Sustainable Technology and Entrepreneurship 1 (2022) 100007

Sustainable Technology and Entrepreneurship

https://www.journals.elsevier.com/sustainable-technology-and-entrepreneurship

Review

Sustainable energy development analysis: Energy Trilemma

Luisa Marti[a], Rosa Puertas[b,*]

[a] Group of International Economics and Development, Universitat Politècnica de València, Camino de Vera s/n, Valencia 46022 (Spain)
[b] Group of International Economics and Development, Universitat Politècnica de València, Camino de Vera s/n, Valencia 46022 (Spain)

A R T I C L E I N F O

Article History:
Received 1 December 2021
Accepted 8 January 2022

Keywords:
Energy trilemma
Cluster
Contingency tables
Country context

A B S T R A C T

Sustainable development is perceived as a socioeconomic system focused on meeting human needs while making long-term progress, with the end goal of ensuring well-being and improving quality of life. The objective of this article is to analyse the sustainable development policies assessed by the World Energy Trilemma Index (WETI) for 2020, based on its three pillars (*Energy security, Energy equity and Environmental sustainability*) and the political and economic context of 128 countries. To that end, cluster analysis and contingency tables are used. The first of these methods allows us to determine whether nations' economic profile influences their sustainable energy development, while the latter method is used to establish the possible connection between the political and economic context and the different aspects of sustainable development. The results of the cluster analysis reveal the existence of three homogeneous groups of countries, showing that the economies with the lowest GDP growth and the highest incomes hold the top positions in the WETI ranking. However, this association is not as clear when analysing the three energy trilemma pillars separately, pointing to the need for a more in-depth examination of each one. The contingency tables confirm the association between the *Country context* and sustainable energy development, showing that countries that are assigned a better grade for political and economic aspects adopt more appropriate energy measures. The research reveals the need for leaders' active engagement in the implementation of international agreements on climate change, thus facilitating the path towards sustainable development.

Introduction

The concept of sustainable development (SD) originally appeared in the Brundtland report published in 1987 by the World Commission on Environment and Development (WCED, 1987). It was the first time that the negative consequences of globalization had been documented, turning the focus of attention to industrialization and uncontrolled population growth. The term has now been extended and linked to all areas of society. It is based on three closely related basic pillars: environmental protection, social development and economic growth. Attempts to tackle challenges such as climate change or water scarcity are only viable if SD is promoted. In short, SD is about trying to meet people's needs in the present without compromising those of future generations. According to the Brundtland report, governments have to adopt population control measures in order to guarantee essential needs: education, health and housing; food security; access to drinking water and sanitation; and the conservation of biodiversity. At the same time, they must reduce fossil fuel consumption and encourage the use of renewable energies. SD can never be linked to unlimited economic growth, as it would be unsustainable and thus oxymoronic (Bolis et al., 2014; Hummels & Argyrou, 2021).

Many different definitions of SD have been proposed, some of which contradict each other, making it difficult to grasp the scope of this term (Klarin, 2018). More than two decades ago, Dobson (1996) documented over 300 definitions of SD; however, despite some differences between them, they all revolved around the original concept established by the WCED. SD can be understood as a socioeconomic system focused on meeting human needs while making long-term progress, with the end goal of ensuring well-being and improving quality of life, all within a framework of respect for the environment (Zhang & Zhu, 2020).

The need to achieve SD at all levels has prompted more than 30 years of international agreements and numerous action plans. This terminology has been included in all the United Nations (UN) programmes, from the Rio de Janeiro summit held in 1992—which gave rise to the United Nations Commission on Sustainable Development—to the Chile climate summit held in Madrid in 2019. Despite this, however, the joint international effort needed to guarantee success has not yet been achieved (Hák et al., 2018). According to

* Corresponding author at: Departamento de Economía y Ciencias Sociales, Universidad Politécnica de Valencia, Valencia, Spain.
E-mail addresses: mlmarti@esp.upv.es (L. Marti), rpuertas@esp.upv.es (R. Puertas).

https://doi.org/10.1016/j.stae.2022.100007

Van Opstal and Hugé (2013), it is because of leaders' lack of proactivity that SD has not had a sufficiently far-reaching influence on the world's population. It is essential that decision-makers evaluate the potential impact of all their proposals on society and the environment (Nogueira, 2019).

The Paris Agreement on Climate Change in 2015 and the publication of the Sustainable Development Goals (SDGs) in the same year marked a turning point in the struggle for a sustainable society. Both entail binding agreements, requiring not only a profound economic and social transformation, but also a commitment from all parties involved: governments, civil society, science and business (Huan et al., 2021). Sachs et al. (2019) propose six transformations needed to achieve the SDGs: (1) education, gender and inequality, (2) health, well-being and demography, (3) energy decarbonization and sustainable industry, (4) sustainable food, land, water and oceans, (5) sustainable cities and communities, and (6) digital revolution for SD.

This study focuses on the third transformation, aimed at ensuring access to modern energy sources, achieving the decarbonization of the energy system by midway through the century, and reducing pollution of the soil, water and air (WEO, 2017; WEO, 2016; Kümmerer et al., 2018). We use the World Energy Trilemma Index (WETI) for 2020 to carry out a thorough examination of this transformation through an analysis of the constituent pillars—*Energy security, Energy equity* and *Environmental sustainability*—while also assessing the specific political and economic context of the different countries. The results will provide answers to the following research questions:

Q1. Does the economic profile of a country influence its sustainable energy development?

The answer to this question can be found through a cluster analysis of the three pillars of the energy trilemma (*Energy security, Energy equity* and *Environmental sustainability*) and their association with the macroeconomic situation of the country measured in terms of GDP growth and GDPpc.

Q2. Is there a direct connection between the political and economic context and the different aspects of sustainable energy development?

Contingency tables can be used to measure the frequency of countries in the sample with similar categories in the analysed dimensions as well as the strength and sign of the association between public and private politics (assessed by the *Country context*) and the dimensions of the energy trilemma.

Building on the existing paradigm, the analysis in this research makes the following novel contributions: (1) it identifies the possible relationship between the economic situation and the energy sustainability (SDG 7) of a large group of countries; (2) it examines the extent to which the policies adopted by public and private decision-makers affect SD; (3) it uses a large database made up of 128 countries, on the basis of which different performance profiles of the countries in the sample are identified; (4) by avoiding the use of the overall WETI score it ensures that the conclusions obtained are not affected by potential shortcomings associated with a method of aggregating the pillars that does not account for possible differences between countries, (5) it uses up-to-date information referring to the year 2020, meaning that the conclusions drawn can be immediately implemented by leaders and can serve as a guide to future decisions on actions to take.

The rest of the article is structured in the following sections. The research on energy sustainability and economic growth is reviewed in Section 2. The composition of the sample and the methodology used in the research are presented in Section 3. The results are analysed in Section 4 and the main conclusions are discussed in Section 5.

Literature review: energy sustainability and economic growth

In the 2030 Agenda approved by the UN in 2015, the 17 SDGs proposed are aimed at ensuring the SD of the entire planet. They address major challenges related to social, economic and environmental issues. When implementing actions aimed at achieving these goals, there is a need to account for the interrelationships among them all in order to harness synergies and thus guarantee the success of the measures adopted (Lusseau & Mancini, 2019; Jiménez-Aceituno et al., 2019; Lucatello & Huber-Sannwald, 2020; Fartash et al., 2020). For example, SDG 7—affordable and clean energy—is central to efforts to eradicate poverty (SDG 1, SDG 2) and make progress on basic issues such as health (SDG 3), education (SDG 4) or care of the biosphere (SDG 13, SDG 14, SDG 15).

