark Howells

Keywords:
Energy security strategy
Energy control system
Strategic collaboration
Technological capability
Waste-to-energy
Energy resilience

A B S T R A C T

This study is to build a causality model to implement energy security strategies (ESSs) in approaching a world-regions comparison. This study contributes to ESSs by indicating a set of valid attributes and those attributes are interrelationships in nature. There is major global interest in ESSs due to the pressure to ensure sustainable energy supply sources. An adequate energy source is decisive for ensuring stable economic growth, enhancing social development, and protecting the environment. Nonetheless, in reviewing the energy literature, generating strategic attributes is still lacking, which leads to difficulties for policymakers in building, executing, and assessing energy policies. This study utilizes a hybrid method: text mining, cluster analysis, fuzzy Delphi method, fuzzy decision-making trial and evaluation laboratory, and entropy weight method. As a result, five aspects and 22 criteria from the data pool are validated. The causal model shows that the energy control system, strategic collaboration and technological capability are the priority. In practice, the effect aspects are waste-to-energy and energy resilience. Although the research trends on ESSs in different regions are quite similar, each continent still has unique concerns such as European countries with distributed energy resources, Asia and Oceania with decarbonization, African countries with new technologies, and Americas with energy planning.

1. Introduction

Energy security strategies (ESS) are a major interest of countries worldwide, as a sufficient energy supply is decisive for ensuring stable economic growth and enhancing sustainable development [1]. In such a context, the global climate is now facing growing influences of the use of using fossil fuels, the deterioration of the environment due to the extraction of extracting excessive resources, and the ambiguity in the geopolitical field [2]. For instance, Lee et al. [3] highlighted that ESSs involve a guideline set describing the manner in which an economy ensures that its energy is sustainably supplied at a steady price and does not influence economic performance. The appropriate ESS attributes remain one of the most prevalent topics of debate in the energy literature, creating impediments for policymakers in devising, executing, and assessing energy policies [4]. Exploring the crucial ESS attributes and examining their interrelationships while determining the opportunities and challenges of ESSs based on them are necessary to deal with future execution difficulties.

One of the major concerns of ESSs is to identify the incompetence in the energy network through an efficient energy control system. Mariano-Hernández et al. [5] emphasized the necessity of this system in managing energy production and allocation in the electric grid to rationalize costs while ensuring electricity usage demand. Sun et al. [6] added that the expansion of technological capabilities made important contributions to reducing the intensity of energy usage, thus promoting ESSs. With the support of technological innovation, waste-to-energy (WTE) becomes a potential solution for not only providing an alternative energy source but also decreasing the negative impacts of waste on the environment [7]. Zhou and Zhang [8] confirmed that as energy demand increases and there is presently an urgent need for emission reduction,

* Corresponding author. Institute of Innovation and Circular Economy, Asia University, Taichung, Taiwan.
E-mail addresses: btdat1991@gmail.com (T.-D. Bui), hahienminh.cs2@ftu.edu.vn (H.M. Ha), tranthiphuongthuy.cs2@ftu.edu.vn (T.P.T. Tran), Ming.Lim@glasgow.ac.uk (M.K. Lim), tsengminglang@gmail.com, tsengminglang@asia.edu.tw (M.-L. Tseng).

https://doi.org/10.1016/j.esr.2024.101345
Received 16 October 2023; Received in revised form 2 February 2024; Accepted 19 February 2024
Available online 29 February 2024

WTE is a mandatory route for practicing ESSs. To complete ESS goals, guaranteeing the resilience of an energy system is also vital since the energy structure can retain normal production, a significant proportion of renewable energy (RE) sources, and appropriate decarbonized activity [9]; (Fan and Wang, 2023). Furthermore, under the trend of integration and globalization, Kapitonov et al. [10] argued that only under the circumstance of stakeholder cooperation in exchanging energy can ESS development be guaranteed. Indeed, strategic collaboration among two or more independent partners toward a common goal is indispensable in ESS implementation.

As a stable supply of energy is fundamental for the sustainability of economic growth, ESSs are becoming a decisive component of national security strategy and are one of the most important priorities all over the world [10]. Meanwhile, Zhang and Chen [11] indicated that promoting energy efficiency across regions is the key to dealing with common energy issues and strengthening international energy cooperation. However, the energy security problem is typically unique to each country due to countries' different sector coverages and geographical locations, as well as the availability of energy sources [12]. In fact, whereas achievement in ESS implementation has been recorded in developed countries, many other regions still face different challenges in pursuing this strategy, such as price volatility, inappropriate economic policies, and nondiversified energy supply [13,14]. The divergence in executing energy strategies is noticeable in countries around the world, which could lead to discrete jeopardy growing between geographic partitions and impact the success of ESSs [15]. However, theoretical and empirical studies on regional differences are still limited, and it is essential to develop a tailored strategy for energy security issues for each country. This study aims to explore overall ESS application and to expand the assessment to specific regions. This study has the following three major objectives:

- To define a set of ESS attributes;
- To analyze the causal interrelationship model among ESS aspects and to reveal the critical criteria expressing overall opportunities and challenges; and
- To reveal the ESS critical criteria for each region compared to others.

To fulfill these objectives, this study employs a hybrid method consisting of text mining and cluster analysis in the first steps. Text mining and cluster analysis are used to explore and categorize ESS keywords [16]; (Wang et al., 2021). Then, the fuzzy Delphi method (FDM), fuzzy decision-making trial and evaluation laboratory (FDEMATEL), and entropy weight method (EWM) are applied in the next steps. In particular, the FDM validates the criteria by calculating the convex combination value based on expert evaluations. The FDEMATEL is utilized to investigate the causal relationships among attributes [17]. The EWM is adopted to compare and detect differences in the awareness of ESSs across regions [18].

The theoretical and practical contributions involve (1) validating a set of ESS attributes from databases; (2) proposing implications for theoretical models and expressing the potential challenges and opportunities to enhance ESSs; and (3) examining the critical indicators for each region compared to others.

The structure of this study is organized into 6 sections. Section 2 conducts the literature review, while Section 3 describes the methodology. Section 4 reveals the results, and Section 5 declares the study's implications for crucial ESS attributes and regional differences. Finally, Section 6 presents the conclusions and suggestions for future studies.

2. Literature review

2.1. Energy security strategies

An adequate supply of energy is imperative for maintaining the stability of economic development while ensuring the sustainable growth of a country [1]. Thus, energy security is one of the main targets of energy policy [19]. An ESS refers to a guideline set that describes the way an economy ensures that its energy is supplied sustainably at a stable price and does not affect economic performance [3]. ESSs are complex and heavily depend on the context of each country, such as the economic growth level, prominent geopolitical issues, perceptions of threats, and the fitness of the power system [20]. However, the relevant aspects of ESSs remain one of the most popular and controversial topics in the energy literature, creating difficulties for policymakers in formulating, implementing, and evaluating energy policies [4]. The results of this challenge are a deficient management of risks as well as a shortage of methodological rigor and a consistent framework for selecting appropriate indicators and metrics for ESS development [2]. To fill this gap, this study aims to clarify important aspects and criteria of ESSs.

One of the primary concerns of ESSs is identifying inefficiencies in the system, thereby finding ways to measure, visualize, and optimize energy opportunities, which requires an efficient energy control system. Mariano-Hernández et al. [5] explained that an energy control system encompassing interconnected electronic equipment is needed to control energy production and allocation in the electric grid to optimize energy costs and demand responses while reducing emissions. Huang et al. [21] emphasized that the key issues of the energy control system are the operational stability and optimal scheduling of devices to meet the energy demand and ensure balance in the system. The energy management network is an essential element of this control system since it administers all the conditions of RE production and the fundamental electricity circulation procedure and greatly supports the resilience of electrical grids (Alassery, 2022). Currently, the development of energy control systems faces difficulties, one of them being the growing complexities of these systems, which are different from standard techniques. Ahmad et al. [22] argued that new cutting-edge technologies have proven their capability to overcome the disadvantages of conventional methods, increasing the precision and reliability of these structures. Meanwhile, Sani et al. [23] added that the greater issue comes from the cooperation of many stakeholders in energy system control when different stakeholders have different views and interests and there are major obstacles to reaching an understanding between them.

In the rising trend of global integration, the security of the energy sector relies on the relationships and comprehensive efforts among partner countries to address emerging issues [10]. Indeed, strategic collaboration that involves a cooperation agreement among two or more independent partners to work together toward a common goal is indispensable in ESS implementation. Kapitonov et al. [10] argued that only by enhancing the mutual support among all parties in the energy exchange activity can ESSs develop since different regions face different obstacles. Zhang and Chen [11] emphasized that international energy reliance and the rise of energy marketization make strategic energy collaboration highly imperative in the context of co-building the economy. Furthermore, strategic collaboration enables technology transfer and advances national science together with technology capabilities as well as policy learning across national borders, facilitating ESS implementation [24,25]. It has been pointed out that promoting international cooperation programs to widen research and novel technologies for REs is a solution that supports energy resilience [26]. Moreover, Yu et al. (2022) highlighted that collaboration among countries is needed to strengthen relations to promote and stimulate the growth of the waste recovery sector, with a focus on achieving ESS targets.

With the rising requirements for energy and the seriousness of emission reduction, WTE has become a fascinating method of practicing ESSs [8,27]. Gil [28] identified WTE as an innovative process of waste management that relies on the truth that energy sustainability involves sustainable energy resources and power systems. Ali et al. [29] argued that this technology has the potential to solve problems such as energy demand response, the greenhouse effect, and waste disposal to realize a circular system. Additionally, to limit the release of harmful pollutants into the environment and increase energy productivity, indirect WTE treatment is now preferred in most countries. In this procedure, waste is transferred to intermediates before recovering energy from them through thermochemical or biological approaches [30]. However, WTE growth is still influenced by technological barriers involving deficiencies in data collection and processing and the complexity of information technology structures [18,27]. Furthermore, decision-makers need to identify appropriate directions and governance, ensure technical proficiency, boost collaboration between the public and private sectors, and affiliate with international organizations to regulate the WTE supply chain under ESS goals.

In the context of Industry 4.0, successfully executing ESSs also depends on the application and utilization of technological capabilities [31]. Technological capabilities refer to the necessary resources to create and administer technological changes, including skills, knowledge, experience, and related institutions [32]. Recent technological developments have enabled the employment of various new technologies, for example, the Internet of Things (IoT), blockchain, artificial intelligence (AI), and data analytics, to realize ESSs [33]. In particular, AI is highly associated with the energy economy, pushing the RE sector to obtain greater outcomes in terms of availability and efficiency [34]. Sun et al. [6] argued that the wide dissemination of knowledge and technological improvement advanced energy utilization efficiency and reduced energy intensity, therefore contributing to ESS implementation. Capitalizing on technological capabilities significantly increases the efficiency of resource consumption and saves energy [21]. With the support of technological advancement, WTE has become a potential alternative to conventional energy sources while reducing the potentially negative effects of waste on the environment [7]. In addition, applying modern technologies to energy networks is a critical issue to be taken into account in designing energy supply systems to ensure resilience.

Resilience is a multidimensional ability of complex systems, involving the ability to anticipate, avoid, absorb, adapt to, and recover from interruptions [35]. Accordingly, Dong et al. [36] defined energy resilience as the ability of energy systems to adapt to and overcome external disruptions such as economic, social, or environmental fluctuations. Under ESS goals, energy resilience is important since a stable and resilient energy system can effectively ensure standard conditions for production, a significant proportion of RE sources, and an appropriate decarbonized system ([9]; Ji e al., 2022). Gatto and Drago [26] emphasized that energy resilience has received growing scientific awareness; however, the concept is still in the process of development. Thus, this concept needs to be explained more through a holistic lens, where sensing and adaptation stem from the preparedness, flexibility, and learning capacity of each applicable subject. Hasselqvist et al. [37] and Fan et al. [38] asserted that energy resilience currently requires special attention from energy policymakers and researchers since energy systems have increasingly faced various difficulties. There is now an urgent need to realize energy resilience policies to achieve sustainability through convenient energy access and low-carbon energy consumption and production.

