Multidimensional energy poverty and convergence: An analysis for Latin America and the Caribbean

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Abstract

Latin America and the Caribbean is one of the most unequal regions in the world, with high levels of poverty and reduced state capacity to solve structural problems. In this paper, we examined the existence of a β-convergence process between countries (i.e., reduction of disparities) in terms of energy poverty indicators. For this, we constructed an annual panel of countries for the last six decades and for thirteen energy poverty indicators covering three dimensions (access, quality, and affordability). The results indicate that, even though substantial differences persist, a convergence process has taken place between countries of Latin America and the Caribbean, which includes all the dimensions analysed. Context-specific recommendations that emerge from the findings aim at promoting greater adoption of renewable energy, reducing delays in obtaining an electricity connection, and cutting subsidies for natural gas and oil.

Keywords: energy poverty, convergence, Latin America, Caribbean.

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Introduction

Various authors recognize Latin America and the Caribbean as one of the most unequal regions in the world (Dabús, Delbianco, & Zinni, 2014; Alvaredo & Gasparini, 2015; Carvajal Rodríguez, & Cuartas, 2019; Gasparini, 2019; Lustig, 2020; Saraví, 2020; Maurizio, 2021). The centrality of this problem has resulted in a significant amount of papers that attempt not only to measure inequality, but also to explain its causes and consequences. Isidro Luna (2022) found that, despite the fact that global wealth is constantly increasing, inequalities between countries have not disappeared, but rather have worsened. In addition, the author concluded that the poorest countries have not managed to match the most prosperous ones and, specifically, that there is a strong internal disparity in Latin America.

Along the same lines, Gasparini (2019) observed that Latin America has experienced significant distributional changes in recent decades. On average, income inequality rose in the 1990s, fell in the 2000s, and slowed in the 2010s. According to the author, the substantial reduction in inequality in the 2000s can be explained based on three main reasons: (i) the natural rebound after some unequalizing shocks in the previous decade, (ii) the favourable international context that led to an episode of high economic growth, and (iii) the support of public policies with a redistributive impact. The same result was found by Maurizio (2021), Lustig (2020), Amarante, Galván and Mancero (2016), and Kliksberg (2005).

Latin America and the Caribbean suffers from both inequality and poverty. Countries of this region are characterized by high poverty rates (Cecchini, Villatoro, & Mancero, 2021; Ciaschi, 2021; Rodríguez, González, & Zurita, 2020; Delgado, 2020). Considering the poverty incidence rate indicator, based on $1.90 per day (2011 PPP) provided by the World Bank, 4.4% of the population of Latin America and the Caribbean lived in poverty in 2019. The multidimensionality related to the measurement of poverty has been discussed, like other social phenomena. There are several studies that analyse multidimensional poverty in these countries, although only a few address the phenomenon in the entire region (Conconi & Ham, 2007). Various authors identified that multidimensional poverty in these nations is high and, also, that there are great disparities between and within them (Boltivinik, 2013; Paz, 2014; Rojas & Ríos, 2015; Ponce, 2018; González & Santos, 2018; Villatoro & Santos, 2019; Paz & Arévalo, 2021; González et al., 2021).

One of the dimensions that have taken centre stage in accounting for situations of deprivation is energy. It is considered a social good that allows satisfying basic needs and increasing the level of well-being of the population. Moreover, it is essential for the processes of development and social inclusion (Guzowski, 2016). Therefore, deprivations in the energy dimension are component and explanatory factors of situations of vulnerability and exclusion.

The relevance of energy and of its deprivation is indisputable. However, energy poverty has acquired greater prominence since the establishment of the Sustainable Development Goals (SDGs) and the Paris Agreement (PA). One of the SDGs, promoted by the United Nations Development Program (UNDP), has to do with "Affordable and Clean Energy" to satisfy human basic needs at affordable costs and includes electricity and appliances such as stoves for cooking. However, because it is a multidimensional phenomenon, energy poverty is also related

to other goals such as "Ending Poverty, Good Health and Well-being, Reduce Inequalities, Sustainable Cities and Communities, Climate Action, Terrestrial Ecosystem Life, among others. Thus, energy is also considered a central issue in pursuit of economies that follow the path of sustainable development.

Additionally, in 2017, the World Energy Council (WEC) incorporated the concept of the energy trilemma to assess the core dimensions of energy sustainability (Figure 1). Energy security is the effective management of primary energy supply from domestic and external sources, the reliability of energy infrastructure, and the ability of energy providers to meet current and future demand. On the other hand, energy equity refers to the accessibility and affordability of energy supply for the entire population. Finally, environmental sustainability encompasses the achievement of energy efficiencies on the supply and demand side and the development of energy supply from renewable and other low-carbon sources (WEC, 2017).

