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Review

An Energy Culture Maturity Conceptual Framework on Adopting Energy-Efficient Technology Innovations in Buildings

Dumindu Soorige [1,2,*], Gayani Karunasena [2], Udayangani Kulatunga [1], Muhammad Nateque Mahmood [2] and Lalith De Silva [1]

1 Department of Building Economics, Faculty of Architecture, University of Moratuwa, Moratuwa 10400, Sri Lanka; ukulatunga@uom.lk (U.K.); lalithds@uom.lk (L.D.S.)
2 School of Architecture and Built Environment, Faculty of Science Engineering and Built Environment, Deakin University, Geelong 3220, Australia; gayani.karunasena@deakin.edu.au (G.K.); n.mahmood@deakin.edu.au (M.N.M.)
* Correspondence: sooriged@uom.lk

Abstract: The building sector is identified as the leading global energy consumer. Adopting energy-efficient technology innovations has been recognised as the most promising approach to reducing energy consumption in buildings. However, such technology adoption is considerably lacking due to traditional techno-economic thinking, which lacks human focus. Energy culture has been identified as a research domain that successfully overcomes the traditional techno-economic focus of technology diffusion. However, available energy culture studies on adopting energy-efficient technology innovations in buildings are limited to exploring specific energy cultures rather than investigating holistic energy culture maturity, which guides incremental diffusion of energy-efficient technology innovations. Conversely, culture maturity has been studied in other cultural research domains such as safety cultures. Therefore, this study aims to develop an energy culture maturity conceptual framework that provides a holistic view of energy culture maturity for adopting energy-efficient technology innovations in buildings. The research method this study implemented was a scoping literature review method, using Web of Science, Scopus, and Engineering Village research databases. The findings of the study include the development of factor categorisation with 14 main factors and 11 subfactors and the development of three energy culture maturity stages, as well as the development of the energy culture maturity conceptual framework as the principal outcome. The proposed conceptual framework significantly contributes to energy culture research as the pioneering framework on energy culture maturity. The framework should be further tested and applied to find its utility.

Keywords: energy culture; energy culture maturity; energy-efficient technology; energy-efficient technology innovation; open innovation; eco-innovation; open eco-innovation; building; conceptual framework

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1. Introduction

Global energy consumption has been a major contributor to greenhouse gas (GHG) emissions [1,2]. Further, global energy consumption is projected to increase by 30 to 50% in the next twenty-five years [3,4]. The building sector is the global leader in energy use [5–9] and is responsible for more than one-third of the world's energy consumption [10,11], Yang et al. cited in [12,13]. Therefore, energy efficiency improvements in buildings can significantly reduce global energy consumption and related GHG emissions [14–19]. Open eco-innovations can increase the energy efficiency in buildings [19–23] throughout their lifecycle [24,25]. According to Ruby [26], Schubert and Stadelmann [27] and Trotta [28], increased adoption of energy-efficient technology innovations in buildings is the most appropriate strategy to reduce energy consumption in buildings. Further, energy consumption reduction through energy efficient innovations provides benefits such as reducing production cost, increasing compliance with regulations and facilitating sustainable development [29]. Therefore, significant diffusion of the widely available energy-efficient technology innovations in buildings has become essential [30,31].

However, despite the availability of various cost-effective energy-efficient technology innovations, their adoption is not at a satisfactory level [32–37]. As a result, potential contribution of buildings to reduce global energy use has not been adequately met. Furthermore, the United Nations [38] reported a significant gap between the targeted and actual rates of global energy efficiency improvements to achieve Sustainable Development Goal (SDG) 7. According to SDG 7, the target is to maintain a rate of energy efficiency improvements of at least 2.7% annually until 2030. However, the actual rate of improvement was as low as 1.3% in 2018. Traditional techno-economic thinking, without considering the human dimension, is one of the major obstacles that prevents the adoption of energy-efficiency technology innovations [39,40]. Promisingly, many authors have proposed to deploy an energy culture research approach that considers the human dimension to overcome the traditional techno-economic focus of technology diffusion [27,39–47].

There are several energy culture studies focused on the diffusion of energy-efficient technology innovations in buildings and similar environments, such as home heating technologies in New Zealand [42], heat pump driers in New Zealand's timber industry [48], hot water systems in Australia [49], Light Emitting Diodes (LED) lighting in the United States Navy [45], and eco-innovations in business organisations in New Zealand [50]. However, one of the major limitations of these energy culture studies is that they only examine the details of the existing energy cultures, such as drivers and barriers for the diffusion of energy-efficient technologies in buildings, without examining the holistic view of energy culture maturity. At the same time, the holistic culture maturity has already been well-established in other culture research domains, such as safety culture and guides for cultural excellence [51–55]. In addition, existing energy management maturity studies are also limited to areas such as energy management in organisations [56–60] and ISO 50001 energy management system (EnMS) [61–63], without focusing on energy culture maturity. Therefore, none of the available energy research studies on energy-efficient technology diffusion in buildings has focused on holistic energy culture maturity, which provides the roadmap for energy culture excellence. Therefore, this study aims to take the innovative step to develop the first energy culture maturity conceptual framework focusing on the diffusion of energy-efficient technology innovations in buildings. The proposed energy culture maturity conceptual framework contributes to expanding the energy culture research domain by adding a novel branch of energy culture maturity research. The framework can be used to assess the status of the energy culture with respect to energy-efficient technology diffusion in buildings and contribute towards the achievement of energy cultural excellence.

The structure of this article can be explained in a few steps. First, a background relevant literature review on energy culture and energy culture maturity is presented. Then, the materials and methods of the study are given, explaining the research methodology employed. The following section, results, explains the findings, including the development of the conceptual framework. Finally, the conclusion section provides the implications and the further research directions of the study.

2. Background Literature

2.1. Energy Culture

Ishak [64] identified the model developed by Lutzenhiser [41] as the first attempt to unveil energy culture as a concept. Stephenson et al. [42] also concurred that the same work was an innovative study. However, Stephenson [46] and Stephenson et al. [42] recognised a significant limitation of the development made by Lutzenhiser [41]; it is not a developed theoretical model since it only describes the energy culture concept. Considering the further advancements of the energy culture research area, Ishak [64] highlighted the development by Stephenson et al. [42] as the first framework that comprehensively explains the energy culture, illustrated in Figure 1.

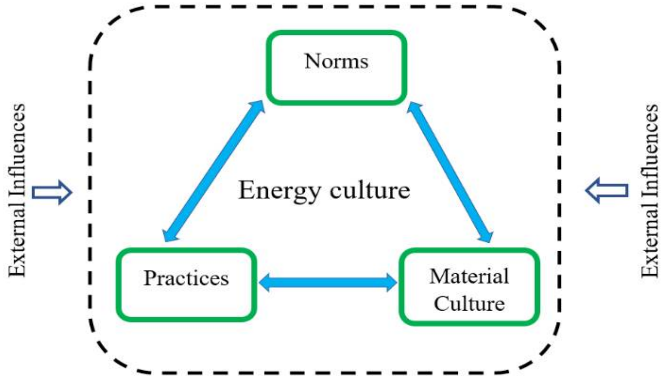

Figure 1. Energy cultures framework (Adapted from Stephenson et al. [43]).

According to Stephenson et al. [42], the framework was comprehensively developed based on systems and behavioural theories. Therefore, the energy cultures approach can resolve considerable gaps in the existing energy behaviour literature since it provides a broader cultural identity, which is lacking in the traditional techno-economic scholarship. Jürisoo et al. [65] also agreed on the inadequacy of existing energy-related models to explain real-life energy behaviours and the potential of energy cultures framework to be utilised in the multidimensional and interrelated examination of complex and multifactor energy behaviour. Furthermore, the energy cultures framework has proven its ability to examine energy behaviours in different contexts, from domestic buildings to firms and industries [66].

Stephenson et al. [42] identified the three core components of the energy culture as norms, material culture and practices. Norms are defined as the shared beliefs regarding the behaviour of persons in a given context; material culture refers to the energy-consuming physical elements, such as machinery; and finally, practices represent usual activities that consume energy. Hence, energy culture can be broadly defined as the interactive energy behaviour between a given subject's norms, practices, and material culture [43]. The energy behaviour of different subjects, such as individuals, households, businesses, or countries, can be studied by examining the interaction between the three components [67,68]. According to Ford et al. [69], energy cultures are distinctive in different settings, such as domestic and industrial; therefore, they impact the occupants differently. Norms impact energy technology choices (material cultures) and energy-consuming activities (practices). Material culture shapes energy technology utilisation, practices and norms. Furthermore, practices control the use of energy technologies (material cultures) and partly influences attitudes, values, and belief systems (norms) [42]. Occupants' energy behaviour in buildings is a combined effect of these three principal components that create a self-reinforcing system [64]. In addition, energy culture is shaped by external influences, which are typically beyond the control of internal actors [70]. External influences, illustrated outside the dotted line of Figure 1, generally include policies, regulations, energy prices, subsidies, information and promotion campaigns and broader social norms [43].

2.2. Energy Culture Maturity Models

According to Schein and Schein [71], organisational culture matures through stages such as founding and early growth, midlife, and maturity, which also applies to energy culture. Therefore, energy culture maturity can be identified as the maturation journey of an energy culture. Hence, the energy culture maturity shows different levels in the evolution of the norms, practices, and material culture. It is essential to note how knowledge on energy culture maturity has emerged in developing an energy culture maturity framework. The Capability Maturity Model (CMM) developed by Paulk et al. [72] was the first recognised maturity model and has been widely used in the software industry [63] and was later propagated in various fields such as engineering and construction, manufacturing, work management, healthcare, eco-design, and mining [62]. The CMM has been adapted to develop culture maturity models and energy maturity models. According to Paulk et al. [72], the capability maturity model guides the establishment of cultural excellence within an organisation. Therefore, the culture enhancement ability of CMM confirms the adaptability for various culture maturity studies. Accordingly, there are various applications of CMM already available, such as the safety culture maturity model [52–55,73–78], the health safety environment culture maturity model [79], the organisation culture maturity model [80] and the food safety culture maturity model [81]. Overall, the literature on culture maturity models confirms the suitability of maturity models for energy culture maturity studies. Furthermore, the existing literature on culture maturity also confirms the unavailability of energy culture maturity studies. Apart from the culture maturity models, there are energy maturity models developed based on the CMM in the literature. However, the energy maturity models are in their infancy [63] due to a lack of research and practical advice on implementation [57]. Table 1 shows a review of the available energy maturity models.

