

# Measurement Of Energy Poverty In The Colombian Caribbean Region: Comparative Analysis.

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## Research

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## Abstract

This research aims to analyze the level of energy poverty and its consequences on the quality of life of the population of the Colombian Caribbean, comparing the results obtained in this region with the data corresponding to the people of Bogotá, the capital of Colombia, and the rest from the country. Energy poverty is the deprivation of goods and services that meet basic needs for the non-use of electricity, which affects the health, education, and social inclusion of the affected population. This study applied the method of meeting absolute energy needs, determining the Energy Poverty in the Home (PEH) index. The results indicate that energy-poor households exceed 60% in urban areas and 96% in rural areas, linking energy poverty and school dropout.

## 1. Introduction

The lack of access and low quality of electrical energy supplied to the home to cover the basic needs of its occupants constitutes a dimension of energy poverty. Other indicators of this dimension include the coverage of electricity, the cost of said energy, and the possession of economic goods related to the final use of electricity [1–3].

The concept of energy poverty was born in the United Kingdom during the 1980s as a response to the difficulties faced by the population in maintaining adequate heating in their homes during the winter, a time when it coincided with the increase in the number of people affected by diseases respiratory diseases, which were torn between paying for their food or buying a heater [4, 5]. In 1991, Boardman stated that a household is in an energy poverty situation if the costs of paying energy bills exceed 10% of their income [6]. Thus, energy-poor families are increasingly vulnerable since they reduce people's quality of life because they are forced to reduce their energy consumption [7].

In [8], it is stated that a dwelling suffers from energy poverty if the sum of the total income of the people who inhabit it is below 60% of the average income of the country and the expenses necessary to achieve thermal comfort are above the average expenditure of the population for this same service. In this way, energy poverty is defined as “The inability of a household to meet the cost of its basic energy needs” [4].

Energy poverty varies according to the level of development and geographical location of a country. In developed countries, with a high percentage of families with access to modern energy, this indicator focuses on the inability to maintain thermal comfort. In contrast, it is due to the lack of connection to the electricity service in developing countries. Currently, there are 1,300 million people who do not have access to electricity in their homes [4]. Therefore, measuring energy poverty constitutes an essential element in formulating and implementing government policies aimed at social and economic development. However, in Colombia, there is no statistical information on the subject, so the research focuses on analyzing the level of energy poverty and its consequences on the quality of life of the urban and rural population of the Caribbean region and compares it with the data from the rest of the country so that decision-makers have sufficient elements that allow me to draw up plans and strategies to reduce and eliminate energy poverty [9, 10].

Electric power improves the population's quality of life by facilitating access to education, health, drinking water, and many other benefits. Furthermore, a physical connection to the electricity grid alone is not enough, as electricity must be affordable, efficient, reliable, and safe. On the other hand, an expensive and low-quality electricity service encourages families to take measures that can affect their health and well-being by using energy substitutes without the minimum standards and requirements for their use [11, 12].

Economic and social growth leads to increases in energy consumption, and there is a close relationship between poverty reduction and improvements in energy services [13]. In this way, the link between electricity consumption and economic growth expands to the Human Development Index (HDI) and the Gross Domestic Product (GDP) per capita because these indicators are directly related to energy consumption.

Over time, the role of access to electricity in the development of a nation begins to be better understood, increasing the interest of governments to expand coverage to the most remote areas of their territories and giving rise to international initiatives such as “Sustainable energies for all,” designed by the United Nations Organization, which seeks to guarantee universal access to modern energies by 2030. In 2010, the European Commission recognized that “Energy poverty, which can deprive households not only heating or cooling, but also hot water, electricity, and other essential domestic needs, is another manifestation of severe deprivation.”

The main obstacles for a country to have full coverage of the electricity system are not concentrated in financing or designing the electricity system itself but in the absence of efficient institutions, government transparency, and appropriate regulations [14, 15]. Governments often focus excessively on reducing energy poverty through energy subsidies instead of implementing service efficiency improvements, reducing energy consumption and consequently subsidy spending [16–18].

Energy scenarios aid decision-making regarding the transformation of the energy supply system [14]. Each territory has its energy characteristics and establishes its social priorities; supply sources depending on sustainability are key.

Currently, energy is considered a strategic problem [15]. It is managed and supplied through centralized management, where the endogenous potentialities of the localities are not adequately appreciated, nor are the alternatives for taking advantage of the energy resources that exist locally. This situation is accentuated in the poorest territories [16].