Figure 1. Energy sustainability - energy trilemma
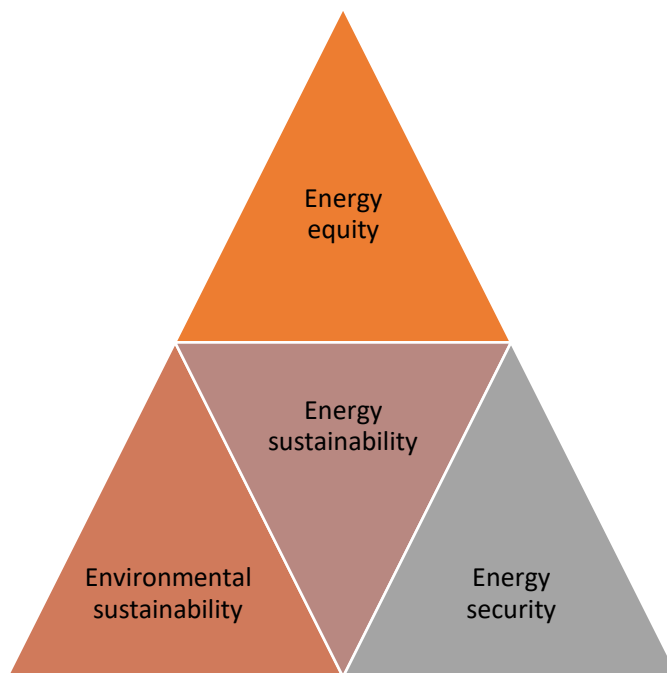
Source: own elaboration based on the WEC (2017)

This trilemma highlights the relevance of energy poverty in the sustainability of the energy system and, transitively, of the economies. The presence of energy poverty implies non-compliance with energy equity, which puts the sustainability of the system at risk. The SDGs propose missions common to the economies, which must be accomplished in order to follow a sustainable path. These goals, as stated above, incorporate reliable and affordable access to energy. Behind compliance with the SDGs is a convergence process between economies, where disparities should be reduced.

Due to the relevance of energy poverty and the multiple aspects comprising this phenomenon, the main aim of this paper was to analyse how the economies of Latin America and the

Caribbean behave in relation to this problem, as well as to assess whether the disparities at the regional level have been reduced in recent decades. For this, and following Salman, Zha, and Wang (2022), an annual panel of countries of the region was constructed for the last six decades, which contains thirteen indicators of energy poverty. Using these data, the existence of conditional and unconditional β-convergence was tested, and an analysis of clusters was also performed to evaluate the behaviour of these countries.

The findings of this study show that, in the last six decades, a process of convergence—conditional and unconditional—took place between these countries. This process included the three dimensions analysed (access, quality, and affordability), and its speed was heterogeneous between indicators, dimensions, and sub-periods. Despite this convergence, important differences persist, giving rise to multiple clusters of countries.

This paper contributes to the convergence literature in three respects. On the one hand, it is the first analysis on the existence of convergence in the energy poverty indicators individually considered. Salman, Zha, and Wang. (2022) addressed the topic of the convergence of energy poverty, but did not take into account the indicators one by one. The authors resorted to the construction of a multidimensional poverty index that summarizes the information of all the indicators in a single and new measure. On the other hand, this is the first paper whose approach is based on a developing region. This facilitates comparisons when considering a pool of countries that are more similar to each other in terms of their productive, demographic, and geographic structure. Previous literature has focused on exploring this topic at a global level or with developed countries. Lastly, this paper examined for the first time the existence of convergence in relation to the affordability dimension. Typically, other analyses concentrated on access and quality aspects.

This paper is structured as follows. After this brief introduction, the following section provides a conceptual review of energy poverty and the indicators used for its measurement. Next, the sources of information and the empirical methodologies used are described, to then give rise to the results obtained. Finally, the conclusions and final discussion of the paper are presented.

Energy poverty and its measurement: background

There are numerous precedents addressing the issue of energy poverty, mostly concentrated on its definition (Caruana & Méndez, 2019; Boemi & Papadopoulos, 2019; Castaño-Rosa et al., 2019; Day et al., 2016; González-Eguino, 2015). Since there is a wide range of definitions, energy poverty (like many social phenomena) can be conceptualized and measured based on a plurality of indicators and criteria.

Energy is considered a key resource for the economic and social organization of a country; it constitutes a means to satisfy basic needs and, therefore, implies a social good (Bouille, 2004). According to the General Assembly of the United Nations (2012), energy can be characterized as the common thread between economic growth, social equity, and environmental sustainability, which is why it occupies a fundamental role in the agendas of government policies. Due to this role, it can be argued that timely access to energy is a necessary condition to achieve economic and social development.

