Energy poverty in ALADI member countries: a study based on multi-criteria methods

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Abstract

Energy poverty is a significant problem in ALADI (Latin American and Caribbean Association of Electrical and Mechanical Engineering) member countries. This study uses multicriteria methods, specifically the CRITIC and Entropy methods, to identify the countries with the highest and lowest energy poverty in ALADI based on information from the World Bank and ECLAC for the year 2020. The study found that Brazil has the lowest energy poverty, while Ecuador and Bolivia have the highest energy poverty. Energy poverty is defined as a lack of access to minimum energy services that fail to meet basic needs, resulting in serious health, economic, and environmental consequences. This study concludes that addressing energy availability is crucial for alleviating fuel poverty, and few studies have investigated the impact of energy poverty.

Keywords

GDP, ALADI, CRITIC Method, Entropy Method, Energy Poverty

1. Introduction

Energy in the world is an essential service due to its environmental influence and its effect on other important aspects of daily life, such as sustainable, economic, and social development. Energy poverty (EP) is defined as the insufficiency of minimum energy services in a household that fails to meet the basic needs necessary to ensure adequate conditions for health and life.

About 1.3 billion people (17%) worldwide lack access to electricity and 2.7 billion (36%) rely on biomass for cooking, with serious health, economic, and environmental consequences; 4.3 million people died in 2012 due to air pollution caused by solid fuels while cooking [1]. The Latin American and Caribbean regions have a high average access to electricity (98.3%), but this figure masks an uneven pattern of access, with an extremely low connectivity rate of 45.3% in Haiti, followed by 88.1% in Nicaragua, and 91.8% in Guyana [2]. In this region, there are islands of access to connectivity as opposed to large disconnected areas.

The interest of the academic sector has been reflected in the existence of content with various options in the definition of energy poverty. Poverty of access to the service becomes a problem

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for households when they cannot pay what is necessary to use the electricity service. Energy-poor households must spend more than 10% of their income on all energy sources used and have a comfortable home temperature. Access to adequate, cost-effective, reliable, secure, and environmentally sustainable energy services that can contribute to economic and human development is insufficient [3, 4].

Few studies have investigated the impact of this issue, possibly because the problem is about addressing energy availability, with the expectation that fuel poverty will be alleviated. In France, households with high income and education are less likely to experience fuel poverty [5]. Another study in the same country showed that the probability of falling into fuel poverty was higher for those who retired and lived alone in rented housing [6].

In Beijing, the impact of the clean heating program on household energy use and expenditure, welfare, and indoor environmental quality has been estimated by comparing treated and untreated villages with different socioeconomic conditions [7]. In China, energy poverty, measured in multiple dimensions, was found to increase significantly when coal was replaced with electricity and gas, while it decreased when coal was replaced with clean coal [8].

Studies of energy poverty in Latin America and the Caribbean, specifically in LAIA countries, show the following results. Although programs have improved access to electricity for traditionally excluded populations, they have limitations in promoting inclusion and capacity-building [9]. On the other hand, in Mexico, an analysis of the factors that contribute to energy poverty, such as income level, size of locality, level of education, sex of the household head, and size of the dwelling, concluded that reducing energy poverty can help mitigate social vulnerability to climate change [10].

Based on the above, the objective of this study is to identify, using multicriteria valuation methods, the countries that present energy poverty within the Latin American Integration Association (ALADI), for which a set of criteria based on the literature review are considered.

This study contributes to academic knowledge by considering empirical valuation methods, reducing the perception bias to determine which of the 13 selected countries has greater and lesser energy poverty. The structure of the paper is as follows: i) the abstract followed by the introduction, ii) the theoretical framework, where a review was made of the theoretical bases that support the work, iii) the methodology applied with its respective data source, iv) results and discussion, v) mention of the conclusions of the work, and vi) the references.

