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# Diagnosis and Context

## Deliverable 2

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## GLOBAL OVERVIEW OF ENERGY COMMUNITIES

**Key Message: The long-term sustainability of energy communities (ECs) depends on aligning technical design with governance, tariff structures, and risk mitigation, rather than just technology. While solar PV is the dominant technology due to modularity, governance is the central determinant of performance.**

Energy communities are collective arrangements in which citizens, local authorities, or small enterprises jointly participate in the ownership, governance, or benefits of decentralized energy systems based on renewable generation, storage, or energy efficiency measures at the community scale. International experience shows that their long-term sustainability depends not only on technology availability but on the coherence between technical design, governance structures, tariff and collection mechanisms, and risk-mitigation strategies. Across diverse contexts, solar photovoltaic systems—often combined with battery storage or diesel backup—have become the predominant technological choice for community-scale solutions due to their modularity, declining costs, and adaptability to different geographies.

Governance consistently emerges as a central determinant of performance. Projects with clearly defined roles and responsibilities, transparent decision-making processes, and accountability mechanisms tend to achieve better operational continuity than those with informal or ambiguous arrangements. Community participation can strengthen outcomes, but only when supported by sustained capacity building rather than one-time training. Financial sustainability similarly hinges on tariff structures that balance affordability with cost recovery and on collection mechanisms that maintain adequate payment discipline. Many international and national cases show that operational deterioration is more often linked to insufficient operation and maintenance (O&M) financing and weak collection systems than to technical malfunction.

## COMPARATIVE ANALYSIS OF INTERNATIONAL AND NATIONAL EXPERIENCES

While Europe has been a leader in the adoption of energy communities, its models operate within contexts of robust grid infrastructure, mature energy markets, and strong institutional capacity that differ from many Colombian territories. Experiences from emerging economies—such as community-based solar in Brazil, distributed renewable energy programs in India, mini-grid development in Kenya, and community microgrids in Indonesia—offer lessons that are more directly comparable to Colombia's rural and off-grid conditions. Colombian pilots in regions such as La Guajira, the Pacific Coast, and the Andean zone reflect similar global patterns: solar and hybrid systems dominate, community engagement improves outcomes, and long-term sustainability depends on governance clarity, collection discipline, and O&M provisions. The key challenge is moving from isolated pilots toward scalable, replicable models that can operate under real territorial and institutional constraints.

## COLOMBIAN ECOSYSTEM FOR THE DEVELOPMENT OF ENERGY COMMUNITIES

Colombia's territorial and institutional context is highly heterogeneous. Most of the country is connected to the National Interconnected System (SIN), but approximately 100,000 households remain without reliable electricity service, concentrated in dispersed rural areas and the 1,710 localities classified as Non-Interconnected Zones (ZNI). These territories face higher provisioning and maintenance costs, logistical constraints, historical dependence on diesel generation, and limited local capacity to sustain robust operating models. The institutional ecosystem involves multiple actors—MME, CREG, UPME, IPSE, FENOGE, XM, and SSPD—whose mandates are complementary but sometimes overlapping. Coordination across these entities remains a structural challenge, particularly for projects that span SIN–ZNI boundaries or require simultaneous regulatory and financial approvals. The distinction between SIN and ZNI is fundamental, as each context implies different cost structures, regulatory obligations, financing mechanisms, and viable business models.

## PUBLIC POLICY FRAMEWORK AND APPLICABLE REGULATION IN COLOMBIA

The public policy and regulatory framework for energy communities in Colombia has advanced significantly in recent years. Law 1715 of 2014 established the framework for Non-Conventional Renewable Energy Sources (FNCER). Decree 2236 of 2023 defined requirements and operating guidelines for energy communities. Resolution 40137 of 2024 established targeting criteria for public resources, Resolution 14136 of 2024 created the Single Registry of Energy Communities (RUCE), and CREG Resolution 101 072 of 2025 set the regulatory framework for community operation in both SIN and ZNI. This architecture enables distributed generation, collective self-consumption, and community participation, but its practical application depends on operational clarity regarding metering and settlement procedures, quality and reporting standards, and the interface between community governance structures and commercial obligations under electricity market rules.

## FINANCIAL INSTRUMENTS AND CAPITAL MOBILIZATION MECHANISMS

Colombia's financing landscape includes both national and international instruments. Nationally, FAZNI, FENOGE, PRONE, the General Royalties System (SGR), and development finance institutions such as Findeter and Bancóldex can support project development. Internationally, facilities from the IDB, World Bank (including ESMAP), KfW, the Green Climate Fund, and bilateral cooperation programs are potentially applicable. However, the current landscape is heavily weighted toward capital expenditure (CAPEX) financing, while dedicated mechanisms for O&M,

working capital, and risk mitigation remain limited, despite the fact that O&M challenges are a primary cause of project underperformance or failure.

## ENABLING CONDITIONS AND GAPS

There are enabling conditions and gaps across four dimensions: regulatory, institutional, financial, and community capacity.

- Regulatory: the legal framework now exists but operational clarity is needed on metering, settlement, and quality standards.
- Institutional: coordination mechanisms exist but transaction costs remain high due to fragmented approval processes.
- Financial: CAPEX instruments are available but fragmented, while OPEX financing represents the critical gap. Risk mitigation instruments are underdeveloped. Collection efficiency assumptions in project design often prove optimistic, leading to financial distress.
- Community capacity: successful projects require sustained technical assistance and governance support, not one-time interventions.

SIN and ZNI contexts require fundamentally different implementation strategies. Grid-connected communities can leverage existing infrastructure and market mechanisms but face regulatory complexity around collective self-consumption. Off-grid communities have more operational autonomy but face higher costs, greater technical challenges, and more limited financing options. Policy and program design must differentiate pathways accordingly.

## TYPES OF ENERGY COMMUNITIES AND DECISION TOOL

A central output of this diagnosis is a decision tree that organizes regulatory, institutional, financial, and community factors into a structured framework for implementation decisions. The tree addresses sequential decision points that determine viable deployment pathways, beginning with territory classification (SIN versus ZNI), then proceeding through community characteristics, technical configuration, and financing pathway.

The first branch distinguishes territory classification: SIN (grid-connected) versus ZNI (off-grid) determines applicable regulations, available instruments, operational models, and cost structures. Subsequent branches address community characteristics including existing organizational capacity, demonstrated payment discipline, and presence of productive uses that can anchor demand and strengthen revenue. Technical configuration decisions address system sizing, storage requirements, and grid connection modalities.

Each pathway through the decision tree leads to differentiated assumptions for financial modeling: distinct CAPEX and OPEX profiles, risk parameters, collection scenarios, and instrument configurations. This framework serves as the methodological bridge between diagnostic findings and the subsequent phase of financial model development, ensuring that modeling reflects the diversity of real implementation contexts rather than assuming a single representative project.

## RECOMMENDATIONS

Based on this comprehensive report, key recommendations for stakeholders are as follows:

- For Policymakers: Consolidate operational definitions that clarify roles, responsibilities, and relationships among energy community participants. Develop differentiated policy tracks for SIN and ZNI contexts rather than applying uniform approaches. Establish incentive structures that align the interests of communities, energy operators, and financial institutions. Strengthen inter-institutional coordination mechanisms to reduce transaction costs and processing times.
- For Regulators: Clarify metering, settlement, and surplus sale procedures for collective self-consumption arrangements. Define quality and reporting standards for registered energy communities that balance accountability with administrative feasibility. Establish transition pathways for existing informal community energy arrangements to achieve regulatory compliance. Address remaining ambiguities in the interface between community governance and commercial obligations.
- For Financial Institutions and Development Partners: Develop O&M financing products specifically designed for energy community lifecycles, including reserve fund mechanisms and working capital facilities. Create aggregation mechanisms that reduce transaction costs for small-scale projects. Pilot risk-sharing instruments that address collection risk, operational risk, and technology risk. Consider blended finance structures combining concessional and commercial capital according to project risk profiles.
- For Project Implementers: Apply the decision tree framework to match project design with territorial and community characteristics rather than replicating standard templates. Build lifecycle cost provisions into project structuring from inception, including explicit O&M budgets and equipment replacement reserves. Prioritize governance capacity building alongside technical installation. Engage with existing community organizations where possible rather than creating parallel structures.

# LIST OF ABBREVIATIONS

| | |
|---|---|
| CA | Colectivo de Autoconsumo / Self-Consumption Collective (regulatory figure under Colombian law) |
| CAPEX | Capital Expenditure |
| CENS | Costo de Energía No Suministrada / Cost of Non-Supplied Energy |
| COP | Colombian Peso (national currency) |
| CREG | Comisión de Regulación de Energía y Gas / Energy and Gas Regulatory Commission (independent regulatory body for electricity and gas sectors) |
| DNP | Departamento Nacional de Planeación / National Planning Department (responsible for development planning and public investment coordination) |
| ESMAP | Energy Sector Management Assistance Program (World Bank technical assistance program) |
| FAG | Fondo Agropecuario de Garantías / Agricultural Guarantee Fund |
| FAZNI | Fondo de Apoyo Financiero para la Energización de las Zonas No Interconectadas / Financial Support Fund for Energization of Non-Interconnected Zones |
| FENOGE | Fondo de Energías No Convencionales y Gestión Eficiente de la Energía / Fund for Non-Conventional Energies and Efficient Energy Management |
| FNCER | Fuentes No Convencionales de Energía Renovable / Non-Conventional Renewable Energy Sources (regulatory category under Law 1715 of 2014) |
| FNG | Fondo Nacional de Garantías / National Guarantee Fund |
| FOES | Fondo de Energía Social / Social Energy Fund |
| GCF | Green Climate Fund |
| GDC | Generación Distribuida Colectiva / Distributed Generation Collective (regulatory figure) |
| GIZ | Deutsche Gesellschaft für Internationale Zusammenarbeit / German Agency for International Cooperation |
| IDB | Inter-American Development Bank |
| IEA | International Energy Agency |
| IPSE | Instituto de Planificación y Promoción de Soluciones Energéticas para las Zonas No Interconectadas / Institute for Planning and Promotion of Energy Solutions for Non-Interconnected Zones |

| | |
|---|---|
| IRENA | International Renewable Energy Agency |
| KfW | Kreditanstalt für Wiederaufbau / German Development Bank |
| kW | Kilowatt (unit of power, 1,000 watts) |
| kWh | Kilowatt-hour (unit of energy) |
| kWp | Kilowatt-peak (rated capacity of solar PV systems under standard test conditions) |
| LCOE | Levelized Cost of Energy (metric comparing lifetime costs to lifetime energy production) |
| MME | Ministerio de Minas y Energía / Ministry of Mines and Energy |
| MW | Megawatt |
| NDP | National Development Plan |
| NGO | Non-Governmental Organization |
| O&M | Operation and Maintenance |
| OECD | Organisation for Economic Co-operation and Development |
| OPEX | Operational Expenditure |
| PAYG | Pay-As-You-Go |
| PPA | Power Purchase Agreement (contract for electricity sale between generator and buyer) |
| PRONE | Programa de Normalización de Redes Eléctricas / Electrical Network Normalization Program (rural electrification program) |
| PV | Photovoltaic |
| RBA | Results Based Aid |
| RBF | Results Based Financing |
| RETIE | Reglamento Técnico de Instalaciones Eléctricas / Technical Regulation for Electrical Installations (mandatory safety and quality standards) |
| RUCE | Registro Único de Comunidades Energéticas / Single Registry of Energy Communities (established by Resolution 14136 of 2024) |
| SGR | Sistema General de Regalías / General Royalties System (public investment mechanism funded by extractive industry revenues) |
| SIN | Sistema Interconectado Nacional / National Interconnected System (main electricity grid covering most urban and accessible rural areas) |

| | |
|---|---|
| SSPD | Superintendencia de Servicios Públicos Domiciliarios / Superintendence of Public Utilities (supervision and control of utility service providers) |
| STN | Sistema de Transmisión Nacional / National Transmission System (high-voltage transmission network) |
| TCF | Transformative Climate Finance (GIZ program supporting climate-aligned investments) |
| UPME | Unidad de Planeación Minero-Energética / Mining and Energy Planning Unit (responsible for sector planning, demand forecasting, and project registration) |
| WRI | World Resources Institute |
| XM | XM S.A. E.S.P. (Colombian wholesale electricity market operator responsible for dispatch, settlement, and market administration) |
| ZEDSI | Zonas Especiales de Desarrollo Social Integral / Special Zones for Comprehensive Social Development |
| ZNI | Zonas No Interconectadas / Non-Interconnected Zones (territories not connected to the national electricity grid, comprising approximately 1,710 localities) |

# INTRODUCTION

Energy communities—collective arrangements in which citizens, local entities, or small enterprises jointly own, manage, or benefit from decentralized energy generation, distribution, or efficiency measures—can accelerate the energy transition through decentralized solutions that combine infrastructure, collective organization, and sustainable operating arrangements. Their promise is not limited to incorporating renewable sources or expanding coverage, but also to transforming how energy is produced, managed, and consumed in the territory, strengthening local participation, resilience, and the ability to capture economic and social benefits associated with the service. In different international contexts, these models have emerged in response to overlapping challenges: decarbonizing the energy mix, ensuring affordability and reliability of supply, and reducing vulnerabilities linked to dependence on fossil fuels, service interruptions, and investment gaps in peripheral areas. Evidence also shows that success depends less on technology availability than on coherence between technical design, governance and organizational structure, tariff and collection arrangements, and the financial instruments and risk-mitigation mechanisms that sustain investment over the asset life cycle.[1]

In practice, a sustainable energy community operates as a socio-technical and financial system. It requires clear roles and responsibilities, operation and maintenance (O&M) capabilities, decision-making rules and resource administration, and mechanisms that align incentives among users, operators, financiers, and public entities. It also requires practical risk management for issues that commonly materialize in operations: insufficient collections, maintenance failures, delayed replacement of critical components, governance weaknesses, and regulatory or institutional changes that affect model stability. In rural contexts or areas with low institutional density, these risks intensify due to limited access to formal financial services, high transaction costs to access resources, organizational informality, and logistical difficulties in sustaining supply chains and specialized technical services. Scaling therefore requires identifying which technical and organizational configurations are viable under real constraints and which mechanisms can turn community initiatives into bankable, operable, and replicable projects.

In Colombia, energy communities develop in a heterogeneous territorial context, where gaps in access, service quality, and relative costs are most severe in dispersed rural areas and in ZNI. These territories face higher provisioning and maintenance costs, historical dependence on diesel generation, logistical constraints, and limited institutional capacity to sustain robust operating models. At the same time, recent public policy and regulation have opened opportunities for distributed generation arrangements, collective self-consumption, and community participation, but practical application depends on operational definitions, clarity of roles, tariff feasibility, and

[1] Tariff: the price structure charged for electricity service, which may include fixed charges, consumption-based rates, and demand charges.

effective articulation among public actors, energy operators, and financing mechanisms. The central challenge is to move from pilots and isolated efforts to models that can scale without compromising financial sustainability, service continuity, or social legitimacy, and that respond to Just Energy Transition principles so benefits materialize in historically lagging territories.

This report corresponds to Phase 1 of TCF's country implementation in Colombia (energy communities) and provides a technical diagnosis of the state of structuring, implementation, and financing of energy communities globally and in Colombia. The diagnosis identifies patterns, enabling conditions, and critical gaps that shape sustainability and scalability in the country, and translates them into criteria applicable to subsequent design phases.