In the social sciences, the definition of poverty is not unequivocal and is usually understood in at least four specific senses. Materially, a population is poor because it lacks something it needs. Another sense has to do with an economic situation considering income. Furthermore, as a social aspect, poverty is related to the concept of social class. Finally, as a moral judgment, the material conditions of the poor are morally unacceptable (Spicker, 2009 in Ibáñez Martín, 2018). However, the real disagreement is around the measurement of the phenomenon, initially focused on income (unidimensional). Later, a multidimensional approach was developed (Conconi & Brun, 2015; Ibáñez Martín, 2018).

The concept of energy poverty cannot depart from the conceptions described above. Initially, it was associated with fuel poverty, under which a household is energy poor if it cannot afford the fuel necessary to maintain heat or the temperature that provides thermal comfort to its members (Lewis, 1982 in García Ochoa, 2014). Another definition of fuel poverty, proposed by Boardman, considers poor a household that spends more than 10% of its income on having adequate heating (García Ochoa, 2014). This interpretation was followed by those that emphasize the lack of access to energy, specifically modern and non-polluting energy such as electricity, liquefied gas, and biogas (UNDP, 2018). Consequently, energy poverty is related to the use of traditional fuels such as garbage, dung, organic waste, coal, wood, and kerosene.

Some authors argue that energy and fuel poverty are interchangeable concepts and represent households deprived of heating, cooling, hot water, electricity, and other essential needs (Castaño-Rosa et al., 2019). On the contrary, others consider them clearly separable concepts, since energy poverty addresses basic issues of energy access, while fuel poverty focuses on affordability aspects (Li et al., 2014). In addition, fuel poverty is usually observed in relatively rich countries with cold climates, while energy poverty is present in all kinds of climates and mainly in poor countries. For this reason, these concepts can only be integrated when it comes to households living in cold climates with difficulties in accessing electricity, modern cooking, and heating at an appropriate cost (Li et al., 2014).

From these one-dimensional conceptions, broader definitions emerge, such as the one proposed by the European Observatory on Energy Poverty (Energy Poverty Advisory Hub, 2023). According to this project, energy-poor households are those that experience inadequate levels of energy services, due to a combination of high energy expenditure, low income, inefficient buildings and appliances, and specific household energy needs. In this line, the most complex definitions incorporate elements such as subjectivity and the temporality of satisfaction (UNDP, 2018).

Day et al. (2016) defined energy poverty as the difficulty (or impossibility) of developing capacities due, directly or indirectly, to insufficient access to affordable, reliable, and safe energy services. These interpretation highlights that energy is necessary to develop various capacities and recognizes the central role of energy services, without specifying which one, being broad enough to adapt to different situations.

García Ochoa (2014) proposed another definition that incorporates the temporal dimension of the satisfaction of needs. According to this author, a home is energy poor when its members do

not meet their absolute energy needs, related to satisfiers and economic goods that are considered essential, in a given place and time, based on social and cultural conventions.

As mentioned above, energy poverty cannot be defined solely as the lack of access to energy, since attributes such as the quantity and quality of energy also matter. At the same time, the latter aspects in relation to the equipment that a home has, as well as its access, are relevant, since energy services are those that determine well-being. In addition, socioeconomic, geographic, building, and cultural factors, among others, affect the aforesaid attributes. Considering these aspects, Ibáñez Martín, Zabaloy and Guzowski (2019) defined energy poverty as "the lack of satisfaction of essential energy services for human life, induced by a lack of access, quantity and quality not only of energy but also of equipment, which is caused by various factors, such as socioeconomic (insufficient level of income, education, etc.), geographic (disconnection to the network), buildings (type of construction, insulation in openings, etc.), and cultural (preferences for certain energy sources), which ultimately affects the level of well-being of household members" (p. 7).

As far as measurement is concerned, leaving aside the unidimensionality, indicators have been developed that try to capture the complexity of energy poverty. In this line, García Ochoa (2014) developed a method called satisfaction of Absolute Energy Needs (NAE, as per its initials in Spanish), which includes energy services for cooking and refrigerating food, heating water for personal hygiene, adequate lighting, and entertainment activities. This methodology uses economic assets as a measurement instrument to determine if a household is in energy poverty, taking into account in this deprivation if it does not have the economic assets to satisfy the NAE. Another approach is the Multidimensional Energy Poverty Index (MEPI) method, introduced by Nussbaumer, Bazilian, Modi and Yumkella (2011). The MEPI proposes to capture, both in quantity and quality, the access to the energy services considered and offers a greater analysis of the elements that configure the energy demand. Consequently, dimensions are defined, in particular energy services for cooking, lighting, food preservation, entertainment, education, and telecommunications. Then, the methodology assigns dichotomous variables for each dimension that inquire about the possession of the necessary equipment and access to electricity and safe energy sources for cooking. Finally, it establishes a weighting for each variable and performs the mathematical calculation to determine the incidence—number of households in energy poverty—and intensity—how energy poor they are—(Nussbaumer et al., 2011). As mentioned above, the application of these multidimensional perspectives has increased in recent years. This growth is associated with the generation of primary information (with costly surveys), the evolution of permanent surveys in developed economies, and the focus of a national survey on energy issues (as in the case of the permanent survey of household expenditure in Argentina in 2018).

