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MULTIDIMENSIONAL ENERGY POVERTY IN COLOMBIA AND NARIÑO: CONCEPTUAL FRAMEWORK AND PROPOSAL FOR A RESEARCH AGENDA

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ABSTRACT

Energy poverty constitutes a critical dimension of multidimensional poverty, articulating simultaneous deprivations in access to, quality of, and affordability of modern energy services. In Colombia, multidimensional indices based on the Alkire-Foster methodology reveal profound gaps between urban and rural areas, with particularly critical situations in territories such as Nariño. This article develops an analytical review of international, regional, and national literature, examining its relevance for interpreting energy poverty in Nariño, a department with approximately 64% rural population where this issue has received limited specific academic attention. A theoretical framework is presented that integrates multidimensional poverty, Amartya Sen's capabilities approach, and just energy transition. Key indicators and methodological decisions for constructing a departmental energy poverty index are discussed. Based on this synthesis, an applied research agenda is proposed for the planning of territorially differentiated energy infrastructures.

KEYWORDS: Multidimensional Energy Poverty; Alkire-Foster Method; Just Energy Transition; Nariño; Colombia; Human Capabilities; Territorial Energy Policy.

1. INTRODUCTION

Modern energy is a critical input whose availability fundamentally conditions real possibilities of human development in peripheral territories. Energy poverty, conceptualized from a multifactorial dimension, simultaneously encompasses restrictions in the quantity of available energy, quality of supply, economic capacity for access, and effective possibility of using it to carry out essential activities: lighting for night study, refrigeration for food preservation, hot water for personal hygiene, and operation of tools that generate income (Nussbaumer et al., 2012).

On a regional scale, Latin America faces a structural contradiction: while urban electricity coverage reaches significant percentages, populations in rural territories depend mainly on traditional biomass for cooking, generating chronic respiratory diseases that particularly affect women (Thomson et al., 2022). This unequal distribution reflects historical patterns of political and economic exclusion where rural, indigenous, and Afro-descendant populations face multiple barriers: geographical barriers that raise infrastructural costs, institutional barriers that weaken local governance, and cultural barriers that exclude communities from decisions about projects that affect their territories (Sareen et al., 2020).

Colombia presents an eloquent case of contradiction between national energy capacity and equitable access. As a regional producer with significant hydroelectric capacity, approximately 15.4% in 2024 of Colombian households experience multidimensional energy poverty according to the Ministry of Mines and Energy (2024). However, urban areas achieve high electricity coverage while rural territories remain with limited access and precarious quality, transforming available electricity into a resource that is not very usable for multiple uses (Ministry of Mines and Energy, 2024).

Nariño, a southwestern department bordering Ecuador, concentrates energy vulnerabilities that deserve specific academic visibility. With approximately 56% rural population (2.4 times higher than the national average of 23%) and mountainous geography characterized by mountain ranges, inter-Andean valleys and the Pacific coast, it faces severe energy deprivation derived from diseconomies of infrastructural scale. According to the 2024 Multidimensional Poverty Index, Nariño has an incidence of 18.1% (higher than the national 17.1%), with particular severity in the dimension of domestic public services where 24.5% of the total population and 40.1% of rural households lack access to improved water (DANE, 2024)

What is particularly problematic is the absence of rigorous departmental academic studies that document the specific magnitude of multidimensional energy poverty in Nariño, differentiated territorial composition, and causal determinants. This gap hinders the design of territorially differentiated policies, prioritization of investment in decentralized infrastructure, and planning of contextually appropriate technological solutions (Tirado Herrero, 2017; Pelz et al., 2018).

2. THEORETICAL AND CONCEPTUAL FRAMEWORK

2.1 Energy poverty: multidimensional conceptualization

The concept of energy poverty lacks a single and universally accepted definition; Its content varies according to historical and geographical context and level of development. In general terms, it is described as a situation in which the household does not have access to the energy services necessary for a dignified life, either due to the physical absence of modern energy, due to high relative costs, or due to housing conditions that prevent effective use (García Ochoa, 2014; Pachauri & Spreng, 2011).