International agreements on climate change seek a proper transition to clean energy, reducing CO_2 emissions. They do so in a context characterized by continuous growth in energy demand driven by population growth, urbanization and industrialization (Lee et al., 2018). Specifically, SDG 7 sets three targets to be achieved by 2030: ensure universal access to affordable, reliable and modern energy services; increase the share of renewable energy in the energy mix; and double the global rate of improvement in energy efficiency. Alongside this ambitious goal (SDG 7), the Paris Agreement prioritizes keeping the global average temperature rise compared to pre-industrial levels well below 2°C. Against this backdrop of multiple interrelated objectives, the complexity involved in assessing the progress made by different countries becomes clear. Consequently, there has been an immediate reaction from the research community, with the publication of abundant literature on the development of synthetic indices that enable comparative analyses, which in turn guide the decisions to be taken by the responsible parties (Diaz-Sarachaga et al., 2018; Venghaus & Dieken, 2019; Horan, 2020).

For example, the International Energy Agency measures both the production and consumption of energy as well as energy self-sufficiency and global energy intensity (IEA, 2019). The International Index of Energy Security Risk estimates global energy security risks using a qualitative and quantitative reference model in order to better understand their importance (Global Energy Institute, 2018). The World Energy Council's WETI, used in this research, measures the energy performance of more than a hundred countries. The WETI is used internationally as a tool to support decision-making in energy policy and governance. Due to the broad spectrum covered by this index, it has given rise to an extensive literature, seeking to highlight the lack of political and ecological aspects, and linking energy security—understood as security of supply—to the other two dimensions of energy equity and environmental sustainability (WEC, 2020).

The WETI establishes an energy performance ranking of countries based on the aggregation of four weighted pillars. This aggregation has sparked a number of controversies due to the underlying differences between the assessed countries. As an alternative, Song et al. (2017) suggest applying stochastic multicriteria acceptability analysis to determine the holistic acceptability indices, facilitating the exploration of the weighting space for each country. Likewise, Šprajc et al. (2019) question the methodology behind the configuration of the index, deeming it somewhat unreliable if only the overall result is evaluated. Asbahi et al. (2019) use the WETI to provide evidence of a negative correlation between *Energy security* and *Environmental sustainability*. They call for all countries to commit to achieving sustainable energy use, with the development of new technologies that ensure efficiency in terms of affordable, clean and reliable energy.

Another branch of the literature has focused on investigating the possible association between the energy trilemma and economic growth. Khan et al. (2021) propose an index merging the three pillars of the energy trilemma, from which they obtain the independent variable used in the second part of their study, where the impact of the energy trilemma on economic growth is analysed. The authors show that in the most advanced countries according to the WETI there is a positive relationship between the two variables over the long term. According to Esen and Bayrak (2017), this positive association requires an efficient use of energy, with the authors reporting evidence of a negative relationship between the level of income and the effect of energy consumption on economic growth. Khan and Hou (2021) expand on these conclusions by showing that higher energy consumption is associated with intense growth and notable CO_2 emissions.

Following this line of research, Armeanu et al. (2021) investigate the possible linkages between energy, CO_2 emissions, economic growth and urbanization at a global scale, using a sample of 106 countries spanning 25 years. Based on the results, some specific recommendations can be made. For example, countries classified as low income by the World Bank should use renewable energy to reduce their energy intensity, and authorities should be encouraged to levy additional charges on carbon emissions. Jun et al. (2021) examine the impact of globalization, non-renewable energy consumption and growth on CO_2 emissions in South Asia. The study shows that the consumption of non-renewable energy increases environmental pollution, with a positive relationship found between economic growth and environmental pollution up to a threshold, at which point the relationship is reversed. Asiedu et al. (2021) investigate the effect of renewable and non-renewable energy on growth in 26 European countries, finding bidirectional causality between renewable energy consumption and economic growth, as well as between renewable and non-renewable energy consumption. European governments are urged to invest in renewable energies, which will reduce CO_2 emissions over the long term.

Furthermore, the analysis of the connection between the macroeconomic situation and the three dimensions of the energy trilemma has also focused on specific countries such as Pakistan (Nawaz & Alvi, 2018), Brazil (Prado et al., 2016), Germany (Coester et al., 2020), and Japan (Gasparatos & Gadda, 2009), among others. This research broadens the scope of action by analysing 128 countries with the latest available information, corresponding to 2020, allowing valuable conclusions to be drawn.

Material and methods

The World Energy Council has published the WETI annually since 2010. Its objective in doing so is to provide an assessment of the performance of the energy systems of 128 countries, establishing a ranking based on the dimensions of the energy trilemma and the countries' political and economic context. Specifically, the analysed aspects are grouped into the following pillars:

- *Energy security* (30%): ability to meet current and future energy demand, taking into account management efficiency, reliability and resilience to shocks that entail supply disruptions.
- *Energy equity* (30%): ability to provide the population with access to an energy supply, with a focus on the affordability of the supply.
- *Environmental sustainability* (30%): ability to avoid environmental degradation and the impacts of climate change. The focus here is on productivity and efficiency of generation, distribution, decarbonization, and air quality.
- *Country context* (10%): measures macroeconomic and governance conditions, the stability of the economy and the government, as well as the country's attractiveness to investors and capacity for innovation.

The percentage indicates the weight of each pillar in the calculation of the overall index score; as such, changes in a country's energy performance have a greater impact than any change in its macroeconomic or governance conditions. The WETI score ranges from 0 to 100, and is used to generate a ranking of the 128 countries based on the aggregation of the aspects considered. The three dimensions of the energy trilemma are quantitatively assessed and a letter (A, B, C, or D) is assigned according to the quartile to which they belong. *Country context* is not given a numerical score but is just assigned a grade of a, b, c, or d depending on the level attributed on the basis of certain facts about the country. By tracking the scores over several years leaders can get a fair assessment of the progress they have made, and benchmark against the successes or failures of their counterparts (Table 1A, 2A, 3A and 4A in the Appendix).

Table 1
Descriptive statistics of the dimensions of the energy trilemma.

	Energy security	*Energy equity*	*Environmental sustainability*
Mean	56.38	76.35	67.93
SD	11.27	23.79	11.44
Min	27.70	8.20	39.00
Max	77.10	100.00	90.00

Table 1 shows the descriptive statistics of the three dimensions of the energy trilemma. All of them have been used to calculate the clusters, thereby responding to the first research question.

Table 1 shows a wide dispersion in *Energy equity* among the countries analysed. In contrast to the highest score registered by Luxembourg (100), there are countries like Niger, which scores just over 8.2 points. Luxembourg is a small, densely populated nation, lacking natural energy resources, but with the highest GDPpc in Europe and a strong connection to international energy markets. All this, together with its low road fuel taxes, contributes to an affordable and accessible energy supply. In the *Environmental sustainability* dimension, Switzerland registers a score of 90 points, closely followed by Sweden and Norway. These are economies that are keenly aware of the need for transformation and the orientation of new technological advances towards renewable energy supplies. They enjoy a very diversified energy system, counting on government support to promote the reduction of greenhouse gas emissions. Lastly, in *Energy security* it can be seen that all countries still have a long way to go to improve their grade. Canada, Finland and Romania top the ranking with 77.1, 75.4 and 74.5 points, respectively. These are countries with abundant hydrocarbon resources and markedly diversified and decarbonized energy systems, giving them an advantage over the rest.

