sustainability

Article

Evaluating Renewable Energy and Ranking 17 Autonomous Communities in Spain: A TOPSIS Method

Danial Esfandiary Abdolmaleki, Shoeib Faraji Abdolmaleki and Pastora M. Bello Bugallo *

TECHNASE Research Group, Department of Chemical Engineering, Universidade de Santiago de Compostela, 15782 Santiago de Compostela, Spain; shoeib.faraji@rai.usc.es (S.F.A.)
* Correspondence: pastora.bello.bugallo@usc.es

Abstract: Transitioning to renewable energy is becoming increasingly imperative, particularly for countries with limited energy supplies. To achieve this transition, all sectors must cooperate and coordinate to focus on renewable energy as a pillar of sustainable development. This study evaluates the status of renewable energy in each Spanish community, considering policies, frameworks, and elements of sustainable development. Using the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) methodology, seventeen autonomous communities of Spain were analyzed based on ten selected indicators. The results show that Castile and León, La Rioja, Murcia, and Aragon are in the top ranks of the first sustainable group, while Navarre, the Balearic Islands, Catalonia, the Basque Country, and Asturias are in the less sustainable group. This research presents novel contributions towards the adoption of sustainability-oriented policies aimed at enhancing energy systems, stimulating economic growth, and achieving zero-carbon energy targets in Spain. By enhancing the self-sufficiency of energy communities, they can attain demand-side energy independence, decreasing the requirement for government intervention, and mitigating concerns regarding the adequacy of energy resources. This can ultimately enhance social well-being, emphasizing the importance of sustainable energy systems for regional development in Spain.

Keywords: renewable energy systems; energy sustainability; the TOPSIS method; autonomous communities of Spain

check for updates

Citation: Esfandiary Abdolmaleki, D.; Faraji Abdolmaleki, S.; Bello Bugallo, P.M. Evaluating Renewable Energy and Ranking 17 Autonomous Communities in Spain: A TOPSIS Method. *Sustainability* **2023**, *15*, 12259. https://doi.org/10.3390/su151612259

Academic Editor: Elisa Marrasso

Received: 17 March 2023
Revised: 9 June 2023
Accepted: 9 August 2023
Published: 11 August 2023

1. Introduction

In the 21st century, the transition from non-renewable to renewable and sustainable sources of energy is of paramount importance for all governments. Industrialized nations have taken significant steps towards this transition by developing and implementing their own strategies, resulting in improvements in their economic, environmental, and social well-being—the three pillars of sustainable development. However, for these objectives to be achieved, all components of an integrated economic or energy system must work together and coordinate their efforts. Identifying and addressing the weaknesses of each component can increase the overall efficiency of the entire system.

Despite the progress made in transitioning towards renewable energy, there is still a significant gap between current practices and what is needed to meet the global demand for sustainable energy. In Spain, energy sustainability has made significant progress, as demonstrated by the increasing share of renewable energy in gross final energy consumption, which went from 18.4% in 2019 to 20% in 2020, in addition to the share of renewable energy in the national electricity mix, which went from 33% in 2010 to 44% in 2020 [1,2]. While significant progress has been made in increasing the share of renewable energy sources in the energy mix, there are still many challenges that need to be addressed to accelerate the transition. Furthermore, there is a need for interdisciplinary research which can integrate economic, social, and environmental perspectives to identify the most effective pathways for achieving a sustainable energy future [1,3,4].

In addition, signs of several gaps in the overall system can be seen, which will be mentioned below. However, Spain is at the forefront of renewable energy, and policy makers and academic literature are investigating and studying this significant and emerging phenomenon [5]. One of the gaps is the lack of specific quantitative goals at the national level, which uses a combined life cycle assessment and energy modeling system to examine the state of energy security at the national level [1]. On the other hand, Spain has seventeen autonomous communities, each with their own unique conditions and objectives. Therefore, the level of development of these local communities in transitioning away from fossil fuels towards renewable energy, as well as their cooperation and integration into an integrated system, is crucial [6,7].

There have been various studies based on renewable energy in Spain, in which Spain has been studied at the scale of EU policies. For example, the study of laws at the national and international level has been done for European countries that are moving towards the use of renewables in a single project. They believe that energy communities facilitate stakeholder access to financial, technical, organizational, and administrative assistance for achieving self-sufficiency, energy security, and independence, including energy consultation, capacity optimization, retrofit advice, and paperwork guidance; and that energy poverty harms social, living, and health conditions [8]. The EU mandates that member states address it with cross-field policies and financial aid. Spain aids disadvantaged consumers based on electricity tariffs and power, but this is not an exact measure of vulnerability [9]. Therefore, the condition of the sustainability of energy in communities seems significant.

Economics versus renewables in Spain indicates logistic growth in solar power development and a proportional relationship between each country's saturation level and GDP [10]. The potential for cooperation in the field of energy to support and export renewable resources can improve the European energy system. In this context, recommendations have been made for the energy market in Spain, strengthening interconnections with France [11]. Also, renewable electricity exchanges between Mediterranean countries face geopolitical and energy security concerns. This profile explores the geopolitics of Moroccan–Spanish cooperation, identifying factors that drive or hinder development [12]. Hence, the level of sustainability at which the communities of Spain can provide and transport enough electricity will be interesting.