Sources of information

In this paper, we combined two sources of information that allowed us to assess the three critical dimensions in terms of gaps in energy services: access, quality, and affordability (CAF, 2022). First, most of the outcomes of interest come from the World Development Indicators (World Bank, 2023). This source of information covers the period 1971-2021. It is worth noting

that some indicators have missing values for particular countries and years: per capita energy use (in kg of oil equivalent), access to clean fuels and technologies for cooking (in % of population), primary energy intensity (megajoules per dollar of GDP per capita), fossil fuel consumption (in % of total final energy consumption), renewable energy consumption (in % of total final energy consumption), access to electricity (in % of population), per capita electricity consumption (in KWh), and time required to get electricity (in days).

Second, from the data reported by the International Monetary Fund (IMF, 2022), we obtained the records of fossil fuel and electricity subsidies by country and year. From this database, which covers the 2015-2025 period (data after 2022 are estimates), it is possible to know the magnitude of the subsidies disaggregated by source (oil, natural gas, and electricity). These indicators were used to assess the affordability dimension.

Table 1 presents descriptive statistics of the variables of interest for the year 2021. A wide variability can be observed in the indicators of per capita energy use (with 20-fold differences between the minimum and maximum of the series), per capita electricity consumption, time required to get electricity, and per capita oil subsidies. This reflects, a priori, the existence of a great disparity between countries of the region. All the indicators in Table 1 are frequently used in the literature (Salman et al., 2022).

Table 1: Descriptive statistics of the outcomes of interest

Indicator	Mean	Standard deviation	Minimum	Maximum
Access				
Per capita energy use	1837.18	4096.5	191.88	40710.11
Per capita electricity consumption	1308.14	1340.41	12.38	7613.07
Primary energy intensity	4.56	4.23	.11	23.47
Access to electricity (in %)	92.03	12.29	30.01	100
Access to clean fuels and technologies for cooking (in %)	81.55	22.57	2.6	100
Quality				
Fossil fuel consumption (in %)	60.96	26.61	0	100
Renewable energy consumption (in %)	22.46	21.90	0	95.04
Time required to get electricity (in days)	67.23	34.21	18	208
Affordability				
Per capita natural gas subsidies	43.43	148.02	0	1396.09
Per capita oil subsidies	487.3	673.9	.397	3467.38
Per capita electricity subsidies	48.21	108.86	0	660.32

Source: own elaboration based on the World Bank and the IMF.

Methodology

In order to analyse the existence of convergence in terms of energy poverty, Equation 1 was estimated. This equation indicates an unconditional β-convergence. This refers to the fact that the variables by which the convergence analysis is conditioned are not considered (e.g., surface,

population, climate, etc.). Equation 2 moves in this direction and contemplates a conditional β-convergence analysis. Here, country (γ_i) and year (δ_t) fixed effects are included.

$$ln\left(\frac{y_{it}}{y_{it-1}}\right) = \alpha + \beta_1 lny_{it-1} + u_{it} \qquad (1)$$

$$ln\left(\frac{y_{it}}{y_{it-1}}\right) = \alpha + \beta_1 lny_{it-1} + \gamma_i + \delta_t + u_{it} \qquad (2)$$

where y_{it} is the outcome of interest *y* in country *i* and year *t*. u_{it} is the error term of the model. The coefficient of interest is β_1 is expected to be negative in the event of a convergence process: this would reflect the fact that the countries that started in *t-1* with a low *y*-value achieved a larger increase between *t-1* and *t* (relative to those that started in *t-1* with higher *y*-values). In other words, a $\beta_1 < 0$ would indicate a reduction in energy poverty disparities between countries of the region.

The unconditional convergence analysis (Equation 1) is stricter than the conditional one (Equation 2). The latter case assesses whether there is a reduction in the disparities between countries, conditional on a set of relevant variables. In this paper, we conditioned the convergence analysis by including geographical and time fixed effects. These allowed us to control for unobservable heterogeneity that differs across countries but not over time (e.g., surface) and for heterogeneity that varies over time but not across countries (e.g., international energy prices).