## I. Methodology

This report integrates four complementary analytical components. First, a systematic documentary review of international and national experiences, including technical, academic, regulatory, and institutional sources, with an emphasis on contexts comparable to Colombia. Second, a comparative analysis of selected cases documenting technological configurations, governance arrangements, tariff and collection structures, financing models, and risk-mitigation strategies. Third, an applied reading, meaning the capacity for the reader to actively use the information in practical, real-world contexts (i.e. an operational interpretation focused on practical implementation implications rather than purely legal or academic analysis) of the public policy and regulatory framework in Colombia, aimed at identifying enablers, restrictions, and gaps that affect design and operating decisions. Fourth, consultation with strategic stakeholders through semi-structured interviews and bilateral sessions (See Appendix for Interview Memoirs), to validate assumptions, contrast findings with real market conditions, and capture operational lessons not available in public sources.

The approach prioritizes applicability. Evidence is organized around critical dimensions that determine feasibility: governance and organizational structures; design of community energy systems and tariff structures; financing mechanisms, bankability, and risk mitigation; and regulatory and institutional conditions for implementation. Based on these dimensions, the report identifies success factors and limits to transferability of international experiences, characterizes the Colombian ecosystem and its gaps, and develops tools to structure decisions and implementation pathways.

The deliverable culminates in a structured analysis of enabling conditions and gaps, a set of operational typologies of energy communities, and a decision tree organizing regulatory, institutional, financial, and community criteria. These tools serve as a methodological bridge toward subsequent phases focused on scenario construction and financial and operating model design, ensuring alignment with the regulatory framework and Just Energy Transition principles.

## II. Purpose of the deliverable

The purpose of this deliverable is to develop a technical diagnosis of the state of structuring, implementation, and financing of energy communities globally and in Colombia. The diagnosis identifies enabling conditions, critical gaps, and limits to transferability that determine operational and financial sustainability, with emphasis on rural territories and ZNI. Based on technical, institutional, and market evidence, the deliverable translates real-world lessons and constraints into criteria applicable to the Colombian context, and produces inputs to guide implementation pathways and the structuring of financial and operational models in subsequent phases, in coherence with Just Energy Transition principles. To this end, this document proposes to:

- Construct an overview of the global landscape of energy communities that identifies trends, development patterns, and prevailing configurations, including governance models and organizational structures, technical and operational design decisions and their relationship with tariff and revenue collection structures, as well as financing mechanisms and risk management strategies that have enabled models to be consolidated and scaled across different contexts.

- Develop a comparative analysis of international and national experiences through the documentation of reference cases under a homogeneous characterization framework, and the comparison of results, barriers, and enabling factors, in order to establish which elements are adaptable to Colombia, under what conditions, and with what limitations, differentiating between scenarios connected to SIN and ZNI environments.

- Characterize the Colombian ecosystem for the development of energy communities, describing the current status of initiatives and identified typologies, key actors and their institutional roles, and the main operational, technical, and governance gaps that condition project sustainability, incorporating differentiated considerations for rural territories and ZNI.

- Analyze the public policy and regulatory framework applicable in Colombia from an operational perspective, systematizing the general regulations of the energy sector and FNCER, as well as specific provisions for energy communities, and assessing their practical implications for system design, metering, billing, tariffs, subsidies, collective self-consumption, surplus management, actor roles, and operation and maintenance responsibilities, identifying frictions and regulatory gaps that affect scalability.[2]

[2] Collective self-consumption: a regulatory arrangement allowing multiple users to share electricity generated from a common local source, such as a community solar installation.

- Identify, describe, and assess relevant financial instruments and capital mobilization mechanisms, mapping national and international options, analyzing access conditions and market constraints, and prioritizing actionable mechanisms to finance CAPEX, sustain O&M, and manage asset replacement, including risk mitigation schemes that improve bankability and reduce transaction costs.

- Integrate the above findings into a structured analysis of enabling conditions and gaps by dimension, consolidating an assessment that identifies critical bottlenecks, success factors, and limits to transferability across regulatory, institutional, community, technical, and financial dimensions, and that derives applicable criteria to support decision-making.

- Propose operational typologies of energy communities and an implementation-oriented decision tool, through the formulation of characterization and classification criteria and the construction of a decision tree that organizes regulatory, institutional, financial, and community factors to guide implementation pathways and serve as a methodological bridge toward scenario building and financial and operational design in subsequent phases.

- Consolidate conclusions, recommendations, and next steps, synthesizing key findings and prioritizing actions to strengthen enabling conditions, close critical gaps, and ensure analytical continuity toward the structuring of the financial and operational model.

## III. Scope and limitations

The scope of this diagnosis includes the construction of a comprehensive vision on the state of structuring, implementation and financing of energy communities at the global level and in Colombia, with emphasis on enabling conditions, gaps and elements transferable to the national context. To this end, the analysis integrates four main components: systematic documentary review of technical, academic and institutional literature, regulations and reports of multilateral organizations and national entities; comparative analysis of international and national experiences through standardized files that allow evaluating governance configurations, technical design, tariff and collection structures, financing models and risk management strategies; applied reading of the public policy and regulatory framework in force in Colombia, including general regulations for the energy sector, specific provisions for energy communities and considerations associated with tariffs, subsidies and financial sustainability; and validation of findings through semi-structured interviews and bilateral sessions with strategic actors in the energy and financial ecosystem, including the public sector, regulators, energy operators, banking, cooperation and multilaterals, as well as selected territorial and community actors.

The diagnosis prioritizes approaches comparable to the Colombian context and, in particular, incorporates differentiated considerations for rural territories and ZNI. Consequently, the analysis contemplates the identification of international standards that are applicable to scenarios with infrastructure restrictions, limited institutional capacities, higher logistics costs and challenges associated with operation, maintenance and collection. Likewise, in the financial dimension, the scope includes the mapping and benchmarking of relevant national and international instruments, the analysis of access conditions and market restrictions, and the preliminary prioritization of actionable mechanisms to finance CAPEX, sustain O&M and manage asset replacement, including risk mitigation schemes.

In terms of outputs, this deliverable includes a set of implementation-oriented inputs: a structured analysis of enabling conditions and gaps by dimension, a proposal for operational typologies of energy communities, and a decision tree that organizes regulatory, institutional, financial, and community criteria to guide implementation routes and serve as a methodological bridge to the subsequent phases of scenario construction and financial design and operational.

The limitations of the diagnosis derive from its nature and execution horizon. The document does not constitute a pre-feasibility or feasibility study of specific projects, nor does it replace detailed engineering analyses, final design, contractual structuring or legal and environmental due diligence required for implementation in specific territories. Nor does it include extensive primary information collection in communities or technical field measurements; the consultation with territorial and community actors is carried out in a limited way and with the purpose of validating assumptions, not as an exhaustive socioeconomic or energy characterization.

In addition, the availability and comparability of public information on international and national cases can vary significantly, especially in financial and operational performance metrics. Where verifiable or consistent data do not exist, the report will explicitly state this and complement the analysis with qualitative sources and stakeholder validation. Finally, given that the regulatory and programmatic framework may evolve, the diagnosis reflects the state of the regulations and instruments identified at the date of preparation of the report, and therefore the conclusions must be interpreted considering possible subsequent updates.

# GLOBAL OVERVIEW OF ENERGY COMMUNITIES

**Purpose:** To synthesize international evidence on how energy communities function technically, organizationally, financially, and institutionally, and identify lessons relevant to Colombia.

- Global experience shows sustainability depends on aligning technical design, governance, tariffs, collections, and O&M.
- Solar PV, often hybridized with battery storage or diesel backup, is the predominant technology across contexts due to its modularity, declining costs and suitability across diverse geographies.

This chapter presents a global overview of energy communities with an applied diagnostic focus: identifying observable patterns in their evolution, the institutional and technical arrangements that prevail, and the conditions that explain why certain models manage to consolidate and scale while others remain as isolated pilots. Rather than a descriptive review of experiences, the analysis seeks to extract regularities that are comparable across diverse contexts, so that the findings can be used to interpret the Colombian case and, in particular, to anticipate critical design, operational, and financing decisions in rural territories and ZNI.

Internationally, "energy community" encompasses heterogeneous initiatives that share organized participation of local actors in the provision, management, or efficient use of energy, combining objectives of access, affordability, resilience, productive development, and social or environmental benefits. Their form varies according to national frameworks, electricity market structures, institutional maturity, and territorial constraints. In robust grid systems, communities typically organize around collective self-consumption and distributed generation, with emphasis on governance and benefit allocation. In decentralized electrification contexts, islands, or mini-grids, the focus shifts toward service continuity and life-cycle sustainability, where O&M, revenue collection, and asset replacement are decisive.

Outcomes depend more on institutional architecture and economic models than on technology alone. International evidence identifies recurrent bottlenecks in the transition from project formulation to stable operation: role clarity, transparent resource management, measurement and settlement schemes, local O&M capacity, and explicit mechanisms for financing replacement and managing performance and revenue risks. Scalability therefore depends not only on resources, but on replicable structures that reduce transaction costs, standardize preparation, and allocate risks in a verifiable manner among communities, public entities, operators, and financiers.

Based on this logic, the chapter is organized into five components: international trends and development patterns; governance models and organizational structures; design of community energy systems and tariff structures; financing mechanisms and risk management strategies; and elements adaptable to the Colombian context.

## I. International trends and development patterns

Purpose: To describe how energy communities have evolved globally and the dominant patterns shaping their deployment.

- Solar PV has become the most common technology because it is modular, cost-effective, and adaptable to both grid-connected and off-grid contexts.
- Successful models integrate technical design with governance, tariff structures, and financial mechanisms to ensure reliability and sustainability.

Energy communities have expanded globally as part of the transition toward clean and renewable energy sources, including solar, hydropower, and wind. Despite sustainability commitments, global emissions from electricity generation continue to rise (IEA, 2025), and energy communities have emerged as a complementary mechanism to accelerate decarbonization while improving access, affordability, community participation, and income generation (Koirala et al., 2016). These decentralized systems have transformed citizens from passive consumers into “prosumers” who both consume and produce electricity (de São José et al., 2021). Their evolution reflects regional differences, ranging from grid-connected cooperatives in Europe to off-grid community mini-grids in the Global South (IRENA, 2018).

### A. Europe

Europe has historical roots in cooperative ownership of renewable energy and has been at the forefront of the emergence of energy communities. The European Union formally recognized the role of “energy communities” in its 2019 Clean Energy Package, which included a recast of the Renewable Energy Directive (RED II) that established a binding renewable energy consumption target (EU, 2018). According to the European Commission, more than 8,000 energy communities exist across the EU as of 2025, with Northern and Western European countries—particularly Germany—leading adoption (European Commission, 2025; Ahmed et al., 2024).

European energy communities often involve prosumers who inject renewable energy into the grid under support frameworks such as feed-in tariffs or net metering. While most projects are driven by decarbonization objectives and citizen participation, some isolated initiatives focus on energy self-sufficiency, such as those in island communities (Kallis et al., 2021). With clear policy support and social innovation, community energy can scale even in advanced and fully electrified systems, delivering benefits such as public support for renewables, lower costs, and enhanced local energy resilience.

### B. Latin America

In Latin America and the Caribbean, energy communities have emerged to expand access and improve reliability in underserved areas. Despite near-universal grid coverage, dispersed rural areas, remote islands, and ZNI face high costs, service interruptions, and continued dependence on diesel generation (IEA, 2024). Community-led initiatives promote local participation in generation and governance, which improves project durability, social acceptance, and long-term performance (Gill-Wiehl et al., 2022).

Several countries support energy communities through public policy. Chile's Comuna Energética program supports municipalities and citizens in local renewable projects, complemented by competitive financing. Brazil and Costa Rica build on rural electric cooperatives, with recent reforms facilitating renewable integration. Colombia has enacted a regulatory framework recognizing energy communities as a legal actor for both grid-connected and isolated systems, particularly in rural and island territories.

### C. Asia and Africa

In Asia and Africa, energy communities primarily address electricity access. Community mini-grids have increased sixfold globally since 2018, with strong growth in Sub-Saharan Africa, supported by more than USD 2.7 billion in committed financing (SEforALL, 2024). Countries such as Nigeria, Kenya, and Tanzania have adopted tailored mini-grid regulations and cost-reflective tariffs, attracting public and private investment.

In Southeast Asia, Indonesia and the Philippines have piloted community mini-grids on remote islands, often engaging villagers in O&M (IRENA, 2018). The Sumba "Iconic Island" initiative aims for 100% renewable energy through multi-actor coalitions. South Asian countries have also deployed community micro-hydropower and household solar systems at scale (Energy Mix, 2025).

### D. Recurring patterns

Several common success factors are repeated across the diversity of contexts shown above:

- Policy and regulation: Clear policies and regulations must be established so that stakeholders share a common understanding of what an energy community is, who can participate, what activities are allowed, and how these initiatives interact with existing infrastructure (e.g., RED II, Colombia). Policymakers must close regulatory gaps to ensure that community schemes operate reliably and interface smoothly with the broader electricity system, thereby legitimizing the model (IEA, 2024). These frameworks are critical to supporting both national policy objectives and grassroots initiatives aimed at expanding energy access in underserved areas.

- Sustainable financing and business models: In both grid-connected and off-grid cases, blended finance is often key, as grants or public financing to cover initial CAPEX are combined with tariffs or savings that cover operation and maintenance.[3] Innovative models such as community investment shares, pay-as-you-go solar tariffs, or anchor-business models in mini-grids can improve bankability (IRENA, 2020; The Democracy Collaborative). Public entities can help de-risk investments by absorbing part of the risk and adopting tariff schemes that ensure projects recover costs while serving low-income users (WRI, 2022).

- Local capacity, commitment and governance: A high degree of community ownership and capacity is a defining characteristic of successful projects. Case studies repeatedly show that when residents have ownership stakes or management roles, projects exhibit better maintenance and longer lifespans (SEADS, 2025; Gill-Wiehl et al., 2022). Community training in technical maintenance, governance, and financial management strengthens the ability to operate the system and increases trust and ownership among members (IEA, 2024). Transparent governance also ensures accountability and inclusiveness. Strong community consensus is essential to avoid a "tragedy of the commons" (Nathan et al., 2021).

- Appropriate technology and scale: Projects must be appropriately sized to each community's needs and implemented with suitable technologies. Models can begin with modest capacity that is manageable for the community and can be expanded over time (SEADS, 2025). Robust design prevents failures that could erode trust. Technical design must align with local resource availability and be resilient to local conditions. Incorporating productive uses of energy (e.g., water desalination) helps amplify local economic impact and revenue generation (Pizzuti et al., 2025).

- Partnerships and knowledge sharing: Successful scaling often involves partnerships, whether with NGOs, development agencies, or private firms, particularly in early stages (IRENA, 2025). External partners can provide technical assistance, initial financing, or support community organization. Knowledge-sharing platforms have also been valuable for disseminating best practices among pilot projects in different countries (IEA, 2024). Such cooperation accelerates learning from previous cases and supports replication in new communities. Some groups are now forming community energy hubs

[3] Blended finance: a financing approach that combines public or concessional funds with private commercial capital to reduce risk and attract investment to projects that might otherwise be unbankable.

or incubators to disseminate templates for legal incorporation, engineering design, and management (Community Energy England; C4CE, 2020; IRENA, 2021).

## II. Governance models and organizational structures

**Purpose:** To explain how governance arrangements influence operational continuity and long-term performance.

- Projects with clear roles, transparent decision-making, and accountability mechanisms show better operational outcomes than those with informal or ambiguous structures.
- Community participation improves results when paired with sustained capacity building rather than one-time training.