To align with the Sustainable Development Goals (SDGs), it is necessary to integrate renewable energy projects into regional development strategies and establish novel governance models to effectively support the energy transition [13]. At this level, investigating renewable energy investment in the community for sustainable energy systems, autonomy, development, and circular economies is necessary.

Upon closer analysis, it becomes apparent that creating energy communities can address political pressures stemming from electricity sector liberalization, price volatility, and reduced subsidies for consumers. These advantages differ from conventional benefits and may not be fully understood by those surveyed. By enhancing the self-sufficiency of energy communities, they can attain demand-side energy independence, decreasing the requirement for government intervention in electricity pricing, and mitigating concerns regarding the adequacy of energy resources. Ultimately, this can heighten social well-being in the electricity sector [8].

Consequently, conducting a study that evaluates the status of renewable energy in each Spanish community, while considering the policies, frameworks, and elements of sustainable development can play a vital role in adopting sustainability-oriented improvement policies, enhancing energy systems, stimulating economic growth, and achieving zero-carbon energy targets.

Renewable energy is becoming increasingly important to mitigate the effects of climate change and reduce carbon emissions. Spain has made significant progress in developing its renewable energy sector, with different autonomous communities playing important roles in this field. However, there is still much to be learned about the specific circumstances of each community and how they can best contribute to a sustainable energy future for Spain. This study aims to conduct a comprehensive study of the autonomous communities in Spain and their roles in the renewable energy sector, with the goal of identifying opportunities for further development and collaboration in this critical area based on the methodology of the TOPSIS. This approach allows for the ability to rank the autonomous communities according to their overall performance and identify opportunities for improvement [14]. This research will contribute to a better understanding of the renewable energy sector in Spain and provide valuable insights for policymakers, researchers, and industry stakeholders.

The potential of renewable energy varies across the different autonomous communities in Spain, depending on factors such as geographical location, climate, and infrastructure. In this regard, some studies have focused on the potential of renewable energy in Spain and the implications of its development for the country's economy and environment. For instance, the authors in ref. [9] provided a review of the public policies, R&D investment, and energy mix of renewable energy in Spain. Scholars in ref. [15] applied the TOPSIS methodology to sustainable energy planning in a Mediterranean region, while ref. [16] used the same approach for renewable energy planning in the Region of Murcia. Duarte et al. (2022) surveyed the significance of each community in terms of its degree of influence, level of perception, and degree of hope regarding renewable energy in rural areas [7]. Additionally, studies have discussed the significance of local communities, the function of cooperatives, and their influence on renewable energy generation.

Overall, this study aims to make a significant contribution to the field of renewable energy in Spain by providing a comprehensive evaluation of the state of the sector in the seventeen autonomous communities. By doing so, this research promotes sustainable energy generation and contributes to the global efforts to mitigate climate change.

2. Materials and Methods

Instead of conducting a general study in Spain to better understand the country's circumstances, a novel approach was used to focus on its seventeen autonomous communities, which are the key players in the field of energy sustainability. Each community was evaluated separately based on its facilities and conditions to better understand Spain. To evaluate each of these autonomous communities and rate their position in renewable energy and its sustainability, we are currently concentrating on Spain's total energy system.

In general, there are five general steps that are taken to implement the study's primary objectives, which are to examine the sustainability of renewable energy, thoroughly examine the research alternatives, and rank them using the TOPSIS method (Figure 1). In the first step, which consists of three general subsets, two brainstorming meetings were held to examine the research strategies as well as how to choose evaluation indicators and select twenty primary indicators. To rank these seventeen alternatives and evaluate the sustainability of energy, practical indicators were required by literature and library resources, and the final twenty indicators have been raised (considering all three dimensions of sustainable development, i.e., economic, social, and environmental).

In the second stage of the research process, after data gathering, the indicators were filtered to ten indicators based on their availability and feasibility in the context of the evaluating data section. This was done to ensure that the indicators were reliable and relevant to the research objectives. The selection of the indicators was a crucial step in the research process as it ensured that the data collected were of high quality, thereby enhancing the validity and reliability of the research outcomes.

Subsequently, a questionnaire was developed and administered with the assistance of seven experts in the field. The questionnaire was designed to obtain information and the responses were weighted according to their relative importance. The weightings were determined based on the expert opinions, and they reflected the significance of each criterion.

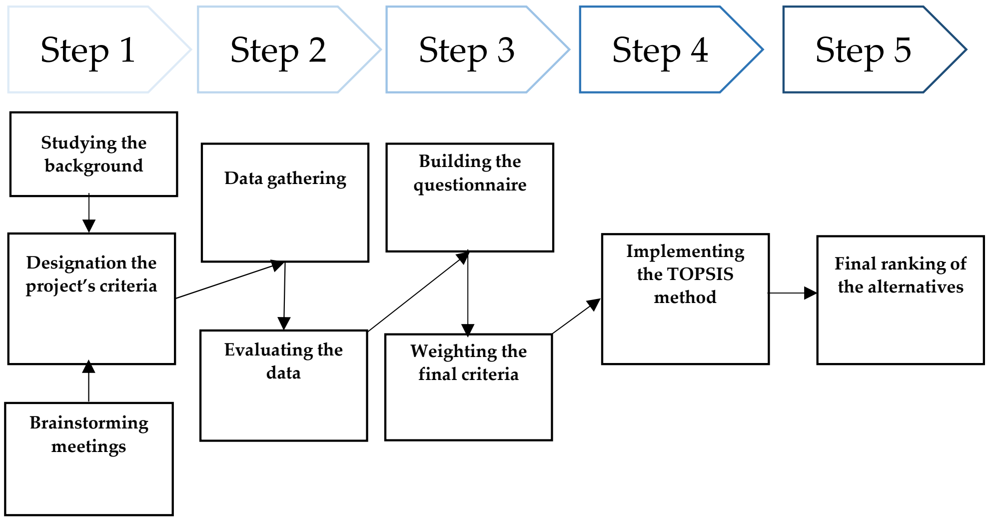

Figure 1. Conceptual model.