The empirical part of the research is based a cluster analysis of the 128 countries in the sample, as well as the construction of contingency tables relating the pillars of the WETI. Cluster analysis is suitable for studies aimed at the grouping of data and has been widely used in several areas: agriculture and the food industry (Reiff et al., 2018), sustainable development indicators (Megyesiova & Lieskovska, 2018), renewable energy and economic growth (Ntanos et al., 2018), climate change (Puertas & Marti., 2021) and waste treatment (Marti & Puertas, 2021). In this paper, it has been applied to identify groups of countries similar to one another in terms of their energy performance *(Energy security, Energy equity* and *Environmental sustainability*). By so doing, we can determine the possible connection with the countries' macroeconomic situation (Q1). Specifically, Ward's method has been used to identify which clusters to merge in successive steps, taking the squared Euclidean distance as a measure of similarity. This method is preferable to others because it minimizes the variance within each cluster, emphasizing internal homogeneity (Ward, 1963; Lance & Williams, 1967). The Kruskal-Wallis test is then used to confirm the adequacy of the defined groups, by verifying that the mean of each one is statistically different from the rest.

Based on the pillars of the WETI categorized into four levels (A, B, C, D), contingency tables have been created to provide an answer to Q2. The aim is to explore the association between the political and economic context and each one of the pillars of the energy trilemma. Three contingency tables have been created, with the following structure (Table 2).

Table 2
General structure of contingency tables of observed frequencies.

	INDICATOR "A"					
	Criterion *i*	A	B	C	D	Total
INDICATOR "B"	A	$n_{1,1}$	$n_{1,2}$	$n_{1,3}$	$n_{1,4}$	$n_{1,\bullet}$
	B	$n_{2,1}$	$n_{2,2}$	$n_{2,3}$	$n_{2,4}$	$n_{2,\bullet}$
	C	$n_{3,1}$	$n_{3,2}$	$n_{3,3}$	$n_{3,4}$	$n_{3,\bullet}$
	D	$n_{4,1}$	$N_{4,2}$	$n_{4,3}$	$n_{4,4}$	$n_{4,\bullet}$
	Total	$n_{\bullet,1}$	$n_{\bullet,2}$	$n_{\bullet,3}$	$n_{\bullet,4}$	$n_{5,\bullet}$

Based on the data in Table 2 the expected frequencies are calculated using the following expression:

$$Eij = \frac{n_{i.} n_{.j}}{N} \tag{1}$$

where, N is the total number of observations in the table, $n_{i,\bullet}$ is the number of observations in row i, and $n_{\bullet,j}$ is the number of observations in column j.

Both the observed and expected frequencies are necessary to perform the χ^2 test showing whether the variables considered in the study are independent or not. The result of the χ^2 test confirms whether the levels of a qualitative variable influence those of another variable. The χ^2 test is defined by the following expression:

$$\chi^2 = \frac{\sum_{i=1}^{h} \sum_{j=1}^{k} \left(n_{ij} - E_{ij}\right)^2}{E_{ij}} \tag{2}$$

where, n_{ij} is the observed frequency, and E_{ij} is the expected frequency. The null hypothesis is that of independence between factors. The alternative hypothesis is that of dependence between factors.

In addition, the Gamma coefficient, which indicates the strength of the link between the two analysed variables, is used as a measure of association. Its value ranges between -1 and 1, with the sign indicating either a direct or inverse relationship between the pillars studied. This method has been widely used in the literature; it can be applied to any field of research to determine the frequency of association between two variables (Sujová & Remeň, 2018; Zelterman & Louis, 2019; Mahieu et al., 2020; Sumekar and Al-Baarri, 2020).

Results and discussion

The pillars of the WETI are aimed at assessing the complicated goals governments face when attempting to guarantee competitive energy supply and access to energy, while also striving to protect the environment. Based on these pillars and countries' macroeconomic situation, this study first seeks to establish a hierarchy of the different countries in the sample to identify similarities in their sustainable energy systems (Q1).

Q1. Does the economic profile of a country influence its sustainable energy development?

The dendrogram resulting from the application of the cluster method reveals three homogeneous groups of countries; the first is composed of 78 countries, the second 27 and the third 23 (Table 5A in the Appendix). The Kruskal-Wallis test confirms the adequacy of the grouping by identifying significant differences between the means of each group (χ^2 is significant at a p-value<0.05). Table 3 shows the mean values for the total sample, as well as those for the three resulting clusters.

By comparing the mean for the sample of 128 countries included in the WETI and the mean for each of the clusters, we can define profiles of their Energy performance (Table 3). These values have been compared with the mean values for economic growth, measured in terms of GDP, and the level of wealth (GDPpc) of the countries that make up each of the resulting clusters. This comparison provides an answer to Q1, clarifying whether the pillars of the energy trilemma are influenced by countries' macroeconomic situation. The clusters can be characterized as follows:

- *Cluster 1* (C1) is made up of 78 countries with a high level of wealth (€26,108/inhab) and a mean GDP growth of close to 2.5%. Fig. 1 shows the 10 countries that hold the top WETI positions in this cluster according to their overall score, with all of them registering more than 80 points: Switzerland, Sweden, Denmark, Austria, Finland, France, UK, Canada, Germany and Norway. They all have a GDPpc of over $40,000 (Luxembourg with $116,640, Switzerland $82,797 and Norway $81,697) and show moderate growth, ranging from 1.3% in Norway to 2.8% in Switzerland. However, there is no uniformity in the levels reached in the three dimensions of the index. On the one hand, all these nations show a strong commitment to environmental sustainability by allocating substantial resources to achieving clean, environmentally-friendly energy, while the situation is very different in the dimensions *Energy equity* and *Energy security*. France, Germany and Sweden hold a much lower position in *Energy equity* (32nd, 33rd and 39th, respectively) compared to other countries such as Iran or Lebanon (9th and 17th, respectively); the latter are characterized by their precarious economic situation (zero growth and a GDPpc of $5628 in Iran, and 0.2% growth and a GDPpc of $ 8270 in Lebanon).

Regarding *Energy security,* the performance of Norway and Luxembourg is noteworthy: while they achieve good scores in the other two dimensions, they register just 60 and 54.3 points, respectively, in this dimension. They both lie behind countries such as Nigeria, Guatemala or El Salvador, all of which are categorized as lower middle income by the World Bank. One of the reasons for this is that Luxembourg's score is influenced by the size of its geographical area, which limits its diversity and capacity to generate energy resources (Belaïd, 2017). The situation in Norway is very different: the results analysed capture the impact of COVID-19. This is a country whose exports far exceed its domestic consumption; however, in the last year the authorities have decided to reduce oil production to help stabilize the world market. Hence, the results contradict those reported in the study by (Asbahi et al., 2019), where Norway held the top position for this dimension in 2015 according to an index based on WETI proposed by the authors.

Table 3
Kruskal-Wallis test and the mean values of the indicators for the 3 clusters.