The way energy communities are organized largely determines their ability to sustain operations over time, manage risks, and turn investment into continuous service. Governance models vary with legal frameworks, traditions of ownership and participation, access to capital, available technical capacity, and policy objectives (e.g., decarbonization, energy security, social inclusion, electrification). These choices affect bankability, revenue-collection discipline, accountability, and operational resilience.

For the Colombian context, governance is not a “social” element separate from technical and financial design. It defines decision-making authority, contractual responsibility, resource management, and how benefits and costs are distributed. In collective projects, sustainability depends on whether the arrangement enables: (i) legitimate and traceable representation, (ii) transparent management of financial flows, (iii) verifiable benefit allocation, (iv) capacity to contract and supervise O&M, and (v) conflict-resolution mechanisms. Common models in the international evidence include cooperatives, associations/committees, local government initiatives, community–private partnerships, hybrid public–private models, and private provision with structured community participation.

*Table 1. Energy community governance models*

| Governance model | Description | Key features |
|---|---|---|
| **Cooperatives** | Member-owned entities, where users collectively own and govern energy assets. | Democratic control; strong local appropriation; reinvestment of surpluses; it requires administrative, accounting and management skills. |

| Governance model | Description | Key features |
|---|---|---|
| **Community Associations or Committees** | Local structures that manage energy systems, most often in rural or off-grid settings. | Less administrative complexity; social legitimacy; vulnerability to technical limitations and risks of capture or rotation of leadership. |
| **Municipal initiatives or local government** | Projects led or owned by local governments, often with citizen participation. | Institutional capacity and potential public solvency; alignment with territorial planning; The degree of community incidence may vary. |
| **Private-Community Partnerships** | Agreements between community and private promoters or support organisations (including NGOs). | Explicit distribution of roles and risks; professional execution; it can improve technical and financial performance; It requires sustained community governance and clear benefit-sharing rules. |
| **Hybrid public-private models** | Joint structures between public authorities, private actors and communities. | Mixed finance and scaling potential; require precise contractual delimitation and flow management architecture. |
| **Private provision with community participation** | Private systems with formal community participation, but without community ownership of the asset. | Consistent technical performance and access to capital; the community has less control over assets and strategic decisions; it requires safeguards of service, rates and user support. |

### A. Cooperatives

The cooperative model is well established where enabling frameworks and traditions of collective ownership exist. In Latin America, rural electric cooperatives in Costa Rica and Brazil expanded access beginning in the 1960s and continue to operate today (IEA, 2024). Their non-profit design and democratic governance (one member, one vote) support legitimacy and reinvestment of surpluses in expansion, quality improvements, or reduced service vulnerabilities. In Costa Rica, rural cooperatives enabled under Law 8345 of 2003 serve large areas and have integrated renewable energy, indicating that the model can remain viable over decades when management capacity and stable operational frameworks are in place (IEA, 2024). Performance nevertheless depends on professional administration, internal controls, accounting capacity, and clear rules for receivables management and asset replacement; without these, cooperatives may face governance tensions, financial deterioration, or constraints in accessing credit.

### B. Community Associations and Committees

In rural environments and isolated systems, communities frequently structure associations or committees to manage energy solutions, with more flexible collective decision-making arrangements than cooperatives. These structures can reduce administrative burden and facilitate social ownership, particularly when representation is legitimate and there is clarity regarding roles, revenue collection, and fund management. In practice, the critical point is ensuring that organizational simplicity does not translate into operational weakness: when responsibilities are not formalized or when there is no minimum system of accountability and resource traceability, risks of discretion, internal conflict, and revenue deterioration increase. As a result, sustainability often depends on continuous technical support, standardized management procedures, and basic social-audit mechanisms that help maintain legitimacy and payment discipline. These associations typically operate through elected governance bodies such as general assembly, board, and committees that manage the energy asset, set tariffs, and handle billing and maintenance through a community fund.

### C. Municipal or local government initiatives

In various countries, particularly in Europe and in some Latin American experiences, local governments play a structuring role in energy communities, either as direct promoters, partial owners, or institutional coordinators through municipal enterprises. In Chile, the Comuna Energética program explicitly incentivizes municipalities to lead local clean energy projects in partnership with citizens (IEA, 2024). This approach can provide capacities that are often scarce in community initiatives: project structuring, inter-institutional coordination, contracting capacity, and, in some cases, a better risk profile to leverage resources. However, effectiveness depends on ensuring that citizen participation is not merely nominal, but rather embedded in clear rules for representation, benefit allocation, and social oversight, avoiding perceptions of the project as exclusively governmental or dependent on political cycles.

### D. Community–private partnerships

In many Global South contexts, private developers or support organizations work with communities to design, finance, implement, and operate solutions. Roles may be shared or delineated: communities contribute local assets (land, organization, territorial knowledge, user management), while private actors or NGOs provide engineering expertise, capital, execution capacity, and sometimes metering, billing, and collection platforms. RMI describes "community-led mini-grids" that may combine community cooperative ownership, private developer participation, and utility involvement (RMI). These models can improve performance by professionalizing implementation and aligning incentives, provided rules are explicit for risk allocation (collection, O&M, asset replacement), service conditions, governance and flow transparency, and verifiable benefit allocation. External partners do not replace community governance; they still require minimum capacity for oversight and legitimacy.

### E. Purely private service with community participation

Many decentralized solutions, especially mini-grids, remain privately owned and operated, incorporating community participation through engagement mechanisms, local operator hiring, or user committees supporting communication, customer service, and collection. In a purely private scheme, a company may install a solar mini-grid while the community manages user registration and payment collection; the operator retains ownership while participation reduces transaction costs and strengthens buy-in. Evidence from Sub-Saharan Africa suggests strictly community-owned projects are relatively rare; most mini-grids are implemented by for-profit or non-profit private entities (Oemmelen et al., 2025). These models can achieve strong technical and financial performance due to experience, scale, and access to capital, but social sustainability depends on structured community voice, reduced information asymmetries, and credible service conditions and safeguards. Best-practice trends point to clear partnerships that avoid two extremes: expecting communities to operate independently without capacity, or excluding them entirely from oversight mechanisms that sustain continuity (Oemmelen et al., 2025; RMI).

## III. Design of community energy systems and tariff structures

Purpose: To show how technical system design and tariff mechanisms jointly determine financial viability.

- Tariff structures must balance affordability with cost recovery, and collection discipline is consistently identified as a key determinant of financial sustainability.
- Many failures stem from insufficient O&M funding and weak financial management rather than from technical malfunction.

In Colombia, the SIN corresponds to the electricity grid that connects most urban centers and main corridors, enabling dispatch across regions and operation under more standardized rules for connection, metering, settlement, and service quality. In contrast, ZNI comprise municipalities, townships, localities, and hamlets that are not connected to the SIN, where electricity supply must be generated and managed locally, with direct implications for technical design, service continuity, billing, and operational sustainability (CREG, 2012). From a territorial perspective, regulatory and sectoral analyses consistently indicate that ZNI cover approximately 52% of the country’s surface area, with dispersed populations and structural challenges related to logistics, operation, and service quality, as well as a high historical dependence on diesel as the predominant source of local generation (CREG, 2012; Office of the Attorney General, 2024). This differentiation is not merely geographic: it conditions the type of technological architecture, the expected level of service, the real costs of provision, and the way in which a project transforms energy into a reliable service with verifiable revenue-collection and asset-replacement rules.

### A. Grid-connected systems (SIN): self-generation and distributed generation with grid settlement

Community projects connected to the SIN tend to be structured as distributed generation or small-scale self-generation solutions, where value arises through (i) reduced energy purchases during generation hours and (ii) where surplus exists, delivery to the grid under the applicable metering and settlement scheme. The grid provides a reliability backstop, so the local system is comparatively lighter from a service-continuity perspective. A typical configuration includes PV modules, a grid-connected inverter, interconnection and protection equipment, and bidirectional metering. In practice, viability is often defined less by installed capacity than by the interconnection pathway and settlement interface: voltage level, Distribution Network Operator requirements, potential works or upgrades, commissioning tests, and conditions for registering exported energy. These systems generally do not pursue full self-sufficiency; they leverage the grid as an operational buffer, with benefits dependent on avoided tariffs and on metering and billing quality (CREG).

In cost terms, the structure is concentrated in equipment acquisition and installation, compliance with technical interconnection requirements, protection and anti-islanding devices, bidirectional metering, and, where applicable, works and tests required by the Distribution Network Operator (CREG; Resolution CREG 174). Battery storage is often optional because the SIN covers nighttime continuity and low-irradiance periods, reducing operational complexity; this does not remove the need to assign clear responsibilities for O&M and performance traceability.

From a tariff and billing perspective, the central implication lies in settlement rules and in how value flows are recognized. Metering enables two distinct components: self-consumption reduces billed purchases, while exported surplus is credited or remunerated according to the applicable scheme (CREG; Resolution CREG 174). For financial modeling purposes, this requires explicitly separating the share of benefits derived from savings versus surplus recognition, avoiding optimistic assumptions about export revenues when the project’s structure in fact depends on reductions in net consumption

### B. Community mini-networks (ZNI): local service delivery and sustainable cost recovery

In ZNI, system design resembles a local utility: the solution must integrate generation, local distribution, dispatch, metering, billing, and a permanent O&M capability. Technical design therefore typically starts from expected service levels rather than a list of equipment. Parameters such as daily availability hours, continuity for critical loads (health, telecommunications, refrigeration), voltage quality, and expected scalability determine sizing of generation, storage, networks, and controls. A typical configuration combines PV generation and storage with a low-voltage distribution network and metering and control systems that enable demand management and revenue collection. In dispersed communities, river corridors, jungle environments, or islands, the objective is sustained service over time, not only asset installation.

Costs reflect this integrated service nature. Beyond PV and batteries, structural items include distribution infrastructure (lines, poles, transformers, switching), control systems, user metering, communications, and organizational costs for continuous operation. Unit costs often increase in dispersed settlements due to longer feeders, higher losses, and logistical costs for maintenance and repair. Where diesel has historically been used, transportation, storage, and fuel-supply volatility increase marginal costs, raising the value of displacing diesel while also introducing operational risks that must be addressed explicitly in O&M and asset-replacement planning (OECD, 2023).

Service parameters are often defined ex ante as operational commitments (availability hours, prioritization of critical loads), and these targets drive CAPEX and OPEX intensity: higher targets require greater storage, more robust networks, more capable controls, and stricter maintenance. From a tariff perspective, the logic centers on sustainable cost recovery because there is no upstream SIN backup. Tariffs typically cover generation, distribution, and commercial components, reflecting technological pathways, logistics, and O&M requirements (Superintendence of Public Utilities). To reduce arrears and improve cash-flow predictability, prepaid or hybrid collection schemes are frequently used, though viability depends on metering and control capacity, social acceptance, and user-service mechanisms (IRENA).

### C. Solar-Diesel Hybrid Systems (ZNI): Operational Transition from Diesel to Renewables with Resilience

Hybrid solar–diesel systems are a common improvement pathway in ZNI because many localities already depend on thermal generation. The objective is not to add solar marginally, but to shift diesel from a primary source to backup, with controls that optimize fuel use and improve continuity. Typically, PV covers daytime base demand, batteries shift energy into late-afternoon and evening peaks and improve power quality, and diesel covers extended low-irradiance periods or peak deficits. In Colombia, this approach has been reported in Bahía Málaga, where a hybrid system enabled expansion of service to 24 hours while retaining diesel for resilience and reducing fossil fuel use, with benefits for continuity and productive uses (Office of the President, 2025).

In cost terms, hybridization reduces exposure to diesel and logistics but introduces life-cycle requirements often underestimated: battery replacement, control-system maintenance, critical spare parts, and sustained O&M capacity. Economic performance depends on the extent to which diesel is displaced and on whether fixed and replacement costs are covered over the life cycle (OECD, 2023). Tariff and billing design must ensure revenues sufficient to cover O&M, residual fuel use, and asset replacement, making metering, monitoring, and collection mechanisms decisive. In remote contexts, prepaid or other controlled schemes are common as payment-risk mitigation, but require clear governance, transparent rules, and local operational capacity to sustain legitimacy and revenue collection (IRENA; OECD, 2023).

## IV. Risk Framework and Verifiable Mitigation Measures for Energy Communities

**Purpose**: To identify common risks faced by energy communities and the strategies used to mitigate them.

- Recurring risks include low collection rates, inadequate maintenance, governance weaknesses, and regulatory uncertainty.

- Effective mitigation requires lifecycle planning, reserve funds for maintenance and replacements, and clear operational procedures.

In energy communities, sustainability depends less on technical sizing or initial funding than on the ability to operate as a continuous service with risks identified, allocated, and managed through verifiable measures. International evidence shows that off-grid and decentralized electrification projects can underperform or become inoperable when risk management is incorporated late or implicitly assumed to be addressed through installation alone (Terrapon-Pfaff et al., 2020). In practice, performance is more often compromised by combinations of operational frictions that affect continuity, user trust, and revenue stability—particularly in remote rural areas and ZNI, where logistics, dispersion, and lower institutional density raise operating costs, lengthen response times, and amplify disruptions (IRENA, 2018; IEA, 2024; SEforAll, 2024).

The first structural risk is revenue-collection and income risk, which determines cash available to sustain operations, address failures, and build reserves. In low-income and high-informality contexts, payment patterns can be irregular; when collection schemes are poorly adapted to territorial realities, cash flows become unpredictable and systems can enter a deterioration spiral: low cash availability leads to reactive maintenance, service quality declines, willingness to pay erodes, and arrears increase. International experience documents that prepaid schemes and digital payment platforms can reduce friction and improve predictability by aligning consumption with payment capacity and lowering collection costs (IRENA, 2020; WRI). The diagnostic issue is not the tool itself, but whether the revenue model uses simple rules, is executable with local capacities, and maintains minimum traceability so communities perceive coherence between payments and service quality. Without that legitimacy, revenue risk becomes a governance risk, not only a financial one (Gill-Wiehl et al., 2022; Nathan et al., 2021).

A second central risk is O&M risk, often underestimated even in well-financed projects. Minor failures become permanent failures when there is no clear responsible party, no inventory of critical spare parts, or when logistical constraints make timely corrective action unfeasible. Field visits in comparable ZNI contexts describe degradation linked to absent routines, incomplete documentation, and deferred maintenance, with direct effects on service availability (Premium Times, 2025). Effective mitigation combines explicit contractual and operational responsibilities, local capacity for routine maintenance, and clear escalation pathways for complex failures. These elements do not function in isolation: training requires ongoing support, service contracts require cash and enforceable rules, and monitoring reduces uncertainty only when it triggers decisions and resources for intervention (IEA, 2024; SEADS, 2025).

Closely related is asset replacement and life-cycle risk, particularly for components that degrade earlier than the rest of the system (e.g., batteries and inverters), which typically require replacement within 5 to 10 years. Many projects succeed in installing assets but fail to establish operational and financial rules for replacing critical components when due, leading to performance decline, outages, and loss of trust. Programs that learned from early experience increasingly require explicit provisions and verifiable replacement mechanisms, to prevent replacement becoming a discretionary decision once cash is constrained (Terrapon-Pfaff et al., 2020; Premium Times, 2025). In practice this requires life-cycle budgeting from the outset, clear rules for reserves, and traceability of replacement decisions, so replacement does not depend on ad hoc negotiations or political cycles.