In the fourth stage, the TOPSIS method was employed to rank the research alternatives. TOPSIS is a multi-criteria decision-making method that is widely used in research and industry. It involves evaluating the alternatives against multiple criteria and determining the relative proximity of each alternative to the ideal solution. To facilitate the implementation of the TOPSIS method, MATLAB (R2022a) software was utilized to code and execute the algorithm. MATLAB is a powerful tool that is widely used in data analysis and scientific research. It allowed the research team to process a large amount of data efficiently and accurately, ensuring the validity and reliability of the research outcomes.

In the final stage of the research process, the outcomes obtained from the TOPSIS analysis were utilized to rank the research alternatives and present the results. The outcome of the research process was a set of ranked alternatives that were evaluated based on the selected criteria.

2.1. Alternatives and Indicators

Among the available twenty parameters for evaluating energy sustainability, the final ten indicators are listed in Table 1 after the indicators were filtered based on availability, practicality, comprehensiveness, expressiveness, and significance.

2.1.1. Share of Renewable

The share of renewable energy is a key indicator in assessing the progress and success of renewable energy deployment in the autonomous communities of Spain. It is the proportion of total energy consumption that is met by renewable sources, such as wind, solar, hydro, biomass, and geothermal. The higher the share of renewable energy, the lower the reliance on fossil fuels and the greater the reduction in greenhouse gas emissions. Achieving a high share of renewable energy requires a combination of policies and strategies, including the development of renewable energy infrastructure, the implementation of supportive regulatory frameworks, and the adoption of innovative financing mechanisms [17,18].

2.1.2. Installed Capacity

This represents the maximum amount of power that can be produced by renewable energy sources installed in a specific region. This indicator is important because it provides a snapshot of the region's potential for generating renewable energy [19]. Installed capacity depends on various factors, including the availability of natural resources, the level of investment in renewable energy infrastructure, and the regulatory frameworks governing renewable energy deployment. A higher installed capacity implies a greater potential for producing renewable energy and a lower reliance on fossil fuels.

Table 1. Indicators set and their explanations with final weights.

Indicators	Weight	Explanation	Direction
Share of RE	9.25	Share of renewable energy generation in total energy generation	+
Installed Capacity	8.1	Installed capacity in energy (MW) per capita (pop) ∗ 1000	+
GDP	7.125	GDP per capita	+
HDI	6.375	Human Development Index	+
Life Expectancy	3.875	The number of years that an individual is expected to live, on average	+
Unemployment Rate	5.15	Total unemployment rate among all groups	−
CO_2 Emission	7.3	Refers to the release of carbon dioxide into the atmosphere	−
Total Generation	8.4	Total energy generation (MWh) per population	+
Electricity Consumption	7.4	Electricity consumption (MWh) per inhabitant	−
Budget Deficit	5.1	By percentage of GDP	−

In this regard, the indicators affect the ranking in three ways: (1) directions; (2) weights; (3) values. In this research, six indicators have a positive direction (the higher the value, the better), and four indicators have a negative direction (the higher the value, the worse).

2.1.3. GDP

GDP (Gross Domestic Product) is an important indicator in assessing the impact of renewable energy on the economic development of the autonomous communities of Spain. It is related to the monetary value of all the goods and services produced in the region over a specified period (a year). The GDP of a region is influenced by various factors, including investment in renewable energy infrastructure, employment in the renewable energy sector, and the reduction of energy costs. Renewable energy deployment can have a positive impact on GDP (and conversely) through the creation of jobs, the development of local supply chains, and the reduction of energy import costs. However, the relationship between renewable energy and GDP can be complex (in this study it is considered as a positive impact), as it depends on a variety of factors, including the level of investment, the cost competitiveness of renewable energy technologies, and the regulatory frameworks that support their deployment [20–22].

2.1.4. HDI

The HDI (Human Development Index) is a measure of human development and well-being in a region. It considers three dimensions of human development: a long and healthy life, access to knowledge, and a decent standard of living. The HDI is a composite index, with values ranging from zero to one, where higher values indicate higher levels of human development. Renewable energy deployment can have a positive impact on HDI through several channels. Firstly, renewable energy technologies can improve access to electricity in rural and remote areas, which can have a significant impact on health and education outcomes. Secondly, renewable energy can reduce the environmental impact of energy production, which can lead to improvements in air and water quality, as well as reduced risks of climate change. Thirdly, renewable energy can create employment opportunities and support local economic development, which can contribute to a decent standard of living [23–25].