Table 1. Review on energy maturity models.

Study	Details	
Jin [61]	Focus	ISO 50001 EnMS based maturity model with a specific focus on China
	Energy-efficient technologies (EETs)	Not included
	Energy culture	Not focused
Finnerty et al. [56]	Focus	Development of a new energy management programme for multi-site organisations to achieve optimum efficiency within the network
	EETs	Included
	Energy culture	Not focused
Finnerty et al. [57]	Focus	Increasing energy efficiency maturity in multi-sites and the network
	EETs	Not included
	Energy culture	Not focused
Prashar [58]	Focus	Pre-assessment of the maturity profile of organisations and a personalised improvement plan for small and medium enterprises
	EETs	Included
	Energy culture	Not focused
Jovanović et al. [62]	Focus	An ISO 50001 EnMS based implementation model
	EETs	Not included
	Energy culture	Not focused
Antunes et al. [63]	Focus	Support the compliance with ISO 50001 EnMS standard
	EETs	Not included
	Energy culture	Not focused
Introna et al. [59]	Focus	Maturity assessment of the organisation's overall energy management
	EETs	Not included
	Energy culture	Not focused
Ngai et al. [60]	Focus	To measure and manage both energy and environmental performance
	EETs	Not included
	Energy culture	Not focused

The studies on energy maturity models were limited to Ngai et al. [60], Antunes et al. [63], Introna et al. [59], Jovanović and Filipović [62], Finnerty et al. [56], Finnerty et al. [46], Prashar [47], and Jin [50], as given in Table 1. The available energy maturity models given in Table 1 were focused on areas such as energy management in organisations [56–60] and the ISO 50001 energy management system (EnMS) [61–63]. Only Finnerty et al. [56] and Prashar [58] have focused on adopting energy-efficient technologies among the available studies. Furthermore, literature on energy maturity models confirms that none of the existing models has focused on energy culture maturity.

Overall, the suitability of the maturity models to examine energy culture maturity can be confirmed through the existing applications in culture maturity and energy maturity, as discussed above. Therefore, there is potential to develop an energy culture maturity framework based on these developments. Thus, the energy maturity model developed by Finnerty et al. [56], shown in Figure 2, was adapted to be the foundation for developing the energy culture maturity framework in this study.

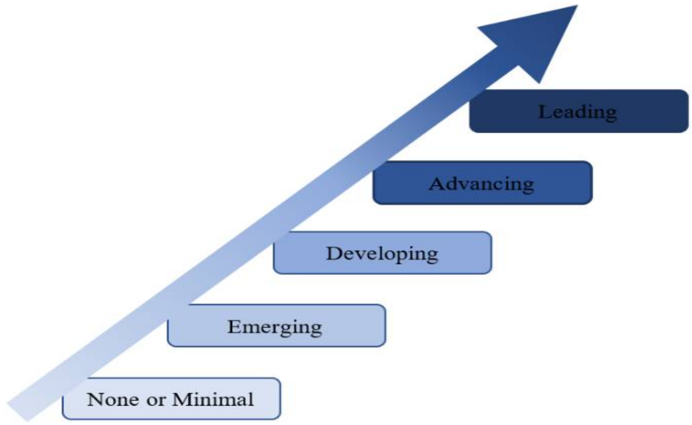

Figure 2. Energy maturity model (Adapted from Finnerty et al. [56]).

The reason for adopting the Finnerty et al. [56] model was its strong focus on adopting energy-efficient technologies compared to the Prashar [58] model, which focused less on adopting energy-efficient technologies. There are five maturity levels: none or minimal, emerging, developing, advancing, and leading in the adapted model. The five different levels of maturity represent the status of energy efficiency. Level 1 (none or minimal) represents the lowest level of energy maturity. Then, the maturity gradually increases to reach the highest level (leading) at level 5. The levels between 1 and 5 represent the roadmap for energy-efficiency enhancement [56].

3. Materials and Methods

3.1. Implementation of Scoping Literature Review Procedure

Integrating best practices within the literature has been identified as a possible way to develop maturity models [63]. Therefore, this paper executed a scoping literature review method that is suitable for identifying key characteristics and factors [82,83] to develop an energy culture maturity conceptual framework using relevant energy culture studies. The procedure proposed by O'Brien and Guckin [84] was used to carry out the scoping literature review. The procedure consists of 10 steps based on the established Cochrane collaboration checklist. Ten steps of the procedure successfully cover the three elements of a research methodology: study design, conducting, and data analysis. Accordingly, the study design is explained in step 1. Then, step 2 to step 9 explains the process of conducting the study. Finally, the data analysis was carried out as in step 10. The steps of the procedure and outcomes of each step are depicted in Figure 3.

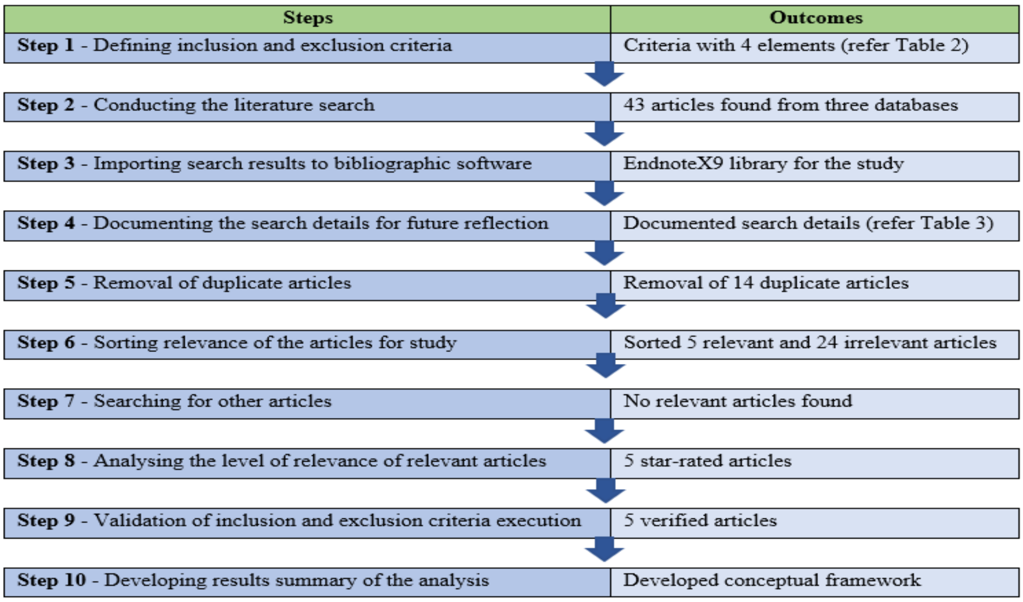

Figure 3. Adapted procedure for scoping review (Source: Author developed based on O'Brien and Guckin [84]).

This inclusion and exclusion criteria of this research are defined on the research question, as outlined in the first step. The inclusion and exclusion criteria and respective justifications, which guided the relevant articles selection process, are provided in Table 2. In the second step, appropriate keywords were developed with the support of a liaison librarian before searching the electronic databases.

Table 2. Inclusion and exclusion criteria.

	Inclusion Criteria	Exclusion Criteria	Justification
1	The document type was limited only to the journal articles.	All other documents, such as conference papers, were not considered.	Kraus et al. [85] stressed the significance of limiting to peer-reviewed journal articles without grey literature to ensure quality.
2	The articles were published between 1990 and 2020, including both years.	The articles outside this time frame were not considered.	According to the scholarship, the innovative study on energy culture was published in 1992. Therefore, 1990 was selected as the starting year to cover all relevant research.
3	Energy culture research on energy-efficient technology diffusion was only included.	Other energy culture research that did not focus on adopting energy-efficient technologies was excluded.	This ensured compliance with the research question.
4	The adoption of energy-efficient technologies in any type of building was considered.	energy-efficient technologies adoption outside the scope of buildings was not considered. Research on the adoption of energy generation technologies on the energy supply side was not considered.	Selected articles were limited to buildings since the research focuses on that area. Furthermore, the research problem was focused on energy efficiency on the energy demand side. Therefore, the adoption of renewable energy sources on the energy supply-side was excluded.

Then, the scoping review literature search was conducted using Scopus, Web of Science, and Engineering Village electronic databases. The suitability of these databases for energy research was recognised by Torreglosa et al. [86] and Princeton University Library [87] for Scopus and Web of Science, and by Bue Library [88] for the Engineering Village database. Table 3 depicts the scoping review searching summary details of the literature review.

Table 3. Scoping review searching summary.