The initial European approach (Boardman, 1991) defined energy poverty by means of the "10% rule": a household incurred poverty when it devoted more than 10% of its income to maintaining heating and energy services. Although operationally simple, it is inadequate for contexts in the Global South where the central problem is lack of physical access to modern services, dependence on traditional biomass, and infrastructural precariousness (García Ochoa & Graizbord, 2016).

In developing countries, literature focused on physical access and type of energy used. The Multi-Tier Framework (Bhatia & Angelou, 2015) distinguishes between homes without access, limited-intermittent access, and reliable-quality access. Although it recognizes that not all access is equivalent, it privileges continuity of service with less attention to effective capacities of use and intra-household inequalities (Pelz et al., 2018).

An explicitly multidimensional approach has gained strength, where energy poverty constitutes simultaneous deprivation in basic energy realizations: fuels-clean technologies for cooking, safe lighting, food preservation-medicines, adequate thermal conditions, access to media-information, use in productive activities (Nussbaumer et al., 2012;

Pereira et al., 2018). A systematic review by Fernández et al. (2023) covering 2005-2023 identified more than 30 globally proposed operational definitions, revealing a lack of consensus, especially in Latin America, regarding conceptual and metric boundaries (Fernández et al., 2023).

In Latin America, García Ochoa (2014) argues that energy poverty is not reduced to fuel or thermal comfort; manifested in the absence of basic equipment, housing precariousness, digital disconnection and institutional weakness. Calvo et al. (2021) propose a three-dimensional index integrating: access to quality energy services for food-hygiene, lighting-electrical devices, home air conditioning, plus a cross-cutting dimension of equity in the distribution of energy expenditure. Thomson et al. (2022) document in Argentina, Brazil, Colombia, Peru, and Uruguay that energy poverty is intertwined with income inequality, labor informality, housing precariousness, and climate vulnerability.

For this article, energy poverty is operationally defined as: a situation in which households experience simultaneous deprivation in access, quality, affordability, and effective use of modern energy services, restricting the ability to meet basic needs, protect health, and participate fully in economic and social life. In territories such as Nariño, this conception goes beyond simple quantification of electricity connections or declared expenses. It requires examining whether electricity is continuous-safe, if fuels are clean, if housing allows efficient use, if home has equipment and if economic-institutional conditions make it feasible to sustain services over time.

2.2 Human Capabilities and Energy Poverty Approach

Amartya Sen's (1999) theory of human development introduces a fundamental conceptual break with how poverty is understood. Faced with the conventional equation that equates it with insufficient income, Sen proposes that poverty constitutes a restriction of human capacities: real substantive freedoms that each person possesses to achieve achievements that he or she has valid reasons to value. A person who is poor in income may not be poor in skills if he or she has education, health, and information; conversely, someone with moderate income may be severely deprived if he or she lacks real opportunities to convert income into meaningful accomplishments (Sen, 1999; Sen & Nussbaum, 2011).

Modern energy is no ordinary consumer good. It is a critical facilitator of capacities: an input whose availability determines whether fundamental human achievements are accessible. With reliable access to electricity, people can: study after sunset expanding learning, preserve food in refrigeration safety by improving nutrition, maintain home temperatures compatible with health-dignity, access information-participate in communication networks structuring economic opportunities-digital citizenship, operate tools that generate productive income (Day et al., 2016; Nussbaumer et al., 2012). Without modern energy services, particularly in rural territories where informal alternatives are costly-non-existent, people face structural exclusion from opportunities that others exercise without reflection (Pereira et al., 2018).

However, the physical existence of available energy is not a sufficient condition. Robeyns (2003) proposes crucial concepts, such as conversion factors, mechanisms by which external resources (available electricity) are transformed into successful functioning (effective ability to study with adequate light or preserve refrigerated food). Conversion depends on three orders of factors:

- **Personal factors:** biological characteristics, technical capacities and human endowments. Age, gender, health status, previous education and specific technical skills determine how each member of the household effectively uses available energy. A woman without technical education in electricity may have a formal connection but lack real capacity to diagnose faults; a chronically malnourished child lacks the biological energy to convert artificial light into learning (Robeyns, 2003).
- **Environmental factors**: physical, geographical, climatic characteristics of the territory. Tropical climates require refrigeration differently than temperate climates; mountainous geography significantly increases electricity infrastructure costs; Geographical dispersion of settlements determines whether centralized networks are economically viable or whether decentralized solutions are required. Nariño presents an extreme case with topography where population density is low, access is difficult, and infrastructure investment is disproportionate (Robeyns, 2003; García Ochoa & Graizbord, 2016).
- **Institutional and social factors**: norms, policies, governance structures. The presence of local governments with technical-fiscal capacity, energy subsidy policies, regulatory frameworks favorable to rural investment, access to formal credit for efficient equipment, and legal recognition of indigenous land rights are

determining factors that allow conversion. Chronic institutional weakness, regulatory capture, exclusion of indigenous populations, patriarchal norms, and absence of community participation act as structural barriers (Robeyns, 2003; Thomson et al., 2022; Sareen et al., 2020).

In Nariño, these three orders of factors make up a particularly adverse framework. Rugged topography imposes prohibitive costs that private operators do not finance under conventional market models. Municipal governments with insufficient budgets, limited technical capacity in decentralized systems, legacies of state fragility do not have the resources to design-finance innovative solutions. Institutional barriers are intertwined with socio-cultural factors: gender norms limiting female power, historical exclusion of indigenous populations in territorial planning, weak community participation. The result is that even where there are potential sources (micro-hydroelectric plant, abundant solar radiation), restrictive conversion factors prevent the transformation of theoretical availability into real operational capacities (Day et al., 2016; García Ochoa & Graizbord, 2016).

2.3 The Alkire-Foster Method for Multidimensional Measurement

The traditional view of poverty as a one-dimensional phenomenon concentrated in insufficient income has proven to be progressively inadequate to capture the complexity of the deprivations experienced by households and communities in low-income contexts. Empirical research accumulated over the past few decades shows that individuals can experience various deprivations simultaneously in multiple aspects of their well-being: access to quality formal education, physical and mental health status, decent housing, formal and productive employment, access to essential public services (water, electricity, sanitation), civic and political participation (Alkire & Foster, 2011). These deprivations are often not independent; they overlap, reinforce each other and generate cycles of exclusion that are difficult to break. An uneducated person finds fewer opportunities for well-paying employment; without formal employment, they lack the income to access adequate housing; without safe housing, their health is compromised; without health, their productive capacity decreases. Each deprivation increases vulnerability to others, creating intergenerational traps where entire families are trapped in multidimensional poverty even if their monetary income improves marginally (Hernández et al., 2018; García et al., 2024).

In response to this complexity, Sabina Alkire and James Foster (2011) developed a rigorous axiomatic framework specifically designed to measure and decompose multidimensional poverty in a systematic way. The Alkire-Foster (AF) method is based on a fundamental theoretical assumption: that poverty is best understood as simultaneous deprivation in multiple dimensions relevant to human well-being, and that proper measurement requires not only identifying who is poor, but quantifying how much deprivation each person or household experiences and how these deprivations are distributed in the population. This contrasts with previous binary approaches (poor/not poor with respect to an income threshold) that miss crucial information on the depth and composition of deprivation (Pelz et al., 2018). The AF method is flexible: it allows the incorporation of varied dimensions according to context (education, health, housing, energy, etc.), the selection of specific indicators that capture each dimension, the establishment of realistic deprivation thresholds and the assignment of weights that reflect the relative importance of different dimensions. Precisely because of this flexibility, it has been adopted and adapted in more than 100 countries to measure multidimensional poverty (Alkire & Foster, 2011; Fernández et al., 2023).

The Alkire & Foster (AF) method structures measurement in two phases, identifying who is multidimensionally poor, and *aggregating* indicators to obtain synthetic measures. Where in phase 1 is the identification of Multidimensional Poor, which considers a set of *dimensions* relevant to well-being (education, health, housing, energy, etc.), each with one or more specific indicators. For each household i and each dimension j, data are collected on the corresponding indicator, denoted as xij . These data are compared against predefined t_j deprivation thresholds. If the household does not reach the threshold in dimension j (i.e., $x\_ij< t\_j$), it is considered private in that dimension.