2.1.5. Life Expectancy

Life expectancy is a measure of the average number of years that a person can expect to live in each region. It is influenced by a variety of factors, including access to healthcare, nutrition, sanitation, and environmental conditions. Renewable energy deployment can have a positive impact on life expectancy through several channels. Firstly, renewable energy can reduce air pollution and greenhouse gas emissions, which can lead to improvements in respiratory and cardiovascular health. Secondly, renewable energy can improve access to electricity, which can support the provision of healthcare services and improve living conditions. Thirdly, renewable energy can create employment opportunities and support economic development, which can contribute to better health outcomes [26,27].

2.1.6. Unemployment Rate

Renewable energy deployment can have a negative impact on unemployment if it leads to the closure of traditional fossil fuel industries and the displacement of workers who are not able to transition to new jobs. In some cases, the skills required for traditional fossil fuel industries may not be transferable to the renewable energy sector, leading to a potential skills mismatch and higher levels of structural unemployment. Additionally, some argue that renewable energy deployment may lead to an overall reduction in the demand for energy, which could result in job losses in related industries such as transportation and manufacturing. For example, if renewable energy sources become more prevalent and efficient, there may be a decreased demand for fossil fuel-based transportation and products that require high energy input during production. Governments can implement training and education programs for workers to acquire the necessary skills for renewable energy jobs, as well as provide financial support for job retraining and placement services. Additionally, investment in research and development of new technologies can create new job opportunities in emerging industries [28,29].

2.1.7. CO_2 Emissions

Carbon dioxide (CO_2) emissions are key indicators in assessing the environmental impact of renewable energy deployment. Renewable energy technologies produce little to no CO_2 emissions during their operation, which helps to reduce the overall carbon footprint of energy production. Therefore, as more renewable energy is deployed, the level of CO_2 emissions associated with energy generation is lowered. Overall, the reduction in CO_2 emissions associated with renewable energy deployment is a key benefit that supports global efforts to mitigate climate change [30–32].

2.1.8. Total Generation

Total generation refers to the total amount of electricity generated by renewable energy sources in each period. This indicator is important in assessing the contribution of renewable energy to the overall energy mix and electricity supply in each region or country. A higher level of total generation from renewables indicates a greater reliance on clean energy sources and a reduced reliance on fossil fuels. Total generation can be influenced by a range of factors, including the availability of renewable resources (such as wind and solar), the level of investment in renewable energy infrastructure, and the regulatory and policy frameworks in place to support renewable energy development. In addition, total generation can be affected by the overall level of electricity demand and the competitiveness of renewable energy sources relative to conventional energy sources [33–35].

2.1.9. Electricity Consumption

Electricity consumption is a crucial indicator in the field of renewable energy as it reflects the demand for energy and the potential for renewable energy sources to meet that demand. Renewable energy can play a significant role in reducing electricity consumption in Spain, particularly with solar and wind power. In recent years, the Spanish government has implemented policies to encourage the adoption of renewable energy sources, such as feed-in tariffs and tax incentives. These policies have helped to drive growth in the renewable energy sector and reduce Spain's dependence on fossil fuels [36,37].

2.1.10. Budget Deficit

The budget deficit is an important indicator in the field of renewable energy as it reflects the financial resources available for investment in renewable energy infrastructure and technology. When there is a budget deficit, governments need to borrow money to finance their spending, and this can have significant implications for renewable energy development. Budget deficits can also limit the government's ability to invest in research and development of renewable energy technologies or to support the growth of domestic renewable energy industries. This, in turn, can hamper the development and adoption of renewable energy in each country or region [38,39].

2.2. Data Gathering

The subject investigated in this research is Spain, which has a population of 47.5 million people and was divided into seventeen autonomous communities after the constitution's adoption in 1978. As a result, each region's requirements and challenges were better understood, and more effective measures were taken to raise the level of social welfare throughout the country (Andalusia, Aragon, Asturias, Cantabria, Castile and León, Castilla La Mancha, Canary Islands, Catalonia, Estremadura, Galicia, Balearic Islands, Murcia, Madrid, Navarre, Basque Country, La Rioja and Comunidad Valenciana). However, it has ceased to study its autonomous cities [40].

The following statistics websites and library resources were used to gather data: (https://www.iea.org/, accessed on 3 November 2022), (https://worldbank.org/, accessed on 3 November 2022), (https://countryeconomy.com/, accessed on 10 November 2022), (https://www.statista.com/, accessed on 21 November 2022), (https://www.ree.es, accessed on 19 November 2022), and (https://www.miteco.gob.es/, accessed on 17 November 2022). Additionally, every piece of information has been taken from 2022 (for some indicators, it has been extracted from 2021 because of non-availability) and relates to a one-year period. Finally, Table 2 presents the data regarding the seventeen autonomous communities and the ten introduced indicators.

Table 2. Indicators database.