2.2. Energy security strategies by region

Economic growth and increasing population are driving the demand for energy in countries. Meanwhile, substitute energy sources are still unable to guarantee a balanced energy supply. Since a stable energy supply is one of the crucial elements for sustainable economic development, ESSs are becoming vital to national security and are one of the most important priorities all over the world [10]. Achievement in ESS implementation has been recognized in many countries in Europe, the Americas, and Oceania. For example, the most developed energy markets, including those in Germany, the United Kingdom, and Australia, undertook their changeover by increasing the management of distributed energy resources (DERs) and by allowing the direct participation of users and virtual power plants in wholesale energy markets (González et al., 2022). Countries in the Americas, such as Paraguay and Costa Rica, have achieved very high rates of decarbonization through the increasing usage of REs, such as wind, solar, or hydro energy, to generate electricity [37]. In Asia, China is a prominent representative in the pursuit of an ESS, with its wind and solar photovoltaic (PV) installed capacity among the highest in the world [39]. Additionally, concerns related to ESSs will push Asian importers to continually diversify their natural gas purchases while balancing with other optimal controls or energy security goals under different economic, strategic, and geopolitical conditions [40].

Despite the growing interest, the implementation of ESSs in some regions still faces many obstacles. Typically, in Africa, while energy is viewed as an economy wheel, the concept of energy security is known but is hardly understood. Although the region has vast energy resources, its wealth of resources still does not guarantee energy security. Major energy crises coupled with the increasing threats of climate change are hindering industrialization and socioeconomic growth in African nations, especially among low-income groups [14]. Energy production in this region is affected by price volatility and a heavy reliance on other countries, but most economic policies concentrate solely on energy connectivity and factors determining consumer demand in the market [15]. Regarding Asia, despite being at the forefront of ESS implementation, China can dominate in novel technological innovations and materials that have implications for global energy security, thereby creating threats to others [39,41]. In addition, the fact that the majority of South Asian countries depend on a single source for electricity generation limits their ability to meet diverse energy requirements, increases their import reliance, and raises growing concerns about energy security [42]. Latin America has great potential to enhance its energy security, but the international relations and trust among neighbors are not high. Thus, countries in this region often consider self-sufficiency more than investment costs and sustainability while limiting theoretical and empirical research on the energy interconnecting divergence advantages [43]. In addition, a low technical level, a lack of modern technologies, and inadequate innovation activities are common obstacles of most countries on different continents to implementing ESSs [10].

In summary, due to regional variations in ESS implementation, regional comparisons are needed to develop an appropriate strategy for this energy security issue for each country.

3. Method

3.1. Proposed method

Previous studies have used both quantitative and qualitative methods to examine ESS topics. Nonetheless, the capability of data criticization and the numerical depiction of qualitative information are lacking when validating attributes along with evaluating their complicated structural relationships. Engaging in a hybrid methodology is vital for interrogating the causal interrelationships among ESS attributes and achieving greater research efficiency.

Due to the vagueness and complications of ESSs, this study exploited a hybrid method with five major steps. Text mining and cluster analysis were exploited to collect data and classify keywords. Then, the FDM was utilized to verify the criteria, whereas the FDEMATEL was employed to explore the causal relationships among attributes [17]. The EWM was exploited to convert the appearance of criteria into entropy weights to indicate the decisive criteria [18]. Experts in academic and practical fields with 10 years or more of experience related to ESSs were engaged. The profile of the experts is shown in Appendix A.

The analysis steps were presented in Fig. 1:

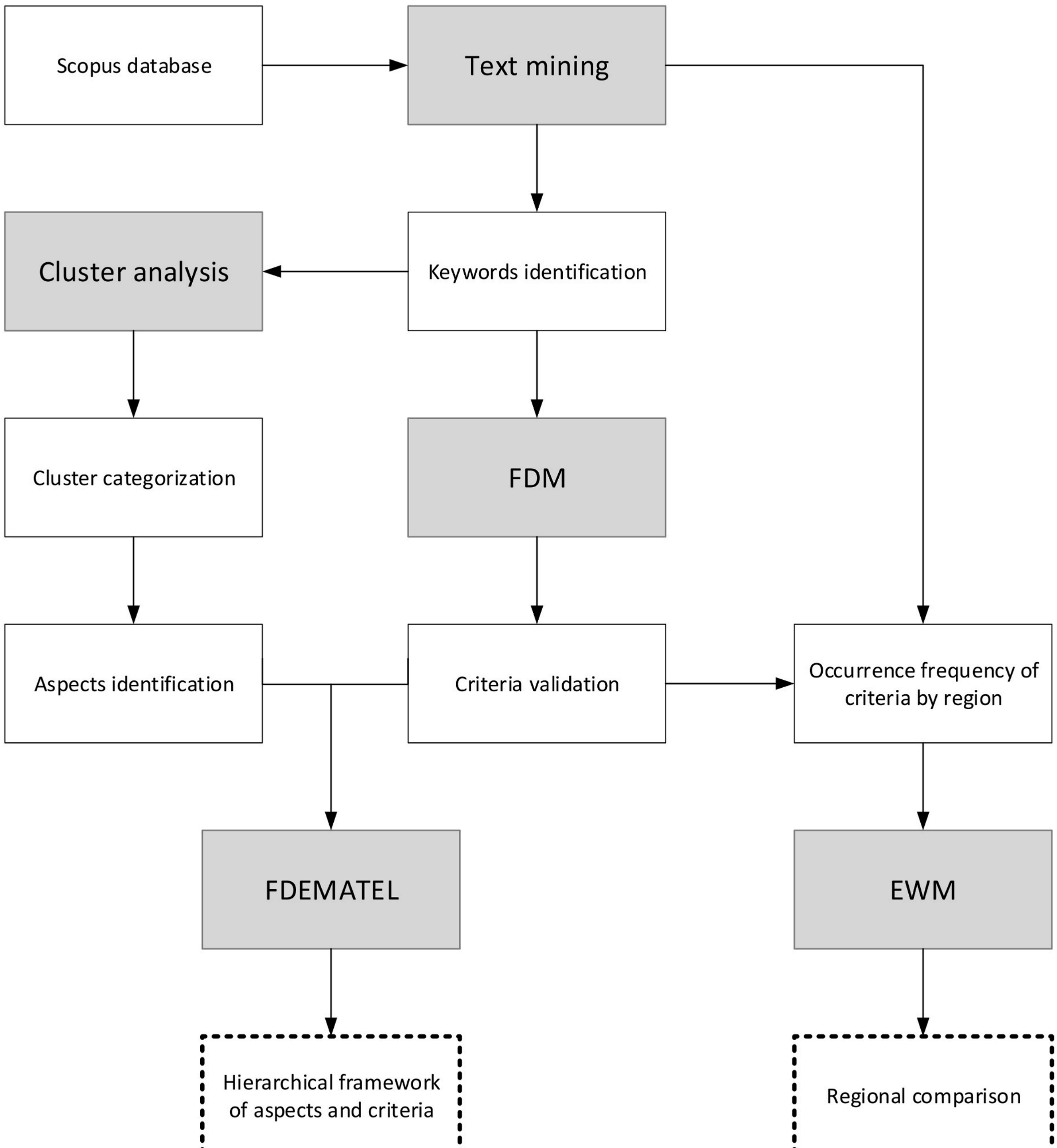

Fig. 1. Recommended analysis steps.

3.2. *Text mining*

Text mining allows researchers to inspect substantial collections of words in an effective way [16]. This technique is among the most widely used approaches for analyzing textual data in a management-linked study. Text mining in VOSviewer has the capability to compose network maps of co-occurring keywords sourced from the abstracts and bodies of research articles. Capitalizing on VOSviewer, publication information is transformed into a text corpus to conduct a statistical analysis of words, the citation connections between publications, and the co-occurrence relationships between scientific terms [44].

In this study, text mining was first utilized to depict a complete analysis of contemporary knowledge concerning ESSs through VOSviewer 1.6.11. The search terms "("energy" OR "energies") AND ("secur*") AND ("strateg*")" were predefined to assess the ESS topic in the literature in Scopus. These inquiries were executed on April 27, 2022. The search was limited to English-language articles and reviews with no chronological constraints. Then, proper keywords appertaining to ESS were identified for further steps. In addition, text mining was used to collect the frequency of valid criteria by each world region.

3.3. *Cluster analysis*

Cluster analysis is utilized to arrange initial attributes into specific clusters complying with the extent of their likeness [45]. Due to this method, the attributes classified in one cluster have a greater correlation with each other than with others in other clusters. This method was employed in the study by using VOSviewer 1.6.11. First, this software assisted in collecting information such as titles, abstracts, and keywords from the specific database. Next, the keywords were compiled via a co-occurrence analysis of author keywords. After cleaning the keywords, the clustering technique was exploited to form the remaining attributes

Table 1
Transformation table of linguistic terms.

Scale	Linguistic terms	Corresponding triangular fuzzy numbers (FDM process)	Corresponding triangular fuzzy numbers (FDEMATEL process)
5	Very high importance	(0.75, 1.0, 1.0)	(0.7, 0.9, 1.0)
4	High importance	(0.5, 0.75, 1.0)	(0.5, 0.7, 0.9)
3	Strong	(0.25, 0.5, 0.75)	(0.3, 0.5, 0.7)
2	Low importance	(0.0, 0.25, 0.5)	(0.1, 0.3, 0.5)
1	Very low importance	(0.0, 0.0, 0.25)	(0.0, 0.1, 0.3)

into suitable clusters [18]. In the outcome, each cluster involved a set of attributes, and each attribute was included in only one specific cluster, and each cluster was distinguished by an ordinal number to differentiate it from the others.

3.4. FDM

Table 1 shows the linguistic term scale used for translating experts' evaluations into respective triangular fuzzy numbers in the FDM process.

The significance value related to criteria i is judged by expert h as $j_{ih} = (o_{ih}; p_{ih}; n_{ih})$, in which $i = 1, 2, 3, \ldots, k$ and $h = 1, 2, 3, \ldots, l$.

The weight j_i of attribute i is $j_i = (o_i; p_i; n_i)$.

$$o_i = min(o_{ih}) \quad (1)$$

$$p_i = \left(\prod_{1}^{l} p_{ih}\right)^{1/l} \quad (2)$$

$$n_i = max(n_{ih}) \quad (3)$$

The convex combination value D_i is calculated as follows:

$$D_i = \int (u_i, l_i) = \epsilon[u_i + (1-\epsilon)l_i] \quad (4)$$

$$u_i = n_i - \epsilon(n_i - p_i) \quad (5)$$

$$l_i = o_i - \epsilon(p_i - o_i) \quad (6)$$

The scope of ϵ commonly pertains to (0; 1), expressing experts' negative or positive view. Commonly, the ϵ value is chosen as 0.5 to show an equalized evaluation among experts.

$$\vartheta = \sum_{i=1}^{k} (D_i / k) \quad (7)$$

The threshold ϑ for validating criteria is estimated. Criterion i is accepted if $D_i \geq \vartheta$.

3.5. FDEMATEL

Regarding the FDEMATEL procedure, the linguistic scale in Table 1 is applied. Assume that expert h is suggested to indicate the importance of attribute f to attribute g, which can be denoted by A^h_{fg}. Triangular fuzzy numbers are computed from linguistic values and designated as $(a_{\ell fg}^{h}, a_{mfg}^{h}, a_{rfg}^{h})$. Finally, crisp values CP^h_{fg} are calculated from these triangular fuzzy numbers.

Normalizing procedure

$$\overline{A}^h_{fg} = \left(\overline{a}_{\ell fg}^{h}, \overline{a}_{mfg}^{h}, \overline{a}_{rfg}^{h}\right) = \left[\frac{\left(a_{\ell fg}^{h} - min\, a_{\ell fg}^{h}\right)}{max\, a_{rfg}^{h} - min\, a_{\ell fg}^{h}}, \frac{\left(a_{mfg}^{h} - min\, a_{mfg}^{h}\right)}{max\, a_{rfg}^{h} - min\, a_{\ell fg}^{h}}, \frac{\left(a_{rfg}^{h} - min\, a_{rfg}^{h}\right)}{max\, a_{rfg}^{h} - min\, a_{\ell fg}^{h}}\right] \quad (8)$$

Gaining the left (L^h_{fg}) and right (R^h_{fg}) normalized value

$$\left(L^h_{fg}, R^h_{fg}\right) = \left[\frac{\overline{a}_{mfg}^{h}}{\left(1 + \overline{a}_{mfg}^{h} - \overline{a}_{\ell fg}^{h}\right)}, \frac{\overline{a}_{rfg}^{h}}{\left(1 + \overline{a}_{rfg}^{h} - \overline{a}_{mfg}^{h}\right)}\right] \quad (9)$$

Computing the crisp values (CP^h_{fg}).

$$CP^h_{fg} = \frac{\left[L^h_{fg}\left(1 - L^h_{fg}\right) + \left(R^h_{fg}\right) \times \left(R^h_{fg}\right)\right]}{\left(1 - L^h_{fg} + R^h_{fg}\right)} \quad (10)$$

Before placing the crisp values in the direct relation matrix $[DR]$, it is necessary to accumulate all experts' crisp values dr_{fg}:

$$dr_{fg} = \frac{\sum_{h=1}^{n} CP^h_{fg}}{n} \quad (11)$$

$$[DR] = \left[dr_{fg}\right]_{d \times d} \quad (12)$$

After normalizing the direct relation matrix $[\overline{DR}]$, the total relation matrix $[TR]$ is constructed to acquire the driving and dependence powers. $[TR]$ can be denoted as $[tr_{fg}]_{d \times d}$.