2. Theorical Framework

The connection between energy and poverty has become increasingly important in public policy. Access to clean and affordable energy services is essential for improving the quality of life and reducing poverty. This is due to the fact that energy is related to almost every aspect of people's daily lives. This section demonstrates important points about fuel poverty, providing reasons for its investigation and application within multicriteria analysis.

2.1. Poor energenetic conception and definition

Energetic poverty is difficult to define, because it is not considered a fixed state. There is a debate about the theoretical assumptions, between Sen (1981) and Peter Townsend (1979)

about the definitions of absolute and relative deprivation. Townsend's proposition that the exact termination of social qualities limits the concept of absolute necessity, there is a general relativism in a given time and space, because the qualities vary according to customs, culture, economic climate, and geographic environment.

García Ochoa, [11] indicates that the ideas de Sen [12], raised about the complement between relative deprivation, absolute deprivation and the difference between needs and those who satisfy them, are important contributions to different areas that allow to know the conception of energy poverty. It allows the determination of needs and motives through energy consumption, but it is necessary to know that the deprivation of these needs makes that there is a violation of human rights, which means living without this service.

Energy is a material requirement for obtaining important capabilities, as is the case for other resources. The demand for energy does not come from preferences for energy as a commodity but from the desired energy services derived from that energy commodity. In addition to energy, other resources are also needed, usually a system for converting this service so that it is efficiently converted into heat, which means that it requires different amounts of gas and other derivatives [13].

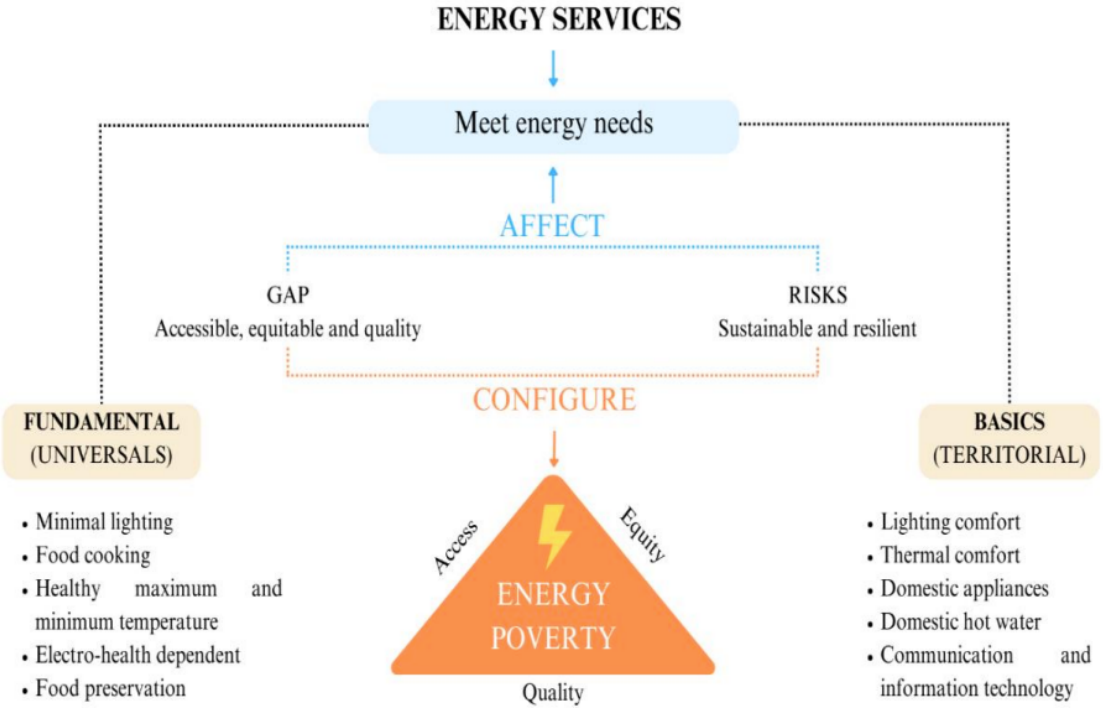

Figure 1: Basic and Fundamental Needs of Energy Services

The main needs are those that have a direct impact on human health if not met (Figure 1). They must be universally met regardless of the context. Examples include cooking and preserving food, having access to hot water, maintaining a healthy temperature range, and

providing a continuous supply of electricity to people with electrical dependence. Household energy demands should be understood as energy service demands such as heating, cooling, cooking, and lighting. Without such prerequisite materials, it is difficult to live in a home that requires a good level of energy services, as there is an inevitable link between energy supply and capacity.