The document is grouped into five sections. The first contains a literary review of energy poverty, its importance, and its consequences for the population. The second section exposes the methodology used to characterize the energy landscape and the measurement of energy poverty according to [19]. The third section shows the results obtained according to the methods used, and the fourth discusses the implications of energy poverty in the population of the Caribbean region. Finally, the conclusions are detailed according to the results obtained.

## 2. Materials And Methods

The lack of reliable statistics necessary for developing indicators, actions, and plans to reduce energy poverty is one of the main obstacles to measuring this important index. These indicators are tools for communication and understanding energy problems and allow institutions to develop policies to solve them and reverse the situation [1, 20]. In Colombia, the quality of the electricity supply is quantified by the System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI), which calculate the average frequency and duration of interruptions that users have in each period [21]. The analysis of the percentage of income that households dedicate to paying energy bills corresponds to the approach of [6]. In general, the energy outlook for the departments of the Caribbean region is not good, since the departments of Atlántico, Bolívar, Cesar, Córdoba, La Guajira, Magdalena, and Sucre have a low level of electricity coverage, the quality-of-service electricity is not adequate, families must allocate a high percentage of their income to paying energy bills, and they also have few electrical appliances to satisfy their basic needs [22, 23].

To analyze the energy panorama of the analyzed region, the Household Energy Poverty Index (PEH) was calculated using the needs satisfaction method described in [19] and which is based on expression 1.

$$PEH = \frac{1}{n} \sum_{i=1}^n BE_i < 1$$

1

Where:

**PEH**

Household Energy Poverty Index.

**BE<sub>i</sub>**

economic good i.

**n**

Number of economic goods.

According to [19], the PEH index will be less than 100% when a household lacks some of the economic goods considered essential to satisfy its absolute energy needs. The number of goods (*n*) will change according to the geographical region where the household is located, so the value *n* in the equation will be different in each locality where this index is applied. The figures for electricity coverage and possession of economic goods were extracted from the Great Integrated Household Survey (GIHS) of the National Administrative Department of Statistics (DANE) for the year 2018; the data reflect each department's situation, whether urban or urban-rural areas.

The SAIDI and SAIFI indices were provided by the Single Information System of Home Public Services of September 2018. The data for the analysis of income and expenses in energy bills were extracted from the survey of Monetary and Multidimensional Poverty in Colombia of the DANE for the year 2018, where the average per capita income was determined for the capital and each department of the country. These figures were multiplied by the number of people living in a household, considering an average of 3.8 for the departments of the Caribbean region, 3.1 for Bogotá, and 3.3 for the rest of the country, obtaining, in this way, the average monthly income of household members.

Using the income and expense approach of [6], the average monthly income of families in the Caribbean region, Bogotá, and the rest of the country is determined. The value of the average monthly bill for electricity service during 2018, Table 1.

Table 1  
Comparison between the average monthly income and the average monthly bill for electricity service.

Department	Monthly average income (\$)	Average monthly energy bill (\$)	Monthly energy expenditure (% of income)
Atlántico	2,216,308	185,205	8.4
Bolívar	1,690,856	167,255	10
Cesar	1,551,114	193,584	12.5
Córdoba	1,302,097	190,464	14.6
La Guajira	1,335,320	136,863	10.2
Magdalena	1,350,809	154,240	11.4
Sucre	1,396,819	149,189	10.7
Bogotá	3,263,035	74,531	2.3%
National Average	2,061,827	108,292	5.2

According to Table 1, the average value of the monthly income Colombians dedicate to paying electricity service bills is 5.2%, a proportion lower than the 10% threshold proposed in [6]. Households in Bogotá have the lowest expenditure on electricity service bills in the country, with 2.3% of their income. However, all the departments of the Caribbean region, except the Atlantic, are in a situation of energy poverty because they spend more than 10% of their monthly income on electricity bills, exceeding both the Boardman limit and the national average.

### 3. Results

According to figures from the GIHS in 2018, the urban areas of the departments of the Caribbean region, Bogotá, and the rest of the country have 99.8% electricity coverage. However, when analyzing rural areas, another behavior is observed, Figure 1.

In La Guajira, 44.6% of the rural population does not have an electrical connection, while in Bolívar and Cesar, the coverage deficit reaches 18.8% and 26.6% of households, respectively. Córdoba with 0.7%, Atlántico with 6.4%, and Sucre with 6.6% are the only departments in the Caribbean Region below the national average of 6.8%.

