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Review

Understanding, recognizing, and sharing energy poverty knowledge and gaps in Latin America and the Caribbean – because *conocer es resolver*

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ABSTRACT

Despite specific historical, geographical, sociodemographic, and infrastructural conditions that in combination could produce very high levels of energy vulnerability, there are significant and enduring knowledge gaps concerning energy poverty in Latin America and the Caribbean. Bringing together a multi-disciplinary and multi-national team, we focus on establishing the state-of-the-art in knowledge and policy for 5 diverse case studies - Argentina, Brazil, Colombia, Cuba, and Mexico - as well as for the wider region. Our article has three specific aims: to establish the range of approaches used to research energy poverty across the region; to examine national and supranational policy obligations; and to lay the framework for new research and policy agendas. In combination, our extensive academic and grey literature reviews, and accompanying scientometric, legal and statistical analyses, confirm that energy poverty is a relatively nascent topic, with only 62 scientific articles on the region published since 1991. From this body of knowledge, we identify key differences in the geographies of energy poverty identified by different metrics, with energy services-based approaches generally indicating higher vulnerability within rural areas, while energy expenditure metrics point towards higher risk in urban areas. We also find a dominance of quantitative approaches that tend to use existing (and often limited) forms of survey data, and a relative absence of detailed qualitative research. As such, we argue there is an urgent need for transformative research and policy activities within Latin America and the Caribbean, in order to support access to clean, reliable, and affordable energy services for all.

1. Introduction

As Josè Martí (the famous Cuban poet) put it, a key aspect of solving a problem is understanding it (*conocer es resolver*[1]). Yet, despite the maturity of energy poverty (EP) literature, and Latin America and the Caribbean (LAC) being one of the most diverse and populous regions of the world, there is an enduring knowledge gap concerning the specific forms of vulnerability to EP that exist within LAC [1,2]. In part, this

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[1] This phrase featured in his seminal essay Nuestra América, a Cuban text written in 1891 during which time Cuba was simultaneously under Spanish occupation and facing threats from an expansionist United States. The essay distinguishes Latin America from North American and European cultural values and emphasises the importance of unity and self-determination.

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arises from a path dependency established by European-led development and research projects, whereby donors typically focus investment on their former colonies within sub-Saharan Africa and Asia [3]. Other aspects that contribute to the explanation of this knowledge gap are related to differences in how LAC researchers approach energy issues. The scale of analysis seems to be more at a national (as opposed to household) level, particularly when studying energy security as the renewables transition takes off [4–8]. There is also a large body of literature around energy justice, which focuses mainly on the negative impacts of energy infrastructures on local communities [9–11], rather than on EP as a justice issue in its own right [12,13].

Overall, the LAC region has a high average rate of access to electricity (98.3%), but this figure disguises 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 [14]; it also ignores the additional challenges of electrification within so-called 'Small Island Developing States' [15]. Moreover, it overlooks issues around quality of supply and affordability. Data from the World Bank's Enterprise Surveys shows that 64.8% of businesses in LAC have experienced electrical outages, with an average of 2.1 outages in a typical month, each lasting 2.7 h on average, leading to 26.0% of businesses owning or sharing a generator [16]. This is despite the fact that many parts of LAC are rich in energy resources. Indeed, the history and identity of many LAC communities is deeply intertwined with natural resources and the conflicts around its extraction and use by colonial and neocolonial powers [17–19].

In spite of its size (spanning 33 countries and 15 recognized territories of other countries) and many shared characteristics - including languages, cultures, climate, and processes of post-colonial recovery - LAC lacks institutional 'unity' akin to the European Union polity. This lack of institutional integration in LAC has been the subject of much analysis. On the one hand, the region enjoyed several waves of institutional integration that resulted in the creation of political or economically oriented regional institutions, such as UNASUR, CARICOM, MERCOSUR, and many others [20,21]. On the other hand, the results of these integration blocks are questionable in political and economic terms. For example, intra-regional exports in LAC only account for 14.6% of total exports, as opposed to 68.0% in Europe [22]. LAC is far from having a solid supranational body of norms equivalent to European law. In addition, some of the political regional organizations, overlap and compete in diplomatic affairs [23]. These circumstances help explain the absence of regional measures to address EP in the region to date.

To address this EP knowledge gap, our paper aims to provide a broad view of the state of the art on EP in the LAC region, while also focusing on 5 countries (Argentina, Brazil, Colombia, Cuba, Mexico), which together represent a variety of political, economic, social, and bioclimatic contexts. This approach allows for both a general overview of the region, and a more detailed dive into some countries.

Moreover, our article has three specific objectives. First, to establish the range of approaches used to research EP across the region. We identified 3 main approaches: energy services, expenditure, and electricity access and reliability. These have been used in the EP literature before, but it is interesting to study where and how they have been applied in LAC. Second, to examine national and supranational policy obligations to alleviate the condition. We divided these into international obligations countries have signed up to, constitutional arrangements that impact action on EP, policies to increase electricity access and reliability, and policies for differentiated energy tariffs. And third, to lay the framework for new research and policy agendas. In the next section, we describe the methods utilized in our comparative study, and outline the specific contexts of the case study countries. Thereafter, we examine the current state-of-the-art in knowledge on EP across LAC, with a focus on existing studies, as well as comparative statistics from the World Bank and Latinobarómetro. From there, we critically review existing policy obligations to address EP, both in terms of supranational targets, such as Sustainable Development Goal 7 (SDG7), and national-level frameworks.

We take a wide view of EP within our study, with the inclusion of evidence on energy access, energy as a social good, frameworks for providing rights to energy, and generally, energy as it relates to people and society. In that sense, we find it instructive to define EP as "the inability to attain a socially and materially necessitated level of domestic energy services" [24] which allows for recognition of the fact EP is a complex, culturally sensitive, multidimensional concept. Our concluding discussion reflects on the state of current knowledge in LAC on EP severity, geography, and underlying causes, summarizes current policy responses, and ends by proposing new agendas for enhanced research and policy action.

2. Methods

Our analyses are based on comparative evidence drawn from across the LAC region, with an in-depth focus on Argentina, Brazil, Colombia, Cuba, and Mexico. We utilized documentary evidence from a range of academic and grey secondary literature,[2] including national policy reports, journal articles, and legal texts. Our extensive academic literature reviews involved a combination of conventional literature searches by individuals from each case study country, as well as comprehensive scientometric analysis of all literature concerning the LAC region, to understand dominant trends in the evolution of the field. The Web of Science Core Collection (Science Citation Index Expanded, Social Sciences Citation Index, Conference Proceedings Citation Index in Science and Social Sciences and Humanities) and Google Scholar were all searched. In addition, we searched the Redalyc (Red de Revistas Científicas de América Latina y El Caribe, España y Portugal) bibliographic database to capture research published outside of mainstream English-speaking scientific journals., Lastly, we complemented our review with broader grey literature searches on the websites of national government ministries, the World Bank, and United Nations.