Database	Date of Search	Keywords	Timespan	Number of Articles
Scopus	11 October 2020	TITLE-ABS-KEY("energy culture*") AND TITLE-ABS-KEY (technolog* OR equipment* OR machin* OR system* OR "building service*" OR tool*) AND TITLE-ABS-KEY(adopt* OR diffus* OR use OR acquir* OR acquis*) AND TITLE-ABS-KEY (building* OR domestic OR non-domestic OR "nondomestic" OR house* OR home* OR organisation* OR organization*)	1990–2020 inclusive	19
Web of Science	11 October 2020			18
Engineering Village	11 October 2020			6

As the third step outlines, the search results from all the databases were imported to EndnoteX9, the bibliographic software used. Before removing the duplicate articles using EndnoteX9, in the fourth step, relevant search details were recorded to facilitate future replications of this research. In the fifth step, 14 of the 43 articles found were identified as duplicates and subsequently removed from the results in the bibliographic software. Then, in the sixth step, the remaining 29 articles underwent a rigorous sorting process to identify the relevant and irrelevant articles, utilising the inclusion and exclusion criteria. The sorting process consisted of three steps: reading titles of articles, reviewing abstracts, and browsing through the full article. The articles that did not meet the inclusion criteria were recorded as irrelevant in each step. Only five articles met the inclusion criteria to qualify as relevant articles based on the sorting process. The five articles were: Walton et al. [50], Dew et al. [45], Gill et al. [49], Bell et al. [48] and Stephenson et al. [42]. The seventh step included additional searching using the reference lists of the five studies screened in the previous step to identify other articles relevant to this study. However, no other relevant articles were found from the reference list of the five studies. Then, the eighth step included examining the five articles to identify the level of relevancy to the research question and were ascribed with a star rating. In addition to the relevancy examination by categorising articles, a word cloud analysis was also performed using NVivo 12 software for the five articles, to further understand the results' relevancy to this study. Implementation of the inclusion and exclusion criteria in the above steps was validated with the support of another researcher, which was the ninth step of the protocol. The tenth and final step of the protocol detailed the findings. This involved an in-depth investigation of the selected articles to understand the factors of energy culture affecting the adoption of energy-efficient technologies, the overall maturity stage of the respective energy cultures, and identification of the maturity descriptors. Ultimately, the findings were integrated, and the energy culture maturity conceptual framework was developed.

3.2. Validation Procedure for the Framework

The validation procedure comes after the development of the energy culture maturity conceptual framework, in the tenth step of the scoping literature review procedure, as detailed in Section 3.1. Then, the framework should be validated from a panel of energy experts from a particular industry. The need for an industry-specific validation is based on the recommendations of Stephenson, et al. [43] and Lutzenhizer [41], whose research studies are the leading literature in the energy culture research domain. Both studies stressed the need to specialise energy culture studies to a particular industry due to the existence of distinctive industry-specific energy cultures. Accordingly, the framework presented in this study should be validated for the focused industry with the support of experts before carrying out the energy culture maturity assessment.

4. Results

This section explains the findings of the study, where the preliminary results of word cloud analysis are presented first. The development of the energy culture maturity conceptual framework and related components follows, which is the outcome of the in-depth analysis of the five articles. Table 4 summarises the selected five articles from the scoping review, including contexts, energy-efficient technologies, and the types of organisations.

Table 4. Summary of the selected studies.

Articles	Context	Details	
		EETs	Type of Organisation
Walton et al. [50]	Context A (CA)	Eco-innovations	Business organisations located in New Zealand
	Context B (CB)	Eco-innovations	Business organisations located in New Zealand
Dew et al. [45]	Context C (CC)	Light Emitting Diodes (LED) lighting	Ships of the United States Navy
Gill et al. [49]	Context D (CD)	Solar hot water systems	Domestic buildings in Australia
Bell et al. [48]	Context E (CE)	Heat pump dryers	Timber factories in New Zealand
Stephenson et al. [42]	Context F (CF)	Heating technologies	Domestic buildings in New Zealand
	Context G (CG)	Heating technologies	Domestic buildings in New Zealand

Considering the identification of the above seven contexts from CA to CG, Walton et al. [50] and Stephenson et al. [42] consisted of two different contexts within each study, while all the other studies are limited to single contexts. Accordingly, CA and CB belong to Walton et al. [50], representing two different contexts of energy cultures relating to the eco-innovation linked to the adoption of energy-efficient technologies in New Zealand business organisations. CC refers to a study adopting LED lighting technologies in the ships of the United States Navy [45]. CD is the study conducted on the diffusion of hot water systems in Australian domestic buildings [49]. CE presents the case of adopting energy-efficient heat pump dryers in the timber industry in New Zealand [48]. Lastly, Stephenson et al. [42] provide two other contexts, CF and CG, regarding the adoption of heating technologies in New Zealand homes before and after an energy culture change programme.

4.1. Word Cloud Analysis of Scoping Review Results

Word cloud analysis is a visual representation tool that reviews the frequency of words recurring in an article. The size of the words in a word cloud represents the frequency with which the words appear in an article [89]. As a result, word cloud analysis has been identified as a tool that analyses the relevance of an article for a given context. Figure 4 depicts the word cloud analysis developed using NVivo 12 software for the five articles selected from the scoping review.

Firstly, "energy" and "cultures" are prominent words in the word cloud. This demonstrates the focus on energy culture in the screened studies. Further, "using" and "technology" are identified as two prominent words, which reveals the focus of the selected studies on "adoption of technologies". According to McNaught and Lam [90], word clouds enable users to gain a preliminary understanding of the nature of the data on hand. Furthermore, the most frequent words in this word cloud analysis show the relationship between the scoping review results and the research aim. Therefore, the word cloud analysis results have further confirmed the suitability of the selected articles from the scoping review for this study. Moreover, the word cloud analysis strengthened the eighth step of the scoping review to examine the relevancy of the results.

Figure 4. Word cloud analysis (Source: Outcome of the NVivo 12 word cloud analysis).

4.2. Energy Culture Maturity Conceptual Framework

This section presents the development of the energy culture maturity conceptual framework based on the findings of five studies representing three countries, as given in Table 4. Even though there might be cultural differences among different countries [91–95], there are similarities under certain conditions. In particular, there are previous studies on the cultural similarities between the five Anglosphere countries, namely, the United States, Canada, the United Kingdom, Australia and New Zealand [96–98]. This study's five articles represent three Anglosphere countries: the United States, Australia, and New Zealand. Therefore, the suitability of the selected studies to develop the conceptual framework can be justified due to the cultural similarities among the selected Anglosphere countries. Development of the conceptual framework was carried out in several steps. First, the conceptual framework components were developed, including factors and factor categorisation, energy culture maturity stages, and energy culture maturity descriptors. Then, the conceptual framework was developed as the study's outcome by integrating the factor categorisation, energy culture maturity stages, and energy culture maturity descriptors.

4.2.1. Factors and Factor Categorisation of Energy Culture

This section explains the development of the factors and factor categorisation. First, the selected studies were analysed in depth to understand the factors of the energy culture affecting the diffusion of energy-efficient technologies in buildings. Khan [99] defined the factors of energy culture that promote adopting energy-efficient technologies as the "drivers" and, conversely, the factors that limit adopting energy-efficient technologies as the "barriers". The selected five studies given in Table 4 have already defined drivers and barriers of energy culture for each study. This study directly identified drivers and barriers considering the classifications of the drivers and barriers in the selected five studies. Accordingly, Walton et al. [50] consisted with four barriers under context A and 11 drivers under context B. Dew et al. [45], which is identified as context C, contained seven barriers. Five drivers were given in Gill et al. [49], which is named as context D. Bell et al. [48], as context E, owned 11 barriers. Finally, Stephenson et al. [42] comprised of three barriers under context F and four drivers under context G. The identified drivers and barriers are presented in Table 5. The drivers and barriers were assigned with codes for easy reference.

For example, for “CAD1”, CA represents the relevant context, “D” denotes the driver, and 1 represents the respective driver number. Instead of “D”, “B” is used as the coding letter when coding barriers. Altogether, 45 factors were identified from the studies as the factors of energy culture affecting the adoption of energy-efficient technologies. The factors have been distributed between drivers and barriers as 20 and 25, respectively.

Further, considering the origin of the factors, the 45 factors can be categorised under the three components of the energy culture, namely, norms, practices, and material culture. Out of the 15 factors of Walton et al. [50], three barriers and 10 drivers were presented under norms. Further, one barrier and one driver were identified under practices. Considering the Dew et al. [45] study, six barriers were presented under norms and one barrier was presented under practices out of the total of seven factors. Furthermore, Gill et al. [49] allocated all five factors under the norms as drivers. Bell et al. [48], out of the 11 factors, had nine barriers under norms, one barrier under practices and one barrier under material culture. Finally, Stephenson et al. [42] presented two barriers under norms, three drivers under norms, one barrier under material culture and one driver under material culture out of the total of seven factors. Accordingly, altogether, 38, 4 and 3, factors were originated from norms, practices, and material culture, respectively. Each study has shown that the norms are the principal originator of factors, rather than practices or material culture, when adopting energy-efficient technologies.

Then, the factor categorisation was developed as main factors and subfactors using the identified 45 factors. The purpose of developing factor categorisation is to identify the common factors under which to group the similar drivers or barriers. Subsequently, factor categorisation was used to develop the final framework of this study. The factor categorisation creates a proper structure for the factors in the final framework without repetitions. As the first step, all 45 factors were categorised under main factors. Then, if a further subdivision of the drivers or barriers identified under the main factors was meaningful, the subfactors were developed under the main factors. Overall, the factor categorisation as main factors and subfactors was carried out considering the similarities of the identified 45 factors. Furthermore, codes were assigned for the main factors and subfactors. For example, MF1 represents the first main factor, and SF1 represents the first subfactor. Table 5 outlines the development of the factors and factor categorisation.

As per the factor categorisation, 14 main factors and 11 subfactors were derived by analysing all drivers and barriers. Under norms, the main factors are attention to economic benefits, readiness for energy-efficient technologies, prioritisation for energy-efficient technologies, energy policies and strategies, knowledge of energy-efficient technologies, green values of owners, focus on green marketplaces, and the commitments of top management to presence of internal politics and industry norms acceptance. Further, changing business practices for energy-efficient technologies and acceptance of industry practices are the main factors under practices. Then, industry material culture acceptance and availability of energy-efficient technologies are identified as the main factors under material culture.

In addition, the subfactors were identified under the main factors. The subfactors identified under attention to economic benefits were investment return analysis and operational cost-saving focus. Readiness for energy-efficient technologies consists of three subfactors: whole organisation’s readiness, willingness to adopt energy-efficient technologies, and actively seeking energy-efficient technologies. The level of acceptance of energy-efficient technologies and priority in the procurement criteria are the two subfactors under the prioritisation for energy-efficient technologies. In addition, supportive key performance indicators and supportive energy policies and strategies were identified as subfactors under energy policies and strategies. Finally, knowledge of the benefits and the suitability of new energy-efficient technologies were identified as subfactors under knowledge of energy-efficient technologies.