According to [21], in the departments of the Caribbean region, 72.5 power outages were recorded, with a total duration of 66.5 hours, between January and September 2016. Figures 2 and 3 show the behavior of these power outages.

As shown in figure 2, Córdoba is the department with the most extended duration of power outages with 11.1 hours during September and an average occurrence of 13.8 times. The departments of Magdalena and Sucre also have a negative behavior, compared to the national average, with 9.7 and 8.7 hours, respectively. The rest of the departments of the Bolívar Region present values lower than the national average.

Figure 3 shows that after Córdoba with 13.8, Magdalena is the second department with the highest frequency of outages, with an average of 11 power outages in September; Sucre follows with an average of 10.6 and Cesar with a value of 9.5. All these departments have average power outages above the national average value of 9.19 times.

#### 3.1 Household Energy Poverty Index (PEH)

Figure 4 shows the results of the calculation of the PEH index in 2018, yielding values of energy poverty in many urban areas of the departments of the Caribbean region if we compare it with the value of the national average. This situation shows that more than 60% of households in the Colombian Caribbean area suffer from energy poverty. Only the department of Atlántico has a PEH value below the national average.

Figure 5 shows the geographical distribution of the different departments of the Caribbean region and the percentage of energy poverty that each of these departments has. The most critical case is the department of Sucre, with a PEH index of 81%, in contrast to the department of Atlántico, which has a value of 64% and is the only one to be below the national average of 67.8%.

Regarding the PEH index in rural areas, the situation at the national level is alarming since the average is 90.52%. All the departments of the Caribbean region have levels above the national average, with Atlántico being the lowest value with 96% and Sucre the highest value with 98.5%, Figure 6.

Figure 7 shows that in all the departments of the Caribbean region, the percentage of the energy poverty index in households is high. The most critical case is in the homes of the department of Sucre with a value of 98.54%; the PEH of the dwellings in the department of Atlántico is the one with the lowest value with 96.03%, although it is also high.

#### 3.2 Links between household energy poverty and school dropout

Energy-poor households may present poor conditions to guarantee adequate education; for example, there may be low or poor lighting quality, poor thermal comfort, difficult access to the computer, low level of use of information and communication technologies (ICT), among others. From the preceding, it is inferred that a direct relationship between energy poverty and the conditions make it difficult to study; therefore, increases in the PEH index will contribute to school dropout [24, 25].

The number of students by the department who dropped out of their studies at the end of the school year is recorded in the DANE Formal Education Survey [26], both in urban and rural institutions, Table 2. The study includes students who dropped out of their studies from preschool to high school. In general, the dropout rate in rural areas exceeds that of urban areas, with the departments of Sucre and Magdalena having the highest rates of student dropout in the Caribbean Region.

Table 2  
The school dropout rate in the departments of the Caribbean region and Bogotá compared to the value of the national average.

Department	Urban zone	Rural zone
	Dropout rate (%)	Dropout rate (%)
Atlántico	2.2	3.5
Bolívar	3.4	4.4
Cesar	3.0	4.0
Córdoba	3.7	3.9
La Guajira	3.6	3.3
Magdalena	3.2	4.5
Sucre	4.9	5.5
Bogotá	2.2	1.2
National average	3.2	4.2

With these data, a linear regression was adjusted by Ordinary Least Squares (OLS) between the school dropout rate and the percentage of the population in energy poverty in rural areas of the Caribbean departments. Table 3 presents the regression results, in which it is observed that energy poverty significantly increases the student dropout rate. Rural areas, although not statistically significant, also influence school dropouts.

Table 3  
Result of the simple linear regression between the student dropout rate, energy poverty, and rural areas.

	Coefficient	Standard error	p-value
PEH	0.034	0.007	0.001
Rural zone	0.014	0.362	0.778

This result agrees with the studies of [27–31], who state that access to quality electrical energy combined with the possession of economic goods that satisfy basic needs is essential for access to education, favoring the creation of comfortable environments that improve academic performance and reduce household spending on inefficient fuels, which increases the possibility of family investment in education for its members, especially children, and youth.