Our searches included all 33 countries and 15 recognized territories of other countries within LAC, as well as regional terms for "South America", "Central America", "Latin America" and "Caribbean". All searches were conducted in English, Portuguese, and Spanish to ensure broad coverage of literature However, we recognize that by not searching in French, we risk overlooking material from territories such as French Guiana, Haiti, and St. Lucia. We included all papers that in their title, abstract or keywords featured any of the following terms:

- "energy deprivation"
- "fuel poverty"
- "energy poverty"
- "energy vulnerability"

The resulting literature was manually scanned for relevance and excluded if it was not directly related to the region, or EP issues as defined in the previous section. This documentary evidence was supplemented by descriptive statistics drawn from the World Bank's DataBank, and the United Nations' Economic Commission for Latin America and the Caribbean (abbreviated to ECLAC in English, and CEPAL in Spanish and Portuguese).

2.1. Background to case studies

Our five case study countries capture a variety of social, economic, and geographical/climatic conditions, spanning North to South America and the Caribbean, as our map in Fig. 1 and data in Table 1 highlight.

[2] The grey literature search covered the work of researchers from the region that are not employed in research institutions, but rather in government agencies.

Fig. 1. Map of climatic zones in Latin America and the Caribbean
Source: Adapted from The Koppen-Geiger climate zones [25]

Table 1
Socio-economic characteristics of case study countries.

Country	Life expectancy at birth in 2020[a] (females/ males, years)	Literacy[b] (% of total adult population)	GDP per capita in 2020[a] (current USD)	Unemployment in 2020[a] (% of labour force)	Gini Index[b]
Argentina	79.8/73.0	99% (2019)	11,687.0	10.4%	42.9 (2019)
Brazil	79.3/71.9	93% (2018)	8920.7	12.0%	53.4 (2019)
Colombia	79.8/74.2	95% (2018)	6649.6	9.7%	51.3 (2019)
Cuba	80.7/76.7	100% (2012)	8821.8	1.6%	–
Mexico	77.8/72.1	95% (2018)	9694.9	3.6%	45.4 (2018)

[a] UN [26].
[b] World Bank [14].

The main socio-economic differences between the case study countries are around GDP per capita, unemployment and the Gini Index. These reflect the different historical contexts of the case study countries.

Furthermore, the countries represent a significant variety of energy systems, with varying degrees of dependence on fossil fuels (Fig. 2) and different average levels of energy use, as shown in Table 2. These systems will be subject to different vulnerabilities due to context-specific effects of climate change [27]. Another compounding issue in the region is the exposure to natural disasters, the effects of which represent significant physical vulnerability to energy infrastructures [28].

As summarized in Table 2, all five countries have more or less universal access to electricity. However, when taking a closer look at indicators of quality and affordability of electrical supply, we can see that electrical outages are a serious problem for both private sector companies and domestic consumers in general. Furthermore, access to clean cooking is still a pervasive issue in the case study countries [14] and there is a significant proportion of people who consistently struggle to pay their electricity bill and who have difficulty sleeping on very hot (or

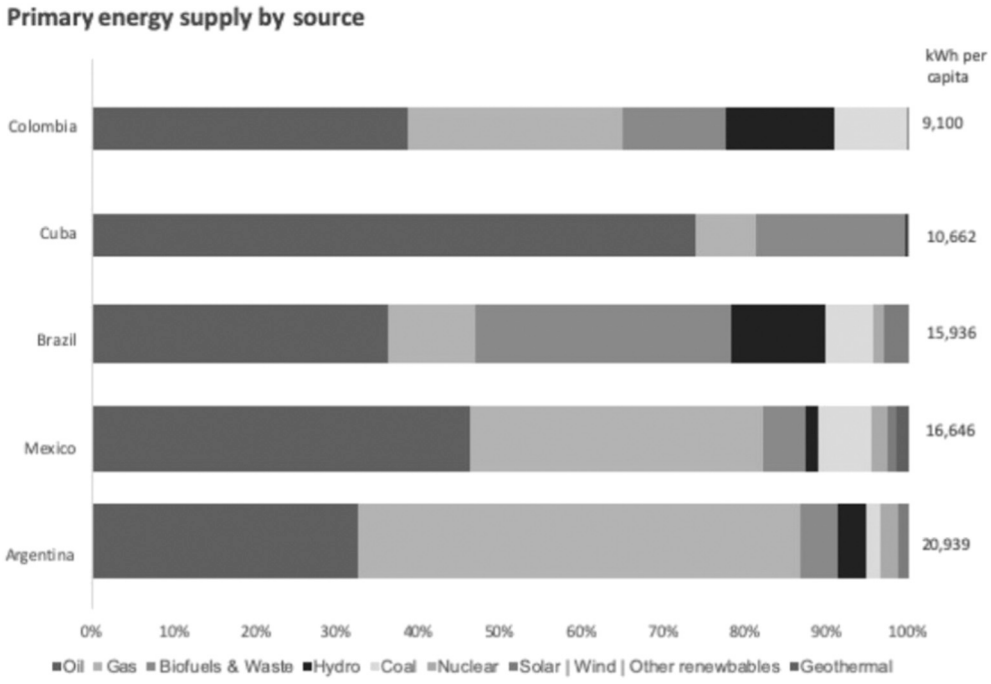

Fig. 2. Per capita total primary energy supply by source in 2018
Source: IEA [29] & WB [14]

Table 2
Summary of key energy statistics for case study countries.

	Access to electricity (2018)	Companies (with ≥ 5 employees) experiencing electrical outages	System average interruption duration index (SAIDI) (2019) (hours)	Access to clean fuels and technologies for cooking (2016)	Difficulties to pay electricity bill (2018)	Difficulty to sleep in the last 12 months when it's too hot (cold) (2018)
Argentina	100%	65.1% (2017)	4.51	98%	5.7%	30.1% (18.1%)
Brazil	100%	45.8% (2009)	6.26	96%	17.9%	56.4% (7.2%)
Colombia	99.9%	53.9% (2017)	4.50	92%	14.2%	46.% (12.4%)
Cuba	100%	–	–	79%	–	–
Mexico	100%	45.1% (2010)	0.63	85%	10.2%	66.2% (5.5%)

Sources: World Bank [14,16,30] and Latinobarómetro [31].

cold) days.