Table 5. Factors and factor categorisation.

No	Factors (Drivers (D)/Barriers (B))	Factor Categorisation	
		Subfactors (SF)	**Main Factors (MF)**
	Norms (N)		
1	CAB1—No whole organisation approach to support the adoption of Energy Efficient Technologies (EETs)	SF1—Whole organisation's readiness	MF1—Readiness for EETs
2	CAB2—EETs are not adopted considering energy efficiency mostly but due to other factors	SF2—Level of acceptance	MF2—Prioritisation for EETs
3	CAB3—Poor monitoring of investment return that is limited to the simple payback period	SF3—Investment return analysis	MF3—Attention to economic benefits
4	CBD1—Established approaches in whole organisation for energy-efficiency enhancement driven by knowledge and learning	SF1—Whole organisation's readiness	MF1—Readiness for EETs
5	CBD2—Well-established energy policy and planning is available.	SF4—Supportive energy policy and strategies	MF4—Energy Policy and strategies
6	CBD3—Energy-efficient thinking is firmly embedded into norms of the whole organisation	SF1—Whole organisation's readiness	MF1—Readiness for EETs
7	CBD4—KPIs with a rewarding system for employees to promote EETs. Thus, employees develop capabilities that lead to competitive advantage, which is hard to imitate	SF5—Supportive KPIs	MF4—Energy Policy and strategies
8	CBD5—High employee commitment to become energy efficient	SF1—Whole organisation's readiness	MF1—Readiness for EETs
9	CBD6—Employees are developing capabilities on energy efficiency through learning.	SF6—Knowledge of benefits	MF5—Knowledge of EETs
10	CBD7—Organisation has clearly realised the potential cost savings of energy efficiency	SF7—Operational cost-saving focus	MF3—Attention to economic benefits
11	CBD8—Owners have strong green values that continually shape the business direction and strategies. Therefore, EETs are the usual choice of organisations to meet the green values.	Not available (n/a)	MF6—Green values of owners
12	CBD9—Organisation focuses on a customer base that seeks environmental sustainability	n/a	MF7—Focus on a green marketplace
13	CBD10—Organisation even seeks for external energy experts when required	SF8—Active seeking for EETs	MF1—Readiness for EETs
14	CCB4—Lack of support from top management because energy efficiency is not their priority	n/a	MF8—Top management commitment
15	CCB5—Failure to see a clear link between the adoption of EETs and sustainability	SF6—Knowledge of benefits	MF5—Knowledge of EETs
16	CCB6—Less attention from top management on issues of energy inefficient technologies	SF6—Knowledge of benefits	MF5—Knowledge of EETs
17	CCB7—Identifying potential energy saving as an intangible benefit by the top management.	n/a	MF8—Top management commitment
18	CCB8—Disagreements for EETs due to internal politics in the top management.	n/a	MF9—Presence of internal politics
19	CCB9—Energy efficiency is not considered in evaluation criteria for technology adoption.	SF9—Priority in procurement criteria	MF2—Prioritisation for EETs

Table 5. *Cont.*

No	Factors (Drivers (D)/Barriers (B))	Factor Categorisation	
		Subfactors (SF)	Main Factors (MF)
20	CDD11—Availability of financial savings of EETs adoption	SF7—Operational cost-saving focus	MF3—Attention to economic benefits
21	CDD12—User satisfaction on environmental benefits of energy savings	SF6—Knowledge of benefits	MF5—Knowledge of EETs
22	CDD13—Thinking to lead by example for energy savings	n/a	MF6—Green values of owners
23	CDD14—Willingness to reduce the energy consumption in buildings	SF7—Operational cost-saving focus	MF3—Attention to economic benefits
24	CDD15—Actively seeking ways of increasing the energy efficiency	SF8—Active seeking for EETs	MF1—Readiness for EETs
25	CEB10—Misbelief on advantages of energy inefficient technologies which is not realistic	SF6—Knowledge of benefits	MF5—Knowledge of EETs
26	CEB11—Energy inefficient technologies are the choice of both large and growing firms	SF6—Knowledge of benefits	MF5—knowledge of EETs
27	CEB12—Misbelief on EETs as highly energy consuming	SF6—Knowledge of benefits	MF5—Knowledge of EETs
28	CEB13—Strategies for profits is reaching the niche markets and not the energy cost reduction	SF7—Operational cost-saving focus	MF10—Attention to economic benefits
29	CEB14—Strong acceptance for energy-inefficient technologies by the firm management	n/a	MF8—Top management commitment
30	CEB15—Misbelief in energy-inefficient technologies as most suitable for core business than EETs	SF10—Suitability of new EETs	MF5—knowledge of EETs
31	CEB16—Belief in firms that energy-inefficient technologies as the industry standard	SF10—Suitability of new EETs	MF5—knowledge of EETs
32	CEB17—Considering EETs as only suitable technologies for smaller firms	SF10— Suitability of new EETs	MF5—knowledge of EETs
33	CEB18—Strong industry norms for accepting energy-inefficient technologies	n/a	MF11—Industry norms acceptance
34	CFB19—Lack of energy literacy	SF6—Knowledge of benefits	MF5—Knowledge of EETs
35	CFB20—Lack of awareness on global and local essentiality for improved energy efficiency	SF6—Knowledge of benefits	MF5—Knowledge of EETs
36	CGD16—Improved energy literacy	SF6—Knowledge of benefits	MF5—Knowledge of EETs
37	CGD17—Improved awareness on global and local essentiality for energy efficiency	SF6—Knowledge of benefits	MF5—Knowledge of EETs
38	CGD18—Readiness to accept the EETs when available	SF11—Willingness for EETs	MF1—Readiness for EETs
	Practices (P)		
39	CAB21—Organisation is not ready to change current practices to adopt EETs	n/a	MF12—changing business practices for EETs
40	CBD19—Organisation changes current business practices to adopt EETs and develop new competencies required for that.	n/a	MF12—changing business practices for EETs

Table 5. *Cont.*

No	Factors (Drivers (D)/Barriers (B))	Factor Categorisation	
		Subfactors (SF)	**Main Factors (MF)**
41	CCB22—Operational decision-making delays when replacing EETs	n/a	MF12—changing business practices for EETs
42	CEB23—Strong research and technical support for inefficient technologies than EETs	n/a	MF13—industry practices acceptance
	Material culture (MC)		
43	CEB24—Energy inefficient technologies has been well implemented in the industry	n/a	MF14—Industry MC acceptance
44	CFB25—Existence of the well-established energy-inefficient technologies	n/a	MF15—Availability of EETs
45	CGD20—Availability of the EETs up to some extent	n/a	MF15—Availability of EETs

4.2.2. Energy Culture Maturity Stages

As previously mentioned, this study adapted Finnerty et al.'s [56] energy maturity model with five maturity levels. However, it was challenging to identify the energy culture maturity for five maturity levels due to limited literature. Therefore, this study had to modify the Finnerty et al. [56] model with five maturity levels to be operationalised while keeping the original structure. Accordingly, a framework with three energy culture maturity stages was developed based on the original maturity model. The development of the three stages is illustrated in Figure 5. The three-staged maturity design covers the five maturity levels of the Finnerty et al. [56] model, where Stage 1 represents Level 1, Stage 2 represents Level 2, 3 and 4, and Stage 3 represents Level 5.

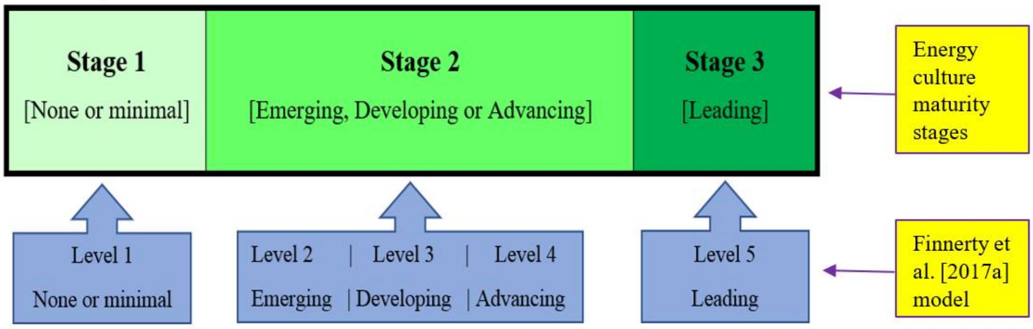

Figure 5. Development of maturity stages (Source: Author developed based on Finnerty et al. [56]).

Then, the energy cultures of seven contexts given in Table 4 were grouped into the three energy culture maturity stages, considering the energy culture's overall support for adopting energy-efficient technologies. Energy culture's overall support ranged from the energy cultures that strongly prevent adopting energy-efficient technologies to the energy cultures that exceedingly support adopting energy-efficient technologies in the seven contexts. Accordingly, CA, CC, CE, and CF contexts could be identified as the energy cultures that strongly prevent adopting energy-efficient technologies due to significant resistance from the energy culture. Therefore, those contexts were categorised for Stage 1. Then, CB could be identified as an energy culture that remarkably supports adopting energy-efficient technologies due to intense drivers in energy culture to adopt energy-efficient technologies. CB energy culture demonstrates a world-class example of energy culture excellence. Therefore, CB, categorised as Stage 3, was the topmost stage of the energy culture maturity. As the remaining contexts, CD and CG represented some drive for adopting energy-efficient technologies. However, there is room for further improvement of the energy culture to reach the energy culture excellence of Stage 3. Therefore, CD and CG were placed under the Stage 2 energy culture maturity, between Stage 1 and Stage 3. Figure 6 depicts the grouping of seven contexts of the selected five studies under three energy culture maturity stages.