In the same context, access to energy is essential for maintaining physical and mental health; therefore, energy-related poverty is a barrier that must be overcome. In addition, there is a strong link between this phenomenon and employment and education opportunities, which can also affect people's well-being and quality of life [14].

Energy poverty can be said to have health effects when the temperature is too low. The use of contaminated sources for cooking or heating increases the risk of diseases. Dampness in dwellings and the effects of fuel poverty on mental health are considered severe health problems.

2.2. Characteristics of energy poverty

Energy poverty, in general, is due to three factors: i) household income, i) energy prices, and iii) housing quality. These factors affect the economic burden of households and, thus, meet their energy needs. Within this problem Public policies, such as transfers, social tariffs, and housing policies that promote energy efficiency in needy households, should be implemented.

Two sources of energy poverty can be seen: (i) declared energy poverty, which refers to households receiving assistance from social services due to a declared situation of vulnerability; and ii) undeclared energy poverty, which refers to households at risk of exclusion, and refers to households paying for energy at the cost of poor nutrition, clothing, or poor quality of life. These cases are often not addressed because of feelings of shame, lack of knowledge, or social alternatives [11].

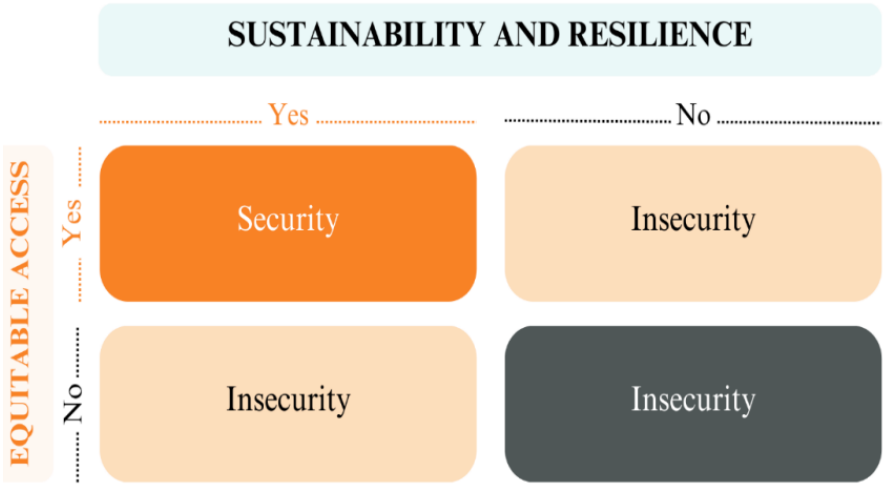

Figure 2: Energy segurity conditions

In relation to the above, it can be said that this problem is largely due to low household income. This is a facet of general poverty, which means that households lack resources to meet

their basic energy needs, such as housing and food. Low energy efficiency in housing and high energy costs can also contribute to fuel poverty [15].

This aspect also covers the situation of energy security, which must meet two conditions (Figure 2): (i) the territory must provide equitable access to essential energy services of sufficient quality and quantity to meet the different uses and demands, in particular the domestic needs of its population, and (ii) it must also guarantee the sustainability and resilience of these services in the face of possible threats.