3. Results

3.1. State-of-the-art knowledge on energy poverty across Latin America and the Caribbean

3.1.1. Scientometric analysis

The body of knowledge concerning EP in LAC is quite recent. As Urquiza et al. [1] point out, most international studies on EP have been done either in countries with High/Very High Inequality-adjusted Human Development Index (IHDI), or Low IHDI, leaving LAC out of international focus. Our scientometric analysis of published academic literature on EP shows that up until June 2021, there had been 62 papers published that focus on one or more LAC countries. The first paper was published in 1991 [32], and then scientific production in the field and region was scarce until 2016, after which 80% of the papers were published. Fig. 3 shows the distribution of these articles by country; in total, evidence exists for 12 countries in LAC, with the majority of published research focusing on Brazil and Chile. We have made a distinction between single country studies, and comparative studies that cover multiple LAC countries. We also found 8 papers that included regional terms (e.g., Latin America, Caribbean), but no specific countries in their title, abstract or keywords, some of which were making comparisons with other regions such as Africa and Asia.

It is interesting to note that 67.74% of the papers are led by authors who are institutionally affiliated to a discipline in Science, Technology, Engineering or Maths (STEM), as opposed to Social Sciences or Humanities. This might help explain the lack of qualitative studies on EP in the region, and suggests that research on the region is still, overall, following a techno-economic approach [33] to energy issues. Therefore, it is perhaps not surprising that gender, and other characteristics such as ethnicity, age, disability, are very rarely part of the lens of analysis of EP in the region (as elaborated in the discussion section). Furthermore, almost all papers were written in English, despite 50% of papers being written by entirely Spanish-speaking teams and 12% by entirely Portuguese-speaking teams (based on the institutional affiliation of all authors). This reflects the pressure that LAC researchers face to publish in English, something that could be thought of as a form of academic imperialism, or linguistic privilege as conceptualized by Muller [34].

3.2. Approaches used to assess EP in LAC

Even though the field of EP is only emerging in the LAC region, there is a growing body of literature on the topic, mostly from recent years. The approaches used to study EP can be organized into three main categories:

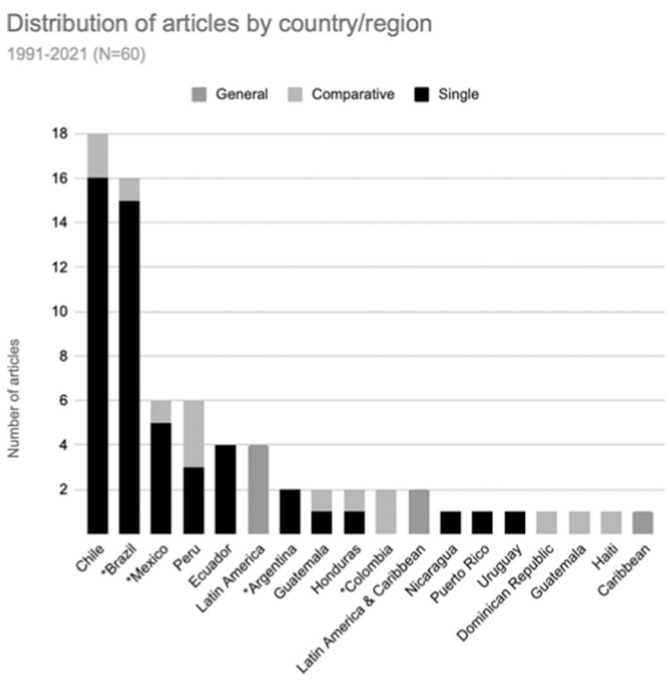

Fig. 3. Distribution of articles on energy poverty and related terms by LAC country, between 1991 and 2021.
Countries represented in this study are marked with *.

- EP through energy services: These stem from the work of Nussbaumer et al. [35], replicating it in different countries but also building on it and adapting it to better fit the LAC context.
- EP through expenditure: These were less common and show evidence of being inspired by European measures of EP, while accounting for indirect expenditure measures that are specific to the region.
- EP through electricity access and reliability: These are in line with the way SDG7 is conceptualizing energy issues.

We also added a category of "other approaches", where EP is being assessed in innovative ways, using methods and concepts that capture regional specificities and thus broaden the possibilities of analyzing EP.

3.2.1. *EP through energy services*

An energy service approach to exploring EP is the most commonly applied in the region, and in our five case studies in particular. Nussbaumer et al. [35] were the first to undertake a comparative study of EP which included LAC countries. They constructed a multidimensional energy poverty index (MEPI) for 54 countries worldwide, including 8 in LAC, which captures energy deprivation against 6 dimensions (cooking, lighting, appliances, education/entertainment, and communication). This index ranges from 0 (non-existent EP) to 1 (absolute EP). Of our case study countries, they only analyzed Colombia, which they found to have low EP (less than 0.3). Santillan et al. [36] took a closer look at seven LAC countries, applying Nussbaumer et al.'s MEPI and the Human Development Index. Using national surveys, they calculated EP on the basis of the population lacking at least one energy service, and extreme EP where the population lacks at least 30% of basic energy services. Their headlines for our case study countries are as follows (extreme EP results shown within parentheses): Colombia 29% (18%), Mexico 30% (17%). Particularly high levels of EP were found for countries such as Haiti, Peru, Honduras, Guatemala, and Nicaragua, showing this is a significant problem for LAC [35,36].

Research by García and Martínez [37] confirmed the situation of EP in Colombia Adapting the MEPI approach, they showed that Colombia has been on a positive trajectory in reducing EP, with incidence reducing from 50% to 30% between 2010 and 2017. Similarly, Hernández et al. [38] and Martinez [39], also implementing a modified MEPI, found that approximately 23% of the Colombian population is deprived of any kind of energy access or service. There is a noticeable increase within rural and peripheral areas, where calculations suggest that in 2018 an estimated 50% of households were in a condition of EP [38,39]. The peripheral areas with higher rates of energy deprivation are the Caribbean and the Pacific, with rates similar to some countries in Africa [40].

The results for Mexico were also confirmed by other authors. Garcia Ochoa [41] classified 43.4% of Mexican households as energy poor in 2010 using household surveys, on the basis that they lacked at least one of 6 essential energy services (cooking, refrigeration, entertainment, lighting, water heating, thermal comfort). Garcia Ochoa and Graizbord [42] sought to refine this approach by characterizing households by levels of deprivation of different energy services. Their cluster analysis identified 70.7% of Mexican households with all energy needs met (all services accessed). Per capita income was a strong predictor of EP, i.e., of being deprived of one or multiple energy services. There were also geographical specificities: rural location was a strong predictor of multiple service and clean cooking fuel deprivation; warmer climate zones were a strong predictor for those lacking ventilation or air conditioning. 87% of those in the most severe EP, i.e., lacking 5 out of 6 energy services, were located in warm climate rural areas (albeit the climate type classification being somewhat arbitrary [43]). More recently, Robles Bonilla and Cedano [44] have adapted MEPI to include thermal comfort as an additional energy service dimension. Moreover, they utilized bioclimatic regionalization, and found it had a better fit than traditional geopolitical regions when assessing energy services deprivation, since it addresses exclusively geographical and weather-related conditions, instead of artificial political divisions.