In the case of observing this process, it is interesting to know its speed; that is, the proportion of the gap with respect to the steady state of the outcome of interest that is eliminated each year. For this, Equation 3 was used (Blasko & Yusran, 2017):

$$V = -\left(\frac{1 - e^{-\beta T}}{T}\right) \qquad (3)$$

where β is the coefficient of interest estimated according to Equation 1 or 2. T refers to the number of years considered for each outcome.

In Equations 1 to 3, each outcome of interest is taken into account separately. This allowed a detailed analysis of each one rather than simply summarising the information contained in several of them into a single new indicator (e.g., Factor Analysis or Principal Component Analysis). In this regard, previous literature has already highlighted the existence of the three critical dimensions in the evaluation of energy service gaps: access, quality, and affordability (CAF, 2022). In this paper, the outcomes of interest were grouped according to this classification. Therefore, the study of each of them provided greater granularity to the analysis.

In addition to estimating these equations for the full sample, we proceeded with multiple disaggregations. First, we disaggregated by sub-region within Latin America and the Caribbean (Central and South America). Second, this was done between the pre- (up to 2015) and post-PA (2015 onwards) stages. This disaggregation attempted to detect changes in the convergence result based on the environmental commitments made by the countries of the region in the context of the PA and the SDGs (also agreed in 2015). Third, we performed the same process by country's per capita income (high, upper-middle, lower-middle, low). A convergence result may

not be observed in the full sample, but it is possible when considering subgroups of nations with similar incomes.

Fourth, a clustering of analogous countries was provided according to their evolution in terms of energy poverty indicators. For this purpose, a K-means clustering algorithm was used. This methodology allows grouping observations based on certain characteristics (Pardo & Del Campo, 2007). The type of analysis is agglomerative: starting from individual cases, a grouping process is carried out until reaching the formation of relatively homogeneous groups. The technique used, following the guidelines of González Fernández, Donolo and Rinaudo (2009), consists in grouping cases based on the distances between them with respect to a set of variables. It begins by analysing the most distant cases and then, case by case, assigning them to the closest centre. When the number of groups is not determined, the methodology updates the number of centres in relation to the dissimilarities found between the observations. Once all the observations have been assigned to one of the groups, an iterative process is started to calculate the centroids of those groups.

In this way, the steps followed by the K-means algorithm to find the groups based on the data are detailed below (Sinaga & Yang, 2020):

1. The coordinates of the initial K centroids of the data set are randomly chosen. The centroids are the points that mark the centre of each cluster.
2. Once the centroids have been initialized, each point is clustered with the nearest centroid. For this, a measure of distance such as the Euclidean is used.
3. The centroids are updated by changing their position to the centre of the samples that were assigned to them.
4. Steps 2 and 3 are repeated until a certain stop criteria set by the user is met.

These stopping criteria can be as follows:

- Cluster assignments do not change, or a defined tolerance threshold is reached.
- A maximum number of iterations is reached.

To calculate the centroids and iterative assignment, based on Yuan and Yang (2019), we used the Euclidean distance squared in this clustering analysis, specified by Equation 4:

$$d(x,y)^2 = \sum_{j=1}^{m}(x_j - y_j)^2 = \|x - y\|_2^2 \quad (4)$$

where m is the number of dimensions to be analysed. When applying the Euclidean distance, the aim of the algorithm was to choose the centroids that minimize the sum of squared errors (SSE):

$$SSE = \sum_{i=1}^{n}\sum_{j=1}^{k}\|(x^i - \mu^j\|_2^2 \quad (5)$$

where k is the number of clusters and $\mu^{(j)}$ is the centroid of cluster j.

Results

Table 2 below shows the results obtained by estimating Equations 1 to 2 for the full sample of countries of the region. Three important conclusions can be drawn. First, the estimated coefficients report a broadly robust result: Latin American and Caribbean countries have experienced a process of β-convergence, conditional and unconditional, in energy poverty indicators in recent decades. Second, the β coefficients estimated with Equation 2 (conditional convergence) are larger in absolute value. This indicates that, when conditioning for country- or year-specific factors, the differences tend to narrow more rapidly. Third, the speed of convergence varies widely across indicators, being 0.78% for per capita energy use—each year

0.78% of the average steady-state discrepancy is removed—and 59% for per capita natural gas subsidies. In cases of conditional convergence, these speeds increase significantly. This indicates that, while the region is converging towards a shared path, these rates vary across dimensions and indicators.