Formally, a household-weighted vector of deprivation is constructed:

$$do_i = \sum_{j=1}^{d} w_{yo} \cdot gramo_{yo}$$

where:

- do_i Weighted Home Deprivation I
- w_{yo} Dimension J Weight
- $gramo_{yo}$ Deprivation indicator (1 if household I is deprived in dimension J-, 0 if not)

A household i is identified as multidimensionally poor if its weighted deprivation exceeds a predefined identification threshold k :

$$do_i \geq k$$

Where k partially takes values between 0.20 (light poverty, 20% of weighted deprivations) and 0.50 (severe poverty, 50% or more of deprivations). The choice of k is a normative political decision: it reflects how many simultaneous deprivations society considers unacceptable. Different thresholds (k = 0.20, 0.33, 0.50) generate identifications of increasing intensity that facilitate the analysis of public policy scenarios (Okushima, 2017; Khanna et al., 2019).

In phase 2: Aggregation — Synthetic Measures, where once the multidimensional poor have been identified, the method calculates three aggregate indicators that synthesize information on the magnitude and severity of poverty in the population:

Incidence (H): proportion of the population identified as poor:

$$H = \frac{q}{norte}$$

Where q is the number of households identified as poor (which meet $c\_i \geq k$) and n is the total number of households. $H \in$; a value of 0.237 indicates that 23.7% of the population experiences multidimensional poverty.

Intensity (A): average depth of deprivation among the identified poor:

$$A = \frac{1}{q}\sum_{yo:c_i \geq k} do_i$$

This measure captures how many additional deprivations, on average, each poor person experiences. If A = *0.60, it means that the multidimensional poor face on average 60% of all possible deprivations. Different households may have the same H* but different A, indicating that the depth of deprivation is variable.

Adjusted Multidimensional Index (M_0): simultaneous synthesis of incidence and intensity:

$$METRO_0 = HxA$$

This index incorporates information on both how many households are poor and how profoundly poor they are. Mathematically, M_0 measures the "proportion of deprivation achieved" in the total population. If H = 0.237 and A = 0.60, then M_0 = 0.142, indicating that 14.2% of all potential deprivations are reached in the population. This property makes M_0 useful for temporal comparisons (did poverty improve or worsen?) and spatial comparisons (which region has greater severity?).

The AF method satisfies important axioms that make it robust for public policy analysis:

- **Axiom of Symmetry:** Each dimension is treated equally unless explicit weightings reflect differential importance.
- **Axiom of Focus:** Changes in non-poor status do not impact poverty indicators; the measure focuses on the poor.
- **Axiom of Reply**: If the population replicates identically, the measures of poverty do not change.
- **Transfer Sensitivity Axiom**: Improvements in poor deprivation reduce M_0, and improvements in more severe poor generate greater reductions.

These axioms are not merely mathematical; reflecting ethical principles on how we should behave a measure of poverty. For example, the axiom of transference sensitivity ensures that reducing the deprivations of the poorest has a greater impact than reducing the deprivations of the marginal poor (Alkire & Foster, 2011).

The main virtue of the Alkire-Foster method lies in its remarkable adaptability, allowing the selection of dimensions, indicators, thresholds and weightings according to the territorial context and specific public policy priorities (Alkire & Foster, 2011). This flexibility is evidenced in recent applications: the MEPI by Nussbaumer et al. (2012) structured five energy dimensions (cooking, lighting, household appliances, education/entertainment, communication) replicated in 54 countries; the CEPI by Khanna et al. (2019) organized three for South Asia (availability, accessibility, affordability); the three-dimensional index of Calvo et al. (2021) incorporated equity for Latin America (food, lighting, air conditioning); and the Colombian IPEM by García et al. (2024) expanded to seven dimensions with a digital emphasis. Each adaptation preserves the axiomatic structure of the FA but responds to local realities (Fernández et al., 2023; Tirado Herrero, 2017). Analytically superior to one-dimensional measures, it offers disaggregation of the M_0 by dimension to prioritize interventions, temporal comparability year after year, municipal spatial analysis to detect critical foci, sensitivity to the intensity of deprivation (distinguishing "almost poor" from "profoundly poor" households) and legitimacy through participatory selection of indicators, facilitating in contexts such as Nariño a rational allocation of scarce resources towards deprivation more severe (Hernández et al., 2018; Pelz et al., 2018).