## 4. Discussion

The absence of an electrical connection in 117,213 homes in the Caribbean region leads to energy poverty and low quality of life since these families cannot meet their basic energy needs. The results obtained by applying the SAIDI and SAIFI indicators show that there are adverse effects on the productivity and quality of life of the affected population because many economic, social, commercial, and industrial activities are forced to stop due to frequent cuts and prolonged electricity.

Following the approach of [4], the higher the percentage of income that a family spends on electricity bills, the more difficulties it will have to guarantee minimum comfort. At the national level, households in the capital have higher income levels and spend only 2.3% on paying the electricity bill. In the Caribbean region, the department of Atlántico has the lowest bill spending with 8.4% and the highest income in the area, being above the national average. On the contrary, the departments of Córdoba and Magdalena occupy the last positions in terms of payment and at the same time have one of the highest levels of energy expenditure, with 14.6% and 11.4%, respectively.

The figures for possession of assets show the gaps in the quality of life between urban and rural families. While a high percentage of families living in urban areas have adequate cooking and refrigerating food, means of entertainment, thermal comfort, and access to ICTs, families living in rural areas have a low percentage of devices home appliances.

Those rural households without a stove and refrigerator that cook with fuels derived from biomass and do not refrigerate their food are more likely to suffer from diseases of the digestive and respiratory systems due to the decomposition of food and the harmful gases emitted by burning these fuels. In 2016, respiratory tract infections were among the ten leading causes of death in urban and rural areas in Colombia, with 15.73 and 9.76 people per 100,000, respectively [27]. This type of risk assumed by people in rural areas coincides with a higher PEH index for these areas; for example, in the Caribbean region, this value exceeds 96%, indicating that most rural households in the territory suffer deprivation of assets essential to meet their energy needs.

The department of Atlántico constitutes the best of the cases in the Caribbean Region, with a coverage deficit of 6.4%, infrequent outages in service, and the highest percentage of homes with good kitchens, means of entertainment computers, and means of thermal comfort in urban and rural areas. These figures translate into the fact that the department has the lowest urban and rural PEH indices in the entire region, being below the value of the national average in the case of urban areas, and has the least number of students who have abandoned their studies in rural areas with 1,320 points in 2016. In contrast, the department of La Guajira has the second-highest urban PEH in the region with 79% and a rural PEH of 96.8%. Additionally, La Guajira concentrates the most significant number of students who abandoned their studies in rural areas of the region, with 5,489 cases in 2016.

## 5. Conclusions

The high levels of energy poverty in urban and rural areas of the Caribbean region represent an obstacle to improving the population's quality of life because it directly affects people's basic needs, such as food, health, education, rest, and social inclusion. Likewise, people who live in homes without an electrical connection or with low quality of this service find it difficult to perform satisfactorily in their daily lives, negatively affecting their income, personal and family development, and the sustainable progress of the territory. The preceding is evidenced in the direct relationship between energy poverty and school dropout, which expresses that energy-poor households do not provide the necessary conditions for children and young people to complete their studies; on the contrary, it is common to let abandon them.

The results obtained in this research show that there is energy poverty in all the departments of the Caribbean region, with more significant impact in rural areas, where more than 96% of the departments present deprivation in their basic energy needs, exceeding the national average in rural areas which is 90.7%, a value that is also high. In this context, it is essential that government entities formulate and implement policies and strategies in the Caribbean region that expand access, coverage, and improve the quality of electricity service in such a way that it contributes to the socio-economic development of the territories with higher degrees energy poverty and reduce the gap in quality of life between households in the Colombian Caribbean and those in the rest of the country.

## Declarations

### Availability of data and materials

During the investigation, all data generated or analyzed during this study were obtained by the authors and can be shared with the international scientific community.

### Competing interests

The authors declare they have no competing interests.

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### Authors' contributions

Etna Bayona, Ana Pirela, Ever Marín: Conceptualization, Methodology, Software. Etna Bayona, José R. Nuñez, Ana Pirela, Ever Marín: Data curation, Writing-Original draft preparation. Etna Bayona, José R. Nuñez, Ever Marín: Visualization, Investigation. Ana Pirela, José R. Nuñez, Ana Pirela: Supervision. Etna Bayona, Ana Pirela, Ever Marín: Software, Validation. José R. Nuñez, Etna Bayona: Writing- Reviewing and Editing. All authors read and approved the final manuscript.