In Argentina, using an energy service approach, 1 out of every 4 Argentinian households has been found to be in a situation of EP [45]. Castelao Caruana et al. [46] focused on the province of Santa Fe and generated a composite EP index based on household level access and energy services provision. They found EP affects rural households to a greater extent, where there is still a lack of adequate infrastructure, no gas network, relatively low incomes, and thermally unsuitable housing.

In Brazil, Oliveira et al. [47] studied urban EP, in particular the favelas in the city of Rio de Janeiro. They outlined the concept of EP considering the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe, and environmentally benign energy services to support economic and human development. Mastrucci et al. [48] focused on analyzing the lack of essential indoor cooling as a dimension of EP and human well-being. They ran simulations to better understand energy needs to attain thermal comfort and include in their study data from Brazil, Mexico, and Peru. Their findings confirm the need to include thermal comfort as a highly relevant dimension of EP. We did not find any studies of EP using an energy service approach in Cuba.

3.2.2. *EP through expenditure*

Work that takes an expenditure approach is limited in the region, with a couple of exceptions in Mexico and Brazil. Seuret Jimenez et al. [49] classified the 32 states of Mexico according to level of energy access – high, medium, or low – based on expenditure on transport, cooking fuel and electricity, taken from 2018 national household surveys. Using a fuzzy logic technique, they identified 17 states with low energy access or at the border of low and medium; 6 with medium energy access; and 9 with high energy access, with patterns of energy access (expenditure) broadly following GDP per capita averages per state, with a few exceptions. More recently, Silva de la Torre et al. [43] took four mainstream expenditure-based indicators of EP used in Europe and applied these to household survey data from 2014. The indicators were: twice-median (2M), half-median (M/2), Low Income High Costs (LIHC), and Low Income Low Costs (LILC). Across these four metrics, they found that 19.6 million households were facing EP in Mexico, equivalent to 62% of the population. In contrast to other, energy services-based research, they

found urban households faced a higher risk of EP than rural households, which they attributed to reduced opportunities for using locally sourced firewood, as well as increased expenditure on electricity.

In Brazil, the study by Piai Paiva et al. [50] develops specific metrics for evaluating the ability to pay throughout the Brazilian territory, considering every electric power company. They find that when measured in terms of inability to pay, EP is focused in urban areas in Brazil. EP could also be inferred from indirect expenditure-related proxies, such as: the number of households who receive a discounted social energy tariff (explained further in Section 3.2), which is used by roughly 25% of the population; or the population that does not pay for electricity (non-technical losses), which is on average 15.2% of the population [51], and in certain regions this percentage reaches 45.7% of total consumption (city of Rio de Janeiro – Light Utility [51]). Interestingly, in Ecuador there was a study of EP using a combination of expenditure-based indicators and a MEPI approach to calculate overall rates of EP, which found that rural households experienced greater levels of EP [52].

3.2.3. EP through electricity access and reliability

In countries where there are few or no studies of EP specifically, and a limited amount of literature and data concerning the overlaps between energy and poverty, EP can still be somewhat assessed through the lens of energy access and electrification. Cuba has made tangible progress in increasing access to energy, moving away from a situation pre-1959 of only 56% of the Cuban population having access to electricity [53], all oil and its derivatives being imported, foreign ownership of the energy sector, and electricity tariffs that stimulated overconsumption. Cuba now has a 100% electrification rate, for which the support of the Soviet Union was fundamental. However, the fall of the socialist bloc in 1991 created a commercial deficit in oil and energy generation, leading to new national energy programmes and slow national recovery [53]. Despite the official electrification rate, in many isolated areas, only partial electricity access is obtained from renewable sources, such as solar photovoltaic, which is heavily contingent on the amount of solar radiation, on the one hand (the annual average being 5 h a day [54]), and the capacity of energy storage systems on the other.

A similar situation occurs in remote areas of Colombia. Although overall access to energy is high in the country, existing literature and official statistics highlight that this access is unevenly distributed, and the regions with the lowest levels of access to electricity are also the poorest, located on the periphery of the country, especially to the south and east, and including indigenous peoples such as the Wayuu [55]. Moreover, the quality of supply is variable. The Energy Superintendency calculate the quality of the energy supply through the SAIDI indicator. The SAIDI data shows 80% of the country's municipalities for which data is available have SAIDI of less than 140 h per year. Average interruptions reached 39.5 h and 51.3 times per year in 2017, an increase on 2016, and in the northern region reached up to 800 h and 900 times in 2018 [56,57]. This coincides with Montoya's [58] assessment that the efforts in Colombia towards universal energy access are remarkable in general, however, there is much more to do regarding rural and post-conflict areas.

In Argentina the positive impact of distributed generation systems on rural households' wellbeing has been evaluated by several authors [59–61], which is consistent with other region-wide studies focused on renewable energy sources [62]. Similarly, in Brazil, there has been a tradition of highlighting the multiplier effects of expanding access to electricity, going beyond a strictly engineering focus, to note the benefits for citizens and the state [63–67]. Electricity is not capable of breaking the cycle of poverty by itself, but noted that the arrival of electricity is transformative, increasing individuals' opportunities for converting capacities into income, and the expansion of these freedoms, in turn, feeds back the virtuous circle of development [65]. As in many other LAC countries, rural areas are behind urban areas in relation to electricity access, and thus should be prioritized [67].

In a broader comparative study, Bagnoli et al. [68] focused on the electrical system (ownership and distribution) and its relationship with EP. In a comparative study (including Brazil and Mexico), they conclude that the ownership structure of utility companies has a strong relationship with access to electricity, but having an independent regulator of the sector seemed to be more relevant to EP.

3.2.4. EP through other approaches

As well as the approaches we have summarized above, EP, the variables related to it and its risk factors, can be studied through other lenses. For instance, how some measures to reduce household air pollution might lead to inadequate indoor temperatures and thus EP [69]. Another example includes how the variables thermal comfort, condition of dwelling, heating system, energy expenses, respiratory illness and medical expenses are correlated to EP [70]. An emerging body of literature, particularly focused on Chile, evaluates EP risks in social housing allocation [71,72] and future dwellings in the Chilean context, considering climate change, income, and energy price trends, including in different areas of Chile [73–75].

In Argentina Castelao Caruana & Méndez [76] studied the relationship between EP and unpaid labour of women in urban settings. There are also studies that drill down into energy use in certain geographical regions of the country, where access is shaped by technological and economic factors such as lack of gas networks, fragmented and unregulated urbanization, unemployment, informal temporal jobs, and small-scale home businesses (such as crafts and private services) [77,78]. Of the existing work, some studies analyze the reach and spread of EP [45,79] and its evolution at national level [80] by using indirect indicators such as access to energy carriers, type of cooking fuel used, or level of income.