The driving value (D) and dependence value (R) are adopted as follows:

$$D = \sum_{f=1}^{d} \left[tr_{fg}\right]_{d \times d} = \left[tr_f\right]_{d \times 1} \quad (13)$$

$$R = \sum_{g=1}^{d} \left[tr_{fg}\right]_{d \times d} = \left[tr_g\right]_{1 \times d} \quad (14)$$

The cause-and-effect model is presented based on the coordinated values [(D + R), (D - R)]. Here, (D + R) is the horizontal axis, where the higher the value of the criterion is, the more important it is. (D - R) is the vertical axis for categorizing the criteria into the causal group and the effect group. If $(D_f - R_f)$ is greater than zero, the criterion is categorized into the causal group, whereas the effect group consists of the attributes for which the value of (D_f – R_f) is less than zero.

3.6. EWM

The entropy value is a benchmark that illustrates how volatile a system is when an attribute is weighted. Accordingly, the higher the entropy weight is, the more strongly the attribute affects the scheme [18]. Based on the EWM, a high entropy weight is a result of a low entropy value and vice versa. Furthermore, a low entropy value indicates that the attribute holds little data. Hence, attributes with high entropy weights need to be studied more to clarify the remaining issues.

Each attribute weight ($w_a, \sum w_a = 1$) is computed by applying the formulation of the gray entropy method, as below:

First, the total coefficient C_a (the total coefficient of attribute a) is estimated for each attribute:

$$a = 1, 2, \dots, u$$

$$b = 1, 2, \dots, v$$

$$C_a = \sum\nolimits_{b=1}^{v} x_b(a) \tag{15}$$

Attribute a is formed by items, in which $x_b(a)$ stands for item b of attribute a

Second, the entropy value of each attribute and the total entropy value are calculated:

$$k = \left(e^{0.5} - 1\right)v \tag{16}$$

$$e_a = k \sum_{b=1}^{v} f\left(\frac{x_b(a)}{C_a}\right) \tag{17}$$

$$E = \sum_{a=1}^{u} e_a \tag{18}$$

Finally, the entropy weight of each attribute is determined:

$$w_a = \frac{\frac{1}{(v-E)}(1 - e_a)}{\sum\nolimits_{a=1}^{u} \frac{1}{(v-E)}(1 - e_a)} \tag{19}$$

4. Results

4.1. Step 1 – text mining – keyword identification

For a more realistic view, this study started by searching for all keywords related to ESSs. The search terms employed were (“energy” OR “energies”) AND (“secur*”) AND (“strateg*”). With 3162 publications, Europe is found to pay great attention to the ESS topic. Following this continent are Asia and the Americas, which have 2583 and 1476 articles, respectively. Meanwhile, this issue still receives inadequate interest in Oceania and Africa, with only 332 and 318 studies, respectively.

Table 2 displays the final outcome of text mining using VOSviewer 1.6.11. A total of 6829 publications were researched, and 14,350 keywords related to the ESS search terms were identified. Nonetheless, only 208 keywords with a frequency of appearance equal to or more than ten times remained. Finally, 97 meaningful keywords were retained for further steps after deleting 111 similar or meaningless keywords.

4.2. Step 2 – cluster analysis – cluster identification

Table 2 also displays the cluster analysis outcome from executing VOSviewer 1.6.11. At a result, 8 ESS clusters were identified. These clusters were then utilized to categorize ESS aspects.

Specifically, cluster 1 focuses on control systems related to ESSs, such as demand side management, DERs, the energy storage system, the integrated energy system, and optimal control. Therefore, this cluster is

Table 2
Result of text mining and cluster analysis.

ID	Keyword	Average published year	Cluster
1	Cyber security	2019.2941	1
2	Demand response	2018.4103	
3	Demand side management	2018	
4	Distributed energy resources	2019.3333	
5	Economic dispatch	2017.8182	
6	Electric vehicle	2017.8	
7	Electricity market	2017.55	
8	Energy management system	2020.1	
9	Energy storage system	2019.8333	
10	Energy transition	2019.9111	
11	Frequency control	2016.5	
12	Frequency regulation	2019.8182	
13	Genetic algorithm	2016.7857	
14	Integrated energy system	2019.9091	
15	Microgrid	2018.1538	
16	Optimal control	2016.9	
17	Optimal power flow	2016.5833	
18	Power system	2014.9167	
19	Reinforcement learning	2020.0769	
20	Reliability	2017.85	
21	Risk assessment	2018.8462	
22	System dynamics	2017.7333	
23	Transient stability	2013.2	
24	Uncertainty	2017.8936	
25	Unit commitment	2016.5	
26	Economic development	2015.6	2
27	Economic security	2017.9091	
28	Energy cooperation	2013.2727	
29	Energy market	2016.3333	
30	Energy planning	2014.1538	
31	Energy policy	2014.9041	
32	Energy resources	2018.7692	
33	Geopolitics	2016.1905	
34	International relations	2014	
35	National security	2014.2778	
36	Nuclear energy	2014.0345	
37	Sustainable development	2014.9785	
38	Terrorism	2011.3125	
39	Trade	2010.6	
40	Bioenergy	2015	3
41	Circular economy	2019.2727	
42	Environmental impacts	2014.5	
43	Ethanol	2013.8	
44	Innovation	2015.9474	
45	Life cycle assessment	2017.1818	
46	Microalgae	2017.5	
47	Pipelines	2015	
48	Recycling	2010.5455	
49	Technology	2015.5455	
50	Waste management	2013.5833	
51	Adaptation	2016.4571	4
52	Battery	2018.3636	
53	Climate change	2015.25	
54	Decarbonization	2019.4545	
55	Diversification	2015.25	
56	Greenhouse gas emissions	2015.8333	
57	Hydrogen	2015.4	
58	Infrastructure	2016.1538	
59	Resilience	2017.7632	
60	Security of supply	2014.8421	
61	Vulnerability	2013	
62	Wind power	2015.725	
63	Coal	2015.1364	5
64	Governance	2014.5625	
65	Hydropower	2016.7857	
66	Renewable energy	2016.2562	
67	Solar energy	2014.7826	
68	Water security	2018.4091	
69	Water-energy nexus	2018.7	
70	Blockchain	2020.2927	6
71	Deep learning	2020.7143	
72	Energy efficiency	2016.6832	
73	Energy harvesting	2019.037	
74	Energy saving	2016.9565	

(continued on next page)

Table 2 (*continued*)

ID	Keyword	Average published year	Cluster
75	Internet of things	2019.5769	
76	Network lifetime	2017.6667	
77	Optimization	2018.0312	
78	Physical layer security	2018.75	
79	Privacy	2020.0769	
80	Resource allocation	2019.5714	
81	Resource management	2019.7692	
82	Secure routing	2019.2727	
83	Smart city	2019.4375	
84	Trust	2018.6923	
85	Wireless sensor networks	2016.5167	
86	cyber-physical systems	2018.1538	7
87	Distributed generation	2016.5161	
88	Energy conservation	2015.7143	
89	Network security	2016.2	
90	Smart grid	2017.629	
91	Sustainable energy	2014.75	
92	Artificial intelligence	2019.1	8
93	Cloud computing	2018.8841	
94	Energy consumption	2018.2034	
95	Machine learning	2020.619	
96	Scheduling	2013	
97	Virtual machine placement	2019.125	

formed into aspect 1, the energy control system (A1). Cluster 2 concentrates on energy cooperation, the energy market, energy planning, energy policy, geopolitics, international relations, and national security. This cluster comprises aspect 2, strategic collaboration (A2). Cluster 3 emphasizes the energy recovery from waste in ESSs, encompassing the keywords bioenergy, circular economy, innovation, life cycle assessment, and recycling. This cluster forms aspect 3, WTE (A3). Clusters 4 and 5 reveal more concerns about the resilience of ESSs by involving the keywords adaptation, decarbonization, diversification, vulnerability, security of supply, governance, and RE. The merger of these clusters generates aspect 4, energy resilience (A4). Cluster 6, cluster 7 and cluster 8 further the utilization of new technologies into ESS execution by listing effective techniques consisting of blockchain, deep learning, the IoT, smart grids, AI, machine learning, and cyber-physical systems. Aspect 5 is created from these clusters: technological capability (A5).

4.3. Step 3 – FDM – aspects and criteria validation

FDM analysis was executed in two rounds to validate the ESS criteria. In the first round, the original set of 97 criteria was analyzed by applying Eqs. (1)–(7). The result of this round was shown in Appendix B, in which 47 ESS criteria remain. This process was repeated in the second round, and as a result, 22 criteria with a value above the threshold of 0.452 were retained. The final set of ESS criteria and the threshold based on the FDM calculation are presented in Table 3.

Table 4 specifies 22 validated criteria after FDM analysis. These criteria are categorized into five aspects formed by cluster analysis, including the energy control system (A1), strategic collaboration (A2), WTE (A3), energy resilience (A4), and technological capability (A5).

4.4. Step 4 - FDEMATEL - aspects and criteria hierarchical framework formation

Tables 5 and 6 present the FDEMATEL result of the ESS aspects exploiting Eqs. (8)–(14). Specifically, Table 5 shows the crisp value of the ESS aspects, and Table 6 displays the total interrelation matrix of the ESS aspects. The D and R values in Table 6 represent the driving index and dependence index of the aspects.

Fig. 2 indicates the interrelationships of the ESS aspects. The causal group consists of the energy control system (A1), strategic collaboration (A2), and technological capability (A5), while the effect group includes the two remaining aspects, WTE (A3) and energy resilience (A4). From Fig. 2, the causal aspects have a significant impact on the effect aspects, suggesting meaningful implications for executing ESSs. Evaluating the interrelationships between attributes in each group, the causal aspects have strong influences on each other, whereas the effect aspects have no significant interaction.

Tables 7 and 8 show the FDEMATEL result of the ESS criteria applying the same Eqs. (8)–(14). In particular, Table 7 reveals the crisp values of the ESS criteria, while Table 8 exhibits the total interrelationship matrix of the ESS criteria. The driving value D and dependence value R of the criteria are calculated and presented in Table 8. Criteria with a (D-R) value greater than or equal to zero belong to the causal group, whereas all other factors are in the effect group.

Fig. 3 presents the framework of the criteria, in which criteria lying above the horizontal axis pertain to the causal group. The top five ESS criteria with the highest driving and dependence values are DERs (C2), optimal control (C5), international relations (C9), decarbonization (C15), and AI (C18). Hence, managerial implications for decision-makers on the ESS topic should focus on such criteria.

Table 3
FDM result for criteria – The second round.