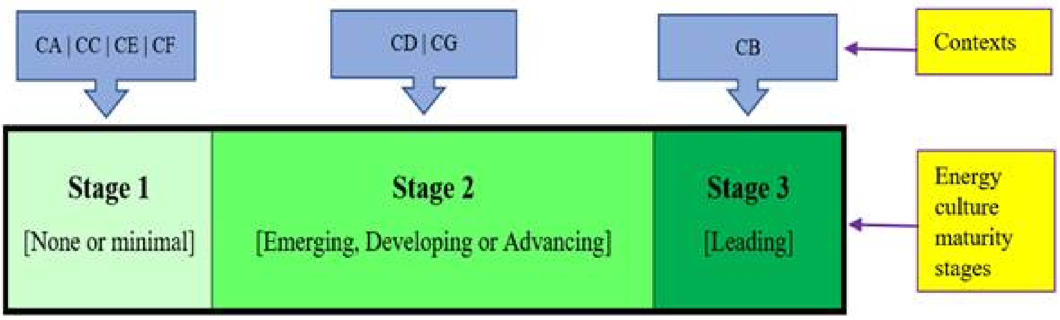

Figure 6. Grouping contexts under energy culture maturity stages (Source: Author developed).

4.2.3. Energy Culture Maturity Stage Descriptors

The third element of the energy culture maturity conceptual framework requires establishing different maturity stage descriptors for each maturity stage against the previously developed factor categorisation in Table 5. The maturity descriptors are the descriptions of energy culture in the different maturity stages against the available factor categories. Antunes et al. [63] proposed developing maturity descriptors using best practices found in the literature. This study also incorporated a similar approach to developing energy culture maturity descriptors for the three stages. The drivers and the barriers identified for the seven contexts in Table 5 best describe the energy culture features in given contexts. For instance, drivers in CB presents the best practices of excellent energy cultures, whereas barriers in CC show the factors of an energy culture that has obstructed adopting energy-efficient technologies. Hence, this study uses the drivers and barriers from seven contexts to develop the energy culture maturity descriptors. Accordingly, maturity descriptors were developed for all three stages, including some projections when direct drivers or barriers were not clearly available. Accordingly, each subfactor in the factor categorisation owns maturity descriptors for all three maturity stages. When there is no subfactor, the main factor directly relates to the maturity descriptor.

4.2.4. Development of the Energy Culture Maturity Conceptual Framework

Ultimately, the development of the energy culture maturity framework integrates previous findings under factor categorisation, energy culture maturity stages and energy culture maturity descriptors. Accordingly, Figure 7 and Table 6 jointly present the developed energy culture maturity conceptual framework by integrating previous findings. Figure 7 depicts the integration of the three-staged energy culture maturity. Each stage represents the interaction between norms (N), practices (P), and material culture (M) as the three components of energy culture. This relationship is illustrated using two-way arrows that connect each of the components. The framework's maturity moves from Stage 1, the lowest energy culture maturity, to Stage 3, the topmost energy culture maturity. The green arrows illustrate the possible trajectory of energy culture maturity towards energy culture excellence. The three stages of energy culture maturity are defined below, considering the overall support of energy culture for adopting energy-efficient technologies.

1. Stage 1 (S1): Energy cultures that obstruct the adoption of energy-efficient technologies.
2. Stage 2 (S2): Energy cultures that support the adoption of energy-efficient technologies to some extent. There is still room for improvement in terms of reaching energy culture excellence.
3. Stage 3 (S3): Energy cultures that support at the best level for adopting energy-efficient technologies.

Table 6 outlines a detailed integration of the energy culture maturity conceptual framework in the form of a matrix table consisting of factor categorisations presented in rows and energy culture maturity stages outlined in columns. The factor categorisation's main factors or subfactors link with the respective maturity descriptors under three stages. Furthermore, the three maturity stages vertically distribute the maturity descriptors of each stage. Thus, the maturity descriptors are shared by the factor categorisations and the three maturity stages to form the energy culture maturity conceptual framework.

The conceptual framework elaborates norms, practices, and material culture. The norms section of the framework consists of 10 main factors, such as the green values of owners, top management commitments, energy policies and strategies, a focus on a green marketplace, knowledge of energy-efficient technologies, readiness for energy-efficient technologies, attention to economic benefits, prioritisation of energy-efficient technologies, presence of internal politics, and industry norms acceptance. Moreover, the practices section comprises two main factors: changing business practices for energy-efficient technologies and industry practices acceptance. Lastly, the material culture section includes the availability of energy-efficient technologies and industry material cultures acceptance as the two main factors. In addition, all 11 subfactors belong to the norms section.

The subfactors include investment return analysis, operational cost savings focus, whole organisation readiness for energy-efficient technologies, willingness for energy-efficient technologies, actively seeking energy-efficient technologies, levels of acceptance for energy-efficient technologies, energy priorities in procurement criteria, supportive key performance indicators, supportive energy policies and strategies, knowledge on benefits of energy-efficient technologies, and the suitability of new energy-efficient technologies. Furthermore, the energy culture maturity descriptors of a given main factor or subfactor explain its maturity in the three stages. Overall, the conceptual framework outlines the structure to assess the energy culture maturity in three stages against the factors and subfactors.

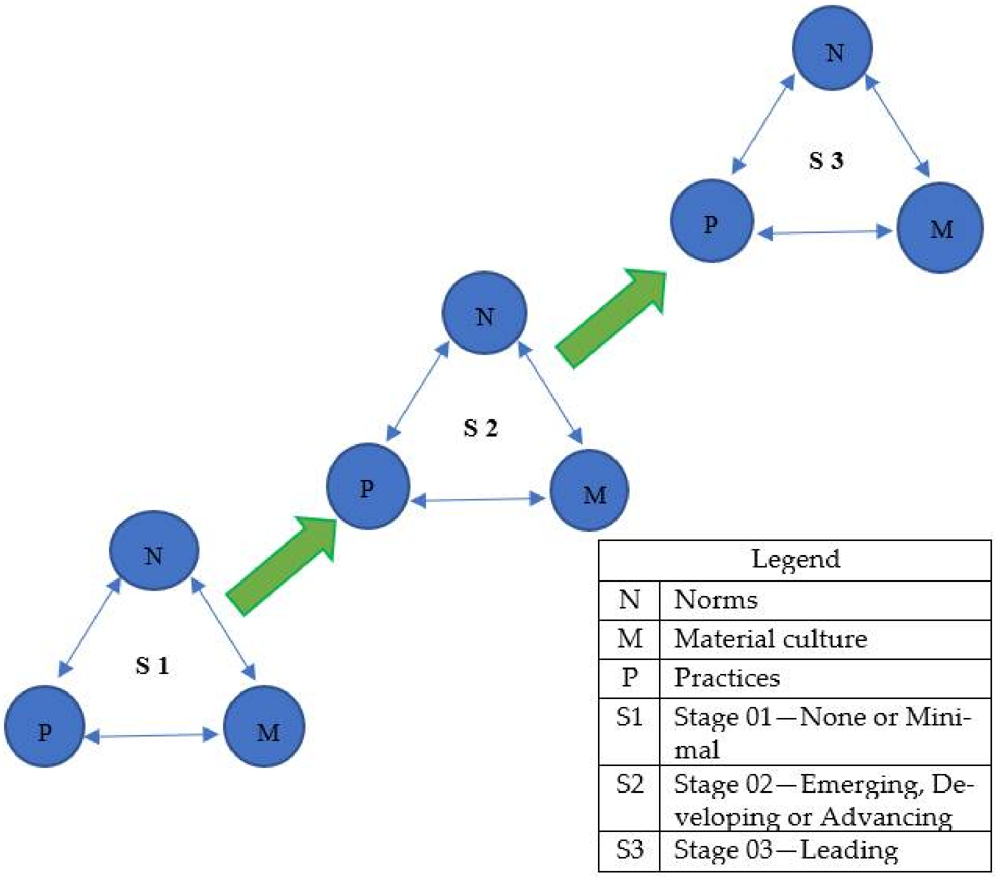

Figure 7. Energy culture maturity conceptual framework (Source: Author developed based on energy cultures framework [43] and Finnerty et al. [56]).

Table 6. Factors and maturity stage descriptors of the framework.

Factor Categorisation		Energy Culture Maturity Stages and Descriptors		
Main Factors	**Subfactors**	**Stage 01 (None or Minimal)**	**Stage 02 (Emerging, Developing or Advancing)**	**Stage 03 (Leading)**
Norms				
Green values of owners	n/a	Owners do not have green values that promote the adoption of EETs.	Green values of owners may range from the basic level to a level where it has been advanced. However, there is room for improvement.	Owners have strong green values that continually shape the direction of the business. As a result, EETs are the usual choice of the organisation.
Top management commitment	n/a	Top management undervalues energy saving as an intangible benefit.	Top management commitment is available to adopt EETs to some extent, but this fluctuates from low to high. It requires further improvement.	Top management always identifies the need for the adoption of EETs. Therefore, they commit to the adoption of EETs.
Energy policy and strategies	Supportive policy and strategies	No energy policies and strategies are available.	Energy policies and strategies are available. However, the implementation mechanisms require improvement.	Well-established energy policies and strategies are available. Policies are always supported with an implementation mechanism.
	Supportive KPIs	KPIs are not available to support the adoption of EETs.	KPIs relating to the adoption of EETs are available. However, there is no robust incentive system, and the employees do not always follow KPIs.	Availability of KPIs to promote EETs and incentive systems is available for achievements. Employees always undertake the KPIs.
Focus on a green marketplace	n/a	The organisation does not seek a green marketplace.	The organisation integrates environmental sustainability to attract customers. There is no sole focus on a green marketplace	The organisation always approaches green marketplaces with a customer base that seeks environmental sustainability
Knowledge on EETs	Knowledge of benefits of EETs	The organisation lacks knowledge on the potential energy saving of EETs and the drawbacks of available energy-inefficient technologies.	The organisation knows the benefits of the EETs. Knowledge needs to be further improved. Less dependency on external energy experts.	Employees have sound knowledge of EETs and actively develop capabilities around energy efficiency through learning. The organisation seeks external energy experts when required.
	suitability of new EETs	Lack of knowledge on the suitability of new EETs for core business and scale of organisation. Therefore, suitable ETTs are not adopted.	The organisation has some knowledge of the suitability of new EETs for the core business and the scale. However, there is a need for further advancement of knowledge.	The organisation is adequately knowledgeable about the suitability of new EETs for the core business and scale of the business.