A fourth risk is demand risk: systems require consumption levels and patterns that can sustain operations and replacement. In small communities or where payment capacity is limited, consumption may be insufficient to cover fixed costs even with affordable tariffs. International evidence shows that deliberate user-mix design, incorporation of stable consumption profiles, and promotion of productive uses can strengthen economics and willingness to pay (ScienceDirect, 2021; Energypedia; IRENA, 2018). Risk increases when demand is overestimated at pre-feasibility or consumption growth is assumed to occur "naturally," exposing projects to recurring deficits and reactive management.

A fifth risk is governance and capture risk. Internal conflict, diffuse roles, and elite capture can erode legitimacy, compromise transparency, and deteriorate collection and sustainability. Studies of community mini-grids document shutdowns and inefficiencies driven by unclear responsibilities, local disputes, and weak accountability mechanisms (Energy, Sustainability and Society, 2019; Energy, Sustainability and Society, 2024). Mitigation is not merely creating a committee, but establishing a minimum viable governance scheme: decision rules, defined responsibilities, expenditure traceability, conflict-resolution mechanisms, and simple, consistent reporting. When sustained, these rules function as institutional infrastructure that reduces operational and revenue risks (Gill-Wiehl et al., 2022; IEA, 2024).

Regulatory and public policy risk often appears less as abrupt change than as uncertainty regarding tariffs, licensing, grid interaction, and expansion rules. Regulatory clarity can enable investment by extending planning horizons and lowering the implicit cost of capital; uncertainty functions as an "invisible tax" that increases financing costs and reduces appetite for long-term projects (SEforAll, 2024). A sensitive element in mini-grids is the rule governing grid arrival, because it drives stranded-asset risk and the feasibility of integrating or compensating investments; clarity improves bankability and reduces medium-term conflicts (SEforAll, 2024).

Finally, in ZNI and remote territories, logistics and supply-chain risk amplifies all others by raising unit costs, increasing response times, and complicating spare-part availability. This helps explain why technically sound solutions fail operationally when designed as if operating in urban environments. Resilience depends on practical decisions: defining critical spare parts from the outset, establishing realistic maintenance routines, building basic local capacity, and setting support agreements that recognize territorial constraints (IRENA, 2018; IEA, 2024).

To integrate this assessment into a project management tool, the following matrix translates risks into observable conditions, early warning signals, and mitigation measures that can be incorporated as operational and monitoring criteria:

*Table 2. Risk matrix*

| Critical risk | How it manifests in operation | Verifiable early signs | Operational mitigation measures | References |
|---|---|---|---|---|
| **Collection and revenue** | Growing non-performing loans, insufficient cash, inability to finance O&M | Increased overdue accounts, dropped payments, collection conflicts | Simple payment rules, reduced transactional friction, payment traceability, sustained community discipline | (IRENA, 2020); (WRI); (Nathan et al., 2021) |
| **O&M and continuity** | Small recurring failures, long repair times, drop in availability | Increased outages, maintenance backlog, persistent complaints | Defined managers, maintenance routines, scalable technical support, monitoring connected to action | (IEA, 2024); (Premium Times, 2025) |
| **Life cycle replenish-ment** | Battery/inverter degradation, failure due to lack of replacement | Drop in usable capacity, low performance, repeated events | Replenishment plan and provision by design, rules for the use of reserves, traceability of decisions | (Terrapon-Pfaff et al., 2020); (Premium Times, 2025) |
| **Insufficient demand** | Low consumption to cover fixed costs, structural cash deficit | Low load factor, stagnant consumption, lack of stable loads | Deliberate mixing of users, promotion of productive uses, anchors of consumption where applicable | (ScienceDirect, 2021); (Energypedia); (IRENA, 2018) |
| **Governance and capture** | Conflicts, mismanagement, perception of inequity | Recurring disputes, lack of minutes/reports, low turnout | Minimum rules of decision, accountability, basic community audit, conflict resolution | (Energy, Sustainability and Society, 2019; 2024) |

| Critical risk | How it manifests in operation | Verifiable early signs | Operational mitigation measures | References |
|---|---|---|---|---|
| **Regulatory and policy** | Uncertainty that slows down investment or affects operation | Delays in permits, undefined rules, integration disputes | Procedural clarity, operational agreements, rules for network expansion, operational legal certainty | (SEforAll, 2024) |

## V. Elements and conditions adaptable to the Colombian context

**Purpose**: To identify which global lessons can realistically be applied in Colombia.

- Lessons from emerging economies are more relevant to Colombia than European models because they share similar rural, off-grid, and institutional conditions.
- Transferability depends on territorial characteristics, community capacity, regulatory requirements, and financing availability.

Colombia can draw on international practices for energy communities, but adaptation depends on whether regulatory, institutional, financial, and community conditions make the model executable at the territorial level. Transferability is less about copying instruments and more about reproducing mechanisms that reduce uncertainty across the project life cycle: clear rules for interaction with the electricity system, inter-institutional coordination pathways, sustained technical support, payment and revenue-collection structures aligned with payment capacity, and governance safeguards that sustain legitimacy and operational continuity.

### A. Regulatory conditions for adaptation

Resolution CREG 101,072 of 2025 establishes a legal basis for energy communities in Colombia, drawing on European Union directives and regional experiences such as Brazil and Costa Rica (IEA, 2024). It defines legal forms, objectives, and permitted activities and includes the possibility of virtual aggregation within local distribution areas (PV Magazine, 2025). However, implementation challenges remain, particularly in ZNI, where many community models are expected to operate and where reliable access gaps persist (Rodríguez-Urrego & Rodríguez-Urrego, 2021). In these contexts, the question is not only what the regulation permits, but whether it reduces risk enough for developers, public entities, and financiers to commit capital and long-term support.

*Table 3. Regulatory conditions for adaptation*

| Regulatory element | Current status in Colombia | Gap or Required Condition |
|---|---|---|
| **Legal recognition of energy communities** | Established by Resolution CREG 101,072 (2025) | More precise deployment rules for specific ZNI contexts |
| **Tariff flexibility for off-grid systems** | The FAZNI framework allows rates that reflect costs in ZNI | Clearer guidance on tariff methodology applicable to schemes managed with community participation |
| **Compensation on arrival of the network** | Not yet addressed | Explicit policy to protect investments and prevent stranded assets if the main net expands into ZNI areas |
| **Inter-institutional coordination protocols** | There is no formal mechanism | Coordination agreements and routes for projects in protected areas, indigenous territories or marine areas |
| **Technical and safety standards** | There are general standards for mini-grids | Community-appropriate standards that balance security with real local deployment capability |

Among the gaps, the most decisive for investment and scaling is the **grid-arrival policy**. International experience shows that when rules are unclear for what happens if the main grid expands into a project's service area, investment willingness declines and the cost of capital increases due to stranded-asset risk. Nigeria's Mini-Grid Regulation (2016) offers a reference: it allows conversion to grid-connected operation or asset transfer with compensation equivalent to remaining depreciated value plus 12 months of revenues (IEA, 2016). Tanzania and Kenya have developed comparable approaches combining tariff flexibility, simplified licensing, and compensation mechanisms (SEforAll, 2024). For Colombia, an analogous design for ZNI is a condition to reduce uncertainty and support investment decisions with a full life-cycle horizon.

Inter-institutional coordination is another binding constraint with specific relevance for Colombia. Many ZNI communities are located in protected areas, marine parks, or Indigenous territories, requiring alignment among sectoral, environmental, and territorial authorities. The La Plata Archipelago case in Bahía Málaga illustrates delays associated with its location within a national park and the need to reconcile energy infrastructure with environmental regulations (WRI, 2025). Formal coordination protocols—such as memoranda of understanding and predefined permitting pathways—can reduce timelines and prevent administrative complexity from becoming the primary schedule risk.

### B. Institutional conditions for adaptation

A recurring bottleneck is the gap between national frameworks and local implementation capacity. Energy communities require support across the life cycle—not only installation—

including formulation, structuring and contracting, operational training, resolution of recurring failures, revenue-collection management, transparency, and social oversight. International evidence shows that external partners (NGOs, development agencies, specialized firms) often provide capacities that are unrealistic to assume communities possess from the outset.

*Table 4. Institutional conditions for adaptation*

| Institutional element | International Practice | Required Condition in Colombia |
|---|---|---|
| **Technical Assistance Providers** | NGOs, development agencies and specialized firms support development and initial operation | Network of qualified organizations with a presence in ZNI, currently limited |
| **Knowledge exchange platforms** | Hubs and incubators disseminate legal templates, designs and management guides | National or regional platform to systematize Colombian pilots and standardize learning |
| **Local government capacity** | Dedicated City Teams Coordinate with Communities | Training and resources for territorial teams in ZNI municipalities |
| **Ecosystem of operators** | Professional operators available for alliances or service contracts | Development of firms, cooperatives or organizations with sustained operational capacity |

A consistent lesson is that technical assistance must function as a system rather than a one-off intervention. Panama's Solar Champions program illustrates structured training: 280 hours over seven weeks, delivered in Indigenous languages, covering installation, maintenance, financial sustainability, and women's empowerment; by 2024, 85 Indigenous women had graduated and 24 were working in solar companies (REN21, 2024). In Colombia, pilot initiatives exist; the scaling condition is sustaining comparable training and making it programmatic, with explicit pathways for maintenance, replacement, administration, and governance.

The operator ecosystem is also decisive. Evidence from Sub-Saharan Africa suggests strictly community-owned projects are relatively rare; most mini-grids involve private entities (for-profit or non-profit) that contribute professional experience and access to capital (Oemmelen et al., 2025). This does not imply displacing communities; it implies designing partnerships and service agreements that avoid assigning communities the full operational burden from day one and that define performance, service, and transparency expectations.

### C. Financial conditions for adaptation

Community self-financing—common in some European contexts where citizens invest personal savings—is not viable in most ZNI territories in Colombia. Poverty and limited payment capacity constrain capital contributions, making external financing indispensable for infrastructure; at the same time, service revenues and productive uses must sustain O&M over time (OECD, 2024; Cogent Engineering, 2021). The key condition is therefore not only "having resources," but structuring flows and rules so systems remain sustainable without permanent subsidies.

*Table 5. Financial conditions for adaptation*

| Financial element | International evidence | Required Condition in Colombia |
|---|---|---|
| **Capital Grants for Infrastructure** | Performance-based grants linked to verified results; Zambia's ZEDSI program links disbursements to actual use (SEforAll, 2025) | Structured FAZNI resources with verifiable milestones and the possibility of complementing with international climate finance |
| **Concessional credit** | Commercial banks are often absent from direct financing of mini-grids (Power For All) | Dedicated lines through development banks with conditions compatible with EC flows and risks |
| **Blended finance structures** | In 2023, global mini-grid financing reached USD 2.5 billion with grant-loan-equity combinations (SEforAll, 2024) | Designs that integrate FAZNI, climate resources and, progressively, private capital according to a history of performance |
| **Payment systems** | Prepaid metering and mobile payments reduce collection risk; PAYG scaling tested in multiple countries | Colombia has a network of agents and mobile wallets; wallet users increased from 11.5 million to 22.4 million between March 2020 and March 2021 (Better Than Cash Alliance, 2021); Prepaid meter deployment and training required |
| **Financing for productive use** | Energy-integrated production equipment improves demand and revenues | Credit or lease schemes for productive equipment linked to CE deployment |

A further enabling factor is the global reduction in costs of key technologies. Between 2010 and 2024, total installed costs for utility-scale photovoltaics fell by 87% and battery costs by 93% (IRENA, 2025), improving competitiveness relative to diesel in remote contexts. In Colombia, studies show the economic viability of transitioning from diesel to renewables in off-grid communities (Garcés et al., 2023). Capturing this benefit depends less on engineering than on incorporating replacement, O&M, revenue collection, and governance from the design stage.

For cooperative or community models to function without significant community capital, adaptation must rely on alternative channels: FAZNI grants for infrastructure, concessional credit for equipment, and, selectively, community participation schemes with nominal thresholds (labor contributions or small fees) that reinforce ownership without requiring substantial monetary investment. Regional evidence from Brazil and Costa Rica shows that external capital can coexist with community governance and produce sustainable systems; the key factor is structuring ownership, roles, and decision rules to maintain community engagement regardless of capital source (IEA, 2024).

### D. Community conditions for adaptation

The success of an energy community depends on the existence of sufficient social organization to manage collective assets and make binding decisions. The literature consistently highlights that community participation improves sustainability when it is early, inclusive, and accompanied by capacity-building, but it also warns that "community capacity" cannot be assumed: it must be assessed and, where necessary, built prior to commissioning (Gill-Wiehl et al., 2021).

*Table 6. Community adaptation conditions*

| Community element | International evidence | Required Condition in Colombia |
|---|---|---|
| **Pre-existing social organization** | Higher performance where functional structures exist (councils, associations, cooperatives) | Identify existing organizations; where they do not exist, invest in organizational development prior to technical deployment |
| **Duration and scope of training** | Solar Champions: 280 hours in seven weeks, with technical and business skills (REN21, 2024) | Sustained support of comparable duration, including maintenance, financial management and governance |
| **Governance structures** | Community Transparency and Oversight Reduce Elite Capture | Structured training in governance and external oversight mechanisms during initial operation |
| **Gender inclusion** | Improving sustainability and benefit-sharing | Deliberate inclusion of women in training, leadership and decision-making |
| **Anchor Institutions** | Schools and health centers provide demand and legitimacy | Integrate anchor loads and involve them in operating and governance rules |

The Colombian pilots show relevant signs of successful adaptation by integrating productive uses that strengthen appropriation and cash flow, enabled by community conditions. In Natagaima, solar energy enables water pumping and fish cooling; in Mingueo, the community operates electric motorcycle charging; in La Plata, access to energy supports ecotourism along with traditional fishing (WRI, 2025). Amazonian experiences in Brazil that linked solar cooling with fishing increased production by more than 160%, raising revenues and enabling contributions to maintenance funds (IEA, 2024). The operational learning is clear: integrating productive uses from the beginning creates economic incentives that reinforce discipline of payment, maintenance and continuity.

The evidence also confirms that governance failures are a critical risk. Studies in India identify that local conflicts and elite capture can subvert effective participation, and that unclear roles cause inefficiencies and closures (Energy, Sustainability and Society, 2019). In Tanzania, 12 out of 14 community mini-grids failed in four years, with poor management being attributed as the main cause (Energy, Sustainability and Society, 2024). For Colombia, the enabling condition is not only to "train", but to uphold simple rules of accounting, traceability and accountability, ideally with external supervision during start-up.

### E. Items that are not transferred directly

Some practices face structural barriers that prevent their literal application. European grid-connected models rely on surplus sales to utilities, feed-in tariffs, net metering and virtual aggregation on robust infrastructure. In the absence of a network, these logics do not apply: in ZNI the system must operate as a local supply-demand balance, with priority given to service continuity and life cycle management.

There are also conditions of security and access that distinguish the Colombian case from much of the international literature. Some ZNI communities have been affected by armed conflict or illicit economies, introducing risks of theft, sabotage and access restrictions for contractors. This context requires that site selection, O&M logistics, and governance design incorporate territorial security criteria as part of operational risk, not as a peripheral element.

Finally, the scale of continuous operating subsidies available in developed countries is not replicable given fiscal constraints. This limitation reinforces a central implication of the diagnosis: the design must be supported by realistic tariff structures, income from productive uses, and maintenance and replacement funds that reduce dependence on recurrent support.

### F. Conditions for a viable program

For the energy communities program to scale in a sustained way, a coordinated intervention in four dimensions is required. In the regulatory sphere, recent progress is significant, but implementation in ZNI requires complementary rules and, in particular, clear mechanisms for the arrival of a network, inter-institutional coordination for environmental and indigenous territories, and appropriate technical standards for models managed with community participation. Closing these gaps reduces uncertainty and protects investments.