Criteria	l_i	u_i	D_i	Decision
Demand response	0.340	0.910	0.540	Accepted
Demand side management	(0.381)	0.881	0.345	Unaccepted
Distributed energy resources	0.348	0.902	0.538	Accepted
Electric vehicle	(0.383)	0.883	0.346	Unaccepted
Electricity market	(0.395)	0.895	0.349	Unaccepted
Energy management system	0.340	0.910	0.540	Accepted
Energy storage system	0.329	0.921	0.543	Accepted
Frequency regulation	(0.395)	0.895	0.349	Unaccepted
Optimal control	0.352	0.898	0.537	Accepted
Risk assessment	(0.380)	0.880	0.345	Unaccepted
System dynamics	(0.395)	0.895	0.349	Unaccepted
Unit commitment	(0.383)	0.883	0.346	Unaccepted
Energy cooperation	(0.417)	0.917	0.354	Unaccepted
Energy market	0.374	0.876	0.532	Accepted
Energy planning	0.312	0.938	0.547	Accepted
Energy policy	0.312	0.938	0.547	Accepted
Energy resources	(0.002)	0.877	0.438	Unaccepted
International relations	0.340	0.910	0.540	Accepted
Bioenergy	0.340	0.910	0.540	Accepted
Circular economy	0.329	0.921	0.543	Accepted
Environmental impacts	0.009	0.866	0.435	Unaccepted
Innovation	0.005	0.870	0.436	Unaccepted
Life cycle assessment	0.340	0.910	0.540	Accepted
Recycling	(0.022)	0.897	0.443	Unaccepted
Waste management	0.340	0.910	0.540	Accepted
Adaptation	0.340	0.910	0.540	Accepted
Decarbonization	0.316	0.934	0.546	Accepted
Diversification	0.344	0.906	0.539	Accepted
Greenhouse gas emissions	(0.332)	0.832	0.333	Unaccepted
Renewable energy	0.320	0.930	0.545	Accepted
Security of supply	(0.340)	0.840	0.335	Unaccepted
Water security	(0.388)	0.888	0.347	Unaccepted
Water-energy nexus	(0.414)	0.914	0.354	Unaccepted
Artificial intelligence	0.356	0.894	0.536	Accepted
Blockchain	0.344	0.906	0.539	Accepted
Cloud computing	0.002	0.873	0.437	Unaccepted
Cyber-physical systems	(0.383)	0.883	0.346	Unaccepted
Deep learning	(0.332)	0.832	0.333	Unaccepted
Energy efficiency	0.012	0.863	0.435	Unaccepted
Internet of things	0.356	0.894	0.536	Accepted
Machine learning	0.348	0.902	0.538	Accepted
Optimization	0.012	0.863	0.435	Unaccepted
Resource allocation	(0.380)	0.880	0.345	Unaccepted
Resource management	(0.020)	0.895	0.443	Unaccepted
Smart grid	0.344	0.906	0.539	Accepted
Virtual machine placement	(0.422)	0.922	0.356	Unaccepted
Wireless sensor networks	(0.391)	0.891	0.348	Unaccepted
Threshold			0.452	

Table 4
Criteria result from FDM and proposed aspects.

Criteria		Aspect
C1	Demand response	Energy control system (A1)
C2	Distributed energy resources	
C3	Energy management system	
C4	Energy storage system	
C5	Optimal control	
C6	Energy market	Strategic collaboration (A2)
C7	Energy planning	
C8	Energy policy	
C9	International relations	
C10	Bioenergy	Waste-to-energy (A3)
C11	Circular economy	
C12	Life cycle assessment	
C13	Waste management	
C14	Adaptation	Energy resilience (A4)
C15	Decarbonization	
C16	Diversification	
C17	Renewable energy	
C18	Artificial intelligence	Technological capability (A5)
C19	Blockchain	
C20	Internet of things	
C21	Machine learning	
C22	Smart grid	

Table 5
Crisp value of the ESS aspects.

	A1	A2	A3	A4	A5
A1	0.705	0.472	0.664	0.573	0.571
A2	0.623	0.706	0.623	0.634	0.511
A3	0.420	0.367	0.740	0.100	0.400
A4	0.387	0.473	0.120	0.743	0.467
A5	0.628	0.644	0.572	0.614	0.685

Table 6
Total interrelationship matrix of the ESS aspects.

	A1	A2	A3	A4	A5	D
A1	1.366	1.242	1.341	1.272	1.267	6.488
A2	1.387	1.367	1.371	1.343	1.292	6.761
A3	0.902	0.848	1.017	0.742	0.855	4.364
A4	0.976	0.977	0.856	1.083	0.964	4.857
A5	1.422	1.379	1.385	1.370	1.381	6.937
R	6.053	5.815	5.970	5.810	5.760	

4.5. Step 5 – EWM – identification of critical ESS criteria by regions

Fig. 4 presents the frequency of occurrence of critical ESS criteria by region collected from the Scopus database. There are five main regions researched in this study, consisting of Europe, the Americas, Asia, Africa, and Oceania. Compared to other criteria, RE was the most frequently mentioned criterion, while AI, optimal control, and international relations were criteria that appeared the least frequently in ESS studies.

In addition, the interest of each region in different criteria is not the same. Fig. 4 shows that RE was a prominent issue in ESS studies all over the world. However, energy policy was also a popular topic in Europe, the Americas, and Asia. Africa paid great attention to the adaptation problem of ESSs, whereas Oceania published many studies related to smart grids. However, the criteria that have not been studied much in the past contain important meanings that need to be explored more deeply in the future.

Table 9 reveals the result of EWM analysis applying Eqs. (15)–(19), in which the frequency of occurrence of ESS criteria collected from the Scopus database was input data. Based on the EWM, a high entropy weight indicates that the attribute is less mentioned. Thus, criteria with a high entropy weight have an important role and need further study since the information contained in these attributes is still ambiguous. Overall, the EWM result is consistent with the viewpoint of experts in the steps above, and the criteria with a high entropy weight are AI, optimal control, and international relations.

Fig. 5 illustrates the comparison of entropy weights by region. In general, the trends in research on ESSs in different regions of the world are quite similar. Criteria that have not been approached much include optimal control, international relations, and AI. Moreover, energy policy has a particularly low entropy weight in Australia, while adaptation has a particularly low value in Africa. This result shows that although there have not been various studies on ESSs, these two areas are remarkably interested in policy and adaptability under ESSs. Further discussion related to this result is presented in the next section.

5. Discussion

5.1. Theoretical model discussion

The results of this study strengthen the literature by providing theoretical insight into ESSs. In particular, the energy control system (A1), strategic collaboration (A2), and technological capability (A5) are part of the causal group, while WTE (A3) and energy resilience (A4) are part of the effect group. Thus, to execute ESSs, the energy control system, strategic collaboration, and technological capability should be prioritized.

Belonging to the causal group, the energy control system (A1) has moderate impacts on the attributes of the effect group. This result confirms the critical role of this aspect in ESS goals in regard to measuring, monitoring, and optimizing energy production and distribution to guarantee the efficiency of power systems [5,38]. The energy control system is confirmed to highly contribute to the stability and resilience of electrical grids as a function of managing all the conditions of essential RE manufacturing [34]. However, in reality, novel technologies and collaboration pressures have still been challenges in developing these systems [22,23]. Given that technological development is conducive to ESSs, innovative technologies should be encouraged in energy control systems and effectively applied to improve the power structure, promote energy conservation and decrease emissions [44]. Furthermore, from a regulatory viewpoint, it is necessary to bolster flexibility and allow the appearance of novel business models to integrate different stakeholders, including distributed grid operators, prosumers, project developers, energy societies, and aggregators, to jointly implement energy control systems [13].

Strategic collaboration (A2) is classified into the causal group, which confirms its decisive role in executing ESSs. Strategic collaboration emphasizes the mutual cooperation and comprehensive endeavors of partner countries in achieving ESS targets with relevance to global energy dependence and the growth in energy marketization [10,11]. Furthermore, strategic collaboration promotes ESS implementation by enabling the transfer of technology and advancing national science and technological capabilities together with policy learning across national boundaries [24,25]. Moreover, this aspect exerts a certain impact on effect aspects, including WTE and energy resilience. In particular, strategic collaboration intensifies relations to further the development of the waste recovery sector with a focus on attaining ESS objectives [27,46]. Energy resilience is supported by boosting international collaboration schemes for promoting research and technology for renewables [26,38]. Stimulating strategic collaboration requires an adequate and sound coordination mechanism in terms of interest cooperation, negotiation, legal safeguards, and the exchange of talent with energetic engagement by the governments and firms of all related nations [47].

Technological capability (A5) is the prominent aspect of the causal group, as it not only has a high influence on the effect attributes but also strongly impacts other attributes in the same group. This supports the argument that successfully implementing ESSs heavily relies on the utilization of technological capability, especially in the Industry 4.0

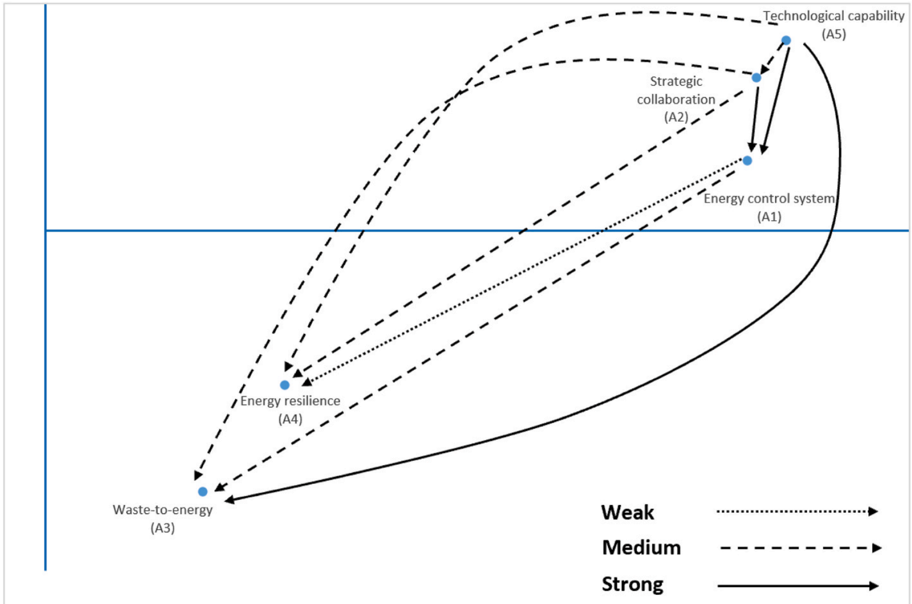

Fig. 2. Cause-and-effect diagram of the ESS aspects.

context [31]. Accordingly, the application of advanced technologies to energy networks helps ensure the resilience of energy supply systems [24]. It also facilitates the WTE method in creating other sources of energy while reducing harmful impacts on the environment [7,27]. Furthermore, novel technologies have proven their capability to conquer the threats of usual methods for enhanced precision, optimization and accuracy for conventional energy control systems [22]. However, enhancing the realization of widespread social infrastructure with a view to ensuring extensive adoption and stable usage of novel technologies and enabling the natural shift of energy schemes is critical [33]. In addition, decision-makers need to regard the demands of people's livelihoods and society in numerous ways to achieve technological improvement in a more prudent and diverse manner.

Although WTE (A3) and energy resilience (A4) are included in the effect group, such aspects still have a crucial part in implementing ESSs. To advocate WTE adoption, privileges in terms of financial incentives should also be granted to operators through policy mechanisms. Continuous research on WTE should be maintained to further bolster its technological maturation to satisfy industrial requirements [30]. In addition, as one of the task forces in regulating the WTE supply chain with a focus on achieving ESS targets, collaboration is needed. Furthermore, ensuring ESS implementation calls for sound energy resilience to efficiently ensure normal production, a considerable proportion of RE sources, and a suitable decarbonized power system [9,38,39]. With the aim of enhancing energy resilience, countries need to enhance their independent innovation competency via mutual collaboration and increase the advancement of innovative human capital to provide apparent ideas for optimizing the industrial structure and achieving energy conservation together with emission reduction [36]. The attention and development of these aspects are highly necessary to strengthen ESSs in a comprehensive manner.

5.2. Policy opportunities and challenges

5.2.1. Distributed energy resources (C2)

DERs refer to small-to-medium-sized resources generated by distributed generators together with storage equipment founded on RE sources to help countries implement ESSs [48]. DERs provide several resolutions appropriate to microgrids within satisfying models and mastery strategies with reference to power quality, and they simultaneously contribute to the relevant environmental, economic, and social goals [13]. Currently, the development of DERs has become the consensus of all countries globally since they have the advantages of recycling, low emissions, and solving energy shortages. The governments of countries with great DER penetration started their shift with RE creation regulations, adjustments in energy policy and subsidies to prompt the development of installed solar capacity. Furthermore, the application of information and communication technologies to improve system flexibility and supposed smart grid modernization presents the potential for DER integration [49]. For example, enhanced grid planning and control following the manner of driving the load and generation from DERs are being used in many countries. Accordingly, net metering models have been adopted for prosumers, in which their electricity export is adjusted against imports in the electricity invoice, thereby benefiting users.

5.2.2. Optimal control (C5)

Optimal control involves the procedure of determining control as well as state paths for a dynamical scheme over a period of time to optimize an accomplishment index. Currently, the concept is being widely applied in many fields of the energy industry to complete ESS goals, including the design of high-rise buildings, railways, electric vehicles, or gas supply systems. For example, the corresponding minimization strategy for fuel usage is one of the methods employed for realizing the actual time optimal control for prolonged range electric vehicles [50]. In addition, optimal control regarding static energy storage schemes is a method of decreasing all energy supplied by all relevant traction substations for railway firms. The optimal control of energy schemes also plays an important role in achieving the goal of nearly zero energy in high building performance through the efficient management of generation systems as well as energy storage systems [51]. Furthermore, the enhanced optimal control strategy is then used in the online system application of energy storage devices to obtain the minimal value of operating costs [52]. The high utilization of stochastic optimization methods combined with dynamic programming techniques is turning into a critical tendency owing to growing amounts of accessible data, and specifically, reinforcement learning methods are generally adopted for energy governance [53]. With the outstanding advantage of being able to reduce the initial investment cost incurred by people, an optimal control strategy is a trend in developing countries lacking access to electricity [54].