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## Figures

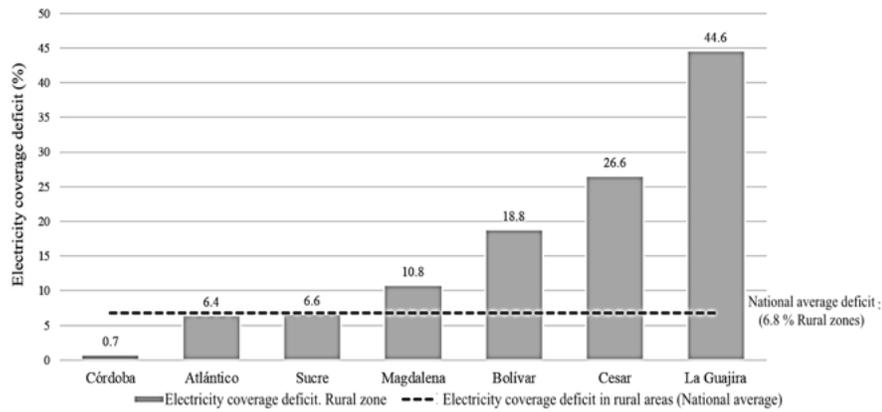


Figure 1

Electricity coverage deficit in rural households in the Caribbean region compared to the national average, 2018.

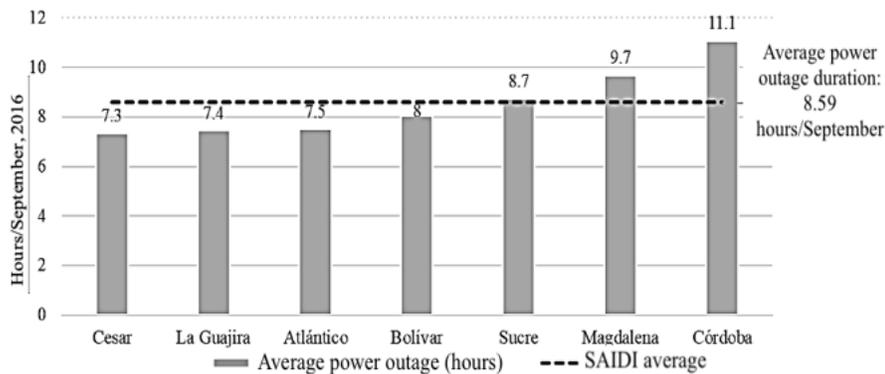


Figure 2

Duration of electricity service interruptions in the Caribbean region.

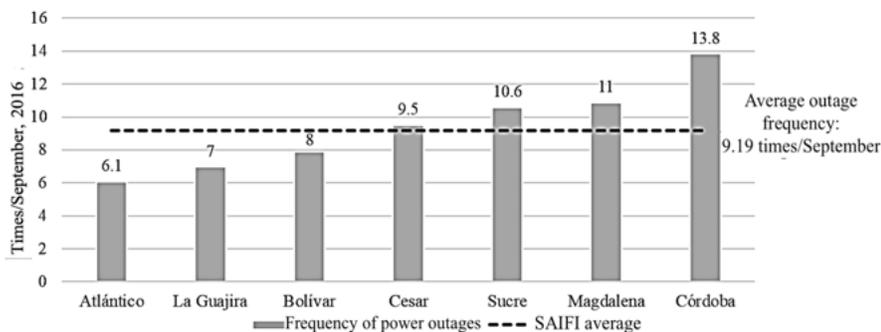


Figure 3

Frequency of electricity service interruptions in the Caribbean region.

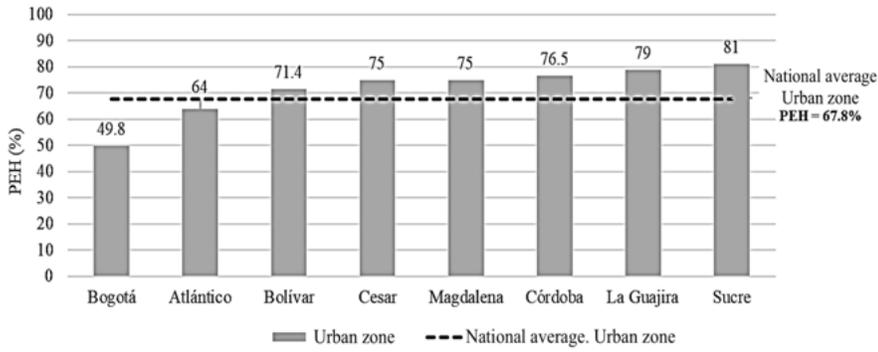


Figure 4

Household Energy Poverty Index (PEH) in urban areas of the Caribbean region, Bogotá, and national average.