3. REGIONAL AND LOCAL OVERVIEW OF ENERGY POVERTY

3.1 Latin American regional situation

Latin America faces a profound paradox regarding energy access. Although several nations have significant resources such as considerable hydroelectric capacity, abundant solar-wind potential, there is a systematic disparity between urban and rural access.

The rural-urban disparity is a structural characteristic. While urban electricity coverage reaches high levels, rural coverage remains low, and when it exists, quality is dramatically lower. In scattered rural municipalities in Colombia, Peru, Bolivia, and Paraguay, electricity supply is intermittent, insufficient in voltage, and concentrated in hours of low demand, severely limiting usefulness for essential activities (Thomson et al., 2022).

This unequal distribution reflects historical patterns of political-economic exclusion. Rural, indigenous, Afro-descendant, and low-income populations face multiple barriers: geographical barriers that generate prohibitive infrastructural costs, institutional barriers derived from local state weakness and regulatory frameworks that favor urban private investment, economic barriers reflected in the concentration of public investment in dynamic centers, and cultural barriers that exclude indigenous populations from decisions about energy projects that affect their territories (Thomson et al., 2022; Sareen et al., 2020).

3.2 Colombia: Territorial Disparities and Multidimensional Measurement

Colombia is an eloquent case of contradiction between national energy capacity and equitable access. As a regional producer with significant hydroelectric capacity (~70% of generation), approximate electricity coverage of 94.92% according to the Indicative Coverage Expansion Plan (UPME 2023), and growing share of renewable energy (10% in 2024, 13% in 2025), it simultaneously maintains deep territorial gaps in equitable access and quality.

At the aggregate level, according to the Ministry of Mines and Energy IPEM (2024), multidimensional energy poverty was 22.71% in 2022, increased to 24.3% in 2023, and fell to 22.3% in 2024, reflecting that approximately 760,000 people left this condition in 2024 thanks to policies focused on rural electrification and non-interconnected areas. At the same time, Fundación Promigas reports IMPE 2024 of 15.4%, a lower figure but with a methodology that incorporates seven energy dimensions. Despite these improvements, extreme regional disparities persist: urban areas reach 98.9% electricity coverage with stable supply, while rural territories remain with 73.6% coverage and precarious quality in 61.8% of municipalities (BBVA Research 2025; Promigas IMPE Foundation 2024).

Application of multidimensional methodologies to national data showed disproportionate incidences in the Pacific region (25.6%, with Chocó reaching 52.8%), Amazon-Orinoquía regions (32.9%), the Caribbean (29.4%), and Andean rural areas where mountainous geography fragments territories. Decomposition of indices revealed that in rural territories, the dimension of quality of supply was particularly critical, affecting 61.8% of the energy poor (Fundación Promigas IMPE 2024; Ministry of Mines and Energy IPEM 2024).

The Ministry of Mines and Energy (2024) developed the Multidimensional Energy Poverty Index (MPI) measuring three main dimensions: access to electricity and food preparation, functional housing, and ability to learn-communicate. For its part, Fundación Promigas (2024) developed the Multidimensional Energy Poverty Index (IMPE) with seven dimensions: electricity access, quality of supply, affordability, clean fuels, equipment, digital connectivity, and productive uses. Application to national surveys identified affordability as a critical dimension in IMPE: approximately 45% of energy-poor households experienced deprivation in this dimension. Households in the lowest quintile experienced significantly higher rates of multidimensional energy poverty compared to the highest quintile. Likewise, households headed by women experienced energy poverty at a higher rate than households headed by men, reflecting that women's economic vulnerabilities are exacerbated in terms of energy access (Ministry of Mines and Energy IPEM 2024; Promigas IMPE Foundation 2024; Thomson et al., 2022).

3.3 Nariño: Context, Knowledge Gaps, and Inferences

Nariño, a southwestern department bordering Ecuador, concentrates energy vulnerabilities that deserve specific academic visibility, but have remained comparatively invisible in the national scientific-public policy literature. With approximately 64% rural population (vs. 23% nationally) and mountainous geography with mountain ranges, inter-Andean valleys and the Pacific coast, it faces severe energy deprivation derived from diseconomies of infrastructure scale.