Table 7
Crisp value of the ESS criteria.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22
C1	0.812	0.425	0.519	0.391	0.500	0.433	0.473	0.362	0.526	0.463	0.522	0.450	0.399	0.481	0.392	0.515	0.426	0.506	0.480	0.453	0.480	0.405
C2	0.451	0.798	0.478	0.486	0.498	0.458	0.579	0.420	0.511	0.487	0.502	0.397	0.457	0.502	0.437	0.523	0.354	0.572	0.414	0.492	0.446	0.490
C3	0.471	0.469	0.793	0.468	0.487	0.402	0.518	0.368	0.440	0.416	0.492	0.373	0.485	0.455	0.444	0.450	0.363	0.437	0.497	0.374	0.465	0.436
C4	0.536	0.455	0.505	0.815	0.445	0.464	0.502	0.350	0.472	0.365	0.511	0.397	0.449	0.475	0.530	0.414	0.376	0.463	0.412	0.498	0.465	0.464
C5	0.542	0.494	0.499	0.493	0.783	0.548	0.445	0.432	0.548	0.470	0.522	0.476	0.469	0.543	0.479	0.493	0.540	0.527	0.486	0.533	0.484	0.482
C6	0.369	0.371	0.253	0.352	0.421	0.795	0.264	0.394	0.376	0.273	0.269	0.340	0.357	0.350	0.469	0.375	0.365	0.319	0.384	0.362	0.356	0.420
C7	0.450	0.497	0.410	0.391	0.402	0.347	0.838	0.509	0.398	0.406	0.529	0.473	0.434	0.454	0.476	0.457	0.464	0.403	0.383	0.481	0.502	0.424
C8	0.329	0.393	0.324	0.217	0.370	0.283	0.427	0.803	0.405	0.289	0.507	0.334	0.464	0.415	0.422	0.437	0.382	0.353	0.423	0.440	0.277	0.398
C9	0.490	0.513	0.506	0.511	0.550	0.522	0.510	0.472	0.780	0.451	0.528	0.500	0.463	0.511	0.442	0.558	0.424	0.558	0.449	0.530	0.511	0.442
C10	0.377	0.450	0.429	0.367	0.390	0.351	0.361	0.325	0.324	0.814	0.373	0.385	0.358	0.326	0.410	0.343	0.282	0.269	0.398	0.350	0.336	0.429
C11	0.407	0.366	0.474	0.446	0.383	0.414	0.486	0.464	0.370	0.406	0.781	0.404	0.395	0.404	0.466	0.478	0.393	0.406	0.401	0.473	0.494	0.449
C12	0.401	0.321	0.319	0.339	0.253	0.302	0.391	0.413	0.336	0.263	0.346	0.798	0.389	0.270	0.437	0.278	0.466	0.320	0.369	0.313	0.280	0.354
C13	0.467	0.413	0.467	0.447	0.357	0.338	0.404	0.322	0.399	0.321	0.429	0.405	1.000	0.524	0.467	0.369	0.385	0.384	0.319	0.389	0.445	0.424
C14	0.413	0.455	0.493	0.440	0.428	0.383	0.503	0.484	0.382	0.316	0.534	0.365	0.442	0.783	0.450	0.553	0.365	0.360	0.435	0.416	0.535	0.500
C15	0.475	0.490	0.441	0.446	0.441	0.458	0.429	0.512	0.528	0.418	0.435	0.526	0.471	0.460	0.777	0.475	0.400	0.544	0.498	0.494	0.516	0.424
C16	0.382	0.454	0.416	0.436	0.379	0.346	0.504	0.294	0.368	0.341	0.417	0.277	0.411	0.409	0.373	0.796	0.301	0.385	0.325	0.431	0.382	0.354
C17	0.390	0.417	0.449	0.422	0.371	0.323	0.531	0.448	0.330	0.339	0.515	0.496	0.383	0.438	0.401	0.392	0.795	0.372	0.356	0.403	0.498	0.348
C18	0.385	0.552	0.512	0.493	0.492	0.426	0.505	0.490	0.509	0.428	0.522	0.446	0.512	0.563	0.474	0.495	0.538	0.795	0.467	0.530	0.465	0.375
C19	0.451	0.429	0.401	0.415	0.467	0.439	0.485	0.445	0.454	0.441	0.442	0.366	0.424	0.458	0.458	0.400	0.407	0.438	0.793	0.433	0.412	0.457
C20	0.496	0.482	0.446	0.441	0.397	0.376	0.572	0.395	0.411	0.418	0.522	0.410	0.420	0.494	0.557	0.439	0.431	0.449	0.432	0.800	0.478	0.488
C21	0.466	0.470	0.431	0.436	0.482	0.464	0.535	0.383	0.388	0.464	0.540	0.454	0.462	0.409	0.480	0.494	0.411	0.400	0.443	0.449	0.783	0.379
C22	0.377	0.477	0.480	0.417	0.451	0.483	0.441	0.377	0.467	0.374	0.421	0.457	0.440	0.488	0.484	0.465	0.445	0.510	0.424	0.532	0.505	0.782

Table 8
Total interrelationship matrix of the ESS criteria.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	D
C1	0.375	0.347	0.352	0.328	0.341	0.322	0.369	0.319	0.342	0.313	0.372	0.329	0.342	0.354	0.348	0.357	0.320	0.342	0.334	0.350	0.351	0.331	**7.537**
C2	0.353	0.393	0.359	0.348	0.351	0.334	0.390	0.334	0.351	0.325	0.381	0.334	0.358	0.367	0.364	0.369	0.323	0.359	0.337	0.365	0.359	0.349	**7.801**
C3	0.335	0.343	0.368	0.327	0.331	0.311	0.363	0.311	0.326	0.301	0.359	0.313	0.341	0.342	0.344	0.342	0.306	0.327	0.327	0.334	0.341	0.325	**7.318**
C4	0.350	0.350	0.350	0.367	0.335	0.325	0.371	0.317	0.337	0.303	0.370	0.324	0.346	0.353	0.361	0.347	0.315	0.338	0.327	0.354	0.350	0.336	**7.524**
C5	0.376	0.380	0.376	0.363	0.391	0.357	0.394	0.350	0.369	0.336	0.399	0.356	0.374	0.386	0.383	0.381	0.354	0.369	0.359	0.384	0.378	0.363	**8.178**
C6	0.269	0.275	0.261	0.261	0.269	0.294	0.278	0.260	0.265	0.236	0.277	0.256	0.272	0.274	0.288	0.277	0.254	0.261	0.262	0.275	0.273	0.269	**5.908**
C7	0.333	0.344	0.332	0.319	0.322	0.305	0.392	0.324	0.321	0.299	0.362	0.322	0.336	0.341	0.347	0.342	0.315	0.323	0.315	0.343	0.344	0.324	**7.306**
C8	0.279	0.292	0.282	0.262	0.278	0.259	0.309	0.311	0.281	0.250	0.315	0.269	0.296	0.295	0.298	0.297	0.268	0.277	0.279	0.296	0.280	0.280	**6.249**
C9	0.369	0.380	0.375	0.363	0.368	0.352	0.398	0.352	0.388	0.333	0.397	0.356	0.372	0.381	0.378	0.385	0.342	0.370	0.353	0.381	0.378	0.357	**8.127**
C10	0.276	0.289	0.284	0.268	0.272	0.259	0.294	0.259	0.266	0.292	0.294	0.266	0.278	0.278	0.289	0.280	0.251	0.262	0.269	0.279	0.277	0.276	**6.056**
C11	0.318	0.321	0.327	0.314	0.309	0.301	0.348	0.309	0.308	0.289	0.373	0.305	0.321	0.325	0.334	0.332	0.298	0.313	0.307	0.331	0.332	0.315	**7.029**
C12	0.263	0.261	0.258	0.251	0.244	0.240	0.280	0.253	0.252	0.227	0.275	0.290	0.266	0.257	0.275	0.258	0.255	0.252	0.252	0.260	0.256	0.253	**5.679**
C13	0.316	0.318	0.320	0.307	0.300	0.287	0.332	0.289	0.303	0.274	0.333	0.298	0.370	0.330	0.327	0.315	0.290	0.304	0.292	0.315	0.320	0.306	**6.846**
C14	0.327	0.338	0.338	0.322	0.323	0.306	0.359	0.319	0.318	0.289	0.360	0.310	0.334	0.369	0.342	0.349	0.303	0.317	0.318	0.335	0.345	0.329	**7.252**
C15	0.351	0.361	0.352	0.340	0.342	0.331	0.372	0.340	0.349	0.315	0.371	0.343	0.356	0.359	0.391	0.360	0.324	0.353	0.342	0.361	0.361	0.339	**7.709**
C16	0.288	0.301	0.294	0.286	0.282	0.269	0.320	0.267	0.281	0.259	0.310	0.267	0.295	0.298	0.297	0.333	0.263	0.284	0.273	0.299	0.293	0.280	**6.340**
C17	0.306	0.315	0.314	0.301	0.298	0.282	0.341	0.298	0.294	0.273	0.338	0.304	0.309	0.318	0.317	0.314	0.325	0.299	0.292	0.314	0.321	0.295	**6.770**
C18	0.353	0.376	0.368	0.354	0.356	0.337	0.390	0.347	0.357	0.324	0.390	0.344	0.369	0.379	0.373	0.372	0.346	0.385	0.348	0.374	0.367	0.344	**7.953**
C19	0.327	0.333	0.326	0.316	0.323	0.309	0.354	0.313	0.321	0.298	0.348	0.307	0.329	0.336	0.339	0.331	0.304	0.321	0.348	0.333	0.330	0.322	**7.168**
C20	0.345	0.351	0.344	0.332	0.330	0.315	0.377	0.321	0.330	0.308	0.370	0.324	0.342	0.354	0.363	0.348	0.319	0.336	0.328	0.380	0.350	0.338	**7.504**
C21	0.337	0.345	0.337	0.326	0.332	0.319	0.367	0.315	0.323	0.307	0.366	0.323	0.341	0.340	0.350	0.348	0.312	0.326	0.324	0.343	0.372	0.322	**7.372**
C22	0.332	0.349	0.345	0.328	0.333	0.323	0.362	0.317	0.333	0.301	0.358	0.326	0.342	0.351	0.354	0.349	0.319	0.339	0.325	0.354	0.350	0.362	**7.452**
R	**7.177**	**7.362**	**7.262**	**6.982**	**7.029**	**6.736**	**7.759**	**6.825**	**7.015**	**6.451**	**7.720**	**6.867**	**7.289**	**7.386**	**7.462**	**7.384**	**6.705**	**7.059**	**6.909**	**7.358**	**7.326**	**7.015**	

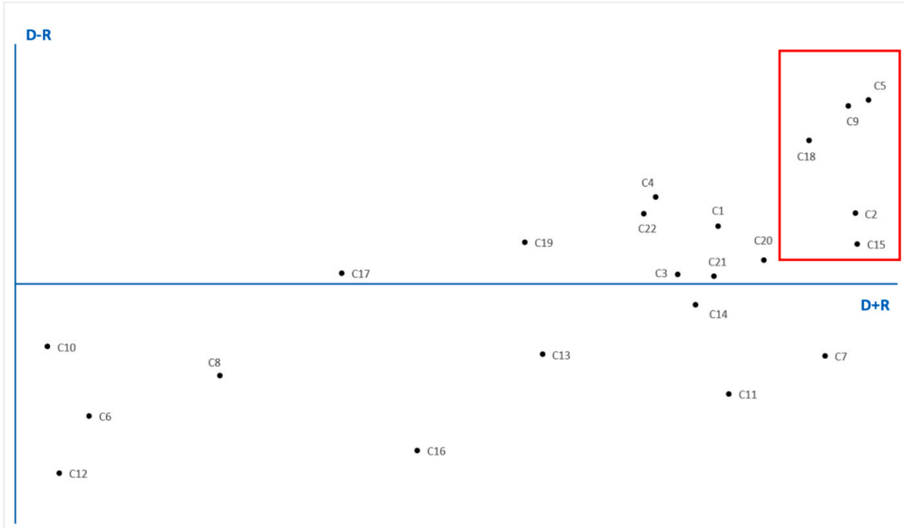

Fig. 3. Cause-and-effect diagram of the ESS criteria.