Table 6. *Cont.*

Factor Categorisation		Energy Culture Maturity Stages and Descriptors		
Main Factors	**Subfactors**	**Stage 01 (None or Minimal)**	**Stage 02 (Emerging, Developing or Advancing)**	**Stage 03 (Leading)**
Readiness for EETs	Willingness for EETs	No or minimum willingness for adopting EETs.	Willingness for adopting EETs is available up to some extent.	Willingness for adopting EETs is excellent and always visible
	Active seeking for EETs	Not actively seeking EETs.	Active seeking is available for EETs up to some extent. Still, further improvements are needed.	Active seeking for EETs is always available.
	Whole organisation's readiness	No whole organisation approach for the adoption of EETs.	There is evidence for the whole organisation's support for adopting EETs based on employee commitment, knowledge, and competencies. However, it requires further improvement.	Energy-efficient thinking is embedded into organisational norms. Whole organisation readiness with high employee commitment for EETs is clearly visible. Employees consistently learn capabilities for EETs, which is hard to imitate. As a result, the organisation gains a competitive advantage.
Attention to economic benefits	Operational cost-saving focus	Possible operational cost savings by the adoption of EETs is not considered.	The possibility for operational cost savings by adopting EETs is considered. However, the area needs further improvements.	The organisation has clearly realised the potential of optimum cost savings by adopting EETs.
	Investment return analysis	The investment return is poorly monitored and limited to simple payback period.	Further to the simple payback period analysis, the organisation implements other effective investment analysis methods to some extent.	Further to the simple payback period analysis of EETs, the organisation consistently implements other effective investment analysis methods
Prioritisation for EETs	Priority in procurement criteria	Energy efficiency is not considered in the procurement criteria for technologies.	Energy efficiency is prioritised in the procurement criteria up to some extent.	Energy efficiency is strongly considered in the procurement criteria.
	Level of acceptance	Strong acceptance for inefficient technologies despite the drawbacks and necessity of EETs not being believed. EETs are adopted due to reasons other than energy efficiency.	The organisation may accept both EETs and energy inefficient technologies. The acceptance of EETs may not be believed to be a necessity sometimes.	Adoption of EETs is always believed as a necessity. Energy-inefficient technologies are not accepted at all.
Internal politics presence	n/a	EETs are rejected due to the internal politics of the employees.	EETs are adopted to some extent despite the internal politics of the employees.	EETs are always adopted despite the internal politics of the employees.
Industry norms acceptance	n/a	The organisation accepts energy-inefficient industry norms but not energy-efficient industry norms.	The organisation may accept both inefficient and efficient industry norms.	The organisation always accepts energy-efficient industry norms. On the other hand, inefficient industry norms are never accepted.

Table 6. *Cont.*

Factor Categorisation		Energy Culture Maturity Stages and Descriptors		
Main Factors	**Subfactors**	**Stage 01 (None or Minimal)**	**Stage 02 (Emerging, Developing or Advancing)**	**Stage 03 (Leading)**
Practices				
Changing business practices for EETs	n/a	EETs that require alterations in current business practices are not adopted.	The organisation is ready to change its business practices by adopting some EETs. There may be resistance and operational decision-making delays.	The organisation constantly changes their business practices by developing new capabilities and competencies around EETs. There is no resistance or operational decision-making delays.
Industry practices acceptance	n/a	The organisation accepts energy-inefficient industry practices but not energy-efficient industry practices.	The organisation may occasionally accept both inefficient and efficient practices of their industry.	The organisation always accepts energy-efficient industry practices. Inefficient industry practices are never accepted.
Material Culture				
EETs Availability	n/a	No or minimum EETs are available in the building.	EETs are available up to some extent in the building.	Most of the available EETs have been adopted in the building.
Industry material culture acceptance	n/a	Inefficient material cultures in the industry are accepted, but efficient material cultures are not.	The organisation may occasionally accept both inefficient and efficient material cultures of the industry.	Energy-efficient material cultures at the industry level are always accepted. Inefficient material cultures are never accepted.

The background colours of three maturity stages changes from light green to dark green. Green colour getting more darker reflects the increase of the maturity.

5. Conclusions

As evidenced by the existing literature, an energy culture maturity framework is absent. Therefore, this study contributed to developing the first energy culture maturity conceptual framework on adopting energy-efficient technology innovations. This pioneering framework has significantly contributed to the scientific literature by adding a three-staged energy culture maturity conceptual framework to the energy culture research area, which can be identified as a novel contribution.

To date, the existing energy culture scholarship has not focused on holistic energy culture maturity and has not provided an energy culture roadmap for adopting energy-efficient technology innovations in buildings. This framework can be used to understand the current maturity status and provide a roadmap for reaching energy culture excellence, which continually improves the adoption of energy-efficient technology innovations in buildings. Furthermore, the proposed framework also provides policy implications. The framework can be used by the energy policy-related regulatory bodies to assess the energy culture maturity of different industries and organisations within industries. As a result of such a maturity assessment at the organisational or industrial level, benchmarking and baselining ability are acquired by the regulatory bodies as well as the organisations. Accordingly, the energy regulatory bodies can use the framework as a roadmap to guide organisations to achieve higher maturity levels, towards energy cultural excellence. Hence, the overall result increases the diffusion of energy-efficient technology innovations that support the demand-side management-related policy deployments.

Development of this framework was solely based on a scoping literature review and was limited to three maturity stages due to the limited literature, compared to the widely available maturity models with five maturity levels. As a result of this limitation, the framework's ability to provide the energy culture maturity assessment results will be limited to three stages. However, this limitation may not be a major obstacle to using the proposed framework since there are other scientific maturity models in the literature that are also limited to three levels. Further, the energy culture articles considered when developing the framework were limited to three Anglosphere countries. Hence, further empirical studies should be conducted based on the different countries and organisations to add additional scholarly value to this research area. Currently, an ongoing study is exploring the energy culture maturity of the textile and apparel industry in a developing country. Therefore, it would be fruitful to further research by empirically applying this novel framework to establish the energy culture maturity research approach.

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References

1. International Energy Agency. World Energy Outlook. 2018. Available online: https://webstore.iea.org/download/summary/190?fileName=English-WEO-2018-ES.pdf (accessed on 1 August 2019).
2. Qerimi, D.; Dimitrieska, C.; Vasilevska, S.; Rrecaj, A.A. Modeling of the solar thermal energy use in urban areas. *Civ. Eng. J.* **2020**, *6*, 1349–1367. [CrossRef]
3. Mariano-Hernández, D.; Hernández-Callejo, L.; Zorita-Lamadrid, A.; Duque-Pérez, O.; García, F.S. A review of strategies for building energy management system: Model predictive control, demand side management, optimization, and fault detect & diagnosis. *J. Build. Eng.* **2020**, *33*, 101692. [CrossRef]
4. Gerarden, T.D.; Newell, R.G.; Stavins, R.N. Assessing the energy-efficiency gap. *J. Econ. Lit.* **2017**, *55*, 1486–1525. [CrossRef]
5. Wagiman, K.R.; Abdullah, M.N.; Hassan, M.Y.; Radzi, N.H.M. A new metric for optimal visual comfort and energy efficiency of building lighting system considering daylight using multi-objective particle swarm optimisation. *J. Build. Eng.* **2021**, *43*, 102525. [CrossRef]
6. Ghaderian, M.; Veysi, F. Multi-objective optimisation of energy efficiency and thermal comfort in an existing office building using NSGA-II with fitness approximation: A case study. *J. Build. Eng.* **2021**, *41*, 102440. [CrossRef]
7. Dervishi, S.; Pashako, F.; Dushaj, X.; Dervishi, I.O. Energy performance optimisation of traditional housing in Mediterranean climate. *J. Build. Eng.* **2022**, *45*, 103423. [CrossRef]
8. Al-Homoud, M.S.; Krarti, M. Energy efficiency of residential buildings in the kingdom of Saudi Arabia: Review of status and future roadmap. *J. Build. Eng.* **2021**, *36*, 102143. [CrossRef]
9. Duan, J.; Li, N.; Peng, J.; Wang, C.; Liu, Q. Full-response model of transient heat transfer of building walls using thermoelectric analogy method. *J. Build. Eng.* **2021**, *46*, 103717. [CrossRef]
10. Nazeriye, M.; Haeri, A.; Haghighat, F.; Panchabikesan, K. Understanding the influence of building characteristics on enhancing energy efficiency in residential buildings: A data mining-based study. *J. Build. Eng.* **2021**, *43*, 103069. [CrossRef]
11. Kalhor, K.; Ememinejad, N. Qualitative and quantitative optimisation of thermal insulation materials: Insights from the market and energy codes. *J. Build. Eng.* **2020**, *30*, 101275. [CrossRef]
12. Raza, R.; Hassan, N.U.; Yuen, C. Determination of consumer behavior-based energy wastage using IoT and machine learning. *Energy Build.* **2020**, *220*, 110060. [CrossRef]
13. Wagner, A.; O'Brien, W.; Dong, B. *Exploring Occupant Behavior in Buildings*, 1st ed.; Springer International Publishing: Berlin/Heidelberg, Germany, 2018.
14. Duarte, J.G.C.D.L.M.; Zemero, B.R.; de Souza, A.C.D.B.; de Lima Tostes, M.E.; Bezerra, U.H. Building Information Modeling approach to optimise energy efficiency in educational buildings. *J. Build. Eng.* **2021**, *43*, 102587. [CrossRef]
15. Song, I.H.; Lhee, J.H.; Jeong, J.W. Energy efficiency and economic analysis of variable frequency drive and variable pitch system: A case study of axial fan in hospital. *J. Build. Eng.* **2021**, *43*, 103213. [CrossRef]
16. Tavakolan, M.; Mostafazadeh, F.; Jalilzadeh, S.; Safari, A.; Mirzaei, K. A simulation-based multi-objective optimisation framework for economic analysis of building energy retrofit: A case study in Iran. *J. Build. Eng.* **2021**, *43*, 103485. [CrossRef]
17. Costa, J.F.W.; Amorim, C.N.D.; Silva, J.C.R. Retrofit guidelines towards the achievement of net zero energy buildings for office buildings in Brasilia. *J. Build. Eng.* **2020**, *32*, 101680. [CrossRef]
18. González-Zamar, M.D.; Abad-Segura, E.; Vázquez-Cano, E.; López-Meneses, E. IoT technology applications-based smart cities: Research analysis. *Electronics* **2020**, *9*, 1246. [CrossRef]
19. Braungardt, S.; Elsland, R.; Eichhammer, W. The environmental impact of eco-innovations: The case of EU residential electricity use. *Environ. Econ. Policy Stud.* **2016**, *18*, 213–228. [CrossRef]
20. Civelek, F.; Kulkarni, R.; Fritz, K.P.; Meyer, T.; Troulos, C.; Guenther, T.; Zimmermann, A. Open-Eco-Innovation for SMEs with Pan-European Key Enabling Technology Centres. *Clean Technol.* **2020**, *2*, 26. [CrossRef]
21. Arnold, M.; Barth, V. Open innovation in urban energy systems. *Energy Effic.* **2012**, *5*, 351–364. [CrossRef]
22. Cagno, E.; Ramirez-Portilla, A.; Trianni, A. Linking energy efficiency and innovation practices: Empirical evidence from the foundry sector. *Energy Policy* **2015**, *83*, 240–256. [CrossRef]
23. Urbaniec, M. Towards sustainable development through eco-innovations: Drivers and barriers in Poland. *Econ. Sociol.* **2015**, *8*, 179. [CrossRef] [PubMed]
24. Garcia, R.; Wigger, K.; Hermann, R.R. Challenges of creating and capturing value in open eco-innovation: Evidence from the maritime industry in Denmark. *J. Clean. Prod.* **2019**, *220*, 642–654. [CrossRef]
25. Sanchez-Henriquez, F.; Pavez, I. The Effect of Open Innovation on Eco-Innovation Performance: The Role of Market Knowledge Sources. *Sustainability* **2021**, *13*, 3890. [CrossRef]
26. Ruby, T.M. Innovation-enabling policy and regime transformation towards increased energy efficiency: The case of the circulator pump industry in Europe. *J. Clean. Prod.* **2015**, *103*, 574–585. [CrossRef]
27. Schubert, R.; Stadelmann, M. Energy-using durables—Why consumers refrain from economically optimal choices. *Front. Energy Res.* **2015**, *3*, 1–13. [CrossRef]
28. Trotta, G. Factors affecting energy-saving behaviours and energy efficiency investments in British households. *Energy Policy* **2018**, *114*, 529–539. [CrossRef]
29. Šūmakaris, P.; Korsakienė, R.; Ščeulovs, D. Determinants of Energy Efficient Innovation: A Systematic Literature Review. *Energies* **2021**, *14*, 7777. [CrossRef]