A noteworthy example of other approaches to assess EP, due to its use of qualitative methods, is that of Ricalde et al. [2]. Building on previous work in Mexico [44], and integrating participatory workshops in Temixco, they present a new Capabilities-driven Energy Satisfactors Index (CESI). This new multidimensional EP index methodology allows for bottom-up community input on the importance of different energy services, and for local residents to assign meaning to these energy services in terms of their everyday practices.

3.3. Critical review of existing policy obligations to address energy poverty

Access to energy has always been vital for the development of human society, hence, having States acknowledge this in policy and legal frameworks is one of the more efficient ways to address EP. There are now multiple international policy targets that attempt to push governments to address EP, albeit many times with indicators that fail to capture the complexities of EP in the region.

Our analysis of policy documents reveals that while most LAC countries do not have a formal EP definition, some do have policy measures that indirectly address the issue. There is also wider evidence that the LAC region is becoming progressively less indifferent to this matter. For example, trade unions in recent statements such as the Declaration of Mar de Plata, have expressed their desire to strengthen regional integration to defend energy as a fundamental right linked to the dignity of people [81].

The only known comparative study of EP definitions in LAC is by Montoya [58] who analyzed policies in Argentina, Brazil, Chile, Colombia, Peru, and Venezuela. He addresses EP to understand the legal challenges that true energy justice faces in South America, and recognized the complexity of assessing EP in such a variety of contexts with wide-ranging weather and geographical differences and, most importantly, different cultural and social perceptions regarding energy needs. The definition of EP that frames his findings is the one from CEPAL [82] which acknowledges EP in a household when its inhabitants are not able to meet their absolute energy needs: needs that should be considered “essential in the set place and time according to the social and cultural

conventions."

3.3.1. International policy targets

The main supranational target that exists to address EP within LAC is the United Nations Sustainable Development Goal 7 (SDG7), to 'Ensure access to affordable, reliable, sustainable and modern energy for all'. This goal consists of five targets and six supporting indicators. Of most relevance to this study is Target 7.1 'By 2030, ensure universal access to affordable, reliable and modern energy services'. SDG7 represents the most influential global effort to address EP, particularly as "neither the 1992 Rio Declaration on Environment and Development (UN, 2014) nor the Millennium Development Goals 2000–2015) mentioned EP or access as major issues" [83,84]. However, despite the influence of SDG7, there is no single internationally accepted definition of what constitutes energy access, and subsequently there are numerous definitions in operation. The International Energy Agency (IEA) defines energy access as "a household having access to electricity and to a relatively clean, safe means of cooking" [85] in line with indicators 7.1.1 and 7.1.2 of SDG7. This simplistic binary definition of access to modern energy has in turn been used as an international proxy for EP, due to the convenience of simple calculation, ease of communication, and reduced costs compared to other metrics [86].

However, defining energy access in line with SDG7 means excluding factors such as affordability, safety, convenience, and quality of supply. As has been discussed in some of the literature reviewed above, a household can have access to electricity but at the same time be unable to use the service due to prohibitive costs, or frequent interruptions to supply. This approach has also been criticized for the superficiality of resulting policy measures, which typically aim only to reduce the electricity access deficit. That said, the World Bank has made steps to develop the concept by defining Multi-Tier Frameworks, where, for the example of access to electricity, "successive thresholds for supply attributes allow increased use of electricity appliances" [87]. However, this approach has been criticized for institutionalizing misleadingly low power levels that do not meet household needs [88].

The United Nations has played an important role in addressing EP in LAC, via CEPAL and the United Nations Development Programme (UNDP), which have both sponsored reports that have advanced knowledge on the topic [41,89]. Given the region's lack of institutional 'unity', as previously mentioned, CEPAL is the main structure that exists for cross-continental collaboration. Consequently, efforts to legislate on the topics of energy access and EP have been relatively piecemeal and fragmented.

3.3.2. Constitutional responsibility for adequate energy provision

Inclusion of certain elements related to EP in constitutions seems to be commonplace in LAC, particularly in relation to the State's responsibility to guarantee minimum levels of public services. For instance, the national Constitution of Argentina established in 1994 institutes certain guarantees over the quality and efficiency of public services (art. 42), with the objective of ensuring that those services are given in conditions of equality, continuity, regularity, and to all users. Moreover, in response to diverse international treaties that take precedence over the national constitution (art. 75), the Constitution recognizes citizens' right to a healthy environment with access to household and basic public services. In addition, the Convention on the Elimination of All Forms of Discrimination Against Women establishes that States must implement measures that ensure "adequate living conditions, particularly in relation to housing, sanitation, electricity and water supply, transport and communications" (art. 14-h). These norms not only give the State an active role as provider and regulator of household public services, but also establish that these services have a social function and are a necessary condition for people to develop their capabilities [90].

In the case of Colombia, important progress was achieved through the jurisprudence of the Colombian Constitutional Court. This tribunal has stated, in numerous decisions, that the right to electricity access is associated with fundamental human rights, such as the right to live, the right to have good health or the right to have a proper home [91,92]. According to the Constitutional Court, a person or household is in conditions of EP when: (i) they are unable to afford a minimum amount of electricity to satisfy their domestic needs (heating, lighting, refrigeration, and cooking) or; (ii) when they are forced to allocate an excessive part of their income to pay the energy bill [92]. As a result, public utilities are now obliged to respect certain consumer protection conditions before cutting off electricity service to vulnerable populations.

In Cuba, energy access forms the basis for several articles within the Cuban Constitution of 2019, albeit not explicitly. Access to a safe environment (art. 75), conceptualizes that energy access must be acquired by means of sustainable technologies. In terms of jurisdictional protection, the Constitution states the possibility of resorting to courts when faced with a violation of constitutional rights (art. 99); but it remains unclear under what jurisdiction energy access falls, when it has not been explicitly recognized by the legislation. Furthermore, the second paragraph of the same article calls for laws of development which are to establish the constitutional rights subject to jurisdictional protection, implying that there are then constitutional rights which are not granted a jurisdictional guarantee, again leaving the guardianship of a right to energy ambiguous. Also noteworthy is the active Electricity Law No. 1287 of 1975, which, still rules over the generation, distribution, and commercialization of electric power. This norm does not stipulate mechanisms for power cut complaints or any other infringement to the right to energy, other than a complaint procedure for improper and inadequate payment (art. 11).

Regarding discourses on rights to energy, in Mexico, Acuña Zepeda and Díaz Zepeda [93] argue that article 4 of the Mexican Constitution addresses rights to the development of the family and to a decent home, and that these cannot be realized without access to energy, therefore implying a right of access to energy – which goes beyond the constitutional obligation of the state to provide energy infrastructure. In addition, Mexico has ratified the aforementioned United Nations Convention on the Elimination of All Forms of Discrimination Against Women which establishes access to electricity as a human right, and articles 1 and 133 of the Mexican Constitution make this convention a mandatory norm for Mexican authorities. The rights of indigenous and agrarian communities regarding the impacts of energy infrastructure development and the use of land for such are also given preferential status in the Constitution (ibid.).