	Energy security	*Energy equity*	*Environmental sustainability*	GDP Growth (%)	GDPpc (PPP US $)	Number of countries
Total Mean	56.38	76.35	67.93	3.19	18,333.20	128
C1 Mean	62.70	89.52	69.47	2.49	26,108.99	78
C2 Mean	47.55	75.37	71.36	3.13	10,384.52	27
C3 Mean	45.32	32.81	58.68	5.66	1294.17	23
	Test Kruskall-Wallis					
χ^2	61.81	71.02	20.74			
p-value	0.000	0.000	0.000			

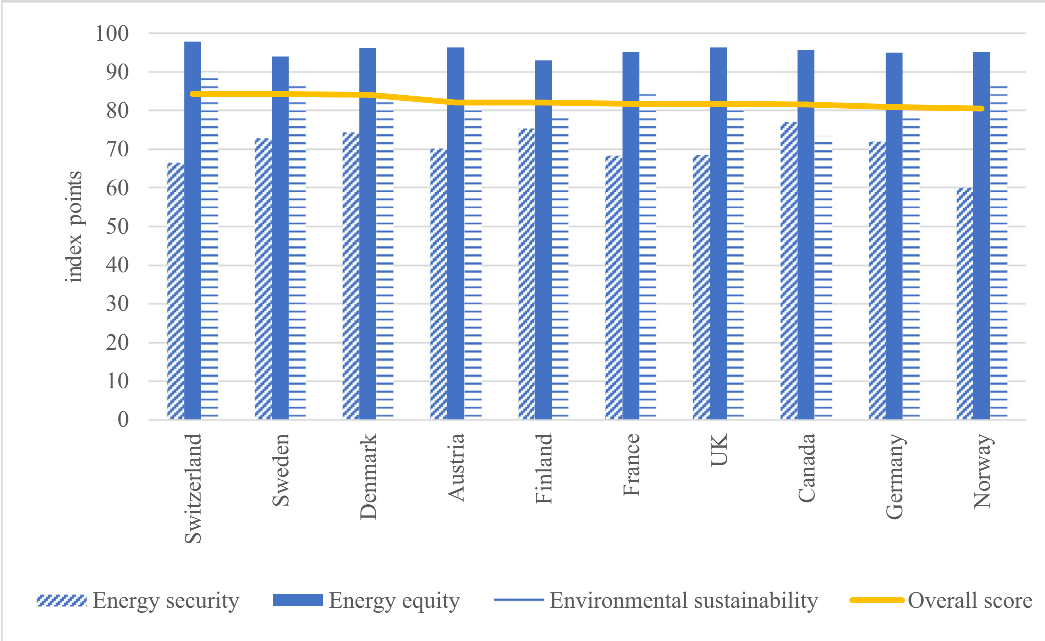

Fig. 1. Energy trilemma of the top 10 countries in cluster 1 according to the WETI overall score.

- *Cluster 2* (C2), comprising 27 countries, with a mean GDPpc of over $10,300 and economic growth of 3.13%, occupies an intermediate position. This group is composed of nations that are very proactive on environmental issues; indeed, it is the cluster that shows the strongest commitment to decarbonization and cutting CO_2 emissions. Fig. 2 shows the top 10 countries in C2 terms of overall WETI score, with values ranging between 66 and 72 points: Singapore, Hong Kong, Cyprus, Costa Rica, Albania, Panama, Armenia, Montenegro, Paraguay and Georgia. This group shows a marked disparity between dimensions of the energy trilemma. They all hold very low positions in *Energy security* (with scores for this pillar ranging between 54.5 for Georgia and 37.9 for Singapore), more middling positions in *Energy equity*, and they are among the top 10 countries in the full sample in terms of *Environmental sustainability* (with Albania in 4th place, Panama 6th and Costa Rica 7th). They are characterized as having focused their policies on mitigating and preventing environmental degradation and the impacts of climate change. In short, these are economies focused on efficient productivity, decarbonization and air quality.

Furthermore, it can be seen that countries such as Singapore, Cyprus and Hong Kong, whose income ranges from $28,159 per capita in Cyprus to $64,582 in Singapore, obtain a very low score in *Energy security* (37.9, 42.7 and 37.9), while they hold the top positions in *Energy equity* (with a score of 92.5, 98.1 and 98.1), and *Energy sustainability*. Authors such as Veloria (2020) demonstrate that Singapore in particular does not need to increase its endowment of energy resources; rather it needs technological innovation policies that make it possible to reduce the existing energy gap between supply and demand, along with international agreements that promote and facilitate its participation in the global energy system. For their part, Ligus and Peternek (2021) propose a composite index incorporating

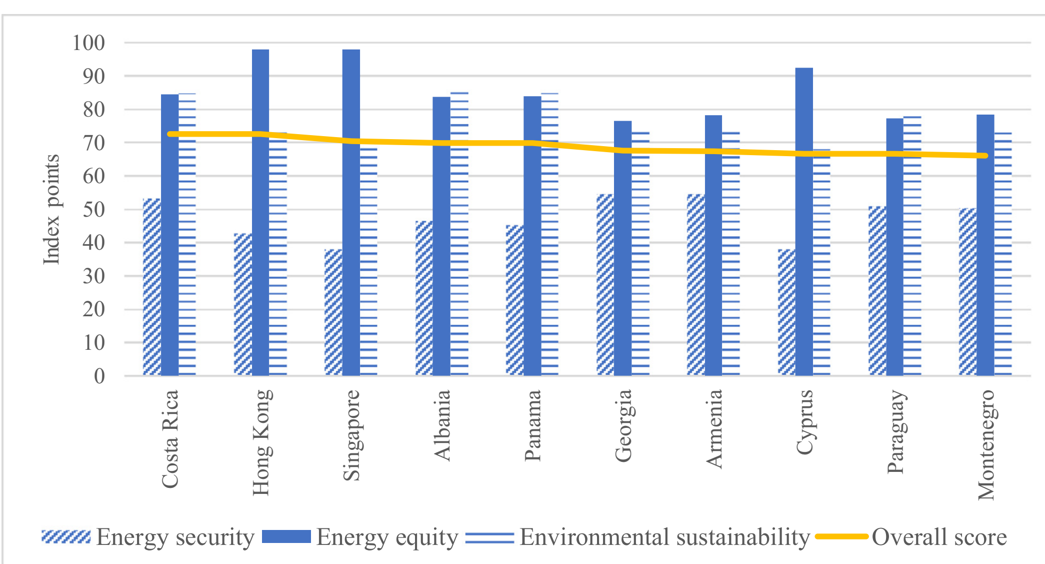

Fig. 2. Energy trilemma of the top 10 countries in cluster 2 according to the WETI overall score.

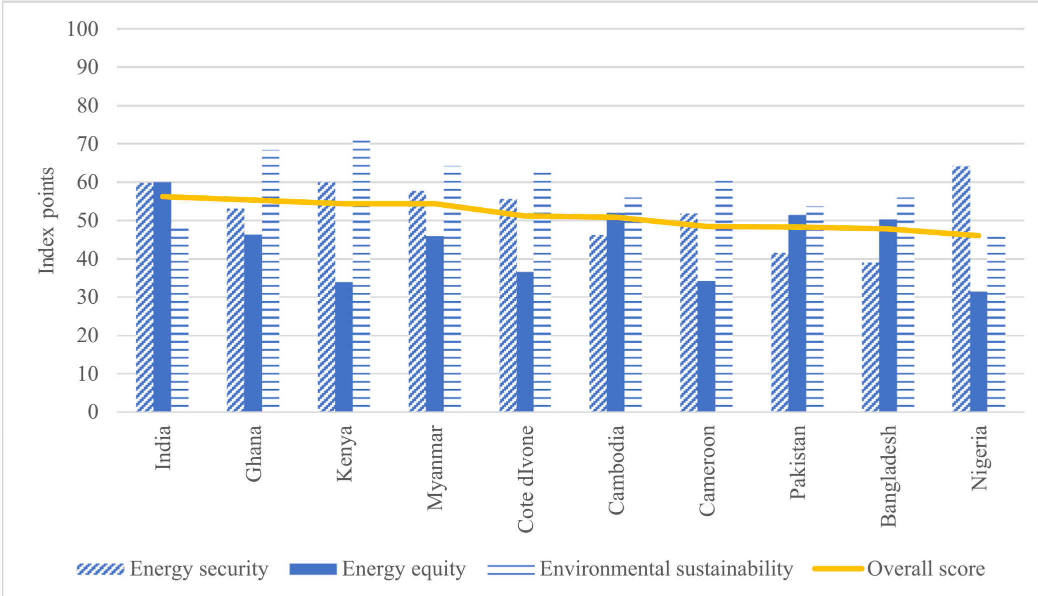

Fig. 3. Energy trilemma of the top 10 countries in cluster 3 according to the WETI overall score.

all the dimensions of the energy trilemma—the Energy Development Aggregated Index—according to which Cyprus is in the penultimate position of all the European countries, only ahead of Bulgaria.