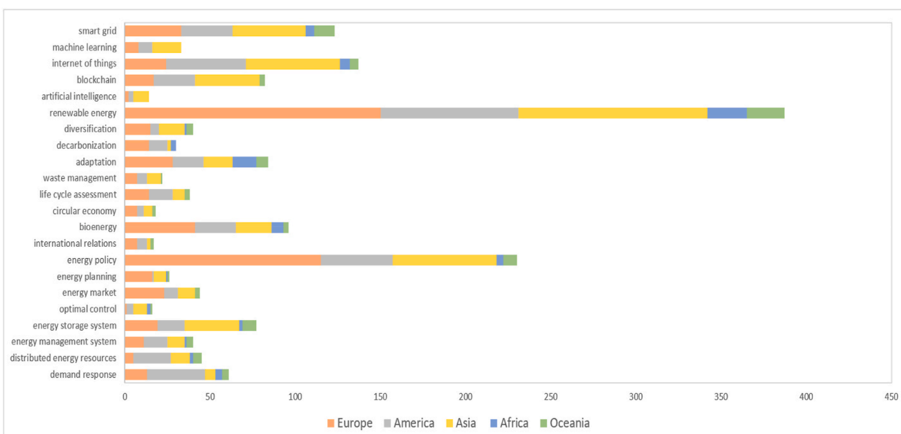

Fig. 4. Occurrence frequency of critical criteria by region.

Table 9
Entropy weight method result.

Criteria		Overall	Europe	America	Asia	Africa	Oceania
C1	Demand response	0.0454604	0.0454697	0.0454310	0.0454769	0.0454493	0.0454577
C2	Distributed energy resources	0.0454668	0.0454791	0.0454501	0.0454701	0.0454671	0.0454508
C3	Energy management system	0.0454689	0.0454721	0.0454628	0.0454715	0.0454761	0.0454577
C4	Energy storage system	0.0454539	0.0454627	0.0454596	0.0454417	0.0454671	0.0454303
C5	Optimal control	0.0454786	0.0454839	0.0454787	0.0454742	0.0454671	0.0454782
C6	Energy market	0.0454673	0.0454580	0.0454723	0.0454715	0.0454850	0.0454645
C7	Energy planning	0.0454745	0.0454662	0.0454834	0.0454755	0.0454761	0.0454782
C8	Energy policy	0.0453921	0.0453497	0.0454183	0.0454024	0.0454493	0.0454303
C9	International relations	0.0454782	0.0454768	0.0454755	0.0454823	0.0454850	0.0454713
C10	Bioenergy	0.0454462	0.0454368	0.0454469	0.0454566	0.0454224	0.0454645
C11	Circular economy	0.0454778	0.0454768	0.0454787	0.0454783	0.0454850	0.0454713
C12	Life cycle assessment	0.0454697	0.0454686	0.0454628	0.0454755	0.0454850	0.0454645
C13	Waste management	0.0454761	0.0454768	0.0454755	0.0454742	0.0454850	0.0454782
C14	Adaptation	0.0454511	0.0454521	0.0454564	0.0454620	0.0453598	0.0454371
C15	Decarbonization	0.0454729	0.0454686	0.0454675	0.0454823	0.0454582	0.0454850
C16	Diversification	0.0454689	0.0454674	0.0454771	0.0454647	0.0454761	0.0454577
C17	Renewable energy	0.0453287	0.0453086	0.0453563	0.0453346	0.0452794	0.0453345
C18	Artificial intelligence	0.0454794	0.0454827	0.0454803	0.0454728	0.0454850	0.0454850
C19	Blockchain	0.0454519	0.0454650	0.0454469	0.0454335	0.0454850	0.0454645
C20	Internet of things	0.0454297	0.0454568	0.0454103	0.0454105	0.0454314	0.0454508
C21	Machine learning	0.0454717	0.0454756	0.0454723	0.0454620	0.0454850	0.0454850
C22	Smart grid	0.0454353	0.0454462	0.0454374	0.0454268	0.0454403	0.0454029

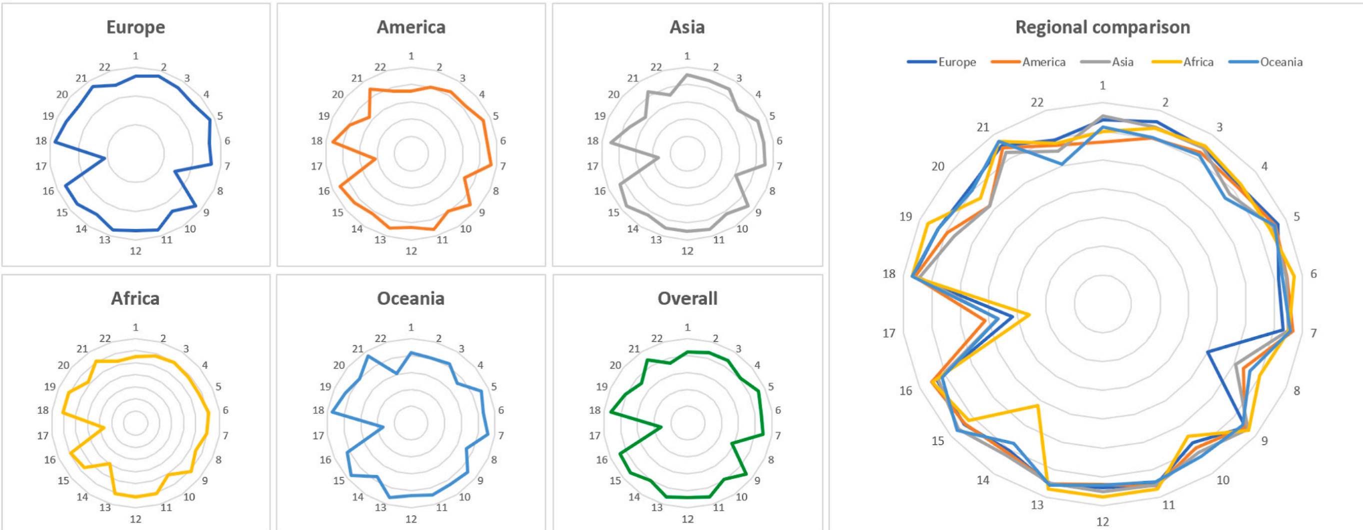

Fig. 5. Comparison of entropy weights by region.

5.2.3. *International relations (C9)*

International relations, which involve the interactions among countries and territories, are essential in fostering the implementation of ESSs to ensure stable development [55]. Indeed, developing international relations has become an increasingly critical foreign policy instrument since nations attempt to strategically position themselves in the prospective energy landscape [24]. Handling international energy relationships is also a compelling matter for many countries because safe and affordable energy supplies are vital in modernized economic life. Because of the unequal geographical distribution of natural resources, nations with restricted energy resources are unavoidably required to interact with other nations with the aim of acquiring sufficient energy supplies to satisfy their economies' demand. In addition, the International Energy Agency seeks to foster all aspects of collaboration among member nations on energy matters, control and enhance systematic reactions to disruptions in oil supply, develop rational energy policies, increase the effectiveness of global energy supply together with utilization, further the worldwide coalition in energy technology, and aid in the synthesis of energy and environmental policies [44]. Furthermore, the energy policy in each country has various policy targets, but there is convergence toward targets that emphasize the complete change of energy systems. Countries execute energy policies that aim at emission reduction and energy efficiency, and they concentrate on a shift from fossil fuels to RE and introduce many policies to support RE in the form of tax reductions, fiscal incentives, public rules, and international collaboration [47,55].

5.2.4. *Decarbonization (C15)*

In ESSs, decarbonization has been a research topic for many years and has attracted more attention in recent times since it not only plays a critical part in CO_2 emission reduction but also implies key adjustments in the power system for many nations (Papadis & Tsatsaronis, 2020; [56]). Decarbonization relies on decreasing emission concentrations, decoupling emissions from developing energy demands, and increasing the usage of clean energy to support the shift to low-carbon activities [57]. Currently, implementing actions on environmental protection and public health, minimizing the use of available resources, encouraging improvements to reduce pollution, and holding polluters accountable are being promoted to support decarbonization [58]. In addition, in Europe and many developed countries, various supporting decarbonization policies, such as cap-and-trade, carbon tax, efficiency improvement, emission requirements, renewable incentives, low-emission zones, carbon labeling programs, waste policy schemes and procurement, are being actively reviewed. Such policies greatly contribute to facilitating other policies and directly supporting people in making the shift to a decarbonized society gentler [57]. Due to decarbonization targets, authorities have also tried to delineate a novel regulatory scheme that would be capable of handling the growing issues in power systems and enhancing energy efficiency.

5.2.5. *Artificial intelligence (C18)*

As one of the main branches in computer science, AI involves an intelligent factor framework, in which such an intelligent factor is capable of performing tasks usually needing human intellect and maximizing the possibility of success [59]. Currently, AI is the most widely applied emerging digital technology, and its new advancements are creating real revolutions in the energy sector [60]. To achieve ESS goals, AI solutions have been utilized in diverse parts of the electricity system, and their potential to generate considerable value in the value chain owing to the increasing data creation capability of the prospective smart grid has been proven [61]. AI utilization is especially prominent in RE studies, helping the energy industry to improve the power grid and successfully maintaining resilience and accuracy [62]. Furthermore, many countries are making efforts to integrate AI applications to perform various types of tasks in energy areas, such as efficient power system control, forecasting, and operation. Modern AI models using support vector machines and deep learning are also recommended to discover energy theft with better accuracy and the smallest model error. In addition, key participants are already aware of the need to have basic knowledge of institutions and policies related to AI technology, especially in the areas of data analysis, machine learning, and automated electrical networks. Such critical opportunities help pave the way for AI technology in the current energy industry.

5.3. *Regional difference implications*

The EWM result based on the Scopus database reveals a great similarity with the expert opinions in the field about the top ESS criteria. However, in addition to the three criteria of optimal control, international relations, and AI determined above, there are two other criteria of ESSs that need great attention: the circular economy and waste management. The circular economy accelerates the abandonment of typical linear production models and promotes a novel industrial model that is competent in providing state-of-the-art solutions for ESSs, particularly regarding the disposal of waste [63]. Nonetheless, the relationship between the circular economy and ESSs has not been fully and effectively explored in recent studies on all continents. Currently, following the circular economy perspective is crucial; accordingly, waste management is transformed into sustainable material management to enhance the spread of RE, increase the efficiency of energy use, reduce the dependence on imported resources, and provide economic opportunities and long-term competitiveness. In addition, each continent still has unique concerns with respect to the ESS issue. Specifically, the views of European countries are quite consistent with the general trend worldwide; however, the issue related to DERs also needs to be resolved in this area. Other countries should learn from the most advanced energy markets in the region, such as the United Kingdom and Germany, to implement their shift toward DERs by promulgating renewable creation directives and allowing the direct engagement of users together with virtual power stations in energy markets [13].

Asia and Oceania share a common interest in the topic of decarbonization. CO_2 emissions reduction is essential for the shift to more sustainable growth pathways. However, it causes many threats in terms of the establishment, operation and market design of such systems [56]. Decarbonization policies would be pivotal in expediting strategy execution, in which focusing on the reduction in industrial emissions, bolstering renewable penetration, supporting firms to allow sustainability approaches, directing people to follow sustainability, and favoring sustainable and circular products are necessary [1,57]. Furthermore, Oceania pays special attention to machine learning applications. Acknowledging the literature regarding energy creation and distribution, the usage of precise predictive models founded on machine learning has emerged as a trend. Such models have led to a growth in safety and reliability when assisting decision-making, for instance, successfully identifying small power vibrations generated by external elements in PV systems, hence ensuring better predictability for electricity production and dispatch [64]. In fact, computer operational ability is no longer a hindrance for the construction of the machine learning model owing to the enhancement of computer hardware technologies.

It seems that technological issues are the prominent weakness of African countries, as their primary concerns in implementing ESSs are mainly derived from new technologies consisting of blockchain, AI, and machine learning. To overcome this challenge, African countries need to comprehensively improve the achievement of their social infrastructures to guarantee the broad adoption and steady usage of novel technologies. Additionally, increasing power generation capability, improving dispatch and distribution networks, and pursuing regional collaboration based on improving energy security are important for countries in the region [65]. Meanwhile, although the Americas do not face technological obstacles in ESS implementation, difficulties related to energy planning have been highlighted in recent times. In this region, energy planning has not been a segment of the strategic lines of growth for many years, and unfortunately, policymakers have established long-term electricity system forecasts and planning such as those of much more developed nations [66]. Thus, promoting energy planning trials and growth strategies founded on reliable and realistic orientations, in which the public and private sectors execute co-decision-making at the local, national, and regional levels, is essential. In addition, energy support programs connecting to community safety networks and appropriate systems to decrease energy deficits are needed.