In Brazil the discourse around energy rights has also emerged and been studied. In particular, Da Silva and Rosa [94] have connected electricity access with human rights, highlighting that the Brazilian Constitution in article 3 states that the fundamental proposal of the federation is to build the means for freedom and justice, thus supporting the eradication of EP, and offering hope for stronger provisions in the future concerning rights to energy.

3.3.3. Policies and programmes to increase energy access

As well as including considerations of a right to energy in national Constitutions and other legislative mechanisms, the governments of the region have developed several policies and programmes to increase energy access. While this is not a sufficient condition to tackle EP, it is a necessary one.

The Government of Mexico has implicitly acknowledged EP as a problem, in terms of access to clean or modern energy. In the "Transition Strategy to Promote the Use of Cleaner Technologies and Fuels' [95], they consider the issue of eliminating EP, mentioning two aims: the first being to develop universal energy access programs, which must be aligned with the United Nations Program "Sustainable Energy for All"; the second to promote the use of rural solid waste to produce biogas, as well as the use of installations of isolated or grid-connected photovoltaic systems. The Legislative Strategy for the 2030 agenda [96] mentions

meeting SDG7, and that EP (not precisely defined) must be eradicated, but not how it should be done.

In recent years in Cuba, significant policy commitments to addressing EP have been made within the 2018 "Conceptualización del Modelo Económico y Social Cubano de Desarrollo Socialista" and later guidelines established in the 2020 "Política Económica y Social del Estado", where energy access receives undeniable support from the national governance institutions. Moreover, the "Plan Nacional de Desarrollo Económico y Social 2030", outlines some strategic development objectives, in which it implicitly seeks to guarantee adequate, reliable, diversified, and modern energy supply, derived from growth in renewable energy. Increasing quality of life is a main objective, with special emphasis on the importance of national energy security as a fundamental good.

In Colombia the recent energy regulatory framework introduced new dispositions to mitigate EP in the Not Interconnected Zones (ZNI's) which are distinguished by low levels of average consumption, users' low capacity to pay and high costs of electric power service [97]. The isolation of these areas makes the logistics of electricity service difficult, resulting in high investment and operational costs [98]. The new policies aim to improve the access and quality of electricity services of ZNIs by promoting renewable energy distributed generation facilities, which can achieve substantial efficiencies in transmission and generation costs [99–101]. Another example is the National Energy Plans (PENs), which, although not binding, establish objectives for the development of Colombia's energy sector. Most recently, PEN 2015 [102] outlined the importance of understanding EP in order to accurately promote the universalization and affordability of electricity, and set out a series of goals. Firstly, it highlights the necessity to adapt the EP concept to local climatic circumstances. Secondly, it proposes the creation of a methodology that could clearly define the parameters that must be considered to calculate the levels of EP in Colombia. Thirdly, PEN 2015 proposes defining the concept of a "vulnerable consumer". Fourthly, it suggests building an EP indicator in Colombia. Finally, in order to finance some of the policy guidelines for the energy sector, Colombia conceived a series of energy funds. For example, FAZNI or Financial Support Fund for the Energization of Interconnected Rural Areas, was created to finance investment plans, programmes, and projects in energy infrastructure ZNIs. Similarly, the Social Energy Fund or FOES is used to cover part of the value of the electricity destined for the consumption by users located in Areas of Difficult Management or Subnormal Urban Areas [103,104].

A noteworthy Argentinian national policy in terms of increasing access and adoption of renewable energy is the Proyecto de Energías Renovables en Mercados Rurales (PERMER). This policy provides access to electric and thermal energy to scattered rural populations by means of distributed renewable energy systems (solar photovoltaic and wind), and equipment such as biofuel cookstoves, boilers, solar water pumps, and electric cattle-herders. In spite of political changes, the project has continued over 20 years, and impacted over 29,000 people by 2012 [105]. However, critics have highlighted the programme's limitations in bringing about sustained and holistic energy access given that the provided equipment and systems are not sufficient to cover basic energy needs - food refrigeration or thermal comfort - and their maintenance and operation is often the responsibility of end users, who are already in precarious conditions [60,61].

Public energy policy in Brazil has mainly focused on the expansion of access to electricity. Since 2003, there has been a major Rural Electrification Program (Programa Luz para Todos) reaching US$5.2 billion investment by 2020, which has expanded access to more than 15 million people [106]. Effort was particularly focused on rural areas. In 2019, the federal government launched "Mais Luz para a Amazônia" seeking to bring electricity to 350,000 people in remote regions of the Brazilian Amazon, with an estimated cost of US$600 million [107]. These programmes have meant Brazil is almost at the point of completely universal electricity access, however, the future of Luz para Todos looks uncertain as it is currently under review with the possibility of removal.

3.3.4. Policies for differentiated tariffs

Another popular way in which governments from the region have tried to (indirectly) tackle issues associated to EP has been through modifying the structure of tariffs to make it easier for low-income households to pay for energy. This type of policy is widespread throughout the region and has become an important social policy tool in the context of the COVID-19 pandemic (see Section 4.2).

For example, in Cuba in January 2021, a new process appeared: with the 'Ordenamiento Monetario' [108], which modified electricity tariffs in order to guarantee energy affordability. Until December 2020, Cuba had a currency duality, which disappeared on the 1st of January 2021. A progressive elimination of undue gratuities and unnecessary subsidies was implemented as a consequence of this, affecting energy tariffs (electricity and gas). The "Ministerio de Energía y Minas" proposed a tariff scheme that, after some modifications that took into consideration the popular opinion, reduced the tariffs scheme making them more affordable for households and small business.

In Mexico, there have been several mentions of the term EP within high level policy documents. In 2018, the official advisor to the Federal Congress, CESOP, noted that a person can be in a situation of 'energy poverty', even if their home is electrified, if they do not have sufficient financial resources to use electricity, gas, or gasoline to be able to use the car [109]. There have not been any specific policies as a consequence of this acknowledgement of EP, however Mexico already has in place a differentiated and subsidized electricity tariff system. Under this system, 73.4% of basic and intermediate levels of electricity consumption (which vary depending on climatic conditions of the region in question) are subsidized on average. Excess levels of consumption are charged at higher rates. However, these types of policies do not always consider households' living arrangements and can become unintendedly regressive. For instance, if several households share an electricity meter, they could be charged higher "excess" rates, while in reality they are still within basic levels of consumption [110].