- *Cluster 3* (C3), composed of 23 countries, brings together African and Asian countries with limited economic resources (Mozambique, Niger and Myanmar with $499, $414 and $1326 per capita) and countries with high growth rates (Armenia, Montenegro and Georgia with growth rates of 5.2, 5.1 and 4.8%). In general, they have very low scores in all the aspects assessed by the energy trilemma, showing huge room for improvement in energy competitiveness and environmental protection. Fig. 3 shows the 10 countries in C3 that register the highest WETI score (with values between 46 and 56 points): India, Ghana, Kenya, Myanmar, Côte d'Ivoire, Cambodia, Cameroon, Pakistan, Bangladesh and Nigeria. When assessing the whole sample, all these countries are in the bottom quartile in terms of *Energy equity* and five of them are for *Environmental sustainability* (Bangladesh, Cambodia, Pakistan, India and Nigeria). Regarding *Energy security*, they are split between the third and fourth quartile, with Pakistan and Bangladesh standing out as the worst rated (41.6 and 39 points, respectively).

According to Oliver Wyman (2015) the countries that are weakest in terms of energy performance should focus on improving their efficiency to reduce energy demand and increase energy security and economic competitiveness. In this vein, Jain and Goswami (2021) show that the endowment of energy resources, the production of renewable energy, the price of crude oil, population density and GDPpc are all factors that significantly influence the energy efficiency of countries in South Asia. Alemzero et al. (2021) develop a composite index of energy security in Africa, based on which they call for more intense intraregional trading of energy, as well as investments in renewable energy and energy infrastructure to guarantee supply and ensure environmental sustainability.

Summing up, in answer to Q1 it can be said that the established clusters show that the countries characterized as having lower growth and higher income on average (cluster 1) are found in the top positions of the WETI. However, when analysing the pillars of the energy trilemma this association is less clear. For example, Luxembourg, which has GDP growth of more than 3% and the highest GDPpc in the analysed sample, holds the top position in *Energy equity*, but just 15th place in *Environmental sustainability* and 78th in *Energy security*. This confirms that the score obtained is not so dependent on the country's macroeconomic situation or on the volume of resources available. *Energy security* is strongly influenced by the country's ability to decarbonize energy systems and introduce alternative energies. Regarding *Energy equity*, public instruments play a key role in supporting this dimension through the adoption of policies that foster extraction and transport of supply. The *Environmental sustainability* pillar essentially depends on countries' degree of engagement in international agreements on climate change. Thus, in this dimension, Albania, with a per capita GDP of only $5269, rubs shoulders with countries classified as high income by the World Bank. This is due to its ratification of the Paris Agreement and its effective commitment to cut greenhouse gas emissions (0.017% of global emissions).

Q2. Is there a direct connection between the political and economic context and the different aspects of sustainable energy development?

In response to the second research question, three contingency tables have been created to measure the level of association between the political and economic context and the three pillars of the energy trilemma (Table 4). The result will indicate whether macroeconomic stability, government effectiveness and innovation capacity influence countries' ability to achieve a top score for the performance of their energy systems.

The results of Pearson's chi-squared test (p-*value*<0.05) confirm the association between the *Country context* and the three pillars. The value of the Gamma statistic (p-*value*<0.05) reveals the positive relationship between the analysed dimensions. As reflected in the contingency tables, the extreme categories for each of the variables (the first quartile A and the fourth quartile D) contain the most countries (Table 4). For example, those countries that get good grades in *Environmental sustainability* also score well in *Country context* (17 countries). These are countries with a highly innovative profile, macroeconomic stability and a good perception of the quality of public services and policies. In general, this association is repeated for the other pillars. Based on these results, we can answer Q2: the countries' political and economic context underpins the scores obtained in

Table 4
Results of contingency tables.

		Country context				
Environmental sustainability		A	B	C	D	Total
	A	17 (13.3%)	8 (6.2%)	6 (4.7%)	2 (1.6%)	33 (25.8%)
	B	14 (10.9%)	5 (3.9%)	14 (10.9%)	7 (5.55%)	40 (31.2%)
	C	3 (2.3%)	4 (3.1%)	10 (7.8%)	11 (88.6%)	28 (21.9%)
	D	2 (1.6%)	5 (3.9%)	8 (6.2%)	12 (9.4%)	27 (21.1%)
	Total	36 (28.1%)	22 (17.2%)	38 (29.7%)	32 (25%)	128 (100%)
Pearson's chi-squared: 30.060 (*p-value*: 0.000)						
Gamma: 0.496 (*p-value*: 0.000)						
		Country context				
Energy equity		A	B	C	D	Total
	A	26 (20.3%)	6 (4.7%)	3 (2.3%)	3 (2.3%)	38 (29.7%)
	B	10 (7.8%)	15 (11.7%)	15 (11.7%)	6 (4.7%)	46 (35.9%)
	C	-	1 (0.8%)	12 (9.4%)	5 (3.9%)	18 (14.1%)
	D	-	-	8 (6.2%)	18 (14.1%)	26 (20.3%)
	Total	36 (28.1%)	22 (17.2%)	38 (29.7%)	32 (25%)	128 (100%)
Pearson's chi-squared: 89.267 (*p-value*: 0.000)						
Gamma: 0.788 (*p-value*: 0.000)						
		Country context				
Energy security		A	B	C	D	Total
	A	15 (11.7%)	7 (5.5%)	6 (4.7%)	5 (3.9%)	33 (25.8%)
	B	12 (9.4%)	5 (3.9%)	13 (10.2%)	7 (5.5%)	37 (28.9%)
	C	4 (3.1%)	7 (5.5%)	10 (7.8%)	3 (2.3%)	24 (18.8%)
	D	5 (3.9%)	3 (2.3%)	9 (7%)	17 (13.3%)	34 (26.6%)
	Total	36 (28.1%)	22 (17.2%)	38 (29.7%)	32 (25%)	128 (100%)
Pearson's chi-squared: 26.002 (*p-value*: 0.002)						
Gamma: 0.383 (*p-value*: 0.000)						

the SD dimensions. Decision-makers responsible for implementing energy measures should foster the introduction of new technologies and proactive policies aimed at integrating clean, accessible energy for all citizens. These suggestions are supported by the conclusions reached in other studies carried out by the research community (Warren & Jack, 2018; Quitoras et al., 2020; Grigoryev & Medzhidova, 2020).