6. Conclusion and policy implications

ESSs are the top concern of countries around the world since an adequate supply of energy is imperative for ensuring the stability of economic growth and promoting sustainable development. There have been numerous studies on the topic of ESSs, yet the critical attributes of ESSs and their interrelationship remain one of the most controversial issues, which creates difficulties for policymakers in formulating and evaluating energy policies. This study is conducted to handle the problem above by applying a hybrid methodology.

From the findings, the causal group includes three aspects: the energy control system, strategic collaboration, and technological capability. These attributes have a significant impact on the effect attributes and possess a strong relationship with each other. Meanwhile, WTE and energy resilience belong to the effect group, which is considerably affected by the causal attributes, and the interrelationships between them are not found in this study. The causal aspects are perceived as the leading aspects of ESSs and need more attention than the others. The major opportunities and challenges of ESSs are inferred from top criteria such as DERs, optimal control, international relations, decarbonization, and AI. The implication for each continent regarding ESS implementation is based on the regional comparison.

This study reveals the diverse concerns of each region regarding ESSs. Specifically, the viewpoints of European countries conform to the general tendency worldwide. However, the matter linked with DERs needs to be solved in this region. Asia and Oceania share a common concern for the decarbonization issue, but Oceania also concentrates on machine learning utilization. Since computer hardware technologies have developed, the operational ability of computers is no longer an obstacle to constructing a machine learning model in this region. In Africa, the basic concerns with regard to executing ESSs are mostly derived from new technologies, which call for enhancing the performance of the social infrastructures of countries within this region. The Americas do not encounter technological impediments in implementing ESSs, but obstacles related to energy planning have recently been emphasized. Hence, the promotion of energy planning trials, growth strategies founded on reality together with trustworthy directions, and energy aid programs are essential in these countries.

There are some limitations in this study. First, the attributes are not entirely complete, as they were derived only from the Scopus database. Thus, future research should use other sources or carry out a cross-analysis for further exploration to enhance the generalizability of the results. Second, one country or territory might have distinct ESS characteristics. Hence, future studies can investigate in greater depth by focusing on specific countries or regional cases to enrich the literature. Third, the frequency of criteria for each region was counted by searching in data generated from Scopus, which inhibits the practical prospects of the study. Therefore, utilizing various social media databases, such as Twitter, Facebook, and Instagram and novel software applications is necessary to address this issue in future studies.

Credit author statement

Tat-Dat Bui, Writing - original draft; Writing - review & editing, Hien Minh Ha, Writing - original draft; Writing - review & editing, Thi Phuong Thuy Tran, Writing - original draft; Writing - review & editing, Ming K. Lim, Writing - original draft; Writing - review & editing, Ming-Lang Tseng:Writing - original draft; Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

This study is partially supported by National Science and Technology Council, Taiwan (NSTC 111-2221-E-468 -008 -MY3).

Appendix A. Respondents' demographic for FDM and FDEMATEL result

Expert	Position	Education levels	Years of experience	Organization type (academia/practice)
1	Manager	Master	20	Practice
2	Manager	Master	20	Practice
3	Professional	Master	17	Practice
4	Professional	Master	17	Practice
5	Professional	Master	15	Practice
6	Professional	Master	15	Practice
7	Professional	Bachelor	17	Practice
8	Professional	Bachelor	17	Practice
9	Professional	Bachelor	16	Practice
10	Professional	Bachelor	15	Practice
11	Professional	Bachelor	15	Practice
12	Professional	Bachelor	14	Practice
13	Professional	Bachelor	10	Practice
14	Professional	Bachelor	10	Practice
15	Researcher	PhD	18	Academia
16	Researcher	PhD	18	Academia
17	Researcher	PhD	15	Academia
18	Researcher	PhD	15	Academia
19	Researcher	PhD	15	Academia
20	Researcher	PhD	12	Academia
21	Researcher	PhD	12	Academia
22	Researcher	Master	12	Academia
23	Researcher	Master	12	Academia
24	Researcher	Master	12	Academia
25	Researcher	Master	11	Academia
26	Researcher	Master	11	Academia
27	Researcher	Master	10	Academia
28	Researcher	Master	10	Academia
29	Researcher	Master	10	Academia
30	Researcher	Master	10	Academia

Appendix B. FDM result for criteria – the first round

Criteria	l_i	u_i	D_i	Decision
Cyber security	(0.418)	0.918	0.355	Unaccepted
Demand response	0.367	0.883	0.533	Accepted
Demand side management	0.340	0.910	0.540	Accepted
Distributed energy resources	0.367	0.883	0.533	Accepted
Economic dispatch	(0.388)	0.888	0.347	Unaccepted
Electric vehicle	0.367	0.883	0.533	Accepted
Electricity market	0.312	0.938	0.547	Accepted
Energy management system	0.356	0.894	0.536	Accepted
Energy storage system	0.359	0.891	0.535	Accepted
Energy transition	0.000	0.500	0.250	Unaccepted
Frequency control	(0.340)	0.840	0.335	Unaccepted
Frequency regulation	0.340	0.910	0.540	Accepted
Genetic algorithm	(0.414)	0.914	0.354	Unaccepted
Integrated energy system	(0.391)	0.891	0.348	Unaccepted
Microgrid	(0.381)	0.881	0.345	Unaccepted
Optimal control	0.344	0.906	0.539	Accepted
Optimal power flow	(0.391)	0.891	0.348	Unaccepted
Power system	(0.377)	0.877	0.344	Unaccepted
Reinforcement learning	(0.332)	0.832	0.333	Unaccepted
Reliability	(0.406)	0.906	0.352	Unaccepted
Risk assessment	0.340	0.910	0.540	Accepted
System dynamics	0.340	0.910	0.540	Accepted
Transient stability	(0.391)	0.891	0.348	Unaccepted
Uncertainty	(0.406)	0.906	0.352	Unaccepted
Unit commitment	0.336	0.914	0.541	Accepted
Economic development	(0.395)	0.895	0.349	Unaccepted
Economic security	(0.395)	0.895	0.349	Unaccepted
Energy cooperation	0.336	0.914	0.541	Accepted
Energy market	0.001	0.874	0.437	Accepted
Energy planning	0.001	0.874	0.437	Accepted
Energy policy	0.367	0.883	0.533	Accepted
Energy resources	0.340	0.910	0.540	Accepted
Geopolitics	0.000	0.500	0.250	Unaccepted
International relations	0.374	0.876	0.532	Accepted

(continued on next page)

(*continued*)

Criteria	l_i	u_i	D_i	Decision
National security	(0.388)	0.888	0.347	Unaccepted
Nuclear energy	(0.370)	0.870	0.342	Unaccepted
Sustainable development	(0.395)	0.895	0.349	Unaccepted
Terrorism	(0.384)	0.884	0.346	Unaccepted
Trade	(0.418)	0.918	0.355	Unaccepted
Bioenergy	(0.004)	0.879	0.439	Accepted
Circular economy	(0.003)	0.878	0.438	Accepted
Environmental impacts	0.359	0.891	0.535	Accepted
Ethanol	(0.406)	0.906	0.352	Unaccepted
Innovation	0.329	0.921	0.543	Accepted
Life cycle assessment	0.340	0.910	0.540	Accepted
Microalgae	(0.384)	0.884	0.346	Unaccepted
Pipelines	(0.417)	0.917	0.354	Unaccepted
Recycling	0.329	0.921	0.543	Accepted
Technology	(0.395)	0.895	0.349	Unaccepted
Waste management	0.352	0.898	0.537	Accepted
Adaptation	0.352	0.898	0.537	Accepted
Battery	(0.383)	0.883	0.346	Unaccepted
Climate change	(0.417)	0.917	0.354	Unaccepted
Decarbonization	(0.388)	0.888	0.347	Unaccepted
Diversification	0.352	0.898	0.537	Accepted
Greenhouse gas emissions	(0.057)	0.932	0.452	Accepted
Hydrogen	(0.422)	0.922	0.356	Unaccepted
Infrastructure	(0.002)	0.877	0.438	Accepted
Resilience	(0.422)	0.922	0.356	Unaccepted
Security of supply	(0.422)	0.922	0.356	Unaccepted
Vulnerability	(0.422)	0.922	0.356	Unaccepted
Wind power	0.359	0.891	0.535	Accepted
Coal	(0.395)	0.895	0.349	Unaccepted
Governance	0.312	0.938	0.547	Accepted
Hydropower	(0.395)	0.895	0.349	Unaccepted
Renewable energy	(0.395)	0.895	0.349	Unaccepted
Solar energy	0.316	0.934	0.546	Accepted
Water security	0.352	0.898	0.537	Accepted
Water-energy nexus	(0.395)	0.895	0.349	Unaccepted
Blockchain	0.312	0.938	0.547	Accepted
Deep learning	0.348	0.902	0.538	Accepted
Energy efficiency	(0.002)	0.877	0.438	Accepted
Energy harvesting	0.348	0.902	0.538	Accepted
Energy saving	0.002	0.873	0.437	Accepted
Internet of things	(0.417)	0.917	0.354	Unaccepted
Network lifetime	(0.395)	0.895	0.349	Unaccepted
Optimization	(0.406)	0.906	0.352	Unaccepted
Physical layer security	0.359	0.891	0.535	Accepted
Privacy	(0.395)	0.895	0.349	Unaccepted
Resource allocation	(0.395)	0.895	0.349	Unaccepted
Resource management	(0.022)	0.897	0.443	Accepted
Secure routing	(0.019)	0.894	0.442	Accepted
Smart city	(0.388)	0.888	0.347	Unaccepted
Trust	0.037	0.838	0.428	Unaccepted
Wireless sensor networks	(0.002)	0.877	0.438	Accepted
Cyber-physical systems	0.037	0.838	0.428	Unaccepted
Distributed generation	(0.370)	0.870	0.342	Unaccepted
Energy conservation	(0.022)	0.897	0.443	Accepted
Network security	0.340	0.910	0.540	Accepted
Smart grid	(0.395)	0.895	0.349	Unaccepted
Sustainable energy	(0.395)	0.895	0.349	Unaccepted
Artificial intelligence	(0.406)	0.906	0.352	Unaccepted
Cloud computing	0.340	0.910	0.540	Accepted
Energy consumption	(0.395)	0.895	0.349	Unaccepted
Machine learning	(0.391)	0.891	0.348	Unaccepted
Scheduling	0.340	0.910	0.540	Accepted
Virtual machine placement	0.340	0.910	0.540	Accepted
Threshold			0.428	