30. Noailly, J.; Batrakova, S. Stimulating energy-efficient innovations in the Dutch building sector: Empirical evidence from patent counts and policy lessons. *Energy Policy* **2010**, *38*, 7803–7817. [CrossRef]
31. Altwies, J.E.; Nemet, G.F. Innovation in the US building sector: An assessment of patent citations in building energy control technology. *Energy Policy* **2013**, *52*, 819–831. [CrossRef]
32. International Energy Agency. World Energy Outlook. 2012. Available online: https://webstore.iea.org/world-energy-outlook-2012-2 (accessed on 1 August 2019).
33. Friedman, C.; Becker, N.; Erell, E. Retrofitting residential building envelopes for energy efficiency: Motivations of individual homeowners in Israel. *J. Environ. Plan. Manag.* **2018**, *61*, 1805–1827. [CrossRef]
34. Davis, A.; Wong-Parodi, G.; Krishnamurti, T. Neither a borrower nor a lender be: Beyond cost in energy efficiency decision-making among office buildings in the United States. *Energy Res. Soc. Sci.* **2019**, *47*, 37–45. [CrossRef]
35. Wong-Parodi, G.; Krishnamurti, T.; Davis, A.; Schwartz, D.; Fischhoff, B. A decision science approach for integrating social science in climate and energy solutions. *Nat. Clim. Change* **2016**, *6*, 563. [CrossRef]
36. Capozza, C.; Divella, M.; Rubino, A. Exploring energy transition in European firms: The role of policy instruments, demand-pull factors and cost-saving needs in driving energy-efficient and renewable energy innovations. *Energy Sources Part B Econ. Plan. Policy* **2021**, *16*, 1094–1109. [CrossRef]
37. Diaz-Rainey, I.; Ashton, J.K. Investment inefficiency and the adoption of eco-innovations: The case of household energy efficiency technologies. *Energy Policy* **2015**, *82*, 105–117. [CrossRef]
38. United Nations. 2019. SDG 7 Policy Briefs in Support of the High-Level Political Forum 2019. Available online: https://sustainabledevelopment.un.org/content/documents/22877UN_FINAL_ONLINE_20190523.pdf (accessed on 5 October 2019).
39. Sovacool, B.K. What are we doing here? Analysing fifteen years of energy scholarship and proposing a social science research agenda. *Energy Res. Soc. Sci.* **2014**, *1*, 1–29. [CrossRef]
40. Dunlop, T. Mind the gap: A social sciences review of energy efficiency. *Energy Res. Soc. Sci.* **2019**, *56*, 101216. [CrossRef]
41. Lutzenhiser, L. A cultural model of household energy consumption. *Energy* **1992**, *17*, 47–60. [CrossRef]
42. Stephenson, J.; Barton, B.; Carrington, G.; Gnoth, D.; Lawson, R.; Thorsnes, P. Energy cultures: A framework for understanding energy behaviours. *Energy Policy* **2010**, *38*, 6120–6129. [CrossRef]
43. Stephenson, J.; Barton, B.; Carrington, G.; Doering, A.; Ford, R.; Hopkins, D.; Lawson, R.; McCarthy, A.; Rees, D.; Scott, M.; et al. The energy cultures framework: Exploring the role of norms, practices and material culture in shaping energy behaviour in New Zealand. *Energy Res. Soc. Sci.* **2015**, *7*, 117–123. [CrossRef]
44. Fowler, L.; Neaves, T.T.; Terman, J.N.; Cosby, A.G. Cultural penetration and punctuated policy change: Explaining the evolution of US Energy Policy. *Rev Policy Res.* **2017**, *34*, 559–577. [CrossRef]
45. Dew, N.; Aten, K.; Ferrer, G. How many admirals does it take to change a light bulb? Organisational innovation, energy efficiency, and the United States Navy's battle over LED lighting. *Energy Res. Soc. Sci.* **2017**, *27*, 57–67. [CrossRef]
46. Stephenson, J. Sustainability cultures and energy research: An actor-centred interpretation of cultural theory. *Energy Res. Soc. Sci.* **2018**, *44*, 242–249. [CrossRef]
47. Rotzek, J.N.; Scope, C.; Günther, E. What energy management practice can learn from research on energy culture? *Sustain. Account. Manag. Policy J.* **2018**, *9*, 515–551. [CrossRef]
48. Bell, M.; Carrington, G.; Lawson, R.; Stephenson, J. Socio-technical barriers to the use of energy-efficient timber drying technology in New Zealand. *Energy Policy* **2014**, *67*, 747–755. [CrossRef]
49. Gill, N.; Osman, P.; Head, L.; Voyer, M.; Harada, T.; Waitt, G.; Gibson, C. Looking beyond installation: Why households struggle to make the most of solar hot water systems. *Energy Policy* **2015**, *87*, 83–94. [CrossRef]
50. Walton, S.; Zhang, A.; O'Kane, C. Energy eco-innovations for sustainable development: Exploring organisational strategic capabilities through an energy cultures framework. *Bus. Strategy Environ.* **2020**, *29*, 812–826. [CrossRef]
51. Zwetsloot, G.I.; van Middelaar, J.; Van der Beek, D. Repeated assessment of process safety culture in major hazard industries in the Rotterdam region (The Netherlands). *J. Clean. Prod.* **2020**, *257*, 120540. [CrossRef]
52. Lee, J. Safety culture evaluation model at construction site. *Int. J. Eng. Res. Technol.* **2019**, *12*, 1972–1977.
53. Jean, M.S.; Zaleschuk, L.P. Safety Culture Assessment and Continuous Monitoring Approach. In Proceedings of the 12th International Pipeline Conference, Calgary, AB, Canada, 24–28 September 2018; Volume 2, pp. 1–7. [CrossRef]
54. Musonda, L.; Lusenga, E.; Okoro, C. Rating and characterisation of an organisation's safety culture to improve performance. *Int. J. Constr. Manag.* **2018**, *21*, 181–193. [CrossRef]
55. Stiles, S.; Ryan, B.; Golightly, D. Readiness to Change: Perceptions of Safety Culture up and down the Supply Chain. In *Congress of the International Ergonomics Association*; Springer: Cham, Switzerland, 2018; pp. 213–223. [CrossRef]
56. Finnerty, N.; Sterling, R.; Coakley, D.; Contreras, S.; Coffey, R.; Keane, M.M. Development of a Global Energy Management System for non-energy intensive multi-site industrial organisations: A methodology. *Energy* **2017**, *136*, 16–31. [CrossRef]
57. Finnerty, N.; Sterling, R.; Coakley, D.; Keane, M.M. An energy management maturity model for multi-site industrial organisations with a global presence. *J. Clean. Prod.* **2017**, *167*, 1232–1250. [CrossRef]
58. Prashar, A. Energy efficiency maturity (EEM) assessment framework for energy-intensive SMEs: Proposal and evaluation. *J. Clean. Prod.* **2017**, *166*, 1187–1201. [CrossRef]
59. Introna, V.; Cesarotti, V.; Benedetti, M.; Biagiotti, S.; Rotunno, R. Energy Management Maturity Model: An organisational tool to foster the continuous reduction of energy consumption in companies. *J. Clean. Prod.* **2014**, *83*, 108–117. [CrossRef]