Conclusions

Achieving the SDGs requires a global commitment from all nations to ensure the adaptation of not just their economies but also of their way of life, moving towards a situation that is more conducive to SD. These goals cannot be analysed in isolation. They constitute a package that needs to be addressed from all possible perspectives: social, economic and environmental. This research carries out a comprehensive analysis of the pillars of the energy trilemma (SDG 7) in order to guide decision-makers, both public and private, in their task of implementing measures that foster the use of clean, affordable energy.

The results show that countries' macroeconomic situation does not determine all the aspects assessed. The active involvement of leaders in the implementation of international agreements on climate change is required. This will ensure that all nations orient their policies in the right direction, fostering the implementation of sustainable energies, avoiding international dependence and guaranteeing that the entire population has affordable access to energy. In addition, the study provides evidence that these measures, assessed in *Country context,* are strongly associated with the level achieved in the different dimensions of the energy trilemma.

The main limitation of this analysis is that it is a dynamic study, requiring regular updates with new statistical information. A country's evolution and involvement in SD issues tends to be notably affected by the political orientation of its leaders; hence, any change in government can alter the situation in the country and change its course. All this underlines the need to continue adapting the conclusions to a multifaceted situation in which the implementation of the established agreements is assured.

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.

Appendix

Table 1A, 2A, 3A, 4A and 5A

Table 1A
Dimensions of the energy trilemma of Africa.

	Energy security	*Energy equity*	*Environmental sustainability*
Algeria	55.2	85.6	57.9
Angola	69.4	54	79
Benin	35.6	20.9	39
Botswana	41.9	70.4	63.9
Cameroon	51.7	34.1	61.8
Congo	35.2	8.4	73.7
Cote dIvone	55.6	36.5	63
Egypt	58.1	84	44
Eswatini	41.1	66	71.5
Ethiopia	36	31.5	61.5
Gabon	58.9	79.5	62.5
Ghana	53.1	46.3	68.4
Kenya	59.9	33.8	70.9
Magascar	43.8	11.2	67.2
Malawi	43.5	8.9	63.1
Mauritania	43.4	33	59.2
Mauritius	42	81	74.6
Morocco	46.1	79.3	65.6
Mozambique	44.8	18.3	60.7
Namibia	42.6	55.3	78
Niger	30.5	8.2	43.3
Nigeria	64.1	31.4	45.7
Senegal	40.8	32.6	57
South Africa	52	77.4	58.6
Tanzania	43.4	22.1	68.1
Tunisia	56.4	83.8	61.4
Zambia	43.1	31.6	60.5
Zimbawe	42.8	38.6	57.8

Table 2A
Dimensions of the energy trilemma of Asia.

	Energy security	*Energy equity*	*Environmental sustainability*
Australia	63.2	95.8	66.9
Azerbaijan	68.4	85.8	69.2
Bahrain	60	99.7	42.2
Bangladesh	39	50.4	56
Brunei	54.1	94.4	60.7
Cambodia	46.1	52	55.9
China	64.5	80.8	57.7
Hong Kong	42.7	98.1	72.9
India	59.7	60	49.1
Indonesia	67.9	72	64.5
Iran	65.1	98.7	54.4
Iraq	42	85	49.7
Israel	50.6	97.3	67.5
Japan	59.4	94.3	74.5
Jordan	41.1	69.9	60.9
Korea Rep	60.5	97.1	64.3
Kuwait	59.8	99.8	47.2
Lebanon	27.7	97.3	60.7
Malaysia	64.3	86.7	69.4
Mongolia	46	77.5	44.3
Myanmar	57.7	45.9	64.1
Nepal	31	47.5	49.9
New Zealand	64.9	94.6	78.9
Oman	50.9	99.7	50.6
Pakistan	41.6	51.5	53.7
Philippines	59.6	56.4	68
Qatar	65.5	99.8	42.9
Saudi Arabia	59.9	99	44.3
Singapore	37.9	98.1	70.3
Sri Lanka	53.8	60.3	71
Tajikistan	45.4	67.5	63.2
Thailand	54	78.5	66.2
United Arab Emirates	59.3	99.8	49.2
Vietnam	61.4	76	61.1

Table 3A
Dimensions of the energy trilemma of Europe.

	Energy security	*Energy equity*	*Environmental sustainability*
Albania	46.5	83.8	85.8
Armenia	54.5	78.3	73.8
Austria	70.2	96.3	81.9
Belgium	60.4	95.2	77
Bosnia and Herzegovina	58.8	74.6	61.4
Bulgaria	72.2	85.9	73
Croatia	67.8	88.1	77.8
Cyprus	37.9	92.5	68
Czech Rep	72.4	93.6	72.4
Denmark	74.4	96.2	83.4
Estonia	62.5	94.8	69.5
Finland	75.4	93	78.1
France	68.3	95.1	85.5
Georgia	54.5	76.5	73.8
Germany	72	95	77.8
Greece	53.8	90.7	73.2
Hungary	72.1	94.5	75.8
Iceland	56	99.3	75
Ireland	56.2	98.1	77.9
Italy	66.6	95.8	81.5
Kazakhstan	69.2	88.2	58.6
Latvia	74.1	83.7	74.6
Lithuania	60.9	95.7	79.2
Luxembourg	54.3	100	80.3
Malta	46.1	95.8	78.8
Moldova	48.7	68.6	56.2
Montenegro	50.4	78.4	73
Netherlands	59.2	98	72.5
North Macedonia	56.7	87.7	69.6
Norway	60	95.1	87.2
Poland	62.7	84.7	65.9
Portugal	63.7	92.2	78.1
Romania	74.5	78.8	79
Russia	69.1	97	62.5
Serbia	62.1	77.7	62.2
Slovakia	70.1	84.2	80.3
Slovenia	67.9	93.4	77
Spain	65.7	92.4	79.8
Sweden	72.8	94	87.5
Switzerland	66.4	97.9	90
Turkey	56.7	83.8	66
UK	68.4	96.3	82.5
Ukraine	70.2	75.4	69.9

Table 4A
Dimensions of the energy trilemma of America.

	Energy security	*Energy equity*	*Environmental sustainability*
Argentina	63.1	95.9	75.5
Barbados	56.1	90.4	75.2
Bolivia	59.8	73.7	62.6
Brazil	72.6	77.8	83.4
Canada	77.1	95.6	73.4
Chile	62	82.3	71.9
Colombia	63.7	75.8	83.8
Costa Rica	53.2	84.6	84.7
Dominican Rep	47.7	83	71.2
Ecuador	65	84.5	78.6
El Salvador	61.1	75.9	78.2
Guatemala	63	65	71.2
Honduras	49.3	67.1	69.7
Jamaica	40.7	82.5	67.2
Mexico	59.9	84.6	69.6
Nicaragua	50.1	59.7	69.6
Panama	45.2	83.9	84.9
Paraguay	50.9	77.4	78.1
Peru	67.3	73.5	74.9
Trinidad and Tobago	50.3	97.9	48.6
Uruguay	60.8	91.2	84.2
USA	72.2	96.7	71.6
Venezuela	67.4	86.2	74.1

Table 5A
Countries in each cluster.