Institutionally, the priority is to build a technical assistance network and an ecosystem of operators with a presence in ZNI, capable of accompanying projects beyond the installation. The gap between national policy and local capacity does not close by itself; it requires deliberate investment in training, staffing, standards and support.

Financially, poverty levels make the mobilization of external capital for infrastructure inevitable. FAZNI resources and climate finance must cover CAPEX, while tariffs and productive uses sustain O&M over time. Blended finance can expand private participation, but scaling it up depends on building a track record of performance. Collection innovations, such as prepayment, reduce cash risk and should be considered standard practice where applicable (Better Than Cash Alliance, 2021; IRENA, 2020).

At the community level, the minimum conditions must be evaluated on a project-by-project basis: functional organization, willingness to participate in training, sufficient cohesion to manage shared assets, and clear rules for decisions and social control. When these conditions do not exist, organizational development must occur prior to technical deployment. Evidence from intensive programs such as Solar Champions suggests that deep training, including technical, financial, and governance components, increases the likelihood of sustainability (REN21, 2024).

Taken together, these conditions are achievable, but they require consistency of design: technical solutions are not enough. Sustainable energy communities emerge when regulatory frameworks, institutional support, financial structures, and community capacity are aligned in the same operating model. Early pilots in Colombia show that such alignment is possible; Scaling depends on systematizing the conditions that made those cases viable and making them the standard of the program.

# COMPARATIVE ANALYSIS OF INTERNATIONAL AND NATIONAL EXPERIENCES

Purpose: To compare global and Colombian experiences and extract lessons that can inform scalable models in Colombia.

- International and Colombian cases consistently highlight the importance of governance clarity, O&M planning, realistic tariffs, and strong collection mechanisms.
- Colombian pilots mirror global patterns, showing that technical installation is rarely the main challenge—long-term operation is.

**Key Message: Lessons from emerging economies (Brazil, India, Kenya) are more relevant to Colombia than European models because they share rural, off-grid, and institutional challenges. Successful projects move from isolated pilots to scalable models by addressing O&M (Operation and Maintenance) and collection discipline**

This section compares international and Colombian energy community experiences to extract lessons applicable to design and implementation in Colombia. The aim is to identify patterns of success, recurring failure modes, and the design choices that explain operational and financial sustainability across contexts, including SIN-connected schemes and isolated systems in rural territories and ZNI.

Comparability is driven less by technology than by the ability to deliver continuous service: role clarity, mechanisms for collecting and allocating benefits, O&M and asset replacement arrangements, and institutional structures that reduce execution risk. The cases are therefore assessed through a common lens of "enforceability," emphasizing actor alignment, flow management, and mitigation of dominant risks (performance, demand, collection, logistics, and regulatory change).

The diagnostic premise is that transferable learning is more often in mechanisms than in forms. Instruments such as performance-based disbursements, prepayment schemes, replacement funds, service contracts with defined care levels, and governance models with transparent accountability tend to be replicable when adapted to local capacity and regulatory constraints. By contrast, practices tied to specific market structures—such as incentives based on surplus sales in highly interconnected systems or permanent operating subsidies—require substantive adjustment to be viable in rural contexts and in Colombia's ZNI.

Based on this logic, the section has two components. First, it presents an integrated reading of international and national experience, highlighting typologies, institutional arrangements, operating models, results, and conditioning factors. Second, it consolidates comparative learning and transferability criteria that feed the decision tree, the enabling-conditions analysis, and subsequent financial and operational design.

## I. National and international experience

Purpose: To identify shared patterns across global and Colombian cases.

- International cases emphasize governance, O&M, tariff design, and collection discipline as core drivers of sustainability.
- Colombian pilots show similar dependencies, reinforcing that these factors are universal across contexts.

The comparative analysis of experiences of energy communities in Europe, Latin America, Africa and Asia shows a double reality. On the one hand, relatively stable patterns are repeated about what enables sustainable projects over time. On the other hand, there are profound differences associated with the starting point of each region (level of electrification, institutional capacity, availability of capital and policy objectives), which change the way in which governance, tariffs, financing mechanisms and risk management are designed. Reading these convergences and divergences is key for Colombia to incorporate international learning selectively, without transferring assumptions that do not fit rurality and ZNI.

*Table 7. Experiences of energy communities*

| Dimension | Consistent pattern | Key variation | Colombia's position |
|---|---|---|---|
| **Governance** | Community participation improves results; clear legal recognition facilitates orderly growth. | Formal cooperatives; private operators with a community interface; informal committees | Community associations supported by NGOs; regulation provides legal basis but governance capacity is still incipient. |
| **Technical Design** | Hybrid configurations with solar are consolidated; Diesel remains as a backup | Europe: grid-connected distributed generation; Africa and Asia: isolated mini-grids; | In ZNI, isolated mini-grids predominate; Solar-battery-diesel configurations are common. |
| **Fees and revenue collection** | Tariff design seeks to balance affordability and cost recovery; Prepayment reduces the risk of collection. | Cost-reflective rates; uniform rates that require permanent subsidies. | Historically, uniform rates via FAZNI/FOES subsidies; The new regulation could enable greater local flexibility. |

| Dimension | Consistent pattern | Key variation | Colombia's position |
|---|---|---|---|
| **Financing** | Capital subsidies are often decisive; trade credit remains limited; blended finance is growing. | Europe: member investment and public incentives; Africa: donors; LA: fragmented international availability. | FAZNI provides a domestic base; It is necessary to combine public funds with international climate finance. |
| **Risk Management** | Revenue, O&M, and replenishment risks should be addressed by design, not as subsequent correctives. | Sophisticated instruments (e.g. first loss) concentrated in Africa; simpler models elsewhere.[4] | Formal risk management is underdeveloped; Early pilots show failures when the life cycle is not planned from the beginning. |
| **Institutional roles** | Clear mandates and easy coordination accelerate deployment. | Single-agency models; multi-agency coordination when overlapping with protected areas | Complex multi-agency landscape: Ministry of Energy, Ministry of Environment, National Parks, local governments and indigenous authorities. |

The most consistent finding across contexts is that energy communities serving low-income populations require sustained external financial support to simultaneously achieve social equity and operational viability. A 2025 review of African mini-grids explicitly stated that achieving financial and social sustainability without subsidies remains exceptionally difficult (Fajardo et al., 2025). This finding holds true when examining cooperatives in Costa Rica, mini-village networks in Kenya, or pilot projects in Colombia's ZNI. The observed pattern is that external support covers initial capital costs, while tariff revenues contribute to the operation; prepaid systems are now standard to reduce the risk of collection in dispersed communities. Colombia's historical reliance on FAZNI and the Social Energy Fund (FOES) to subsidize off-grid diesel service reflects this logic (SAIS Perspectives, 2020), and maintaining similar supports for renewables-based energy communities will be essential to reach marginalized populations.

Community engagement consistently improves outcomes, but the capacity building required is often underestimated. Local involvement from the start builds trust, facilitates implementation,

[4] First loss; A risk-sharing mechanism where one investor (typically a public entity or development fund) agrees to absorb initial losses, protecting other investors and making projects more attractive to commercial lenders.

and sustains systems by solving problems at the local level. Colombian communities that helped design and now manage their energy systems report the use of electricity for new income- and employment-generating activities (WRI, 2025). However, involvement alone is not enough. Communities in Colombia have pointed out that short training periods did not adequately prepare them for the complexity of the system (WRI, 2025), in line with international experience where projects were weakened once initial technical support ended. A comprehensive assessment of off-grid projects in sub-Saharan Africa found that 17 out of 29 became inoperable within six months, with insufficient training and lack of maintenance planning being common causes (Terrapon-Pfaff et al., 2020). Successful programs treat capacity building as an ongoing accompaniment, with maintenance reserve funds built into budgets from the start, rather than as a one-time delivery followed by withdrawal.

Technology decisions are converging globally towards hybrid solar setups, with solar PV's share of mini-grids increasing from 14% to 59% between 2018 and 2024 (SEforAll, 2024). This convergence means that Colombia benefits from the accumulated technical knowledge and the fall in equipment prices, without the need to pioneer solutions. Countries that have provided clear legal frameworks for energy communities, such as Costa Rica's Law 8345 for cooperatives and Colombia's CREG Resolution 101,072 of 2025 (PV Magazine, 2025), have seen more orderly growth and greater investor confidence than those where communities operate in legal ambiguity. The remaining challenge is lifecycle planning: batteries require replacement every five to ten years, and projects that don't budget for this face system failures, regardless of how well designed they were initially. Colombian pilots in San Bernardo and La Plata have already experienced maintenance issues when lifecycle costs were not addressed from the outset (WRI, 2025).

Regional motivations differ. In Europe, energy communities prioritize decarbonization and citizen participation in contexts where households already have reliable grid electricity (Ahmed et al., 2024). In Africa and Asia, programs primarily target rural electrification and first-time access (SEforAll, 2024). Colombia sits in a different terrain: it emphasizes last-mile access for marginalized Indigenous and Afro-Colombian populations within a Just Energy Transition framework, which shapes project selection and success metrics differently from European and African precedents.

These different motivations produce different enabling environments. European citizens may invest personal savings; African programs often benefit from concentrated multilateral and donor presence. Colombia has domestic funding via FAZNI, but lacks both the fiscal capacity for European-scale subsidies and the donor concentration that supports African expansion. Institutionally, some African countries have streamlined deployment through single-agency frameworks, while in Colombia many ZNI communities overlap with protected areas, marine parks, and Indigenous territories requiring multi-agency coordination. The La Plata project experienced delays because its location within a national park required alignment among multiple authorities (WRI, 2025). Security conditions in some ZNI areas, associated with armed conflict and illicit economies, add risks rarely addressed in international technical literature.

For Colombia, the implication is that proven technical solutions, governance principles, and payment innovations can be adopted, but funding routes and institutional coordination mechanisms must be adapted to local conditions. Enablers include the new regulatory framework, established FAZNI funding, favorable solar resources, and early pilots demonstrating productive-use integration. Constraints include limited community capital requiring sustained external support, multi-agency complexity, training periods that have proved too short, and maintenance gaps that have already caused operational problems. Addressing these constraints systematically will shape whether the program achieves scale and sustainability.

## II. International reference cases

Purpose: To present global examples illustrating diverse models and their relevance.

- European cases operate in contexts with strong grid infrastructure and institutional capacity, which differ from many Colombian territories.
- Brazil, India, Kenya, and Indonesia offer more applicable lessons for rural and off-grid environments similar to Colombia's ZNI.

To ground the comparative analysis in concrete examples, this section presents a selection of international energy community cases with documented, verifiable results. The intention is not to rank best practices, but to illustrate diverse combinations of technology, institutional arrangements, and operating schemes, and to extract lessons relevant to Colombia, particularly rural territories and ZNI.

The cases were selected to represent contrasting implementation routes: (i) isolated systems with high renewable penetration and operational rules that protect continuity; (ii) grid-connected models capturing value through self-consumption and surplus compensation; (iii) schemes integrating productive uses to strengthen sustainability and collection; and (iv) governance arrangements ranging from community ownership and cooperatives to private operation with a structured community interface. Together, they highlight enabling conditions behind performance (governance, benefit-allocation rules, O&M and replenishment provisions, and coordination capacity) and elements requiring adaptation for Colombia.

Six reference cases are described below, organized by their central sustainability mechanism and their practical relevance for energy community design in Colombia.

*Table 8. International cases of energy communities*

| Case | Location | Technology | Governance | Key results | Source |
|---|---|---|---|---|---|
| **Isle of Eigg** | Scotland, United Kingdom | Solar PV, wind, hydro, batteries, diesel backup (184 kW total) | Community-owned company (Eigg Electric Ltd.) | 24/7 electricity with 95% renewables; a cap of 5 kW per household ensures equitable distribution. | Isle of Eigg; EU Clean Energy Islands |
| **RevoluSolar Cooperative** | Rio de Janeiro, Brazil | Solar PV on rooftops (26 kWp) | Cooperative in favelas supported by NGOs | First solar cooperative in Brazil; 25+ families with reduced bills; Training for local installers. | 350.org; RioOnWatch |
| **RESEX Solar** | Amazonas, Brazil | Solar PV replacing diesel generators | Community partnership with NGO support | Fish production increased >160% thanks to refrigeration; Community maintenance funds were established. | IEA, 2024 |
| **Coopeguana-caste** | Guanacaste, Costa Rica | Grid-tied distribution with hydro, solar and wind generation | Rural Electric Cooperative (since 1965) | More than 90,000 members; 99.7% electrification in its area; achieved 100% renewable generation. | Madriz-Vargas et al., 2016; Eos-GNSS |
| **Mera Gao Power** | Uttar Pradesh, India | Solar DC microgrids (300 W per farm) | Private company with community clients | More than 1,500 microgrids serving 100,000+ people; $1–2/month per household for lighting. | IGC; EU Commission |
| **Talek Solar Mini-Grid** | Narok County, Kenya | Solar-battery hybrid (50 kW) with diesel backup | County Government Owned, Privately Operated (PowerGen) | 1,500 people served; 40% population growth in the population center; enabled businesses linked to tourism. | New Climate Institute |

### A. Isle of Eigg, Scotland

The island of Eigg represents a pioneering example of complete energy autonomy for an isolated community. This small island of about 100 inhabitants operated exclusively on diesel generators until 2008, when the community established Eigg Electric Ltd. as a community-owned company. The system integrates three hydroelectric generators, four wind turbines and solar panels with battery storage, providing continuous supply for the first time in the island's history. Diesel backup is still available, but it accounts for only 5% of generation.

The relevance for Colombia lies in demonstrating that even very isolated communities can operate renewable-based networks with high reliability. Key success factors include strong community leadership, external grants for capital costs, and clear operating rules, including household consumption caps that ensure equitable distribution without overburdening the system. Isle of Eigg shows that technical success and community self-sufficiency can be achieved in tandem when governance structures are well designed.

### B. RevoluSolar Cooperative, Brazil

RevoluSolar operates in the Babilônia and Chapéu Mangueira favelas (informal urban settlements) overlooking Copacabana. This initiative uses Brazil's net metering policy to reduce electricity bills for member families. The cooperative model does not require a down payment from members; Solar generation offsets bills with the utility, and the savings are partially reinvested in a cooperative fund for new installations.

For Colombia, RevoluSolar illustrates how social organizing combined with supportive policy can offer economic benefits and empowerment to marginalized communities. While off-grid zones in Colombia cannot use net metering with utilities, the principle of joint community investment for shared benefit is transferable. The project also highlights the value of training programs: the cooperative offers courses for community members to train as solar installers, creating local employment and technical capacity.

### C. RESEX Solar, Brazilian Amazon

In the Brazilian Amazon, RESEX replaced diesel generators with solar photovoltaics, allowing a fishing community to power refrigeration equipment for the first time. Annual fish production increased by more than 160 per cent, markedly improving household incomes. The additional revenue allowed the community to establish maintenance funds, creating a path to long-term sustainability, and demonstrates the transformative potential of linking energy access to productive uses.

RESEX Solar is directly analogous to Colombian communities in the Amazon and Pacific where fishing is a main livelihood. Colombia's pilot in Natagaima, where solar power powers water pumping and fish cooling, reflects this approach. This case reinforces why maintenance planning must be built in from the start: even well-designed systems can fail without ongoing support.