Autonomous Community/Parameters	Share of RE	Installed Capacity	GDP	HDI	Life Expectancy	Unemployment Rate	CO_2 Emissions	Total Generation	Electricity Consumption	Budget Deficit
Andalusia	51.4	2.044	20,226	0.853	81.43	19.0%	38.270	2.409	4806	−0.24%
Aragon	75.5	8.092	30,281	0.889	83.27	9.1%	12.53	9.998	8108	−0.07%
Asturias	19.9	3.794	24,216	0.882	82.74	12.8%	16.454	7.140	10,225	1.00%
Cantabria	25	1.37	25,180	0.880	83.67	8.6%	5.241	1.619	7528	0.79%
Castile and León	88	5.417	26,514	0.888	83.92	8.9%	21.489	5.555	5817	−0.13%
Castilla La Mancha	63	5.707	22,063	0.852	83.02	14.4%	16.66	7.090	5766	0.22%
Canary Islands	21.3	1.41	19,931	0.855	82.47	17.7%	11.366	2.172	4249	0.41%
Catalonia	15	1.545	31,704	0.897	83.33	9.3%	41.617	3.233	6307	−0.39%
Estremadura	39	9.354	20,929	0.847	82.11	15.9%	8.175	15.430	4693	0.21%
Galicia	62.6	4.064	25,033	0.880	83.42	10.8%	18.603	4.40409473	7332	−0.15%
Balearic Islands	7.3	1.723	25,085	0.853	83.32	5.8%	6.073	2.638	5402	0.88%
Murcia	24.2	3.452	22,601	0.863	82.30	14.5%	10.094	4.496	6393	−1.44%
Madrid	32	0.067	36,608	0.922	84.64	11.3%	20.413	0.099	4421	0.28%
Navarre	48.3	4.807	33,459	0.905	84.32	9.0%	6.273	8.645	7861	1.28%
Basque Country	11.9	1.356	34,779	0.915	83.68	8.3%	15.678	2.609	7540	0.87%
La Rioja	55	4.463	29,366	0.899	83.25	8.0%	1.978	4.193	5434	−0.09%
Comunidad Valenciana	17.2	1.636	23,700	0.875	82.19	13.5%	22.999	2.089	5469	−0.99%

2.3. Implementation of the TOPSIS

Three standard steps are used in all decision-making processes: data quantification is the first step in the decision-making process, followed by normalization and the right decision-making strategy [36,41]. In this part, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) has been utilized in MATLAB to rank the state of seventeen alternatives while considering the ten presented indications.

The final weight matrix was calculated from the average of the relevant indicators that were weighted in the following phase with the assistance of seven experts.

The following actions have been taken to implement the TOPSIS method using n criteria and m alternatives, with the normalized weights of the criteria being decided by elites (w_j).

$$r_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} {X_{ij}}^2}} \qquad i = 1, \ldots, m; j = 1, \ldots, n \tag{1}$$

In Equation (1), r_{ij} is the normalized vector, X_{ij} is the decision matrix (belongs the alternative of the ith and the criteria jth). To calculate the normalized value of the vector, Equation (2) is used:

$$m_{ij} = w_j r_{ij} \tag{2}$$

After achieving the normalized value of the vector (m_{ij}) using normalized weighted of jth criteria (w_j) and normalized vector (r_{ij}), calculating ideals and anti-ideals (a_j^+, a_j^-) are used so that the best value of each alternative (a_j^+) and the worst value of each alternative (a_j^-) for each criteria (according to the m_{ij}) are obtained. In Equations (3) and (4), the negative and positive ideal solution are achieved:

$$d_i^- = \sqrt{\sum_{j=1}^{n} \left(m_{ij} - a_j^-\right)^2} \quad i = 1, \ldots, m \tag{3}$$

$$d_i^+ = \sqrt{\sum_{j=1}^{n} \left(m_{ij} - a_j^+\right)^2} \quad i = 1, \ldots, m \tag{4}$$

After calculating the Euclidean distance from positive and negative ideals in Equations (3) and (4), calculating the normalized distance will be achieved (c_i). Generally, researchers measure the distance from the negative anti-ideals (5):

$$c_i = \frac{d_i^-}{d_i^- + d_i^+} \tag{5}$$

Finally, in Equation (6), the value of each alternative c_i^* will be normalized:

$$c_i^* = \frac{c_i}{\sum_{i=1}^{m} c_i} \tag{6}$$

As a result, according to the final normalized scores, the alternative with a higher score will be ranked higher (the higher the score means, the much farther it is from the negative ideal value). The terms "ideal solution" and "similarity to an ideal solution" are used to define this procedure.

3. Results and Discussion

Renewable energy has become an increasingly important topic in Spain, as the country aims to reduce its reliance on fossil fuels and transition to a more sustainable energy system. The seventeen autonomous communities of Spain have varying levels of renewable energy sustainability, as measured by several different indicators.

To accomplish the fundamental goal of this study, which was to compare and rank all the alternatives (autonomous communities) in Spain in terms of the sustainability of renewable energy by one of the most frequently used approaches in multi-criteria decision-making (MCDM), the TOPSIS method in MATLAB software was used, and the final scores of seventeen alternatives were obtained using ten criteria from Table 1 without considering autonomous cities.

To better evaluate the results and study the weaknesses and strengths of the renewable energy system (Spain as the entire system and autonomous communities as its main members), the output is divided into four groups: sustainable, relatively sustainable, medium sustainable, and less sustainable. The four categories used in this study were carefully chosen to balance simplicity with meaningful insights.