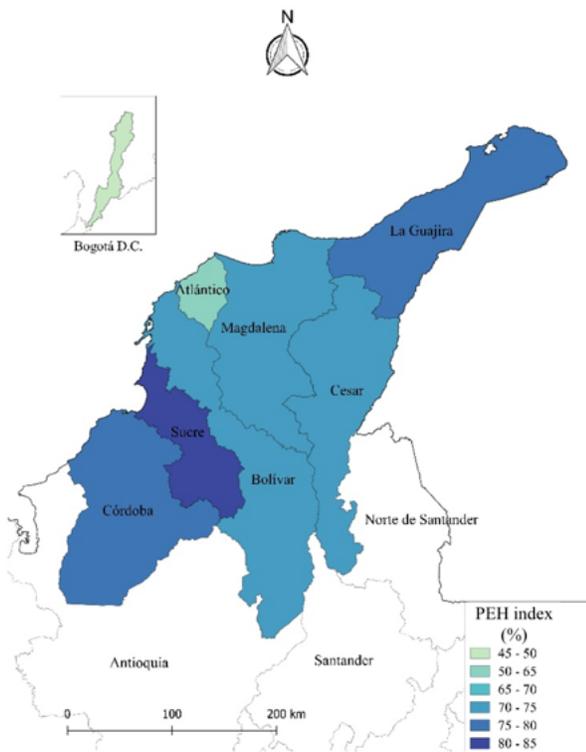


Figure 5

Households in urban areas of the Caribbean region with energy poverty.

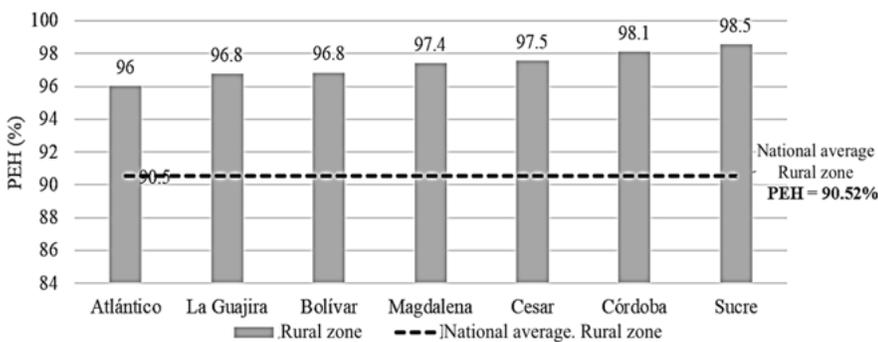


Figure 6

Household Energy Poverty (PEH) in rural areas of the Caribbean region and national average.

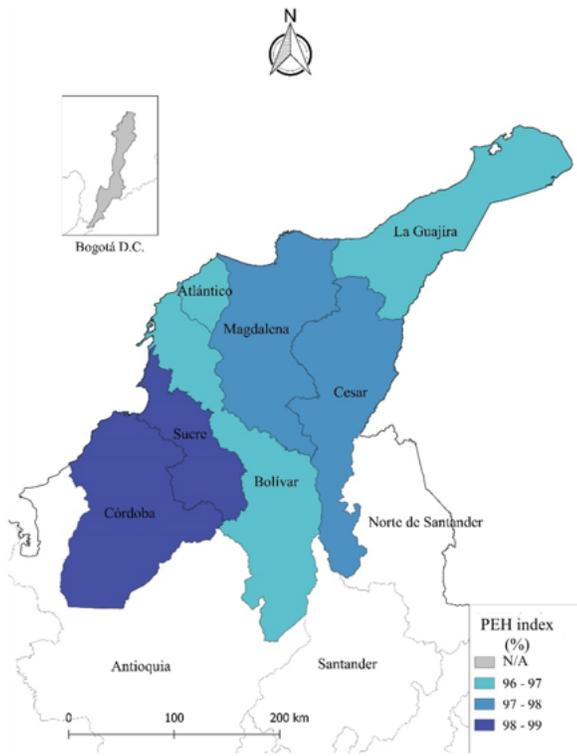


Figure 7

Households in rural areas of the Caribbean region with energy poverty.