### D. Coopeguanacaste, Costa Rica

As one of four rural electric cooperatives operating in Costa Rica since the 1960s, Coopeguanacaste demonstrates that the cooperative model can successfully scale and remain effective for decades. Growing from 229 members in 1965 to more than 90,000 today, the cooperative manages distribution on 3,696 $km^2$ and has achieved 99.7% electrification in its service area. Recent investments in hydroelectric, solar and wind generation have made it possible to reach 100% renewable electricity supply.

Historically, Colombia has not had electric cooperatives of comparable scale, but the Costa Rican experience suggests that allowing energy communities to grow into larger cooperative enterprises can generate sustainable and locally anchored public services. Key enabling factors include Law 8345, which provides a favorable legal framework, decades of professional management development within the cooperative movement, and sufficient initial funding, such as that provided by the Alliance for Progress program.

### E. Mera Gao Power, India

Mera Gao Power represents a private sector approach to ultra-low-cost electrification. The company, funded by three impact investment funds totaling $2.5 million, has installed more than 1,500 solar DC microgrids in Uttar Pradesh, each serving 10–20 households with costs of less than $1,000 per system. The business model uses weekly prepaid and focuses on basic services: LED lighting and mobile phone charging. Although the systems do not power major appliances, they cover critical needs at extremely affordable prices.

For Colombia's poorest or smaller communities, this model suggests that basic solar DC systems could provide lighting and communications as a first step, with larger microgrids later as demand and capacity grow. However, the Colombian program in general has aimed at a greater scope, integrating productive uses that require more substantial generation capacities.

### F. Talek Solar Mini-Grid, Kenya

Talek's mini-grid illustrates a hybrid approach to governance in which infrastructure is publicly owned but operated by a private party. Commissioned in 2015 by GIZ, the 50 kW solar-battery system was transferred to the Narok County Government, which contracted PowerGen for operation and maintenance. The project serves approximately 1,500 people in a population center adjacent to the Maasai Mara National Reserve.

Relevance to Colombia includes demonstrating that community energy can be aligned with local economic activities, in this case ecotourism. The town saw a population growth of 40% after electrification, as new businesses opened to cater to tourists. For Colombian communities close to protected areas or with tourism potential, a similar alignment between energy access and economic opportunity could strengthen the sustainability of the project.

## III. Cases of energy communities in Colombia

Purpose: To summarize Colombian pilots and their operational characteristics.

- Most Colombian pilots use solar or hybrid systems and incorporate community participation in governance or operations.
- Sustainability challenges relate to O&M funding, collection performance, and limited local technical capacity.

Colombia's energy communities program was launched in 2023, and as of October 2024, approximately 100 energy communities were active across the country (WRI, 2025). The first pilots span diverse geographies and operating models and provide early evidence of both positive outcomes in access and well-being and recurring frictions associated with maintenance, operational governance, and life-cycle financial sustainability. Together, these cases allow us to observe how the elements that the diagnosis identifies as critical behavior in practice: continuity of service, clarity of responsibilities, discipline of collection when applicable, local capacities, and verifiable mechanisms of O&M and replenishment.

*Table 8. Experiences of energy communities in Colombia*

| Community | Technology | Productive uses | Key results | Main challenges |
|---|---|---|---|---|
| **La Plata Archipelago (Malaga Bay, Pacific Coast)** | Solar-diesel hybrid mini-grid; Home Solar Systems | Tourism, fishing, refrigeration | 293 families with 24/7 energy; Female leadership in management | Maintenance issues due to contractor negligence; Coordination with the National Park Authority |
| **Mingueo (La Guajira, Caribbean)** | 12-panel solar PV system with battery | Electric motorcycle charging and transportation | Community charging station in operation; Cleaner mobility for local transport | Small-scale pilot; The challenge is to expand to home connections |
| **Tamirco Indigenous Reservation (Natagaima, Tolima, Andean region)** | 20-panel solar array with lead-acid batteries | Fish farming: water pumping, cooling, lighting | Increased fish production; Community Revolving Fund for Maintenance | Remote location limits access to external support; Uncertainty about financing for battery replacement |

| Community | Technology | Productive uses | Key results | Main challenges |
|---|---|---|---|---|
| **Santa Cruz del Islote / Isla Múcura (San Bernardo Archipelago, Caribbean)** | Solar-diesel hybrid | Tourism, fishing | Initial service improvement | Maintenance failures by the contracted operator; frequent interruptions; Community seeks formal energy community status |

### A. La Plata Archipelago, Malaga Bay

Located within the Uramba Bahía Málaga National Natural Park on Colombia's Pacific coast, the La Plata Archipelago comprises four Afro-Colombian island communities that historically relied on diesel generators that provided only four hours of electricity a day. A solar-diesel hybrid mini-grid installed in 2025 now provides 24-hour power to nearly 300 families, significantly improving quality of life and enabling new economic activities.

The project demonstrates the potential for energy access to support both fishing operations and ecotourism. Residents can now refrigerate catches and offer basic visitor services, expanding entry opportunities. Governance has been strengthened through the Community Council of Black Communities, with female leadership playing an essential role in the management of the system.

Challenges have arisen mainly around maintenance. The private contractor initially responsible for maintaining the system failed to adequately attend to batteries and inverters, leading to operational problems towards the end of 2025. The community is now working with government entities to address these issues and formalize the microgrid under the energy communities regulatory framework, in order to secure dedicated funding and technical support. The project also faced delays during construction due to its location in a protected area, which required coordination with National Parks authorities.

### B. Mingueo, La Guajira

In the Caribbean township of Mingueo, a pilot project launched in November 2023 established a community charging station using a 12-panel solar photovoltaic system with battery storage. Rather than directly supplying households, the project primarily functions as a charging station for electric motorcycles, catering to the transportation needs of residents who rely on motorcycles for their livelihoods.

This approach illustrates a creative integration between energy access and income generation. The project converted some gasoline-powered motorcycles to electric and provides solar charging, reducing both fuel costs and pollution. Community members have been trained in solar system maintenance and electric vehicle retrofits, strengthening local technical capacity.

The main challenge is scale. The current pilot serves basic needs, but does not provide household electrical connections. Expansion towards wider microgrid coverage will require additional investment and a more complex distribution infrastructure. However, the multi-stakeholder collaboration model—involving an NGO, a renewable energy company, the MME, and the University of La Guajira—demonstrates a partnership approach that could support scaling.

### C. Tamirco Indigenous Reservation, Natagaima

The Tamirco Indigenous Reservation in Tolima exemplifies the integration of access to energy with productive agriculture. A solar array of 20 panels with lead-acid batteries powers the pumping of water from a 15-meter cistern, lighting over fish ponds and four refrigerators to preserve the fish before they are sold. The system has strengthened the community's fish farming cooperative, improving both food security and income.

Notably, the community has established innovative local financing mechanisms. A Revolving Fund covers the costs of maintaining the solar system, while a Private Savings Fund provides lines of credit to cooperative members for productive and social needs. Both funds are capitalized by allocating 5% of fishing revenues, creating a route to financial self-sufficiency. This approach is supported by the NGO Grupo Semillas, but is managed by the community itself.

The challenges relate to the remote location and long-term sustainability of community-managed funds. If major equipment failures occur, the accumulated resources could be insufficient. Nonetheless, Tamirco's model represents a promising approach to local ownership and financial planning that other communities could adapt.

### D. Santa Cruz del Islote and Isla Múcura

The islands of the San Bernardo Archipelago clearly show the cost of failing to ensure verifiable O&M. A hybrid solar-diesel system initially improved the service, but the operation deteriorated due to inadequate maintenance and failures associated with the management of the contracted operator, with recurring interruptions. Dependence on diesel supply and lack of timely compliance for critical components illustrate how a weak contractual arrangement, without effective incentives and oversight, can lead to "loss of performance" even when CAPEX has already been executed.

The case reinforces the need to provide communities with minimum capacities for monitoring, control and reaction to non-compliance, and to structure mechanisms that prevent the service from being held captive by a third party without consequences. The search for formal status as an energy community also reflects a practical motivation: to access support and financing routes that allow O&M to be stabilized, sustain replenishments and order the governance of the service.

Taken together, the Colombian cases reflect tangible advances in continuity of supply and value creation when energy is connected to livelihoods (fish farming, tourism, mobility). At the same time, they confirm that the main risk is not in the installation, but in the sustained operation: insufficient O&M, short-term training, diffuse responsibilities and lack of replacement provisions tend to translate into service degradation and loss of confidence. Given the goal of scaling to thousands of communities and adding renewable capacity through this approach (PV Magazine, 2025), the pilots' learnings point to clear priorities: strengthening O&M standards and contracts, formalizing reservation and replenishment mechanisms, expanding hands-on training, and ensuring agile inter-institutional coordination, especially in rural territories, ZNIs, and areas with environmental or administrative constraints (WRI, 2025).

## IV. Comparison of Outcomes, Barriers, and Enabling Factors

**Purpose:** To synthesize cross-case lessons on what drives or limits success.

- Strong governance, realistic tariffs, and ongoing technical support are common enablers across successful cases.
- Barriers include fragmented institutional processes, limited O&M financing, and weak community organizational capacity.

Bringing together international and Colombian experiences reveals consistent patterns in outcomes, common barriers that limit operational performance, and enablers that support sustainability over time. This comparison separates three elements often conflated: observable service and socioeconomic results; structural barriers that prevent projects from remaining operational with quality; and enabling conditions that allow a pilot to become a scalable model.

In Colombia, the comparative value is twofold: it confirms widely documented global learning on mini-grids and community energy, and it highlights frictions typical of rural territories and ZNI, where logistics, multi-agency requirements, and local capacity constraints amplify risks that are managed with lower transaction cost in grid-connected settings.

In terms of results, international and national evidence converges that the core impact is improved electricity service: access where it was previously absent, or substantial increases in continuity and quality where service was precarious. Cases such as Isle of Eigg show that 24/7 supply based mostly on renewables is feasible in isolated environments; in Colombia, the La Plata Archipelago shows comparable gains from a few diesel-supplied hours per day to continuous service through a hybrid scheme. More transformative effects tend to materialize when electricity supports productive and organizational capacity. Refrigeration in fishing chains, pumping for agro-productive activities, and electric mobility can raise incomes and reduce costs, while reinforcing legitimacy through visible daily benefits.

Social results also converge: sustained participation strengthens ownership, reduces conflict, and improves operational discipline. Programs combining electrification with training have created green jobs and local skills; in Colombia, comparable signs appear in community leadership and in strengthened governance when clear rules and basic accountability mechanisms are in place. Environmental benefits are cross-cutting: displacing diesel with solar and storage reduces emissions and reduces risks associated with fuel transport and handling; in Colombia these benefits are linked to national climate goals and the Just Energy Transition.

*Table 9. Analysis of results*

| Result Category | International evidence | Evidence in Colombia |
|---|---|---|
| **Electric Service Access and Reliability** | Mini-grids have provided electricity for the first time to villages in Africa and Asia; Isle of Eigg achieved 24/7 supply with 95% renewables. | The La Plata Archipelago went from 4 hours a day with diesel to 24/7 with a hybrid solar system; multiple communities report increased service reliability. |
| **Local Economic Development** | A fishing community in the Brazilian Amazon increased its production by more than 160% through refrigeration. | Fish farming in Natagaima is supported by solar pumping and cold chain; Mingueo enables electric transport services. |
| **Social empowerment** | Training programs in Panama and Brazil have developed local technical capacity and created green jobs. | Female leadership is evident in La Plata and San Bernardo; Community governance structures have been strengthened. |
| **Environmental benefits** | Global switch from diesel to solar on mini-grids reduces emissions and eliminates fuel spills. | The Colombian projects are explicitly linked to the 51% emissions reduction target by 2030. |

The barriers also show a strong convergence, and the most relevant pattern is that bottlenecks are not only located in technology. Even with adequate technology, projects fail if infrastructure cannot be turned into a service: who maintains, how flows are managed and controlled, who decides, how benefits are assigned, how arrears are managed, and what happens when there are defaults or failures. The capacity gap appears when training is short or discontinuous and when trained people are unable to maintain routines of operation, accounting, collection and social control. O&M and replenishment funding is often the most damaging blind spot: when explicit provisions and rules are not established, the system degrades, availability falls, and trust is eroded, which in turn hits revenue and legitimacy. At ZNI, logistics amplifies everything: spare parts, technicians, and response times turn minor failures into prolonged outages. In Colombia, there is a distinctive barrier: the complexity of inter-institutional coordination in ethnic territories, protected areas and marine areas, which introduces delays and transaction costs. Finally, fragile or captured governance can derail the project even with technology and resources, because perceived inequity and unclear roles tend to translate into conflict and operational abandonment.

*Table 10. Analysis of barriers*

| Barrier | Details | Evidence |
|---|---|---|
| **Capacity and training gaps** | Communities face difficulties in resolving technical failures, accounting, and governance when initial training ends. | Colombian communities reported that a 3-month training was insufficient; Similar gaps have been identified in mini-grid programs in Africa. |
| **O&M financing** | Fee revenues in poor communities rarely cover complete maintenance, equipment replacement, admin | Funding was identified as a persistent challenge in all Colombian pilots; Battery replacement costs are particularly concerning. |
| **Initial Capital Restrictions** | Scaling to many communities requires mobilizing substantial capital that commercial investors perceive as risky. | Private investment caution is documented globally; Colombia depends on public funds and donor support. |
| **Maintenance and technical support** | Remote communities lack access to technicians and spare parts; reparations become crises. | System failures in San Bernardo due to contractor negligence; delays when equipment fails in isolated locations. |
| **Institutional coordination** | Multiple authorities must align depending on the area | Construction in La Plata was delayed due to coordination with National Parks; regulatory fragmentation is reported as a barrier. |
| **Community governance challenges** | Local disputes, capture by elites, or unclear roles can derail projects. | Cases of distrust or factionalism are reported; The need for inclusive decision-making is emphasized. |

Enablers appear as the inverse of these barriers, but not as generic "best practices": they work when they become verifiable rules and sustained routines. A clear public policy framework provides legitimacy and reduces uncertainty for territorial actors, operators, and funders, but only if it translates into enforceable procedures, roles, and responsibilities. Access to resources must cover installation and maintenance of the service, incorporating O&M and replacement provisions, to prevent the program from accumulating infrastructure without continuity.

Capacity building works when continuous, with mentoring and reinforcement, and when accompanied by administration, transparency and social control. Community ownership and leadership sustain operations and collection, especially if there are clear rules for benefit-sharing and decision-making. Integration with productive uses is a critical enabler because it aligns system sustainability with economic well-being. Finally, multi-stakeholder alliances are a practical condition for scaling: they combine community legitimacy with technical, administrative, and risk management capacities that are unlikely to fully exist in remote territories from the outset.

*Table 11. Analysis of enablers*

| Enabler | How it works | Evidence |
| --- | --- | --- |
| **Strong public policy support** | Government engagement brings legitimacy, resources, and regulatory clarity. | The inclusion of energy communities in the National Development Plan; first dedicated laws in Latin America. |
| **Access to finance** | Adequate grants and concessional funding allow for the acquisition of quality equipment and proper implementation. | Global mini-grid funding exceeded USD 2.5 billion by 2023; Colombian projects supported by FAZNI and allies. |
| **Capacity building and ongoing support** | Continuous mentoring, technical support and reinforcement training support community management. | Successful cooperatives belong to federations that provide support; Colombian alliances with universities and NGOs. |
| **Community Ownership and Leadership** | Local leaders build trust, ensure compliance and sustain involvement. | Transparent fund management in Natagaima; Female leadership in Pacific Coast communities. |
| **Integration with productive uses** | Linking energy to livelihoods aligns community economic success with project success. | Integration of fish farming, transport and tourism in Colombian pilots; similar patterns globally. |
| **Multi-stakeholder alliances** | Combining strengths of community, government, NGOs and the private sector distributes responsibilities and leverages expertise. | Collaboration in Mingueo between NGOs, companies, ministries and universities; Globally successful models involve similar partnerships. |

Overall, the comparison suggests a direct implication for the expansion of the program in Colombia: success at scale will depend less on "replicating technology" and more on standardizing the operational and institutional package that sustains the continuity of the service. This includes contractual and role clarity, verifiable O&M standards, replenishment and reserve rules, transparency and social control mechanisms, and inter-institutional routes that reduce friction in territories with environmental and governance constraints. When these elements are aligned with community ownership and productive uses, the results of access and local development cease to be attributes of some pilots and become replicable and sustainable results.