3. Methodology

This study uses a quantitative approach and correlational scope, in which the criteria of access to electricity in rural and urban areas are worked in percentages, in dollars the GDP per capita (US$ at constant 2010 prices), and finally, the energy consumption in gigawatt hours. The database was processed to obtain weights and proceed to decision-making. Criteria and inferential statistical processes are related to the results. It is worth mentioning the use of supporting documents for the theory, such as articles, books, and reports.

The data are from secondary sources, mainly national and international organizations. Four criteria are presented: GDP per capita (US$ at constant 2010 prices), access to electricity, rural sector (% of rural population), access to electricity, urban sector (% of urban population) data obtained from the World Bank, and the criterion energy consumption (gigawatt-hours) obtained from ECLAC. The period under study includes the year 2020, being the year with updated and homogenized information, for the ALADI countries: Argentina, Bolivia, Brazil, Chile, Colombia, Cuba, Ecuador, Mexico, Panama, Peru, Paraguay, Uruguay and Venezuela, obtaining as criteria the variables that explain energy poverty and alternatives to the ALADI countries.

First, information was sought to support the use of the appropriate criteria, in this case, the variables and their respective indicators, based on which the following criteria were determined:

- GDP per capita (US$ at constant 2010 price).
- Acess to electricity in the rural sector (% of the rural population).
- Access to electricity in the urban sector (% of the urban population).
- Energy consumption (gigawatt hours).

Extensive databases were obtained from the websites of the World Bank and ECLAC, followed by filtering of values of interest, the year 2020, and the 13 countries that make up ALADI. Thus, a new information base was built with the data to be used in valuation methods, such as the CRITIC method and the entropy method.

In the CRITIC method, normalization by data range is used, considering that there must be an interval between 0 and 1. For each group of criteria, the standard deviation and correlation coefficients of the normalized matrix were calculated. Next, the standard deviation was calculated by multiplying the correlation coefficients, thus obtaining the valuation weights of each criterion, and the weighted sum method was applied to obtain the value that would help us make decisions.

General formula for CRITIC valuation method

$$w_j = s_j * \sum(1 - r_{j^k}) \tag{1}$$

Where

- w_j: weight or weighting of criterion j
- s_j: standard deviation of criterion j
- r_{j^k} correlation coefficient between criteria j and k

Unlike the CRITIC method, the Entropy method requires normalization by the sum, which consists of dividing each element by the total sum of the criterion. Then, a matrix is created, where each element is transformed to a natural logarithm to perform the multiplication of the normalized matrix and the matrix transformed to logarithm. K is the number of categories for the calculation of diversity or uncertainty, which is a unit divided by the natural logarithm of the number of alternatives. Entropy, diversity, and normalization by the sum of diversity are calculated, obtaining the weights, to carry out the weighted sum and to know the ranking to determine the country with less and more energy poverty.

General formula for the valuation method entropy

$$E_j = -k * \sum_i (a_{ij} * \log a_{ij}) \tag{2}$$

Where

- $k = \frac{1}{\log m}$, y m the number of alternatives.
- Therefore, diversity calculations are required. $D_j = 1 - E_j$
- Finally, the diversity of each criterion was normalized by the sum of the weights of each criterion: $w_j = \frac{D_j}{\sum_j D_j}$

4. Results and Discussion

After following the CRITIC method procedure, the following results were found: the weights of the criteria for this method are as follows: first, access to electricity in the urban sector is 0.91; second, GDP per capita is 0.86; third, energy consumption is 0.72, and access to electricity in the rural sector is 0.69.

The weighted sum with the respective weights of the criteria indicates that the country with the least energy poverty is Brazil with a score of 2.70, followed by Uruguay with 2.48 and Chile with 2.39, and the country with the highest energy poverty for this valuation method is Ecuador with 0.70 score.