References

[1] B. Doğan, M. Shahbaz, M.F. Bashir, S. Abbas, S. Ghosh, Formulating energy security strategies for a sustainable environment: evidence from the newly industrialized economies, Renew. Sustain. Energy Rev. 184 (2023) 113551.
[2] C.J. Axon, R.C. Darton, Sustainability and risk–a review of energy security, Sustain. Prod. Consum. 27 (2021) 1195–1204.
[3] C.C. Lee, W. Xing, C.C. Lee, The impact of energy security on income inequality: the key role of economic development, Energy 248 (2022) 123564.
[4] A. Novikau, Rethinking demand security: between national interests and energy exports, Energy Res. Social Sci. 87 (2022) 102494.
[5] D. Mariano-Hernández, L. Hernández-Callejo, A. Zorita-Lamadrid, O. Duque-Pérez, F.S. García, A review of strategies for building energy management system: model predictive control, demand side management, optimization, and fault detect & diagnosis, J. Build. Eng. 33 (2021) 101692.
[6] H. Sun, B.K. Edziah, A.K. Kporsu, S.A. Sarkodie, F. Taghizadeh-Hesary, Energy efficiency: the role of technological innovation and knowledge spillover, Technol. Forecast. Soc. Change 167 (2021) 120659.
[7] A. Kumar, S.R. Samadder, A review on technological options of waste to energy for effective management of municipal solid waste, Waste Manag. 69 (2017) 407–422.
[8] Z. Zhou, L. Zhang, Sustainable waste management and waste to energy: valuation of energy potential of MSW in the Greater Bay Area of China, Energy Pol. 163 (2022) 112857.
[9] R. Gupta, A. Bruce-Konuah, A. Howard, Achieving energy resilience through smart storage of solar electricity at dwelling and community level, Energy Build. 195 (2019) 1–15.
[10] I.A. Kapitonov, V.V. Dorzhieva, N.T. Batyrova, Ensuring energy security in Russia in a transitional economy, Electr. J. 35 (3) (2022) 107098.
[11] C. Zhang, P. Chen, Applying the three-stage SBM-DEA model to evaluate energy efficiency and impact factors in RCEP countries, Energy 241 (2022) 122917.
[12] T. Ahmad, H. Zhang, B. Yan, A review on renewable energy and electricity requirement forecasting models for smart grid and buildings, Sustain. Cities Soc. 55 (2020) 102052.
[13] D.M.L. González, J.G. Rendon, Opportunities and challenges of mainstreaming distributed energy resources towards the transition to more efficient and resilient energy markets, Renew. Sustain. Energy Rev. 157 (2022) 112018.
[14] B. Lin, R. Sai, Sustainable transitioning in Africa: a historical evaluation of energy productivity changes and determinants, Energy 250 (2022) 123833.
[15] T.D. Bui, M.L. Tseng, A data-driven analysis on sustainable energy security: challenges and opportunities in world regions, J. Global Inf. Manag. 30 (6) (2021) 1–38.
[16] D. Antons, E. Grünwald, P. Cichy, T.O. Salge, The application of text mining methods in innovation research: current state, evolution patterns, and development priorities, R D Manag. 50 (3) (2020) 329–351.
[17] M.L. Tseng, T.P.T. Tran, H.M. Ha, T.D. Bui, M.K. Lim, Causality of circular business strategy under uncertainty: a zero-waste practices approach in seafood processing industry in Vietnam, Resour. Conserv. Recycl. 181 (2022) 106263.
[18] M.L. Tseng, H.M. Ha, T.P.T. Tran, T.D. Bui, C.C. Chen, C.W. Lin, Building a data-driven circular supply chain hierarchical structure: resource recovery implementation drives circular business strategy, Bus. Strat. Environ. 31 (5) (2022) 2082–2106.
[19] S. Fuentes, R. Villafafila-Robles, P. Olivella-Rosell, J. Rull-Duran, S. Galceran-Arellano, Transition to a greener Power Sector: four different scopes on energy security, Renewable Energy Focus 33 (2020) 23–36.
[20] S. Bigerna, M.C. D'Errico, P. Polinori, Energy security and RES penetration in a growing decarbonized economy in the era of the 4th industrial revolution, Technol. Forecast. Soc. Change 166 (2021) 120648.
[21] J. Huang, S. Xiang, P. Wu, X. Chen, How to control China's energy consumption through technological progress: a spatial heterogeneous investigation, Energy 238 (2022) 121965.
[22] T. Ahmad, R. Madonski, D. Zhang, C. Huang, A. Mujeeb, Data-driven probabilistic machine learning in sustainable smart energy/smart energy systems: key developments, challenges, and future research opportunities in the context of smart grid paradigm, Renew. Sustain. Energy Rev. 160 (2022) 112128.
[23] S.B. Sani, P. Celvakumaran, V.K. Ramachandaramurthy, S. Walker, B. Alrazi, Y. J. Ying, N.Y. Dahlan, M.H.A. Rahman, Energy storage system policies: way forward and opportunities for emerging economies, J. Energy Storage 32 (2020) 101902.
[24] S. Griffiths, Energy diplomacy in a time of energy transition, Energy Strategy Rev. 26 (2019) 100386.
[25] L. Sanderink, N. Nasiritousi, How institutional interactions can strengthen effectiveness: the case of multi-stakeholder partnerships for renewable energy, Energy Pol. 141 (2020) 111447.
[26] A. Gatto, C. Drago, A taxonomy of energy resilience, Energy Pol. 136 (2020) 111007.
[27] A.S. El-Shafay, Ü. Ağbulut, E.A. Attia, K.L. Touileb, M.S. Gad, Waste to energy: production of poultry-based fat biodiesel and experimental assessment of its usability on engine behaviors, Energy 262 (2023) 125457.
[28] A. Gil, Challenges on waste-to-energy for the valorization of industrial wastes: electricity, heat and cold, bioliquids and biofuels, Environ. Nanotechnol. Monit. Manag. 17 (2022) 100615.
[29] J. Ali, T. Rasheed, M. Afreen, M.T. Anwar, Z. Nawaz, H. Anwar, K. Rizwan, Modalities for conversion of waste to energy—challenges and perspectives, Sci. Total Environ. 727 (2020) 138610.
[30] A.T. Hoang, P.S. Varbanov, S. Nižetić, R. Sirohi, A. Pandey, R. Luque, K.H. Ng, Perspective review on Municipal Solid Waste-to-energy route: characteristics, management strategy, and role in circular economy, J. Clean. Prod. (2022) 131897.
[31] B. Huang, L. Zhang, L. Ma, W. Bai, J. Ren, Multi-criteria decision analysis of China's energy security from 2008 to 2017 based on Fuzzy BWM-DEA-AR model and Malmquist Productivity Index, Energy 228 (2021) 120481.
[32] C. Llamosas, B.K. Sovacool, Transboundary hydropower in contested contexts: energy security, capabilities, and justice in comparative perspective, Energy Strategy Rev. 37 (2021) 100698.
[33] H. Zhu, H.H. Goh, D. Zhang, T. Ahmad, H. Liu, S. Wang, S. Li, T. Liu, H. Dai, T. Wu, Key technologies for smart energy systems: recent developments, challenges, and research opportunities in the context of carbon neutrality, J. Clean. Prod. 331 (2022) 129809.
[34] F. Alassery, A. Alzahrani, A. Khan, K. Irshad, S.R. Kshirsagar, An artificial intelligence-based solar radiation prophesy model for green energy utilization in energy management system, Sustain. Energy Technol. Assessments 52 (2022) 102060.
[35] S. Ahmadi, A.H.F. Khorasani, A. Vakili, Y. Saboohi, G. Tsatsaronis, Developing an innovating optimization framework for enhancing the long-term energy system resilience against climate change disruptive events, Energy Strategy Rev. 40 (2022) 100820.
[36] K. Dong, X. Dong, Q. Jiang, J. Zhao, Assessing energy resilience and its greenhouse effect: a global perspective, Energy Econ. 104 (2021) 105659.
[37] H. Hasselqvist, S. Renström, H. Strömberg, M. Håkansson, Household energy resilience: shifting perspectives to reveal opportunities for renewable energy futures in affluent contexts, Energy Res. Social Sci. 88 (2022) 102498.
[38] W. Fan, W. Lv, Z. Wang, How to measure and enhance the resilience of energy systems? Sustain. Prod. Consum. 39 (2023) 191–202.
[39] L. Ji, Y. Wu, L. Sun, X. Zhao, X. Wang, Y. Xie, J. Guo, G. Huang, Solar photovoltaics can help China fulfill a net-zero electricity system by 2050 even facing climate change risks, Resour. Conserv. Recycl. 186 (2022) 106596.
[40] V. Vivoda, LNG import diversification and energy security in Asia, Energy Pol. 129 (2019) 967–974.
[41] R. Vakulchuk, I. Overland, D. Scholten, Renewable energy and geopolitics: a review, Renew. Sustain. Energy Rev. 122 (2020) 109547.
[42] S.A.A. Shah, P. Zhou, G.D. Walasai, M. Mohsin, Energy security and environmental sustainability index of South Asian countries: a composite index approach, Ecol. Indicat. 106 (2019) 105507.
[43] C. Viviescas, L. Lima, F.A. Diuana, E. Vasquez, C. Ludovique, G.N. Silva, V. Huback, L. Magalar, A. Szklo, A.F.P. Lucena, R. Schaeffer, J.R. Paredes, Contribution of Variable Renewable Energy to increase energy security in Latin America: complementarity and climate change impacts on wind and solar resources, Renew. Sustain. Energy Rev. 113 (2019) 109232.
[44] C.C. Lee, Z. Yuan, Q. Wang, How does information and communication technology affect energy security? International evidence, Energy Econ. 109 (2022) 105969.
[45] J. Wang, M.K. Lim, C. Wang, M.L. Tseng, The evolution of the Internet of Things (IoT) over the past 20 years, Comput. Ind. Eng. 155 (2021) 107174.
[46] Z. Yu, S.A.R. Khan, P. Ponce, H. Muhammad Zia-ul-haq, K. Ponce, Exploring essential factors to improve waste-to-resource recovery: a roadmap towards sustainability, J. Clean. Prod. 350 (2022) 131305.
[47] Q. Chen, B.G. de Soto, B.T. Adey, Construction automation: research areas, industry concerns and suggestions for advancement, Autom. ConStruct. 94 (2018) 22–38.
[48] N. Zhao, F. You, Can renewable generation, energy storage and energy efficient technologies enable carbon neutral energy transition? Appl. Energy 279 (2020) 115889.
[49] P. Johansson, M. Vendel, C. Nuur, Integrating distributed energy resources in electricity distribution systems: an explorative study of challenges facing DSOs in Sweden, Util. Pol. 67 (2020) 101117.
[50] M. Yao, B. Zhu, N. Zhang, Adaptive real-time optimal control for energy management strategy of extended range electric vehicle, Energy Convers. Manag. 234 (2021) 113874.
[51] Y. Lu, S. Wang, K. Shan, Design optimization and optimal control of grid-connected and standalone nearly/net zero energy buildings, Appl. Energy 155 (2015) 463–477.
[52] M.J. Sanjari, H. Karami, Analytical approach to online optimal control strategy of energy storage devices in energy system, J. Energy Storage 29 (2020) 101328.
[53] R. Machlev, N. Zargari, N.R. Chowdhury, J. Belikov, Y. Levron, A review of optimal control methods for energy storage systems-energy trading, energy balancing and electric vehicles, J. Energy Storage 32 (2020) 101787.
[54] M. Azaroual, S. Sichilalu, E.T. Akinlabi, M. Jahangiri, M. Maaroufi, N.I. Nwulu, Optimal control application in a hydrokinetic-battery power generation on seasonal river for energy-enabler for remote rural communities: case of Zambia, Renewable Energy Focus 41 (2022) 69–79.
[55] L. Proskuryakova, Updating energy security and environmental policy: energy security theories revisited, J. Environ. Manag. 223 (2018) 203–214.
[56] F. Verástegui, Á. Lorca, D. Olivares, M. Negrete-Pincetic, Optimization-based analysis of decarbonization pathways and flexibility requirements in highly renewable power systems, Energy 234 (2021) 121242.
[57] R.M. Elavarasan, R. Pugazhendhi, M. Irfan, L. Mihet-Popa, I.A. Khan, P. E. Campana, State-of-the-art sustainable approaches for deeper decarbonization in Europe–An endowment to climate neutral vision, Renew. Sustain. Energy Rev. 159 (2022) 112204.
[58] D. Miniard, S.Z. Attari, Turning a coal state to a green state: identifying themes of support and opposition to decarbonize the energy system in the United States, Energy Res. Social Sci. 82 (2021) 102292.

[59] L. Richter, M. Lehna, S. Marchand, C. Scholz, A. Dreher, S. Klaiber, S. Lenk, Artificial intelligence for electricity supply chain automation, Renew. Sustain. Energy Rev. 163 (2022) 112459.
[60] W. Lyu, J. Liu, Artificial Intelligence and emerging digital technologies in the energy sector, Appl. Energy 303 (2021) 117615.
[61] P. Boza, T. Evgeniou, Artificial intelligence to support the integration of variable renewable energy sources to the power system, Appl. Energy 290 (2021) 116754.
[62] T. Ahmad, D. Zhang, C. Huang, H. Zhang, N. Dai, Y. Song, H. Chen, Artificial intelligence in sustainable energy industry: status Quo, challenges and opportunities, J. Clean. Prod. 289 (2021) 125834.
[63] A. Gatto, C. Drago, Measuring and modeling energy resilience, Ecol. Econ. 172 (2020) 106527.
[64] L. Ramos, M. Colnago, W. Casaca, Data-driven analysis and machine learning for energy prediction in distributed photovoltaic generation plants: a case study in Queensland, Australia, Energy Rep. 8 (2022) 745–751.
[65] C.G. Monyei, K.O. Akpeji, O. Oladeji, O.M. Babatunde, O.C. Aholu, D. Adegoke, J. O. Imafidon, Regional cooperation for mitigating energy poverty in Sub-Saharan Africa: a context-based approach through the tripartite lenses of access, sufficiency, and mobility, Renew. Sustain. Energy Rev. 159 (2022) 112209.
[66] D. Icaza, D. Borge-Diez, S.P. Galindo, Analysis and proposal of energy planning and renewable energy plans in South America: case study of Ecuador, Renew. Energy 182 (2022) 314–342.