# COLOMBIAN ECOSYSTEM FOR THE DEVELOPMENT OF ENERGY COMMUNITIES

**Purpose:** To map the territorial, institutional, and operational landscape shaping energy community development in Colombia.

- SIN and ZNI differ fundamentally in cost structures, regulatory obligations, financing mechanisms, and feasible business models
- Multiple institutions play key roles, but coordination challenges and fragmented processes create structural barriers.

**Key Message: Colombia's context is highly heterogeneous, with a fundamental split between the National Interconnected System (SIN) and Non-Interconnected Zones (ZNI). Coordination among the multiple institutional actors (MME, CREG, IPSE, etc.) remains a structural challenge, especially for projects in ethnic or protected territories.**

This section characterizes the Colombian ecosystem that enables, conditions and, in many cases, determines the real viability of energy communities beyond the technical design. The diagnosis is based on the recognition that the development of energy communities does not depend on a single actor or a single instrument: it is configured as an interaction between national guidelines and criteria, registration and targeting routes, sectoral structuring and implementation programs, implementation capacities in the territory, and coordination mechanisms with the regulated market (connection, measurement, marketing and treatment of surpluses). In this framework, the ecosystem is understood as a set of rules, institutions and capacities that allow community initiatives to be transformed into operable projects and, subsequently, into sustainable energy services.

In Colombia, the enabling framework has been moving towards clearer operational definitions for institutional recognition. For example, the special registry requires that solutions with FNCER be technically framed in regulated figures such as the Self-Consumption Collective (CA) or Distributed Generation Collective (GDC), and establishes procedures, validation times, and associated criteria for accreditation in the registry. This orientation is relevant because, in practice, it not only defines a common language, but also conditions design, documentation, and traceability decisions that are usually decisive when seeking to articulate public support or financing routes.

At the same time, the ecosystem is marked by a recurring gap between the volume of potential initiatives and the proportion that manage to materialize in structured, implemented and sustainable projects. Factors such as structuring capacity (pre-feasibility, engineering, operating model), formalization and legal representation, eligibility requirements and support, and the existence of operation and maintenance arrangements with a defined source of payment weigh in this gap. Sectoral programs such as EN-Comunidad show the dynamism of demand and the structuring effort: the call reported hundreds of applications and a process of selection and expansion of initiatives, along with components of formalization, formulation and organizational strengthening.

Based on the above, this chapter describes the state of progress of the ecosystem from an applied reading: it identifies at what point in the "maturity cycle" the initiatives are located today, what typologies predominate in practice, and what signs of institutional readiness and articulation tend to distinguish initiatives with the highest probability of sustainable implementation.

## I. Status of progress of the initiatives and typologies identified

**Purpose:** To map current initiatives and typologies across Colombia.

- Colombia has diverse pilots in both SIN and ZNI, with solar-based systems being the most common configuration.
- Progress in ZNI is slower due to higher costs, logistical constraints, and limited institutional presence.

The state of progress of energy communities in Colombia can be characterized as an expanding ecosystem, with a growing pipeline of initiatives and a process still in consolidation to turn them into fully structured and operable projects. In particular, two simultaneous signals are observed: (i) a significant increase in initiatives that seek recognition and access to programs, and (ii) a greater formalization of institutional routes (registration, verification, and certification) that raise the standard of documentation and technical coherence. The creation and development of RUCE and the regulation of the special registration procedure reflect this transition towards a more operational recognition architecture, with defined validation times and technical consistency requirements.

At the same time, the programmatic deployment shows that the ecosystem has prioritized, in a first wave, mechanisms to organize and prepare initiatives, in addition to structuring projects with community participation. EN-Comunidad, for example, was designed to create and/or strengthen energy service companies with community participation and defined from its call to whom it is addressed, what documents support the application and what types of energy solutions can be framed. In addition, institutional communications have indicated results associated with the formalization of organizational figures, technical studies and structured projects within the framework of the implementation of the program, which offers evidence of the effort to close early structuring gaps.

The advance can be sorted into five practical states that help differentiate the actual level of structuring and typical bottlenecks per stage:

*Table 12. Progress status and bottlenecks*

| Progress status | What characterizes it | Typical evidence in the ecosystem |
|---|---|---|
| **Initiative identified** | Local interest and initial organization | Intention, basic agreements, application |
| **Eligible Initiative** | It meets minimum formal and technical coherence conditions | Representation documents, definition of beneficiaries, consistency with figures such as CA and GDC when applicable (CREG Regulatory Manager) |
| **Project in structuring** | It has elements of pre-feasibility and implementation path | Basic studies, preliminary design, costs and schedule |
| **Structured project** | Is ready for evaluation, co-financing, or financing | Technical-financial package and defined operating model |
| **Sustainable operation** | Continuous service with O&M and replenishment resolved | Operating Rules, Collection/Benefits, Planned Replenishment |

Within this evolution, the typologies that are identified in Colombian practice can be grouped in an operational way according to the degree of collectivity and the relationship with the technical and commercial figures required for institutional recognition and articulation. This allows you to organize the diagnosis without relying on general labels:

- Collective initiatives aimed at regulatory recognition and articulation: projects that are structured to operate under figures such as CA or GDC, seeking traceability and technical coherence for registration and for potential articulation with programmatic or financial instruments.

- Models of community service provision/management with programmatic support: initiatives that are strengthened through calls aimed at creating or strengthening organizational capacities and service provision with community participation, including formalization, formulation and accompaniment processes.

- Initiatives in the early stage with territorial emphasis: proposals in the initial idea or pre-feasibility phase, where the main challenge is not the technology but the structuring of the "minimum package" (governance, roles, operating model, technical evidence and financing route) to be evaluable.

Overall, the ecosystem shows clear progress in the construction of institutional routes and in the activation of sectoral programs that expand the pipeline and strengthen capacities. At the same time, the diagnosis suggests that the central challenge is to accelerate the transition from eligible initiatives to structured projects and, especially, to sustainable operation schemes, where technical consistency, formalization, traceability and operational design (including O&M and replenishment) become decisive conditions for the ecosystem to move from the massification of initiatives to the consolidation of replicable models.

## II. Key actors and institutional roles

**Purpose:** To clarify the mandates and interactions of institutions involved in energy communities.

- MME, CREG, UPME, IPSE, FENOGE, XM, and SSPD each have defined but interdependent roles in policy, regulation, planning, financing, and oversight.
- Coordination is challenging because mandates overlap and approval processes are fragmented across agencies.

The development and scaling of energy communities in Colombia depends on an institutional framework where the functions of public policy, regulation, planning, implementation, financing, market operation and supervision complement each other, but can also generate friction if they are not articulated from the design. In a diagnosis, this reading of the ecosystem is key because it allows us to understand not only "who the actors are", but also what decisions they control, what restrictions they face and, above all, what conditions enable or block a project from reaching sustainable operation. In particular, the Colombian ecosystem is marked by two realities that stress the deployment: on the one hand, the need to align new figures of community participation with the rules of the electricity market and its metering, settlement and marketing architecture; and on the other, territorial gaps in institutional capacities and transaction costs, especially in dispersed rurality and ZNI.

At the level of sectoral public policy, the MME acts as a guide of guidelines and guides of enabling instruments for energy communities, including operational definitions, targeting and prioritization criteria to guide public resources. In this framework, registration and targeting instruments become a practical condition for access to benefits, calls and support, and contribute to standardizing the "verifiable minimum" that is expected of an initiative to be considered within the eligible universe. This function is critical because it connects the Just Energy Transition narrative with concrete administrative decisions: who can be prioritized, which territories or populations are sought to be served, and what minimum evidence must exist to justify the use of public resources (MME, 2024).

At the regulatory level, the  defines the rules that turn a community concept into an operable arrangement within the electricity system, by establishing how these initiatives are integrated with modalities of participation, commercial borders, measurement, settlement and, when applicable, treatment of surpluses and representation before market agents. Resolution CREG 101 072 of 2025 is recognized as a milestone on this front by enabling community schemes with collective generation and marketing mechanisms, including figures such as collective self-generation and collective distributed generation, and developments such as virtual aggregation under defined conditions (CREG, 2025). This role is decisive for bankability: the greater the regulatory clarity and operationalization of responsibilities, the lower the risk premium perceived by financiers and operators; the greater the ambiguity, the higher the transaction cost and the greater the probability of friction in execution.

In planning, the UPME fulfills a structural function by producing information, plans, technical guidelines and analyses that guide expansion, reliability and infrastructure decisions, which affects the viability of connection in the SIN, the prioritization of interventions and the technical consistency required from early stages. For energy communities, this role translates into two practical effects: it reduces technical uncertainty by providing references and frameworks for sizing and planning, and it strengthens the traceability of the business case when the project requires dialogue with criteria of expansion, reliability, and system costs (UPME, 2025).

In the implementation and promotion of solutions for ZNI, IPSE is central due to its mandate and experience in structuring and accompanying energy solutions for non-interconnected territories. In practice, their role is critical because at ZNI, sustainability does not depend only on CAPEX, but on operational continuity under logistical constraints and local capacities: O&M schemes, spare parts, training, governance for collection, and technical support mechanisms. A diagnosis that ignores this dimension tends to overestimate the real viability of replicable models, given that the conditions of operation and replenishment in ZNI are the main determinant of service continuity (IPSE, 2025).

From the perspective of sectoral public financing, FENOGE operates as a vehicle to channel resources towards energy transition, efficiency and FNCER, typically under programmatic schemes and calls with eligibility, co-financing and verification criteria. Its relevance for energy communities is twofold: it enables pre-investment gap closures and initial CAPEX, and it contributes to creating a pipeline under relatively homogeneous formulation standards, which reduces transactional friction for later phases (FENOGE, 2025).

At the level of intersectoral planning and coordination, the National Planning Department (DNP) has an impact as an articulator of public policy and the national planning framework, including guidelines and priorities that affect the territorial implementation of transition and development initiatives. For energy communities, this role is expressed in the coherence between national instruments, policy goals, and the viability of territorial articulation with subnational entities. Its contribution becomes especially relevant when the design seeks to integrate energy with productivity, inclusion, and closing territorial gaps, since it enables the reading of energy communities as a development intervention and not only as a technological project (DNP, 2025).

In system operation and market administration, XM is a key player because it manages functions associated with the operation of the SIN and the administration of components of the electricity market that impact measurement, settlement and operational coordination. For energy communities, this role is relevant to the extent that collective schemes, border representation, and settlement require consistency with market rules and a robust information architecture. In practical terms, clarity of interaction with the market and traceability of flows and measurement reduce performance and income risks, which are central to financing (XM, 2025).

In supervision and control, the SSPD acts as an inspection, surveillance and control authority over public service providers, which affects compliance, user protection and service stability. In community initiatives, this dimension is often underestimated, but it is critical: the reputational and institutional sustainability of an energy community also depends on operating with clear rules of provision, care, quality and information management. Supervision introduces incentives for operational formalization and robustness of processes, which are enabling conditions for scaling (SSPD, 2024).

Finally, in the financial ecosystem, development banks and guarantee mechanisms operate as "bridges" between public policy and formal credit. Bancóldex and Finagro, together with guarantee instruments such as the Agricultural Guarantee Fund (FAG) and the National Guarentee Fund (FNG), do not necessarily finance energy communities directly in all cases, but they can do so when there is an eligible policyholder, traceable flows, and an operating arrangement that controls dominant risks (e.g. collection, O&M, replenishment). Normative and operational evidence shows that, when these instruments are activated, they tend to do so through financial intermediation and under documentation and eligibility requirements that require raising the standard of project structuring, which reinforces the importance of preparation and contractual architecture from the outset (Bancóldex, 2025; Finagro, 2025).

*Table 13. Ecosystem analysis*

| Ecosystem component | Actor(s) | Institutional role | Direct impact on energy communities |
|---|---|---|---|
| **Sectoral policy and targeting** | MME | Defines guidelines, targeting and enabling conditions | Eligibility, prioritization, articulation with public instruments (MME, 2024) |
| **Regulation and operating rules** | CREG | Defines rules for participation, measurement, settlement, and collective schemes | Reduces or increases operational and market uncertainty (CREG, 2025) |
| **Planning** | UPME | Planning and technical information for expansion and system decisions | Technical feasibility, connection and traceability of the business case (UPME, 2025) |

| Ecosystem component | Actor(s) | Institutional role | Direct impact on energy communities |
|---|---|---|---|
| **ZNI Implementation** | IPSE | Promotion and implementation of solutions for ZNI | Operational sustainability under logistical constraints (IPSE, 2025) |
| **Sectoral public financing** | FENOGE | Channels programmatic resources for energy transition/FNCER | Closes pre-investment and initial CAPEX gaps (FENOGE, 2025) |
| **Public Policy Coordination** | DNP | National planning and intersectoral coordination | Integration with territorial development objectives (DNP, 2025) |
| **Operation and market** | XM | Market Trading/Administration Functions (as applicable) | Consistency of measurement, settlement and operational traceability (XM, 2025) |
| **Supervision and control** | SSPD | Inspection, surveillance and control | Operational formalisation, compliance and user protection (SSPD, 2024) |
| **Financing and guarantees** | Bancóldex, Finagro, FAG, FNG | Development/Development Credit and Collateral Mitigation (depending on instrument) | Access to formal credit when there is an eligible policyholder and controlled risks (Bancóldex, 2025; Finagro, 2025) |

## III. Operational, technical and governance gaps

**Purpose:** To identify weaknesses that limit scalability and sustainability

- Gaps include unclear operational procedures, limited local technical capacity, and governance weaknesses within communities.
- High transaction costs arise from fragmented institutional processes and regulatory complexity.

The diagnosis of the Colombian ecosystem shows that the gaps that most restrict the development of energy communities are not only located in the availability of technology or access to resources, but also in the ability to turn a project into a continuous service with clear rules of operation, verifiable management and financial sustainability of the life cycle. In this transition, recurring bottlenecks appear that are expressed as high transaction costs, delays, uncertainty for operators and financiers, and deterioration of local legitimacy. In rural territories and ZNI, these gaps are usually amplified by logistical constraints and lower institutional density, which makes it necessary to design simpler, more robust, and verifiable operational arrangements from the outset (IPSE, 2025).

A first gap is the incomplete translation of the enabling framework into operational decisions. The registration and targeting route, as well as the requirements associated with the technical configuration of the project, introduce demands that impact the design from the early phase. Resolution 40509 of 2024 establishes conditions for the Registration of Energy Communities and links the possibility of registration to specific technical configurations, such as Collective Self-Generator or Collective Distributed Generator, which conditions the technical and commercial arrangement adopted (MME, 2024). However, in practice, a gap persists between formal compliance with requirements and actual preparation to operate: incomplete documentation, insufficient traceability of the organizational structure, and lack of standardization of the information required to validate viability and continuity of the service.