Figure 3 shows that Brazil has the lowest energy poverty, with a score of 2.70, indicating that it has greater access to electricity, considering that the urban area is more highly valued than the rural area. This is why there is a direct relationship with the GDP per capita, since it is understood that most of the industries and large companies are located in the central area of the country. Relegating access in rural areas and confirming the need for greater intervention by the government, recognizing that this segment of the population does not enjoy an adequate

Table 1
CRITIC Method

ALADI Countries	GDP per capita (US$ at constant 2010 prices)	Energy consumption (Gigawatt-hours)	Access to electricity, rural sector (% of rural population)	Access to electricity, urban sector (% of urban population)	CRITIC Method (Weighted Sum)	Ranking
Argentina	0,69	0,23	1,00	1,00	2,37	4
Bolivia	0,00	0,00	0,16	1,00	1,02	11
Brazil	0,43	1,00	1,00	1,00	2,70	1
Chile	0,80	0,13	1,00	1,00	2,39	3
Colombia	0,24	0,12	1,00	1,00	1,90	6
Cuba	0,35	0,01	1,00	1,00	1,91	5
Ecuador	0,20	0,03	0,73	0,00	0,70	13
Mexico	0,51	0,55	0,77	0,41	1,74	8
Panama	0,76	0,00	0,00	0,07	0,73	12
Peru	0,23	0,08	0,67	1,00	1,63	10
Paraguay	0,26	0,01	1,00	1,00	1,84	7
Uruguay	1,00	0,01	1,00	1,00	2,48	2
Venezuela	0,04	0,11	1,00	1,00	1,72	9

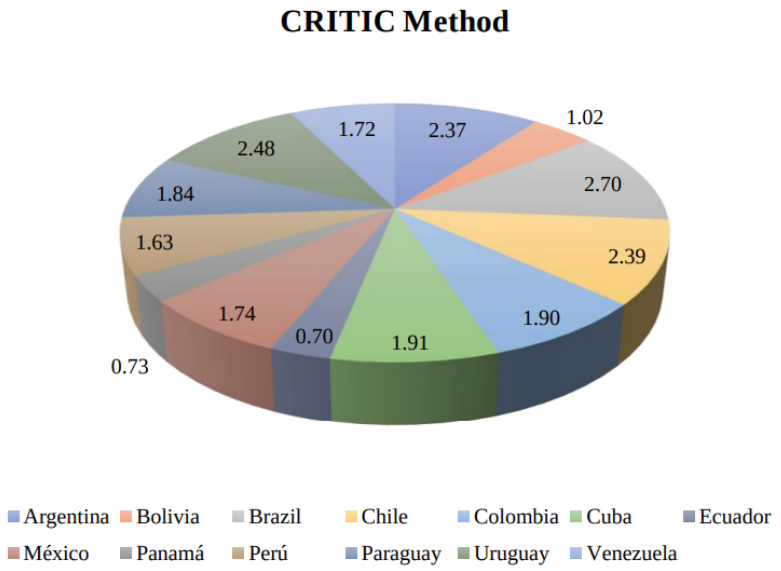

Figure 3: CRITIC Method

quality of life, contracting diseases, and social problems, such as lack of education and access to technology.

The Entropy valuation method indicates a different distribution of weights for the criteria, in which GDP per capita has a weight of 12% and energy consumption of 88%, which is the most important criterion according to the method developed. The types of access in both rural and urban areas have a weight of 0%; therefore, they do not contribute to decision-making. For this

reason, the country with the lowest energy poverty is Brazil, as well as the CRITIC method; in second place is Mexico and in third place is Argentina; and finally, the country with the greatest energy poverty is Bolivia.