Table 2: Unconditional and conditional β-convergence in energy poverty indicators in Latin America and the Caribbean

	Unconditional convergence		Conditional convergence	
Indicator	β coefficient	Standard error	β coefficient	Standard error
Access				
Per capita energy use	-.0065793***	.0024693	-.0650772***	.0102698
Per capita electricity consumption	-.0082246***	.0024052	-.0623678***	.0115017
Primary energy intensity	-.0257388***	.0047545	-.0993993***	.0181857
Access to electricity (in %)	-.0326514***	.0036673	-.0930155***	.0105138
Access to clean fuels and technologies for cooking (in %)	-.0252959***	.0021915	-.0440724***	.0041658
Quality				
Time required to get electricity (in days)	-.0099378	.0061301	-.172781***	.0371201
Fossil fuel consumption (in %)	-.0238195***	.0050593	-.1613555***	.01743
Renewable energy consumption (in %)	-.0290002***	.0058684	-.1454582***	.0160922
Affordability				
Per capita natural gas subsidies	-.1940604***	.0257963	-.4599959***	.0433432
Per capita oil subsidies	-.0957512***	.0152037	-.6177712***	.0378403
Per capita electricity subsidies	-.1655401***	.0358039	-.7907819***	.0609581

Source: own elaboration based on the World Bank and the IMF. Note: * significant at 10%, ** significant at 5%, *** significant at 1%. The number of observations and R^2 of each regression are shown in Table A.1 in the Annex for simplicity.

Next, Table 3 presents a breakdown by sub-region. For simplicity, only the estimates from Equation 1 (unconditional convergence) are shown, which are more stringent than those arising from Equation 2 (conditional convergence). The results suggest that the two sub-regions are quite similar in terms of convergence in energy poverty indicators: when convergence is verified in one of them, it is evidenced in the other as well. However, there are two exceptions: per capita energy use (only verified for South America) and time required to get electricity (only identified for Central America and Mexico). More generally, convergence occurs between countries not only in Latin America and the Caribbean (Table 2), but also in the same sub-region (Table 3).

Table 3: Unconditional β-convergence in energy poverty indicators in sub-regions of Latin America and the Caribbean

Sub-region	South America		Central America + Mexico	
Indicator	β coefficient	Standard error	β coefficient	Standard error
Access				
Per capita energy use	-.0095963**	.0039356	-.0092223	.005624
Per capita electricity consumption	-.0154557***	.003218	-.008563*	.0044788

	β coefficient	Standard error	β coefficient	Standard error
Primary energy intensity	-.0197608**	.0085548	-.0325654***	.0067531
Access to electricity (in %)	-.0653276***	.009984	-.0297526***	.0041523
Access to clean fuels and technologies for cooking (in %)	-.0397027***	.0038386	-.0224965***	.0026327
Quality				
Time required to get electricity (in days)	-.0105162	.0151263	-.0146007**	.0063161
Fossil fuel consumption (in %)	-.0211044***	.0050572	-.0274621***	.0085553
Renewable energy consumption (in %)	-.0202582***	.0060158	-.0329775***	.0083006
Affordability				
Per capita natural gas subsidies	-.2671819***	.042235	-.2035054***	.0416355
Per capita oil subsidies	-.1015264***	.03202	-.089924***	.017428
Per capita electricity subsidies	-.1707355***	.0496825	-.1340059***	.0474208

Source: own elaboration based on the World Bank and the IMF. Note: * significant at 10%, ** significant at 5%, *** significant at 1%. The number of observations and R^2 of each regression are shown in Table A.2 in the Annex for simplicity.

Table 4 presents the unconditional convergence results obtained by disaggregating by sub-periods: pre-PA and SDGs (until 2014) and post-PA and SDGs. From here, it is possible to observe an interesting fact: while most of the indicators of the access dimension suggest a higher speed of convergence in the post-PA and SDGs sub-period, the opposite is true when examining the quality dimension. In the case of the time required to get electricity, there is not even a hint of convergence after 2015. The affordability dimension cannot be examined because the database developed by the IMF starts in 2015.

Table 4: Unconditional β-convergence in energy poverty indicators in sub-periods (pre- and post-PA and SDGs)

Period	Pre-PA and SDGs		Post-PA and SDGs	
Indicator	β coefficient	Standard error	β coefficient	Standard error
Access				
Primary energy intensity	-.024715***	.0054527	-.0300864***	.0101988
Access to electricity (in %)	-.0317123***	.0042893	-.0395193***	.0050039
Access to clean fuels and technologies for cooking (in %)	-.0237147***	.0027376	-.0123004***	.0023977
Quality				
Time required to get electricity (in days)	-.0154964**	.0077116	-.0060392	.0093366
Renewable energy consumption (in %)	-.0419196***	.0086496	-.0208567***	.007262

Source: own elaboration based on the World Bank and the IMF. Note: * significant at 10%, ** significant at 5%, *** significant at 1%. The number of observations and R^2 for each regression are shown in Table A.3 in the Annex for simplicity. Some indicators are not included due to the lack of observations for certain sub-periods.