	Countries
CLUSTER 1	Bahrain, Barbados, Brunei, Croatia Kuwait, Latvia, Lithuania, Malta, Oman, Qatar, Russia, Saudi Arabia, Trinidad and Tobago, United Arab Emirates, Uruguay, Australia, Austria, Belgium, Canada, Chile, Czech Rep, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea Rep, Luxembourg, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, UK, USA, Bolivia, Egypt, El Salvador, Indonesia, Mongolia, Ukraine, Vietnam, Algeria, Argentina, Azerbaijan, Bosnia and Herzegovina, Brazil, Bulgaria, China, Colombia, Ecuador, Gabon, Hungary, Iran, Iraq, Kazakhstan, Malaysia, Mexico, North Macedonia, Peru, Romania, Serbia, South Africa, Thailand, Tunisia, Turkey, Venezuela
CLUSTER 2	Cyprus, Hong Kong, Singapore, Tajikistan, Armenia, Eswatini, Georgia, Guatemala, Honduras, Mauritius, Moldova, Morocco, Nicaragua, Paraguay, Philippines, Sri Lanka, Albania, Angola, Botswana, Costa Rica, Dominican Rep, Jamaica, Jordan, Lebanon, Montenegro, Namibia, Panama
CLUSTER 3	Bangladesh, Benin, Cambodia, Congo, Ethiopia, Kenya, Madagascar, Malawi, Mozambique, Myanmar, Nepal, Niger, Tanzania, Zimbabwe, Cameroon, Cote d'Ivoire, Ghana, India, Nigeria, Pakistan, Senegal, Zambia, Mauritania

References

Alemzero, D. A., Sun, H., Mohsin, M., Iqbal, N., Nadeem, M., & Vo, X. V. (2021). Assessing energy security in Africa based on multi-dimensional approach of principal composite analysis. *Environmental Science and Pollution Research*, *28*, 2158–2171. doi:10.1007/s11356-020-10554-0.

Armeanu, D. S., Joldes, C. C., Gherghina, S. C., & Andrei, J. V. (2021). Understanding the multidimensional linkages among renewable energy, pollution, economic growth and urbanization in contemporary economies: Quantitative assessments across different income countries' groups. *Renewable and Sustainable Energy Reviews*, *142*, 110818. doi:10.1016/j.rser.2021.110818.

Asbahi, A. A. M. H. A., Gang, F. Z., Iqbal, W., Abass, Q., Mohsin, M., & Iram, R. (2019). Novel approach of Principal Component Analysis method to assess the national energy performance via Energy Trilemma Index. *Energy Reports*, *5*, 704–713. doi:10.1016/j.egyr.2019.06.009.

Asiedu, B. A., Hassan, A. A., & Bein, M. A. (2021). Renewable energy, non-renewable energy, and economic growth: evidence from 26 European countries. *Environmental Science and Pollution Research*, *28*, 11119–11128. doi:10.1007/s11356-020-11186-0.

Belaïd, F. (2017). Untangling the complexity of the direct and indirect determinants of the residential energy consumption in France: Quantitative analysis using a structural equation modeling approach. *Energy Policy*, *110*, 246–256. doi:10.1016/j.enpol.2017.08.027.

Bolis, I., Morioka, S. N., & Sznelwar, L. I. (2014). When sustainable development risks losing its meaning. Delimiting the concept with a comprehensive literature review and a conceptual model. *Journal of Cleaner Production*, *83*, 7–20. doi:10.1016/j.jclepro.2014.06.

Coester, A., Hofkes, M. W., & Papyrakis, E. (2020). Economic analysis of batteries: impact on security of electricity supply and renewable energy expansion in Germany. *Applied Energy*, *275*, 115364. doi:10.1016/j.apenergy.2020.115364.

Diaz-Sarachaga, J. M., Jato-Espino, D., & Castro-Fresno, D. (2018). Is the Sustainable Development Goals (SDG) index an adequate framework to measure the progress of the 2030 Agenda? *Sustainable Development*, *26*, 663–671. doi:10.1002/sd.1735.

Dobson, A. (1996). Environmental Sustainabilities: an analysis and a typology. *Environmental Politics*, *5*, 401–428. doi:10.1080/09644019608414280.

Esen, O., & Bayrak, M. (2017). Does more energy consumption support economic growth in net energy-importing countries? *Journal of Economics, Finance and Administrative Science*, *22*, 75–98. doi:10.1108/JEFAS-01-2017-0015.

Fartash, K., Khayatian, M., Ghorbani, S., & Sadabadi, A. (2020). Interpretive structural analysis of interrelationships of the Sustainable Development Goals (SDGs) in Iran. *International Journal of Sustainable Development and Planning*, *16*, 155–163. doi:10.18280/ijsdp.160116.

Gasparatos, A., & Gadda, T. (2009). Environmental support, energy security and economic growth in Japan. *Energy Policy*, *37*, 4038–4048. doi:10.1016/j.enpol.2009.05.011.

Global Energy Institute (2018). *International index of energy security risk 2018 Edition: Assessing risk in a Global Energy Market*. Washington.

Grigoryev, L. M., & Medzhidova, D. D. (2020). Global energy trilemma. *Russian Journal of Economics*, *6*, 437–462. doi:10.32609/j.ruje.6.58683.

Hák, T., Janoušková, S., Moldan, B., & Dahl, A. L. (2018). Closing the sustainability gap: 30 years after "Our Common Future", society lacks meaningful stories and relevant indicators to make the right decisions and build public support. *Ecological Indicators*, *87*, 193–195. doi:10.1016/j.ecolind.2017.12.017.

Horan, D. (2020). National baselines for integrated implementation of an environmental sustainable development goal assessed in a new integrated SDG Index. *Sustainability*, *12*, 6955. doi:10.3390/su12176955.

Huan, Y., Liang, T., Li, H., & Zhang, C. (2021). A systematic method for assessing progress of achieving sustainable development goals: A case study of 15 countries. *Science of The Total Environment*, *752*, 141875. doi:10.1016/j.scitotenv.2020.141875.

Hummels, H., & Argyrou, A. (2021). Planetary demands: Redefining sustainable development and sustainable entrepreneurship. *Journal of Cleaner Production*, *278*, 123804. doi:10.1016/j.jclepro.2020.123804.

IEA. (2019). *IEA Atlas of Energy*International Energy Agency. Retrieved from http://energyatlas.iea.org/#!/tellmap/1378539487 Accessed September 3, 2021.

Jain, P., & Goswami, B. (2021). Energy efficiency in South Asia: Trends and determinants. *Energy*, *221*, 119762. doi:10.1016/j.energy.2021.119762.

Jiménez-Aceituno, A., Peterson, G. D., Norström, A. V., Wong, G. Y., & Downing, A. S. (2019). Local lens for SDG implementation: lessons from bottom-up approaches in Africa. *Sustainability Science*, *15*, 729–743. doi:10.1007/s11625-019-00746-0.

Jun, W., Mughal, N., Zhao, J., Shabbir, M. S., Niedbała, G., Jain, V., & Anwar, A. (2021). Does globalization matter for environmental degradation? Nexus among energy consumption, economic growth, and carbon dioxide emission. *Energy Policy*, *153*, 112230. doi:10.1016/j.enpol.2021.112230.

Khan, I., & Hou, F. (2021). Does multilateral environmental diplomacy improve environmental quality? The case of the United States. *Environmental Science and Pollution Research*, *28*, 23310–23322. doi:10.1007/s11356-020-12005-2.

Khan, I., Hou, F., Irfan, M., Zakari, A., & Le, H. P. (2021). Does energy trilemma a driver of economic growth? The roles of energy use, population growth, and financial development. *Renewable and Sustainable Energy Reviews*, *146*, 111157. doi:10.1016/j.rser.2021.111157.