Table 2
Entropy Method

ALADI Countries	GDP per capita (US$ at constant 2010 prices)	Energy consumption (Gigawatt-hours)	Access to electricity, rural sector (% of rural population)	Access to electricity, urban sector (% of urban population)	ENTROPY Method (Weighted Sum)	Ranking
Argentina	0,1076	0,1001	0,0785	0,0770	0,1010	3
Bolivia	0,0277	0,0067	0,0721	0,0770	0,0093	13
Brazil	0,0778	0,4090	0,0785	0,0770	0,3692	1
Chile	0,1211	0,0574	0,0785	0,0770	0,0650	4
Colombia	0,0556	0,0536	0,0785	0,0770	0,0539	5
Cuba	0,0680	0,0121	0,0785	0,0770	0,0188	11
Ecuador	0,0506	0,0204	0,0765	0,0767	0,0241	9
Mexico	0,0867	0,2271	0,0767	0,0768	0,2102	2
Panama	0,1160	0,0074	0,0708	0,0767	0,0204	10
Peru	0,0545	0,0370	0,0760	0,0770	0,0391	7
Paraguay	0,0578	0,0110	0,0785	0,0770	0,0167	12
Uruguay	0,1441	0,0091	0,0785	0,0770	0,0253	8
Venezuela	0,0324	0,0490	0,0785	0,0770	0,0470	6

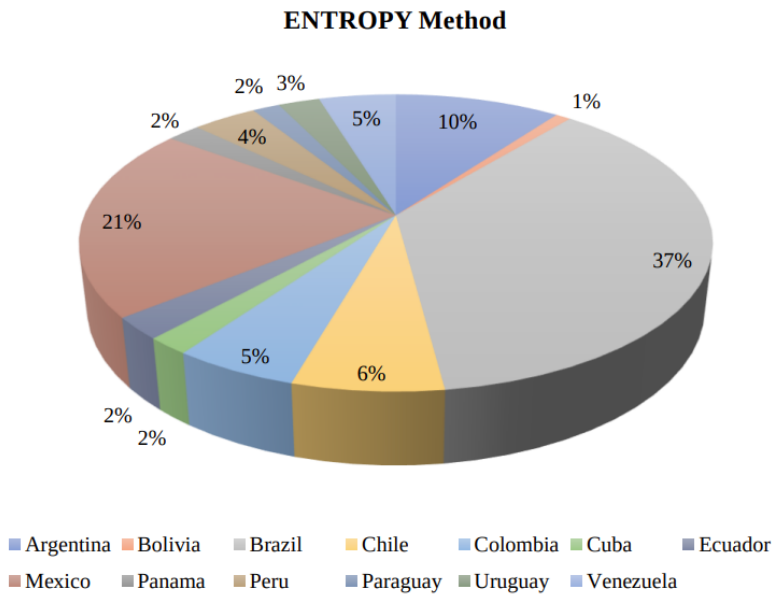

Figure 4: ENTROPY Method

Notorious differences exist between these methods, but it is determined that there is energy poverty in Latin American countries, such as the reflection of poorly implemented public

policies, without the intervention of institutions that present this problem as important and start from it to seek prompt solutions. The lack of access to this basic service creates different scenarios, one of which is low economic development, and the quality of life of the population is affected; therefore, the countries suffer socioeconomic consequences.

It should be understood that electric energy is part of a basic right; for the welfare of the population, it can also be considered an indicator of social inequality, because it is being analyzed that access to this service is greater in the urban area, but the rural area is suffering from this problem where the use of non-renewable energy is a reality, contributing negatively to the practice of sustainable development in each of the countries, avoiding the use of gas, coal, and so on.

The issue of interest that goes hand-in-hand with energy poverty is the investigation of the contribution of this problem to the social and economic inequality gap. In addition, it is considered a challenge in several countries to promote public policies that encourage the reduction of this problem in the search for new development opportunities.

5. Conclusions

Latin American countries that make up ALADI have energy poverty, which is a dilemma for the population due to the lack of access, equity, and quality of this basic service. There are barriers to energy access and deficiencies in its quality, and there is a distortion of reality in the access issue, since it is an urban area that fully enjoys the service, displacing rural areas where there are greater deficiencies. This is consistent with the results obtained from the valuation weights, where access in rural areas is lower than that in urban areas.

GDP per capita was considered a direct indicator of the relationship between a greater production of goods and services in a country and the use of electricity in companies in order to be able to produce goods and provide a large part of the services that are carried out with this basic service. Here, there is a relationship as to why the urban area has greater access to energy, but this does not mean that all homes have high-quality electricity.