So far, we have evidenced that, on average, the region is converging in terms of energy poverty indicators. That is, these countries have reduced the disparities between them. Thus, it is worth asking whether there are subgroups of nations that are more similar to each other in relation to other countries (i.e., that have shown a similar evolution in terms of energy poverty indicators). Therefore, below we present the results obtained from a K-means cluster analysis.

From Table 5 it is possible to identify four clusters of countries. Cluster 1 consists of Central American countries plus Paraguay. This group is characterised by reduced energy intensity (higher efficiency) together with a greater penetration of renewable energies in their

consumption matrix. Cluster 2 comprises Central American countries and presents a low electricity service quality (long time required to get electricity) and the lowest oil and electricity subsidies (high cost). Cluster 3 includes small Caribbean islands and is identified with high energy intensity (low efficiency), low renewable energy penetration, and high oil and electricity subsidies. Finally, Cluster 4, composed of South American countries, evidences the highest natural gas subsidies (low cost) and a long time required to get electricity (low quality).

The above results are reasonable. First, they show that South American countries are more similar to each other than to the other nations. The same is true for the continental countries of Central America in relation to the island ones. Second, it is observed that countries with high energy intensity (low efficiency) are also those with low renewable energy penetration—this is consistent with the higher efficiency of renewable sources relative to fossil fuels. Third, the biggest consumers of natural gas—the large South American countries—are the ones that most subsidise this fossil source. Overall, this indicates that differences between regions and countries persist within Latin America and the Caribbean. That is, although the discrepancies have narrowed over time (i.e., a process of convergence has taken place), substantial differences still exist. If the territory is considered as a socially constructed space and, therefore, is influenced by economic, political, and cultural aspects, the results obtained here show the incidence of energy poverty on the territory. Thus, the existence of groups of countries with various deprivations seems to form a territoriality that exceeds the political limits of the region.

Table 5: Country clusters according to energy poverty indicators (2019)

		Cluster 1	Cluster 2	Cluster 3	Cluster 4
Country		Costa Rica	Grenada	Antigua and Barbuda	Argentina
		El Salvador	Guyana	The Bahamas, St. Kitts and Nevis	Bolivia
		Honduras	Jamaica	Trinidad and Tobago	Chile
		Paraguay			Colombia
		St. Lucia			Ecuador
		St. Vincent and the Grenadines			Mexico
					Suriname
		Mean			
Indicator	Primary energy intensity	1.10	1.29	1.53	1.21
	Access to electricity (in %)	4.58	4.55	4.60	4.59
	Access to clean fuels and technologies for cooking (in %)	4.38	4.43	4.60	4.53
	Renewable energy consumption (in %)	3.08	2.32	-.09	2.72
	Time required to get electricity (in days)	3.82	4.2	3.73	4.28
	Per capita natural gas subsidies	-0.30	1.08	2.52	3.39
	Per capita oil subsidies	5.12	3.51	7.17	5.93
	Per capita electricity subsidies	2.82	-2.54	5.19	3.51

Source: own elaboration based on the World Bank and the IMF. Some countries are not included due to the lack of observations for certain indicators. The number of clusters arises from using the Calinski-Harabasz (1974) criterion.

The results reported here are consistent with previous evidence. Salman et al. (2022) analysed the existence of convergence for a global panel of countries, during 2002-2018, in terms of 13 energy poverty indicators. The authors identified this phenomenon even though developing countries lag substantially further behind than developed ones. This process of convergence seems to deepen after 2008. Similar results were also obtained by Berk et al. (2020) when examining a panel of EU countries in terms of renewable energy penetration between 1990-2014. Other studies published consistent findings (Alatas et al., 2021; Akram et al., 2020; Liu & Lee, 2020; Romero-Avila & Omay, 2022; Cassetta et al., 2022). Thus, the results of this paper complement the previous literature by providing specific evidence for a developing region—Latin America—and for a longer and more recent time period.

Conclusions

Throughout this paper, we have examined the evolution of energy poverty indicators in a developing region: Latin America and the Caribbean. The results showed that a process of (conditional and unconditional) β-convergence took place over the last decades: disparities in terms of energy poverty indicators of three dimensions (access, quality, and affordability) have been reduced between countries. However, differences persist. Indeed, the K-means clustering algorithm optimally identified four clusters of countries.