Although there are no specific departmental measurements of multidimensional energy poverty in Nariño, well-founded inferences can be formulated from applications of the national IPEM disaggregated by department; regional literature on multidimensional poverty; documented geographical-institutional characteristics.

The department presents an official classification of "high incidence" in residential public services. The Pacific region where Nariño is located concentrates

rates higher than the national average. Its rural population reaches approximately 64% (2.7 times the national average) and the mountainous geography significantly raises infrastructure costs. These factors justify an estimated incidence higher than the national average of 22.7% (Ministry of Mines and Energy, 2024; Soares et al., 2023).

Territorial composition probably reflects nationally documented patterns: urban municipalities approaching national urban incidences, while rural municipalities, particularly on the Pacific coast and mountain areas that are difficult to access, probably face significantly higher incidences (Soares et al., 2023; Thomson et al., 2022).

Specific factors intensifying energy poverty in Nariño include: rugged geography with disproportionate infrastructure costs per household; chronic institutional weakness with municipal governments with insufficient budgets and limited technical capacity; dependence on traditional biomass, particularly in coastal municipalities and indigenous territories; low digital connectivity; historical exclusion of indigenous populations from decisions on energy projects (Soares et al., 2023; Tirado Herrero, 2017).

4. METHODOLOGICAL FRAMEWORK FOR DEPARTMENTAL MEASUREMENT

4.1 Recommended Dimensions and Indicators

Construction of a multidimensional energy poverty index specifically adapted to Nariño requires retention of a core of dimensions tested in the national context but incorporating indicators that reflect territorial particularities:

Electricity access: type of supply (centralised SIN, municipal microgrid, decentralised isolated system or no access), critical due to territorial heterogeneity.

Quality of supply: continuity (daily hours), frequency of unscheduled interruptions and voltage stability, determining in rural areas.

Affordability: proportion of income in electricity, ability to pay in the face of economic shocks, access to subsidies, key in the face of high monetary poverty.

Clean cooking fuels: type of fuel (traditional biomass vs. LPG/natural gas/electricity), stove functionality, exposure to indoor pollution.

Basic functional equipment: refrigerator, studio lighting, thermal equipment and its operability.

Digital connectivity: mobile phone, internet, computer/tablet, access to connected public spaces.

Productive uses of energy: income-generating tools, community processing spaces, limitations in planned activities.

4.2 Methodological Decisions: Weightings and Thresholds

Differentiated weighting is proposed according to national priorities of the Ministry of Mines and Energy, assigning greater importance to affordability and clean fuels, reflecting that the most critical deprivations for public policy are ability to pay and exposure to traditional biomass (Ministry of Mines and Energy, 2024).

The identification threshold $k = 0.33$ classifies households with significant deprivations as energy poor, consistent with national applications of the IPEM, complemented by sensitivity analyses for alternative thresholds that will allow decision-makers to evaluate the robustness of the results in the face of different deprivation intensities (Hernández et al., 2018).

4.3 Decomposability and Territorial Analysis

The Alkire-Foster method allows decomposition of M_0 by dimension, showing which deprivations contribute most to total poverty. Municipal governments can direct resources to dimensions where deprivation is maximum. M_0 monitoring allows us to assess whether public policies are reducing energy poverty. Calculation at the municipal-neighborhood level allows identifying areas where intervention is most urgent.

5. RESEARCH AGENDA AND JUST ENERGY TRANSITION

5.1 Dimensions of Energy Justice in Peripheral Territorial Contexts

The conceptualization of energy justice arises from the recognition that energy transitions can reproduce or deepen historical patterns of exclusion if they do not explicitly incorporate dimensions of equity, participation, and recognition of rights. Sareen et al. (2020) summarize that energy justice integrates three interconnected pillars:

Distributive justice: equitable access to energy benefits and fair distribution of costs. In Nariño, this means that renewable energy generation must prioritize serving the energy needs of Nariño populations, with affordable prices for low-income households and with the participation of local communities in decisions about the location and operation of projects.