Table 3 shows the normalized scores obtained from the TOPSIS method. The ranking demonstrates that Castile and León, La Rioja, Murcia, Aragon, Galicia, Castile La Mancha, Comunidad Valenciana, Andalusia, Madrid, Cantabria, the Canary Islands, Estremadura, Navarre, the Balearic Islands, Catalonia, the Basque Country, and Asturias are sustainable to less sustainable communities, respectively.

Table 3. Final rankings.

Ranking	Autonomous Community	Score	Sustainability Degree
1	Castile and León	0.070568	Sustainable
2	La Rioja	0.070391	Sustainable
3	Murcia	0.069482	Sustainable
4	Aragon	0.069163	Sustainable
5	Galicia	0.067574	Relatively sustainable
6	Castile La Mancha	0.063013	Relatively sustainable
7	Comunidad Valenciana	0.061270	Relatively sustainable
8	Andalusia	0.057922	Relatively sustainable
9	Madrid	0.056228	Medium sustainable
10	Cantabria	0.055912	Medium sustainable
11	Canary Islands	0.05491	Medium sustainable
12	Estremadura	0.054595	Medium sustainable
13	Navarre	0.05183	Less sustainable
14	Balearic Islands	0.050807	Less sustainable
15	Catalonia	0.050279	Less sustainable
16	Basque Country	0.049554	Less sustainable
17	Asturias	0.046501	Less sustainable

The autonomous communities of Navarre, Balearic, Catalonia, Basque Country, and Asturias are in the less sustainable group and should improve in the field of renewable energy and relevant indicators so as not to negatively affect the sustainability of Spain as a whole. Conversely, Castile and León, La Rioja, Murcia, and Aragon which were included in the final assessment in the sustainable group could be extremely pioneering in keeping with Spain's 2030 renewable energy goals, a paradigm for other regions.

Surveys indicate that having better economic parameters does not necessarily indicate a better state of energy sustainability. The four autonomous communities of Madrid, Basque Country, Navarre, and Catalonia have the best economic situation based on GDP; however, in the final ranking in the field of energy sustainability, Madrid was in the medium sustainable group and the other three autonomous communities were in the less sustainable group.

To achieve the general goals of sustainable renewable energy, three comprehensive strategies can be considered to enhance the sustainability of renewable energy in Spain. The first strategy is to reach the 2030 goals faster by focusing more on the sustainable group and relatively sustainable groups. The second strategy would be to focus more on the medium sustainable group and less sustainable group by improving the renewable energy situation with the relevant indicators (this requires more time to accomplish or improve the sustainability situation). The third strategy would be to focus on all four alternatives simultaneously with a relatively equal amount of attention, so that the two weaker groups' flaws and issues are acknowledged by making greater investments in renewable energy or domain research, in addition to using the first or second groups as role models to proposition assistance and support from them to promote the objectives (this is a mid-term, but more stable, strategy).

There are significant regional differences in renewable energy sustainability across the seventeen autonomous communities of Spain. While some regions have made significant progress in developing renewable energy infrastructure and promoting the growth of the sector, others have lagged behind. With continued investment, policy support, and public engagement, Spain can continue to transition towards a more sustainable and resilient energy system.

4. Conclusions

In general, energy systems are unified, and each of their components is crucial to the system's sustainability. Hence, a weak or uncoordinated component of this system could seriously harm the system's objectives as a whole. In this research, the study of the Spanish energy system's constituent parts (autonomous communities) allowed for a more thorough and transparent evaluation of the system's strengths and weaknesses. The research involved ranking different alternatives of renewable energy and assessing their sustainability. Furthermore, the study also ranked seventeen autonomous communities in Spain based on ten sustainability indicators, employing the TOPSIS, a commonly-used technique for multi-criteria decision-making. The results of the analysis have shown that there are significant differences in the sustainability of renewable energy among the autonomous communities. While some regions, such as Castile and León, La Rioja, Murcia, and Aragon, have demonstrated strong sustainability performances and have been classified as sustainable, others, such as Navarre, the Balearic Islands, Catalonia, Basque Country, and Asturias, have been identified as less sustainable and require further improvements in their renewable energy systems.

It is important to note that some of the less sustainable regions may have untapped potential for renewable energy development, and targeted investment and policy interventions could help improve their sustainability rankings. This variation in sustainability is due to a variety of factors, including differences in government policies, investment in renewable energy infrastructure, and public attitudes towards renewable energy.

Overall, this study highlights the importance of sustainability assessment in renewable energy systems and provides insights for policymakers and stakeholders to develop effective strategies to transition towards a more sustainable and resilient energy system in Spain. Further research can explore the interrelationships among the sustainability indicators and identify the driving factors of renewable energy sustainability in the autonomous communities.

Author Contributions: Conceptualization, D.E.A., S.F.A. and P.M.B.B.; Methodology, D.E.A., S.F.A. and P.M.B.B.; Software, D.E.A. and S.F.A.; Validation, D.E.A., S.F.A. and P.M.B.B.; Formal analysis, D.E.A. and S.F.A.; Investigation, D.E.A. and S.F.A.; Resources, P.M.B.B.; Data curation, D.E.A. and S.F.A.; Writing—original draft, D.E.A. and S.F.A.; Writing—review & editing, D.E.A. and P.M.B.B.; Supervision, P.M.B.B.; Project administration, P.M.B.B. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of 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.