Some of Colombia's institutions have been referring to EP under the parameters of the definition provided by CEPAL [58]. As a consequence, Law N° 142 of 1994 introduced electricity and gas subsidy schemes, in which the wealthiest social classes pay a tax to support the Basic Subsistence Consumption (BSC) of the most vulnerable social classes. The BSC for gas is 7.26 m3 per month and 130Kw or 170Kw for electricity per subscription, depending on the location [111,112]. Under this scheme, vulnerable populations receive subsidies for their electricity and gas consumption that can reach up to 60% of the BSC [113].

A Brazilian policy to address EP in relation to affordability is the "Social Tariff", which applies to families enrolled in the Single Register for Social Programs of the Federal Government and provides a discount on the energy tariff. The discount is given according to the level of household consumption in kWh per month; those who have consumption less than or equal to 30 kWh receive a 65% discount, between 30 kWh and 100 kWh receives a 40% discount, between 100kwh to 220kwh has 10%, and greater than 220 KWh have 0% discount. It should be noted that the social tariff does induce distortion, because it does not consider energy efficiency and the reality that people in EP often use less efficient equipment and materials, consuming more energy. Brazil has a high rate of non-technical losses (in which consumers do not pay for their energy use), in some areas as high as 46%. There are regulatory targets to reduce these losses, but more oriented by regulatory issues and penalties to electric utilities than social concern within Agência Nacional de Energia Elétrica (ANEEL), the electricity regulatory agency.

The case in Argentina is somewhat different. For the past 20 years, energy services affordability has been subject to political will, in regulating and subsidizing - universally, but with regional differences - tariffs for electricity and gas. The continuous implementation of subsidies and tariff regulation has allowed many low-income households to achieve near adequate consumption levels but has also entrenched inefficient

appliances and consumption practices. However, due to fiscal pressure, the preceding government decided to phase out subsidies and adopted a segmented tariff policy. This led to the creation of two programs: "Tarifa Social" for electricity provision and "Plan Hogar" for bottled gas. Both programs were designed to partially subsidize energy consumption for vulnerable households; however, their reach is still unknown, as requirements for participation and number of subsidies are to be determined by regional governments, and do not respond to infrastructural or social conditions of households. Recently, the national State has passed a law to establish differentiated lower gas tariffs for the coldest provinces in the country, relegating however the discussion on electricity tariffs in the warmest provinces. Whilst EP is not defined at a national level, an interesting example of uncritical policy transfer from the UK can be found at the regional level within the autonomous city of Buenos Aires, where the Ombudsman (Defensoría del Pueblo) defines EP as spending 10% or more of income on gas and electricity [114]. Moreover, the Ombudsman goes a step further in determining that energy vulnerability is a situation in which a household is spending 20% or more of income.

4. Discussion and conclusion

Our analysis confirms that EP is a relatively nascent topic within LAC. Most countries in the region are relying solely on simplistic metrics of access to understand energy deprivation, thus overlooking more complex dynamics associated with EP. At face value, access to electricity metrics show high connectivity rates across LAC, with a handful of studies that confirm multiplier effects of expanding access [64,65]. However, research also highlights issues of affordability [50] and householder inability to convert this access into useful end energy services [36], which need attending to. Given the scarcity of research, it is perhaps unsurprising that there is a lack of systematic knowledge on the structure of EP in LAC. For one of our case study countries, Cuba, there has been no published research on EP in any form.

However, what we can say about the existing evidence base is that knowledge production is generally based on quantitative methods. Work by Ricalde et al. [2] and Brand-Correa et al. [115] are some of the few studies in LAC that incorporate qualitative research, based on participatory workshops with communities in Mexico and Colombia respectively, to create a bottom-up understanding of energy needs. Quantitative energy service-based approaches, such as adapted MEPIs, have been dominant in recent years, with fewer studies applying energy expenditure-based metrics. This is an interesting observation since energy services-based approaches generally indicate that higher levels of EP are found within rural areas [38,46], which has been attributed to lack of adequate infrastructure and poor housing quality. By comparison, metrics based on energy expenditure, as found in Brazil and Mexico [43,50], point towards higher probability of EP in urban areas. This has distribution justice implications and points to the need for research that integrates both energy expenditure and energy services-based approaches, in order to detect different dimensions of EP. The existing literature also highlights the importance of incorporating thermal comfort within assessments of EP [44,48], which is a dimension that Nussbaumer et al. [35] omitted in their original MEPI work.

Work within Brazil highlights interesting tensions around energy subsidies, impacts of state withdrawal of support, and non-payment of electricity bills (e.g., [50]). These are likely to be issues that other LAC countries face, with additional exacerbation of affordability issues during the COVID-19 pandemic. This makes the findings of comparative research by Bagnoli et al. [68] all the more relevant, who highlight the importance of independent regulatory agencies for improving EP outcomes in countries where electricity utilities are privately operated. Some authors emphasize that significant opportunities exist for using renewable energy systems as a means to address EP [62]. However, in doing so, we need to take lessons from historic issues of renewable energy systems being installed that have not provided sufficient levels of energy to meet household needs [54,61].

In terms of policy frameworks, there are no formal definitions of EP in LAC, however, many countries informally use the parameters of the EP definition provided by the UN's CEPAL [58]. Moreover, a number of national written constitutions include clauses that allude to the right to have access to electricity as a fundamental good, and for achieving other constitutional rights. Some national institutions have also provided their own interpretation of EP, for example, the constitutional court of Colombia defines EP in terms of being unable to pay for a minimum amount of electricity for satisfying domestic needs or being forced to allocate an excessive proportion of income to paying for energy. This is in line with the Mexican Center for Social Studies and Public Opinion, the official advisor to the federal congress, whose definition goes slightly further in also including gasoline for car use. At the city-level, the Ombudsman for Buenos Aires defines EP as spending 10% or more of income on gas and electricity [114], evidencing partial policy transfer from the United Kingdom. That being said, efforts to legislate on EP in LAC have generally been piecemeal and fragmented, although we can see some evidence of political will to address EP (e.g., [102] for Colombia, and [96] for Mexico), with proposals to develop new programmes and metrics.

4.1. Future research directions

From the existing evidence, it can be stated that studies in LAC mainly, but not exclusively, answer questions relating to: *How many people are energy poor?* and *Which geographic areas are most impacted?* But fail to provide evidence to questions such as: *What are the characteristics of an energy poor household?* and *Who is most affected?* As such, in order to be able to properly define, analyze and resolve EP, important gaps in understanding need to be addressed. Future research directions indicated in our analysis can be grouped into three overarching themes: intersectional analyses of social vulnerability; interdisciplinary research teams; and interconnecting and improving data.