In another case, household income is part of the inequity of this service because the higher the income, the more they can fully enjoy electrical appliances that improve their welfare, while low-income households do their best to avoid excessive spending by limiting their use of this service.

Brazil ranks as the country with the lowest energy poverty, having a high GDP per capita, which is attributed to the theory of developing countries, presenting similar results to previous research, where it is indicated that countries with higher consumption and therefore higher GDP maintain the position of being important as a means of research in the government as a result of the increase in prices of this service, without forgetting that inequality in different areas is a latent problem, considering several issues such as the price of this service, location of places with greater access to energy, quality of service, development, and welfare of the population.

However, Ecuador and Bolivia, according to the results obtained, are countries with greater energy poverty. Rural households experience a greater lack of access to this service, knowing that they are countries with a large percentage of rural population and low GDP per capita,

influencing their income and giving part to the non-payment of electricity bills, thus supporting the strengthening of research and the axis of development plans to understand in depth the causes of this problem.

To carry out a more in-depth study, updated information is needed for each country and for it to be transparent with its data so as not to create erroneous panoramas at the time of conducting a more thorough investigation on the subject. As future research, it is recommended to analyze indicators related to the population, such as household income, service prices, and energy security. Energy poverty is a problem that prevents the economic and social development of a country and its relationship with education, health, and quality of life. Finally, the study of energy poverty can lead governments to create public policies that benefit the population by considering the implementation of decentralized models to encourage the use of renewable energy, eliminate gas subsidies, and contribute to the construction of a sustainable economy.

Energy poverty is a global problem; therefore, it can be investigated in different countries of the world and is not limited to developing countries with development problems, but it can also be used to determine whether this type of problem exists in developed countries. The results of the study show that energy poverty mostly affects rural sectors, with an impact on the quality of life, being something significant with an emphasis on basic services that involve the use of electricity in daily tasks.

Socioeconomic inequalities have an important relationship with fuel poverty because people with low incomes are more likely to be affected by fuel poverty. In addition, the relationship between health and safety is due to the lack of resources to carry out activities, such as dangerous or unhealthy methods to heat food.

Other relevant aspects to study on the subject are the political aspect, since support programs and aid policies can be implemented to address the issue, such as subsidies, energy efficiency programs, and protection measures for vulnerable sectors, ensuring a sustainable approach with the guarantee of access to energy and promoting sustainable sources and pollution reduction.

Limitations: This study had several limitations, such as the need for accurate and updated data. In this case, the energy poverty indicators were precisely investigated with data for each country under study; some indicators that have a greater impact do not have updated information. Therefore, we worked with indicators provided by the World Bank; one of the most notorious was the year of study, since to date there is only information for that year.

The topic of energy poverty, which is a new concept adapted in each country, changes from one place to another; that is, if a study is carried out in a place other than Latin America, it should have a different impact that can be compared with developing countries. Another limitation of the study was the lack of current data from different countries that comprise the ALADI. The year 2020 was used as the base year to obtain data for the homologation of information. The World Bank has the most information on access to energy, and the ECLAC has information on energy consumption up to the year indicated.

It should be taken into account that indicators of the electric energy category are also important for studies of different kinds, and there is a lack of data in Venezuela, so it was decided to look for information in economic bulletins that provide the necessary information for the study. Countries should maintain transparency in their data for possible studies conducted in academia and contribute significantly to a country.

Multicriteria methods are complex; therefore, according to the results obtained, possible

studies and research directions have been considered, whether in other countries in the Americas or in other continents. Methods other than those applied in this research were applied, such as Normalization by Sum, Normalization by Rank, Weighted Sum, Simple Ordering Method, Binary Relationships, Analytical Hierarchical Process (AHP). This is because analysis from various points of view may imply an expansion of knowledge within fuel poverty with its respective variables.

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