References

1. Heras-Saizarbitoria, I.; Sáez, L.; Allur, E.; Morandeira, J. The emergence of renewable energy cooperatives in Spain: A review. *Renew. Sustain. Energy. Rev.* **2018**, *94*, 1036–1043. [CrossRef]
2. IEA. World Energy Outlook 2022. Available online: https://www.iea.org/reports/world-energy-outlook-2022 (accessed on 15 November 2022).
3. Siksnelyte-Butkiene, I.; Streimikiene, D.; Balezentis, T. Addressing sustainability issues in transition to carbon-neutral sustainable society with multi-criteria analysis. *Energy* **2022**, *254*, 124218. [CrossRef]
4. Richter, M. Utilities' business models for renewable energy: A review. *Renew. Sustain. Energy Rev.* **2012**, *16*, 2483–2493. [CrossRef]
5. García-Gusano, D.; Iribarren, D. Prospective energy security scenarios in Spain: The future role of renewable power generation technologies and climate change implications. *Renew. Energy* **2018**, *126*, 202–209. [CrossRef]
6. Capellán-Pérez, I.; Campos-Celador, Á.; Terés-Zubiaga, J. Renewable Energy Cooperatives as an instrument towards the energy transition in Spain. *Energy Policy* **2018**, *123*, 215–229. [CrossRef]
7. Duarte, R.; García-Riazuelo, Á.; Sáez, L.A.; Sarasa, C. Analysing citizens' perceptions of renewable energies in rural areas: A case study on wind farms in Spain. *Energy Rep.* **2022**, *8*, 12822–12831. [CrossRef]
8. Bashi, M.H.; De Tommasi, L.; Le Cam, A.; Relaño, L.S.; Lyons, P.; Mundó, J.; Pandelieva-Dimova, I.; Schapp, H.; Loth-Babut, K.; Egger, C.; et al. A review and mapping exercise of energy community regulatory challenges in European member states based on a survey of collective energy actors. *Renew. Sustain. Energy Rev.* **2023**, *172*, 113055. [CrossRef]
9. Kyprianou, I.; Serghides, D.K.; Varo, A.; Gouveia, J.P.; Kopeva, D.; Murauskaite, L. Energy poverty policies and measures in 5 EU countries: A comparative study. *Energy Build.* **2019**, *196*, 46–60. [CrossRef]
10. Madsen, D.N.; Hansen, J.P. Outlook of solar energy in Europe based on economic growth characteristics. *Renew. Sustain. Energy Rev.* **2019**, *114*, 109306. [CrossRef]
11. Gürtler, K.; Postpischil, R.; Quitzow, R. The dismantling of renewable energy policies: The cases of Spain and the Czech Republic. *Energy Policy* **2019**, *133*, 110881. [CrossRef]
12. Escribano, G. The geopolitics of renewable and electricity cooperation between Morocco and Spain. *Mediterr. Politics* **2019**, *24*, 674–681. [CrossRef]
13. Prados, M.J.; Pallarès-Blanch, M.; García-Marín, R.; Valle, C.D. Renewable Energy Plants and Business Models: A New Rural Development Perspective. *Energies* **2021**, *14*, 5438. [CrossRef]
14. Mardani, A.; Jusoh, A.; Zavadskas, E.K.; Cavallaro, F.; Khalifah, Z. Sustainable and renewable Energy: An overview of the application of multiple criteria decision making techniques and approaches. *Sustainability* **2015**, *7*, 13947–13984. [CrossRef]
15. Bilgili, F.; Zarali, F.; Ilgün, M.F.; Dumrul, C.; Dumrul, Y. The evaluation of renewable energy alternatives for sustainable development in Turkey using intuitionistic fuzzy-TOPSIS method. *Renew. Energy* **2022**, *189*, 1443–1458. [CrossRef]
16. Sánchez-Lozano, J.M.; Teruel-Solano, J.; Soto-Elvira, P.L.; Socorro García-Cascales, M. Geographical Information Systems (GIS) and Multi-Criteria Decision Making (MCDM) methods for the evaluation of solar farms locations: Case study in south-eastern Spain. *Renew. Sustain. Energy Rev.* **2013**, *24*, 544–556. [CrossRef]
17. Armeanu, D.Ş.; Vintilă, G.; Gherghina, Ş.C. Does renewable energy drive sustainable economic growth? Multivariate panel data evidence for EU-28 countries. *Energies* **2017**, *10*, 381. [CrossRef]
18. Cîrstea, S.D.; Moldovan-Teselios, C.; Cîrstea, A.; Turcu, A.C.; Darab, C.P. Evaluating renewable energy sustainability by composite index. *Sustainability* **2018**, *10*, 811. [CrossRef]
19. Wang, Q.; Yang, X. Investigating the sustainability of renewable energy—An empirical analysis of European Union countries using a hybrid of projection pursuit fuzzy clustering model and accelerated genetic algorithm based on real coding. *J. Clean. Prod.* **2020**, *268*, 121940. [CrossRef]
20. Böhringer, C.; Landis, F.; Reanos, M.A.T. Economic Impacts of Renewable Energy Production in Germany. *Energy J.* **2017**, *38*, 189–209. [CrossRef]
21. Ntanos, S.; Skordoulis, M.; Kyriakopoulos, G.; Arabatzis, G.; Chalikias, M.; Galatsidas, S.; Batzios, A.; Katsarou, A. Renewable Energy and Economic Growth: Evidence from European Countries. *Sustainability* **2018**, *10*, 2626. [CrossRef]
22. Shahbaz, M.; Raghutla, C.; Chittedi, K.R.; Jiao, Z.; Vo, X.V. The effect of renewable energy consumption on economic growth: Evidence from the renewable energy country attractive index. *Energy* **2020**, *207*, 118162. [CrossRef]
23. Cuesta, M.A.; Castillo-Calzadilla, T.; Borges, C.E. A critical analysis on hybrid renewable energy modeling tools: An emerging opportunity to include social indicators to optimise systems in small communities. *Renew. Sustain. Energy Rev.* **2020**, *122*, 109691. [CrossRef]
24. Sasmaz, M.U.; Sakar, E.; Yayla, Y.E.; Akkucuk, U. The Relationship between Renewable Energy and Human Development in OECD Countries: A Panel Data Analysis. *Sustainability* **2020**, *12*, 7450. [CrossRef]
25. Jacobson, M.Z.; Delucchi, M.A.; Bauer, Z.A.F.; Goodman, S.C.; Chapman, W.E.; Cameron, M.A.; Bozonnat, C.; Chobadi, L.; Clonts, H.A.; Enevoldsen, P.; et al. 100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World. *Joule* **2017**, *1*, 108–121. [CrossRef]
26. Halicioglu, F. Modeling life expectancy in Turkey. *Econ. Model.* **2011**, *28*, 2075–2082. [CrossRef]