Klarin, T. (2018). The concept of sustainable development: From its beginning to the contemporany issues. *Zagreb International Review of Economics & Business*, *21*, 67–94. doi:10.2478/zireb-2018-0005.

Kümmerer, K., Dionysiou, D. D., Olsson, O., & Fatta-Kassinos, D. (2018). A path to clean water. *Science*, *361*, 222–224. doi:10.1126/science.aau2405.

Lance, G. N., & Williams, W. T. (1967). A general theory of classificatory sorting strategies. I. Hierarchical systems. *The Computer Journal*, *9*, 373–380.

Lee, K-Y., Tsao, S-H., Tzeng, C-W., & Lin, H-J. (2018). Influence of the vertical wind and wind direction on the power output of a small vertical-axis wind turbine installed on the rooftop of a building. *Applied Energy*, *209*, 383–391. doi:10.1016/j.apenergy.2017.08.185.

Ligus, M., & Peternek, P. (2021). The Sustainable Energy Development Index—An application for European Union member states. *Energies*, *14*, 1117. doi:10.3390/en14041117.

Lucatello, S., & Huber-Sannwald, E. (2020). Sustainable development goals and drylands: Addressing the interconnection. In S. Lucatello, E. Huber-Sannwald, I. Espejel, N. Martínez-Tagüeña (Eds.), *Stewardship of future drylands and climate change in the global south*. Springer Climate.

Lusseau, D., & Mancini, F. (2019). Income-based variation in sustainable development goal interaction networks. *Nature Sustainability*, *2*, 242–247. doi:10.1038/s41893-019-0231-4.

Mahieu, B., Visalli, M., & Schlich, P. (2020). Accounting for the dimensionality of the dependence in analyses of contingency tables obtained with Check-All-That-Apply and Free-Comment. *Food Quality and Preference*, *83*, 103924. doi:10.1016/j.foodqual.2020.103924.

Marti, L., & Puertas, R. (2021). Influence of environmental policies on waste treatment. *Waste Management*, *126*, 191–200. doi:10.1016/j.wasman.2021.03.009.

Megyesiova, S., & Lieskovska, V. (2018). Analysis of the sustainable development indicators in the OECD countries. *Sustainability*, *10*, 4554. doi:10.3390/su10124554.

Nawaz, S. M. N., & Alvi, S. (2018). Energy security for socio-economic and environmental sustainability in Pakistan. *Heliyon*, *4*, e00854. doi:10.1016/j.heliyon.2018.e00854.

Nogueira, C. (2019). Contradictions in the concept of sustainable development: An analysis in social, economic, and political contexts. *Environmental Development*, *30*, 129–135. doi:10.1016/j.envdev.2019.04.004.

Ntanos, S., Skordoulis, M., Kyriakopoulos, G., Arabatzis, G, Chalikias, M, Galatsidas, S, Batzios, A., & Katsarou, A. (2018). Renewable energy and economic growth: evidence from European countries. *Sustainability*, *10*, 2626. doi:10.3390/su10082626.

Oliver Wyman. (2015). *World Energy Trilemma: Priority actions on climate change and how to balance the trilemma*. Retrieved from https://www.worldenergy.org/publications/entry/world-energy-trilemma-2015-priority-actions-on-climate-change-and-how-to-balance-the-trilemma Accessed September 18, 2021.

Prado, F. A., Athayde, S., Mossa, J., Bohlman, S., Leite, F., & Oliver-Smith, A. (2016). How much is enough? An integrated examination of energy security, economic growth and climate change related to hydropower expansion in Brazil. *Renewable and Sustainable Energy Reviews*, *53*, 1132–1136. doi:10.1016/j.rser.2015.09.050.

Puertas, R., & Marti, L. (2021). International ranking of climate change action: An analysis using the indicators from the Climate Change Performance Index. *Renewable and Sustainable Energy Reviews*, *148*, 111316. doi:10.1016/j.rser.2021.111316.

Quitoras, M. R., Campana, P. E., Rowley, P., & Crawford, C. (2020). Remote community integrated energy system optimization including building enclosure improvements and quantitative energy trilemma metrics. *Applied Energy*, *267*, 115017. doi:10.1016/j.apenergy.2020.115017.

Reiff, M., Ivanicova, Z., & Surmanova, K. (2018). Cluster analysis of selected world development indicators in the fields of agriculture and the food industry in European Union countries. *Agricultural Economics*, *64*, 197–205. doi:10.17221/198/2016-AGRICECON.

Sachs, J. D., Schmidt-Traub, G., Mazzucato, M., Messner, D., Nakicenovic, N., & Rockström, J. (2019). Six transformations to achieve the Sustainable Development Goals. *Nature Sustainability*, *2*, 805–814. doi:10.1038/s41893-019-0352-9.

Song, L., Fu, Y., Zhou, P., & Lai, K. K. (2017). Measuring national energy performance via Energy Trilemma Index: A stochastic multicriteria acceptability analysis. *Energy Economics*, *66*, 313–319. doi:10.1016/j.eneco.2017.07.004.

Šprajc, P., Bjegović, M., & Vasić, B. (2019). Energy security in decision making and governance - Methodological analysis of energy trilemma index. *Renewable and Sustainable Energy Reviews*, *114*, 109341. doi:10.1016/j.rser.2019.109341.

Sujová, A., & Remeň, O. (2018). Management of changes in business processes: an empirical study in Slovak enterprises. *Engineering Management in Production and Services*, *10*, 37–50. doi:10.2478/emj-2018-0015.

Sumekar, W., & Al-Baarri, A. N (2020). Study in agroindustry of salted egg: Length of salting process and marketing reach aspects. *Journal of Applied Food Technology*, *7*, 25–28. doi:10.17728/jaft.7427.

Van Opstal, M., & Huge, J. (2013). Knowledge for sustainable development: A worldviews perspective. *Environment, Development and Sustainability*, *15*, 687–709. doi:10.1007/s10668-012-9401-5.

Veloria, M. D. (2020). *Energy security in Singapore*. Naval Postgraduate School Master's Thesis.

Venghaus, S., & Dieken, S. (2019). From a few security indices to the FEW Security Index: Consistency in global food, energy and water security assessment. *Sustainable Production and Consumption*, *20*, 342–355. doi:10.1016/j.spc.2019.08.002.

Ward, J. H. (1963). Hierarchical grouping to optimize an objective function. *Journal of the American Statistical Association*, *58*, 236–244. doi:10.1080/01621459.1963.10500845.

Warren, L., & Jack, L. (2018). The capital budgeting process and the energy trilemma - A strategic conduct analysis. *The British Accounting Review*, *50*, 481–496. doi:10.1016/j.bar.2018.04.005.

WCED. (1987). *Our common future. World commission on environment and development*. Oxford University Press.

WEC. (2020). *World energy trilemma index 2020*. World Energy Council.
WEO. (2016). *Energy and air Pollution. World energy outlook special report*. International Energy Agency.
WEO. (2017). *Energy access outlook. World energy outlook special report*. International Energy Agency.
Zelterman, D., & Louis, T. A. (2019). Contingency tables in medical studies. In J. Bailar, & F. Mosteller (Eds.), *Medical uses of statistics*. (2nd ed.). Boca Raton: CRC Press.
Zhang, S., & Zhu, D. (2020). Have countries moved towards sustainable development or not? Definition, criteria, indicators and empirical analysis. *Journal of Cleaner Production*, *267*, 121929. doi:10.1016/j.jclepro.2020.121929.