Recognition justice: meaningful inclusion of voices of affected communities in decision-making, respect for local knowledge and territorial identities. In Nariño, it especially means recognition of the territorial rights of indigenous populations and Afro-descendant communities that have historically been excluded from decisions on the transformation of their territories.

Procedural justice: decision-making processes that are transparent, participatory and respond to specific needs. It requires municipal governments to generate authentically open spaces where communities actively participate in the design of energy policies (Jiglau et al., 2023; Sareen et al., 2020).

5.2 Decentralized Technology Solutions and Territorial Governance

The geography of Nariño, fragmented by mountain ranges, makes the extension of centralized electricity distribution networks unfeasible under conventional models. The per capita costs of bringing centralized infrastructure to dispersed communities far exceed what poor populations can afford in tariffs.

Residential or community photovoltaic systems represent a suitable option for territories with significant solar radiation, providing reliable lighting, charging of essential mobile devices and limited cooling. Although the initial cost is prohibitive for poor households, it represents a fraction of the expense of extending centralized networks.

Small hydroelectric systems are a viable option in municipalities with rivers with permanent flow, especially in mountainous areas where the natural slope optimizes efficient generation. The assessments demonstrate economic competitiveness by considering eliminated transmission costs and the ability of local governments to manage systems of manageable scale.

Hybrid systems that combine photovoltaic with battery storage offer potential for Nariño. Although storage technology remains expensive, price drops in recent years are making hybrid systems increasingly viable in remote rural contexts.

The sustainability of decentralized energy solutions in municipalities of Nariño requires comprehensive strengthening of territorial governance. This involves developing technical and financial capacities of municipal staff, establishing municipal maintenance funds through pricing models that recover operational costs, strengthening community participation through the formal constitution of user boards, and providing specialized technical support to municipal governments for the design of contextualized territorial energy policies. This multidimensional strengthening of local governance is essential to ensure sustainable operation, preventive maintenance, and effective participation of communities in decisions about energy infrastructure that affects their territories (Jiglau et al., 2023; Sareen et al., 2020; Thomson et al., 2022).

5.3 Recommendations for Territorial Energy Policy in Nariño

The Department of Nariño should entrust the construction of a Multidimensional Energy Poverty Index specifically for Nariño as an official tool for diagnosing and monitoring energy policy, calculated annually to allow evaluation of progress.

The departmental government must develop specific electrification and energy transition plans differentiated according to geographical-institutional context: for urban areas, emphasis on infrastructure renewal; for connected rural areas, emphasis on quality of service; for dispersed rural areas, explicit emphasis on decentralized solutions; for indigenous territories, emphasis on solutions that respect territorial autonomy.

Establish an energy subsidy program that focuses on subsidies on households in lower income quintiles, combines electricity subsidies with specific subsidies for clean cooking fuels, and includes a progressivity mechanism.

Allocate specific funds for the construction of home photovoltaic systems in poor rural households, construction or rehabilitation of community microgrids, institutional strengthening of municipal governments, and support for the constitution of community user boards.

Develop policies that integrate internet access with access to energy, including prioritizing investment in rural telecommunications; ensuring that decentralized energy solutions include the ability to sustain connectivity; establishment of community telecentres as public infrastructure.

6. CONCLUSIONS

Multidimensional energy poverty in Nariño constitutes a severe, complex and little-studied deprivation that requires priority academic-political attention. Despite improvements in national nominal electricity coverage, territories such as Nariño face deep gaps between formal and effective access, due to the adverse interaction of geographical, institutional, and socio-cultural factors that prevent the conversion of available energy resources into real human capacities.

The theoretical framework integrating Sen's capabilities approach, Alkire-Foster method and energy justice perspective provides rigorous analytical tools for differentiated diagnosis, rational prioritization of public interventions and design of territorially appropriate solutions.

Multidimensional measurement of energy poverty at the departmental level is an academic-political urgency that must be implemented through replication of the national IPEM with specific adaptations that capture Nariño realities. The just energy transition in Nariño requires going beyond the simple expansion of electricity coverage. It demands combining investment in innovative decentralized solutions with the simultaneous strengthening of participatory territorial governance, effective recognition of the territorial rights of indigenous-Afro-descendant populations, and genuine participation of communities in decisions about projects that affect their lives.

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