27. Ifaei, P.; Karbassi, A.; Lee, S.; Yoo, C.K. A renewable energies-assisted sustainable development plan for Iran using techno-econo-socio-environmental multivariate analysis and big data. *Energy Convers. Manag.* **2017**, *153*, 257–277. [CrossRef]
28. Boran, F.E. A new approach for evaluation of renewable energy resources: A case of Turkey. *Energy Sources B Econ. Plan. Policy* **2018**, *13*, 196–204. [CrossRef]
29. Stougie, L.; Giustozzi, N.; van der Kooi, H.; Stoppato, A. Environmental, economic and exergetic sustainability assessment of power generation from fossil and renewable energy sources. *Int. J. Energy Res.* **2018**, *42*, 2916–2926. [CrossRef]
30. Lee, C.W.; Zhong, J. Construction of a responsible investment composite index for renewable energy industry. *Renew. Sustain. Energy Rev.* **2015**, *51*, 288–303. [CrossRef]
31. Strantzali, E.; Aravossis, K. Decision making in renewable energy investments: A review. *Renew. Sustain. Energy Rev.* **2016**, *55*, 885–898. [CrossRef]
32. Kourkoumpas, D.S.; Benekos, G.; Nikolopoulos, N.; Karellas, S.; Grammelis, P.; Kakaras, E. A review of key environmental and energy performance indicators for the case of renewable energy systems when integrated with storage solutions. *Appl. Energy* **2018**, *231*, 380–398. [CrossRef]
33. Tietjen, O.; Pahle, M.; Fuss, S. Investment risks in power generation: A comparison of fossil fuel and renewable energy dominated markets. *Energy Econ.* **2016**, *58*, 174–185. [CrossRef]
34. Seljom, P.; Tomasgard, A. The impact of policy actions and future energy prices on the cost-optimal development of the energy system in Norway and Sweden. *Energy Policy* **2017**, *106*, 85–102. [CrossRef]
35. Jafari, M.; Botterud, A.; Sakti, A. Decarbonizing power systems: A critical review of the role of energy storage. *Renew. Sustain. Energy Rev.* **2022**, *158*, 112077. [CrossRef]
36. Ciarreta, A.; Zarraga, A. Electricity consumption and economic growth in Spain. *Appl. Econ. Lett.* **2010**, *17*, 1417–1421. [CrossRef]
37. Inês, C.; Guilherme, P.L.; Esther, M.G.; Swantje, G.; Stephen, H.; Lars, H. Regulatory challenges and opportunities for collective renewable energy prosumers in the EU. *Energy Policy* **2020**, *138*, 111212. [CrossRef]
38. Alabdullatif, A.M.; Gerding, E.H.; Perez-Diaz, A. Market Design and Trading Strategies for Community Energy Markets with Storage and Renewable Supply. *Energies* **2020**, *13*, 972. [CrossRef]
39. Sotnyk, I.; Kurbatova, T.; Romaniuk, Y.; Prokopenko, O.; Gonchar, V.; Sayenko, Y.; Prause, G.; Sapiński, A. Determining the Optimal Directions of Investment in Regional Renewable Energy Development. *Energies* **2022**, *15*, 3646. [CrossRef]
40. Campos, C.M.; del Castillo Fernández, H. Los beneficios de los videojuegos interactivos: Una aproximación educativa y una revisión sistemática de la actividad física. *J. New Approaches Educ. Res.* **2016**, *5*, 115–122. [CrossRef]
41. Nazari, M.A.; Assad, M.E.H.; Haghighat, S.; Maleki, A. Applying TOPSIS Method for Wind Farm Site Selection in Iran. In Proceedings of the 2020 Advances in Science and Engineering Technology International Conferences (ASET), Dubai, United Arab Emirates, 4–9 February 2020; pp. 1–4. [CrossRef]