The above results allow us to outline valuable policy recommendations. First, given the figures in Table 4, it is critical to reduce the disparities in terms of quality of energy services between the countries of the region. This could be achieved by decreasing the time required to get an electricity connection in the large South American economies (Argentina, Bolivia, etc.). Second, according to Table 5, it is clear that countries with a greater penetration of renewable energies also have higher energy efficiency (lower energy intensity). Therefore, it is advisable to encourage the adoption of renewables in those countries that still have a low penetration—generally small island states in the Caribbean. Third, based on the high environmental costs of fossil fuels, it does not seem wise to continue to heavily subsidising them. Hence, the large economies of South America should reduce their natural gas subsidies and those of Central America, their oil subsidies.

The existence of four groups of countries highlights the complexity of the phenomenon of energy poverty. Thus, the factors that determine the energy deprivations of a population are not homogeneous among the countries; then, policies that tend to address this problem should not be the same. In this sense, clearly identifying the most important determinants in the generation of deprivations translates into relevant information to combat energy poverty. Additionally, it is possible to recognize that the implementation of policies in order to alleviate energy poverty has economic and opportunity costs. The endowment of natural resources becomes a very strong operational restriction when it comes to introducing policies for the energy transition and compliance with the energy trilemma. In this sense, it can be considered that energy poverty is a factor that affects the territory and that plays a relevant role when evaluating the grouping of countries within the region under analysis.

Furthermore, despite the evidence of a convergence process between the countries of Latin America and the Caribbean with regard to energy deprivation, this paper highlights the multiplicity of aspects that are included in this concept. Its measurement and evaluation and the

policies that try to alleviate it cannot be applied in the form of a recipe, without analysing the reality of each economy and without contemplating multiple dimensions. In this sense, one of the possible policy recommendations that promote the fulfilment of development objectives is the deep and meticulous study of this phenomenon to formulate policies. Achieving energy sustainability, therefore, the elimination of energy inequity, is a central issue for countries to follow the path of sustainable development.

In the future, it would be relevant to improve the availability of data in terms of the quality of energy services. This especially includes two indicators frequently used in the literature: frequency and duration of service interruptions. Additional information on tariffs paid by users would also be beneficial. On this matter, incorporating issues related to energy prices allows a better assessment of the ability to pay for energy services and approaches the idea of hidden energy poverty (Barrella et al., 2022). This would provide a more comprehensive evaluation of the evolution of energy poverty indicators and the existence of a convergence process.

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Annex

Table A.1: Number of observations and R2 associated with Table 2

Indicator	Unconditional convergence		Conditional convergence	
	N	R^2	N	R^2
Access				
Per capita energy use	1034	0.0068	1034	0.1531
Per capita electricity consumption	1003	0.0114	1003	0.1179
Primary energy intensity	725	0.0417	725	0.1563
Access to electricity (in %)	1154	0.0819	1154	0.1866
Access to clean fuels and technologies for cooking (in %)	660	0.2526	660	0.7445
Quality				
Time required to get electricity (in days)	320	0.0088	320	0.2239
Fossil fuel consumption (in %)	961	0.0226	961	0.1544
Renewable energy consumption (in %)	1081	0.0213	1081	0.1263
Affordability				
Per capita natural gas subsidies	163	0.2326	163	0.7167
Per capita oil subsidies	347	0.0976	347	0.5577
Per capita electricity subsidies	208	0.0295	208	0.5853

Source: own elaboration based on the World Bank and the IMF.

Table A.2: Number of observations and R^2 associated with Table 3

Sub-region	South America		Central America + Mexico	
Indicator	N	R^2	N	R^2
Access				
Per capita energy use	530	0.0126	504	0.0053
Per capita electricity consumption	530	0.0592	473	0.0077
Primary energy intensity	262	0.0201	463	0.0571
Access to electricity (in %)	383	0.1010	771	0.0877
Access to clean fuels and technologies for cooking (in %)	240	0.6251	420	0.2518
Quality				
Time required to get electricity (in days)	116	0.0020	204	0.0258
Fossil fuel consumption (in %)	487	0.0350	474	0.0214
Renewable energy consumption (in %)	393	0.0300	688	0.0212
Affordability				
Per capita natural gas subsidies	97	0.1816	66	0.2870
Per capita oil subsidies	137	0.0492	210	0.1135
Per capita electricity subsidies	97	0.0907	111	0.0007

Source: own elaboration based on the World Bank and the IMF.

Table A.3: Number of observations and R^2 associated with Table 4

Sub-period	Pre-PA and SDGs		Post-PA and SDGs	
Indicator	N	R^2	N	R^2

Access

Primary energy intensity	534	0.0387	191	0.0556
Access to electricity (in %)	962	0.0693	252	0.2301
Access to clean fuels and technologies for cooking (in %)	462	0.2266	198	0.3596
Quality				
Time required to get electricity (in days)	155	0.0257	154	0.0007
Renewable energy consumption (in %)	877	0.0203	204	0.0499

Source: own elaboration based on the World Bank and the IMF.