4.1.1. Intersectional analyses of social vulnerability

By recognizing the interconnected nature of social categories, and embedding factors like race, disability, age, and gender within research on EP, it is possible to better acknowledge and ground the differences among people at risk of experiencing EP. Energy needs should be considered within the overall context of community life and recognizing differential needs according to different communities [116]. Participatory methods can be used to co-generate understanding of the energy services desired by communities, which in turn can help to avoid institutionalizing energy vulnerability by, for example, installing inappropriately small renewable energy systems. Intersectional approaches can also help to centre the importance of cultural practices and help to understand the reasons for particular fuel choices, without stigmatizing users – as has happened with biofuels [78]. Moreover, greater emphasis on intersectionality is critical for understanding the strategies that energy poor households adopt, and the impact of these practices on household wellbeing, especially for women who are, in general, in charge of managing household resources [117].

4.1.2. Interdisciplinary research teams

EP in LAC is often approached from a technical perspective, with limited use of qualitative methods. We argue that understanding EP from the perspective of diverse branches of knowledge is fundamental for achieving inclusive policy design and evaluation. The integration of social scientists and in-depth qualitative research is needed to gain a better understanding of the different energy practices, norms, and needs that exist within particular societies. Moreover, social scientists from critical race and feminist perspectives are well placed to advance research that takes a fundamentally intersectional approach. Interdisciplinary approaches are also key to addressing other challenges identified within the literature, such as how to adequately assign weights to energy services during EP index construction [46]. The latter is a topic

that Ricalde et al. [2] address in Mexico via a mixed-methods collaboration between physical and social scientists, resulting in an index that used both qualitative participatory workshops and quantitative survey analysis.

4.1.3. Interconnecting and improving data

Our third direction for future research concerns the improvement of large-scale data and indicators, which are essential for informing policy design, monitoring, and evaluation [118]. A consistent theme in the literature are the limitations associated with existing survey data (e.g., at a regional level [46] and around thermal comfort [78]). In general, there is a need for a wider range of energy services to be reflected in surveys, moving beyond narrow conceptualizations of 'essential' energy services [2]. As noted earlier, there is also a need for research that integrates both energy expenditure and energy services-based approaches, in order to detect different dimensions of EP, which in some cases implies linking different datasets. In this regard, we would encourage experimentation with unconventional, innovative, and less used forms of data for assessing EP, as advocated by Sareen et al. [119]. Our final observation concerns the lack of strong institutions for pushing forward an agenda of improving and harmonizing data across the whole region, as we have seen the EU Energy Poverty Observatory achieve in Europe [120]. This links back to earlier comments on the extent of collective identity and regionalization across LAC, which has been a key factor in the fragmentation of EP measurement and policy approaches.

4.2. Future policy directions

Across LAC there have been fragmented efforts to legislate on EP, with early indications of growing political will to implement new policy frameworks and alleviation programmes. Moving forward, we see two key areas for policy action: defining energy poverty on a national and regional basis, and creating new EP alleviation policies and programmes.

4.2.1. Formal definitions of energy poverty

Developing a shared understanding and definition of EP is important for raising the profile of the issue, as well as for protecting vulnerable populations against it, particularly within institutions such as Constitutional Courts [58]. However, as detailed across our paper, the variety of contexts in LAC makes a shared detailed definition of EP hard to implement. As such, Thomson et al. [121] recommend creating a simpler common top-level policy definition that avoids being overly prescriptive, and supplementing this with detailed national and local-level definitions. Writing in relation to policy definitions of EP in Europe, Thomson et al. [121] also caution that path dependency often makes definitions 'sticky' and hard to change over time, and so the longevity of definitions needs to be considered, recognizing that living standards and energy needs evolve between generations.

Formal recognition of the concept can exist in various spaces, such as in official government reports, and decrees. Indeed, as noted in Section 3.2, several legal scholars have studied national constitutions in LAC to assess the extent to which rights to access energy are protected by constitutional clauses [93,94], from which it is evident that energy is essential for achieving other human rights. However, further socio-legal work is needed to ensure that equitable access to affordable, reliable, and safe energy can be guaranteed for all in LAC. This includes designing formal and explicit constitutional recognition of access to energy as a fundamental, interconnected, and interdependent right, instituting new mechanisms for systematically evaluating the quality and reliability of energy carriers, and implementing new policies to address any identified energy vulnerabilities. It also necessitates the establishment of independent and autonomous organizations that can investigate complaints concerning energy supply, e.g., following the example of the Ombudsman for Buenos Aires [114].

4.2.2. New public policies and energy policies to alleviate energy poverty

Formal public policies are needed to regulate the role of state institutions in ensuring affordable and equitable energy access for all citizens. Policies and measures to alleviate EP can take a variety of formats, including schemes aimed at addressing structural drivers, such as energy efficiency, renewable energy, and energy audits. Direct financial assistance can also be given to households to address affordability issues in the short-term, e.g., social tariffs and direct cash transfers. Whilst structural support is the most sustainable long-term, it is clear that a mixture of approaches is needed, particularly in countries where there is a high level of existing reliance on subsidized energy tariffs, as in Mexico for example. In any case, it is imperative that synergies are found with other policy areas, in order to integrate EP policies and projects in a holistic way with other improvement efforts relating to health, education, agriculture and job creation [122]. Here we see strong potential for policy entrepreneurship as a vehicle for policy innovation.

New EP policies need to recognize and account for both physical vulnerabilities arising from natural disasters and climate induced changes, and social vulnerabilities resulting from the intersections of characteristics such as age, gender, and ethnicity. Moreover, potential barriers and impediments to policy uptake need addressing, including levels of energy literacy, and financial implications of policy design. To ensure inclusive governance, meaningful citizen participation in decision making must be a fundamental element in the drawing up of new public policies, laws, and norms on energy. Above all, new policies to address EP must be situated within the context of COVID-19. A global mapping exercise by Hesselman et al. [123] shows significant divergence among our case study countries in providing emergency energy policy responses to COVID-19. Mexico has taken little action, thus far only suspending energy tariffs for the highest level of consumption, whilst Cuba has mainly focused on issuing energy saving advice and suspending in-person meter readings and delayed in-person payment of bills. By comparison, Colombia has introduced various policies, such as tariff freezes, delayed payment of bills for up to 36 months, a ban on disconnections, and a scheme to reconnect energy supply to households free of charge - with at least 8400 reconnections made by April 2020 (ibid). In Brazil, the National Electric Power Agency introduced a ban on electricity disconnections, and adjusted tariff increases so that they would be spread over five years to preserve the affordability of energy in the short and medium term. The Brazilian government also introduced a free energy scheme for low-income households on social tariffs, which provided up to 220 kWh per month free of charge in April, May, and June 2020 (ibid). Meanwhile in Argentina, the government introduced a ban on disconnections for various household groups classified as vulnerable, extended a tariff freeze for natural gas and electricity, and approved a price freeze on liquified petroleum gas (LPG) for domestic consumption (ibid.). It is clear that new energy vulnerabilities arising from COVID-19 will continue to unfold for many years to come, particularly when temporary price freezes and disconnection bans come to an end, making the case for transformative action against EP in LAC all the more critical.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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