60. Ngai, E.W.T.; Chau, D.C.K.; Poon, J.K.L.; To, C.K.M. Energy and utility management maturity model for sustainable manufacturing process. *Int. J. Prod. Econ.* **2013**, *146*, 453–464. [CrossRef]
61. Jin, Y.; Long, Y.; Jin, S.; Yang, Q.; Chen, B.; Li, Y.; Xu, L. An energy management maturity model for China: Linking ISO 50001: 2018 and domestic practices. *J. Clean. Prod.* **2021**, *290*, 125168. [CrossRef]
62. Jovanović, B.; Filipović, J. ISO 50001 standard-based energy management maturity model—Proposal and validation in industry. *J. Clean. Prod.* **2016**, *112*, 2744–2755. [CrossRef]
63. Antunes, P.; Carreira, P.; da Silva, M.M. Towards an energy management maturity model. *Energy Policy* **2014**, *73*, 803–814. [CrossRef]
64. Ishak, M.H. Modelling energy consumption behaviour using "energy culture" concept for student accommodations in Malaysian public universities. *Facilities* **2017**, *35*, 658–683. [CrossRef]
65. Jürisoo, M.; Serenje, N.; Mwila, F.; Lambe, F.; Osborne, M. Old habits die hard: Using the energy cultures framework to understand drivers of household-level energy transitions in urban Zambia. *Energy Res. Soc. Sci.* **2019**, *53*, 59–67. [CrossRef]
66. Raggio, R.D.; Ekman, P.; Thompson, S.M. Making energy metrics relevant to service firms: From energy conservation to energy productivity. *J. Clean. Prod.* **2020**, *256*, 120493. [CrossRef]
67. Nie, H.; Vasseur, V.; Fan, Y.; Xu, J. Exploring reasons behind careful-use, energy-saving behaviours in residential sector based on the theory of planned behaviour: Evidence from Changchun, China. *J. Clean. Prod.* **2019**, *230*, 29–37. [CrossRef]
68. Axon, S.; Morrissey, J.; Aiesha, R.; Hillman, J.; Revez, A.; Lennon, B.; Salel, M.; Dunphy, N.; Boo, E. The human factor: Classification of European community-based behaviour change initiatives. *J. Clean. Prod.* **2018**, *182*, 567–586. [CrossRef]
69. Ford, R.; Walton, S.; Stephenson, J.; Rees, D.; Scott, M.; King, G.; Williams, J.; Wooliscroft, B. Emerging energy transitions: PV uptake beyond subsidies. *Technol. Forecast Soc. Change* **2017**, *117*, 138–150. [CrossRef]
70. Ambrosio-Albalá, P.; Upham, P.; Bale, C.S. Purely ornamental? Public perceptions of distributed energy storage in the United Kingdom. *Energy Res. Soc. Sci.* **2018**, *48*, 139–150. [CrossRef]
71. Schein, E.H.; Schein, P.A. *Organisational Culture, and Leadership*, 5th ed.; John Wiley & Sons, Incorporated: Hoboken, NJ, USA, 2017.
72. Paulk, M.C.; Curtis, B.; Chrissis, M.B.; Weber, C.V. Capability maturity model, version 1.1. *IEEE Softw.* **1993**, *10*, 18–27. [CrossRef]
73. Richardson, R.; Watkiss, R. The influence of leadership and Behaviours on safety Performance. In Proceedings of the SPE Offshore Europe Oil and Gas Exhibition and Conference, Aberdeen, UK, 2–5 September 2003. [CrossRef]
74. Fleming, M.; Wentzell, N. Patient safety culture improvement tool: Development and guidelines for use. *Healthc. Q.* **2008**, *11*, 5–10. [CrossRef]
75. Filho, A.P.G.; Andrade, J.C.S.; Marinho, M.M.O. A safety culture maturity model for petrochemical companies in Brazil. *Saf. Sci.* **2010**, *48*, 615–624. [CrossRef]
76. Daher, E. Safety Culture Maturity Model: A Process Worth Implementing? In Proceedings of the SPE Americas E&P Health, Safety, Security and Environmental Conference, Galveston, TX, USA, 18–20 March 2013. [CrossRef]
77. Zhang, F.; Zhang, Y.; Jun, L. Research on the maturity of real estate enterprises safety culture. *J. Appl. Sci.* **2013**, *13*, 2039–2044. [CrossRef]
78. Phusavat, K.; Vongvitayapirom, B.; Hidayanto, A.N. Enterprise development through the safety culture maturity model. *Int. J. Manag. Enterp. Dev.* **2015**, *14*, 89–102. [CrossRef]
79. Bordage, P.; Fox, C.; Arce, L.M.; Villarreal, G.; Celly, J.J.Y. Innovative ways to inspire new employees to embrace an HSE culture. In Proceedings of the International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, Perth, WA, Australia, 11–13 September 2012. [CrossRef]
80. Chaitanya, C.K.; Madala, M.K. A study on board characteristics and corporate performance of indian oil and gas upstream companies-evolving a board performance culture maturity model. *Indian J. Corp. Gov.* **2008**, *1*, 5–23. [CrossRef]
81. Jespersen, L.; Griffiths, M.; Maclaurin, T.; Chapman, B.; Wallace, C.A. Measurement of food safety culture using survey and maturity profiling tools. *Food Control* **2016**, *66*, 174–182. [CrossRef]
82. Munn, Z.; Peters, M.D.; Stern, C.; Tufanaru, C.; McArthur, A.; Aromataris, E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Med. Res. Methodol.* **2018**, *18*, 1–7. [CrossRef] [PubMed]
83. Pham, M.T.; Rajić, A.; Greig, J.D.; Sargeant, J.M.; Papadopoulos, A.; McEwen, S.A. A scoping review of scoping reviews: Advancing the approach and enhancing the consistency. *Res. Synth. Methods* **2014**, *5*, 371–385. [CrossRef]
84. O'Brien, A.M.; Mc Guckin, C. *The Systematic Literature Review Method: Trials and Tribulations of Electronic Database Searching at Doctoral Level*; SAGE Research Methods Cases Part 1; SAGE Publications Ltd.: London, UK, 2016; pp. 1–16. [CrossRef]
85. Kraus, S.; Breier, M.; Dasí-Rodríguez, S. The art of crafting a systematic literature review in entrepreneurship research. *Int. Entrep. Manag. J.* **2020**, *16*, 1023–1042. [CrossRef]
86. Torreglosa, J.P.; Garcia-Triviño, P.; Vera, D.; López-García, D.A. Analysing the Improvements of Energy Management Systems for Hybrid Electric Vehicles Using a Systematic Literature Review: How Far Are These Controls from Rule-Based Controls Used in Commercial Vehicles? *Appl. Sci.* **2020**, *10*, 8744. [CrossRef]
87. Princeton University Library, Energy Resources: Energy Databases. 2020. Available online: https://libguides.princeton.edu/Energy/ (accessed on 5 June 2021).
88. BUE Library, Energy & Environmental Engineering: Databases. 2021. Available online: https://bue.libguides.com/Energy/Databases/ (accessed on 5 June 2021).

89. Atenstaedt, R. Word cloud analysis of the BJGP: 5 years on. *Br. J. Gen. Pract.* **2017**, *67*, 231–232. [CrossRef] [PubMed]
90. McNaught, C.; Lam, P. Using Wordle as a supplementary research tool. *Qual. Rep.* **2010**, *15*, 630–643. [CrossRef]
91. Cherian, J.; Gaikar, V.; Paul, R.; Pech, R. Corporate Culture and Its Impact on Employees' Attitude, Performance, Productivity, and Behavior: An Investigative Analysis from Selected Organisations of the United Arab Emirates (UAE). *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 45. [CrossRef]
92. Kim, C.; Kim, K.A. The Institutional Change from E-Government toward Smarter City; Comparative Analysis between Royal Borough of Greenwich, UK, and Seongdong-gu, South Korea. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 42. [CrossRef]
93. Fayyaz, A.; Chaudhry, B.N.; Fiaz, M. Upholding Knowledge Sharing for Organization Innovation Efficiency in Pakistan. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 4. [CrossRef]
94. Chandler, N.; Krajcsák, Z. Intrapreneurial Fit and Misfit: Enterprising Behavior, Preferred Organizational and Open Innovation Culture. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 61. [CrossRef]
95. Ikram, A.; Fiaz, M.; Mahmood, A.; Ahmad, A.; Ashfaq, R. Internal Corporate Responsibility as a Legitimacy Strategy for Branding and Employee Retention: A Perspective of Higher Education Institutions. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 52. [CrossRef]
96. Yang, Q.; Mitchell, E.S.; Ho, A.; DeLuca, L.; Behr, H.; Michaelides, A. Cross-national outcomes of a digital weight loss intervention in the United States, Canada, United Kingdom and Ireland, and Australia and New Zealand: A Retrospective Analysis. *Front. Public Health* **2021**, *9*, 604937. [CrossRef] [PubMed]
97. Pal, L.A.; Clark, I.D. The MPA/MPP in the Anglo-democracies: Australia, Canada, New Zealand, the United Kingdom, and the United States. *Policy Soc.* **2016**, *35*, 299–313. [CrossRef]
98. Donelan, K.; Blendon, R.J.; Schoen, C.; Davis, K.; Binns, K. The Cost of Health System Change: Public Discontent in Five Nations: Amid widely divergent systems and cultural norms of health care, citizens express surprisingly similar concerns about the future. *Health Aff.* **1999**, *18*, 206–216. [CrossRef]
99. Khan, I. Impacts of energy decentralisation viewed through the lens of the energy cultures framework: Solar home systems in the developing economies. *Renew. Sust. Energ. Rev.* **2020**, *119*, 109576. [CrossRef]