The second gap is associated with operational and commercial interactions with the distribution system. Resolution CREG 101 072 of 2025 seeks to harmonize operational and commercial aspects for the integration of energy communities into the National Energy System, including application conditions for collective activities, SIN and ZNI areas, and relevant definitions for connection and operation under collective schemes (CREG, 2025). Even with these advances, points of friction persist in the implementation such as connection times and costs, coordination with market agents, and complexity of the measurement and settlement architecture when it is intended to operate collectively. These frictions increase the transaction cost and increase the schedule risk, affecting the time of entry into operation and, therefore, the stability of flows to sustain O&M.

A third gap is the systematic underestimation of O&M and replenishment as a condition of service continuity. In particular, at ZNI, technical sustainability depends on spare parts logistics, preventive maintenance, local capabilities and timely technical support. When these elements are not resolved, the technological failure quickly becomes an institutional and financial failure: the availability of the system falls, the perceived benefits are eroded, revenue decreases and local confidence deteriorates. The role of IPSE in structuring and implementing sustainable projects and monitoring ZNI reflects precisely the centrality of these components to ensure continuity and quality of service (IPSE, 2025).

The fourth gap is one of operational governance and legitimacy of the community arrangement, especially critical in collective schemes. Projects tend to fail when there is no verifiable clarity on representation, decision rules, resource management, benefit-sharing, and conflict resolution mechanisms. This gap is expressed in internal disputes, low payment discipline and problems in sustaining unpopular but necessary decisions, such as quotas for the replacement fund, prioritization of critical charges or penalties for arrears. In programmatic instruments that seek to strengthen the provision of service with community participation, such as the EN-Community call, the requirement of legal capacity, representation and documentation reflects the importance of having a minimum organizational base to operate and manage resources with traceability (FENOGE, 2025).

A fifth gap relates to execution capacity and contract management. Even when sources of support or financing exist, execution demands skills to manage suppliers, ensure installation quality, formalize operating agreements, and maintain reports and evidence for disbursements or audits. The lack of contractual standardization and simple control instruments, such as responsibility matrices and user service protocols, increases operational risk and makes integration with external actors difficult. In collective projects, this gap deepens when the actual executor and the eligible policyholder do not coincide, or when the management of flows is not separate from the operation, increasing the risk of inefficient or unverifiable use of resources.

Finally, a cross-cutting gap in pipeline and readiness is identified. Many initiatives do not reach minimum standards of technical and financial prefeasibility, which limits their actual eligibility, increases iterations with public entities and operators, and reduces the likelihood of mobilizing capital. This gap appears as an "invisible filter": there is local will and need, but the absence of basic information and a standardized structuring package prevents the project from moving forward with reasonable time and costs. International and programmatic experience suggests that closing this gap requires preparation processes with clear products, including demand characterization, preliminary design, regulatory path, CAPEX and OPEX estimation, and O&M and replenishment scheme.

*Table 14. Gap analysis*

| Critical gap | How it manifests itself | Effect on the project | Associated policy or institutional references |
|---|---|---|---|
| **Operational translation of the enabling framework** | Requirements and documentation without standardization, incomplete preparation for validation | Delays, withdrawals, low traceability for access to support | Registration and conditions of the RCE, criteria and deadlines (MME, 2024) |
| **Operational and commercial friction in collective schemes** | Complexity in connection, measurement and commercial aspects, coordination with agents | Higher transaction cost, schedule and start-up risk | SIN/ZNI Operational and Commercial Integration, AGRC/GDC Rules (CREG, 2025) |

| Critical gap | How it manifests itself | Effect on the project | Associated policy or institutional references |
|---|---|---|---|
| **O&M and replenishment not funded or operationalized** | Absence of bottom, lack of spare parts, low local maintenance capacity | Degradation of service, fall in profits, deterioration of collection | Sustainability Approach and Monitoring in ZNI (IPSE, 2025) |
| **Unverifiable governance and administration** | Weak decision-making rules, low transparency, internal conflicts | Fragile legitimacy, default, capture of the settlement, risk of abandonment | Community participation and legal capacity requirements in calls for proposals (FENOGE, 2025) |
| **Limited execution capacity and contract management** | Diffuse contracts and liabilities, weak supplier control | Cost overruns, recurring technical failures, uncertainty for third parties | Operational and commercial rules for EC integration (CREG,2025) |
| **Insufficient pipeline and low preparation** | Lack of pre-feasibility, uncharacterized demand, non-traceable assumptions | Actual low eligibility, difficulty in mobilizing capital | Registration and information requirements for EC (MME, 2024) |

## IV. Differentiated considerations for rural territories and ZNI

**Purpose:** To highlight the unique conditions in rural and off-grid areas

- ZNI face higher CAPEX and OPEX, logistical barriers, and historical dependence on diesel generation.
- These areas may require more flexible regulation and dedicated public financing mechanisms.

The analysis of the Colombian ecosystem shows that "rurality" and "ZNI" are not synonymous and, therefore, require differentiated approaches to design, operation, and financing. The ZNI correspond to municipalities, townships, localities, and hamlets that are not connected to the SIN, a condition recognized in the sectoral framework and used as a basis for the targeting of subsidies and service provision schemes (MME, 2022; Constitutional Court, 2017). In turn, the available institutional evidence indicates that ZNI covers a significant proportion of the national territory and concentrates a high number of localities served by providers operating with diesel technologies and, increasingly, with solutions based on non-conventional sources (Superservicios, 2024). At the same time, there is rurality within the SIN with challenges of dispersion, energy poverty, transaction costs and collection restrictions, but with a different regulatory and commercial environment due to its relationship with the regulated market, the grid operator and the marketer.

The most decisive differentiation is the structure of service provision and, with it, the allocation of operational risks. In the SIN, community projects that are framed as collective self-generation or collective distributed generation must "coexist" with a formal commercial and measurement system, with commercial borders, connection procedures, and explicit rules for integration into the Local Distribution System (CREG, 2025). In the ZNI, although the recent framework seeks to enable the integration of energy communities also in their distribution systems, the day-to-day operation tends to be dominated by logistical constraints and by the reality of providers with local generation schemes, often hybrid, where continuity and cost depend more on supply, spare parts and O&M capacity than on procedures for connection to the SIN (CREG,  2025; IPSE, 2022). This has direct implications: in the SIN, friction is concentrated in connectability, measurement, settlement and treatment of surpluses; at ZNI, friction is concentrated in service continuity, supply chain, technical support, and critical asset replacement.

A second differentiator is the political economy of affordability and subsidies. In Colombia, the subsidy and contribution regime is anchored to the criteria of solidarity and redistribution that require distinguishing in the bill the tariff components and the subsidy factors for strata 1, 2 and under defined conditions for stratum 3, supported by solidarity funds at the territorial and national level (Law 142, 1994). In ZNI, in addition, subsidies have a particularly structuring role in closing access gaps and improving service provision hours, with specific mechanisms and reports that condition the transfer and settlement (MME, 2022; Superservicios, 2020). In practice, this implies that the "economic value" that an energy community can capture through savings is not homogeneous: in environments with subsidizable consumption and regulated tariffs, marginal savings may be lower than the average cost of the service, reducing the cash space available to meet O&M, replacement or debt service. Therefore, the financial design in rurality and ZNI must be based on a realistic reading of the effective avoided tariff, the applicable subsidy structure, and the capacity of the scheme to finance life-cycle costs without compromising affordability.[5]

A third differentiator is institutional density and the possibility of building "access routes" to financing. The framework of the Registry of Energy Communities and the targeting and prioritization criteria seek precisely to direct state resources towards community projects, with variables associated with multidimensional poverty and energy poverty, among others, and with a registration procedure that conditions access to benefits (MME, 2024). This enabling

[5] Estrato: Colombia's socioeconomic classification system (1-6) used to determine utility tariffs and subsidies, where stratum 1-3 households receive subsidized rates.

architecture tends to be more "activatable" in rural territories of the SIN where there is a greater institutional presence and document support capacity, while in ZNI the burden of formalization, reporting and traceability can become an additional barrier if it is not accompanied by technical assistance and resource management mechanisms that reduce transactional friction. In ZNI, institutional evidence suggests that articulation with specialized entities is critical, given that the structuring of energy solutions usually requires a fine territorial diagnosis and technological selection adjusted to dispersion, accessibility, and operating conditions (IPSE, 2022).

The following is a summary of the most relevant operational differentiation for diagnosis, organized by decision dimensions:

*Table 15. Analysis of decision dimensions*

| Dimension | Rurality in SIN | ZNI |
|---|---|---|
| **Regulatory and commercial integration** | Rules of connection, measurement and settlement within the Local Distribution System; emphasis on trade borders and surpluses (CREG, 2025). | Integration into the ZNI distribution system also enabled, but with greater weight of operational and local provider restrictions (CREG, 2025; Superservicios, 2024). |
| **Dominant risk** | Connectedness, measurement, profit allocation, and business friction with OR/marketer. | Service continuity, O&M logistics, spare parts availability, and early asset replacement (IPSE, 2022). |
| **Affordability and subsidies** | Savings depend on effective avoided fare; cash space may be limited in subsidized consumption (Law 142, 1994). | Subsidies and reporting rules condition the sustainability of the scheme; changes in subsidized hours/consumption affect the system's cash flow (MME, 2022; Superservicios, 2020). |
| **Priority technical design** | Optimisation of connection, measurement and control; robustness for network operation and eventual surpluses. | Operational robustness and maintenance from the start; hybrid solutions and spare parts plans appropriate to the territory (IPSE, 2022). |
| **Most plausible financing route** | Greater potential to structure intermediated debt if there is an eligible borrower and verifiable governance/flow; need for regulatory traceability (CREG, 2025). | Increased reliance on co-financing, concessionality, and mandatory O&M/replacement provisions; the need to reduce transaction costs and ensure flow management (Superservicios, 2020; IPSE, 2022). |

| Dimension | Rurality in SIN | ZNI |
|---|---|---|
| **Governance and collection** | Payment discipline depends on clear rules of profit allocation and traceability; The formal system can support verification. | The discipline of payment is based on local legitimacy and continuity of service; O&M failures degrade collection more quickly. |

These differences do not imply two completely separate models, but two "risk configurations" that require different emphases. In rurality connected to the SIN, the critical enabler is usually regulatory-operational clarity translated into measurement, settlement and responsibilities with the grid operator and marketer, aligned with the procedures provided for collective self-generation and distributed generation (CREG, 2025). In ZNI, the critical enabler is usually life-cycle sustainability, where the technical design must be subordinated to a verifiable O&M, replacement, and logistics strategy, in coordination with the provider and with support entities that structure solutions based on territorial particularities (IPSE, 2022; Superservicios, 2024). In both cases, the registration and targeting framework plays a transversal role in ordering eligibility and directing resources, but its effective activation depends on technical assistance, reduction of document friction, and mechanisms for traceable administration of resources, especially in territories with lower institutional density (MME, 2024).

# PUBLIC POLICY FRAMEWORK AND APPLICABLE REGULATION IN COLOMBIA

**Purpose:** To interpret the legal and regulatory framework governing energy communities and its implications for implementation.

- Colombia has recently established a comprehensive regulatory architecture for energy communities.
- Effective implementation depends on operational clarity in metering, settlement, reporting, and governance requirements.

**Key Message: Robust regulatory architecture now exists (Decree 2236 of 2023, CREG Res 101 072 of 2025), but its practical application requires more clarity on metering, settlement, and the interface between community governance and commercial obligations.**

This section presents the public policy and regulatory framework applicable to energy communities in Colombia, with a focus on its implementation and financing. The objective is not to compile the normative universe exhaustively, but to interpret the legal and regulatory framework as a set of operational conditions that determine whether a community initiative can be structured, enter into operation and be sustained over time. To that extent, the analysis translates the sectoral rules into practical decisions on technical design, applicable regulatory modality, institutional arrangement, contractual responsibilities and financial sustainability mechanisms.

Regulatory viability does not depend only on enabling rules, but on their applicability to collective arrangements in critical aspects: connection and operation; metering and settlement; relationship with the grid operator and marketer; treatment of surpluses; and articulation with subsidy and contribution schemes. These definitions determine who can act as an eligible policyholder, what obligations and risks each actor assumes, and what requirements must be met to activate public or financial instruments. When these variables are not resolved during structuring, common frictions emerge: role uncertainty, procedural delays, unforeseen transaction costs, and weakening of the collection and O&M scheme.

These tensions tend to be more pronounced in rural territories and ZNI, where implementation faces additional logistical constraints, limited institutional capacities, and increased demands for operational continuity to protect social legitimacy and payment discipline. Therefore, the normative reading is complemented by an enforceability perspective: the points at which the design must anticipate requirements, minimum evidence, and administration and traceability mechanisms that reduce uncertainty for public actors, operators, and funders are identified.

Based on this logic, the section is organized into four components: (i) the general framework of the electricity sector and FNCER; (ii) specific provisions for energy communities, including authorized actors and registration conditions; (iii) the subsidy and tariff scheme and its implications for financial sustainability in SIN and ZNI; and (iv) regulatory implications for project design and operation, highlighting frictions, gaps, and verifiable criteria that feed the decision tree and later financial design phases.

## I. General regulations of the energy sector and FNCER

**Purpose**: To outline the legal basis for renewable energy and distributed generation

- Law 1715 established the framework for Non-Conventional Renewable Energy Sources (FNCER).
- Subsequent regulations define incentives, technical standards, and participation mechanisms.

The Colombian electricity sector operates under a functional unbundling scheme that distinguishes generation, transmission, distribution, and retailing, framed by the public utility services regime and by economic regulation and service quality regulation. This design seeks to ensure efficiency, continuity, and coverage, and incorporates solidarity mechanisms through subsidies and contributions for vulnerable users, which is particularly relevant when evaluating community-based models in territories with low payment capacity and high sensitivity to service continuity (Law 142, 1994).
From an operational perspective, Law 143 establishes the electricity service regime and defines sector activities, as well as key concepts for transactions and the relationship with end users: the wholesale market, the retailing activity, and the distinction between regulated and non-regulated users, with direct implications for tariff structure and revenue-flow predictability (Law 143, 1994). In parallel, the creation and dynamics of the Wholesale Energy Market were consolidated as part of the sectoral restructuring derived from Laws 142 and 143, enabling a competitive environment for the exchange of large energy blocks within the SIN, with segmentation between bilateral contracts and the power exchange (Superservicios, n.d.).

Within this framework, the roles that condition the participation of community schemes can be understood as follows, from an applied perspective:

- Generation: produces energy for the system, either in centralized or distributed schemes; when generation is located close to consumption and on a smaller scale, it becomes especially sensitive to rules for connection, metering, and treatment of surpluses (Law 143, 1994).
- Transmission: transports energy through the STN associated networks, determining part of the charges for network use and dispatch conditions in the SIN (Law 143, 1994).
- Distribution (Network Operator): manages and operates local networks, enables (or conditions) the connection of users and distributed energy resources, and becomes a

determining actor in terms of time, costs and technical requirements of the project (Law 143, 1994).

- Commercialization: buys and sells energy to end users, and manages billing and collection; therefore, their role is critical for the stability of the flow and for any collection architecture that seeks to sustain O&M and replenishment (Law 143, 1994).

For diagnostic purposes, the distinction between regulated and non-regulated users is considered a first-order financial constraint[6,7]. For regulated users, electricity purchases are subject to tariffs defined under regulatory methodologies, which tends to stabilize the tariff signal, although it does not eliminate collection risks. For non-regulated users, purchases are made at freely negotiated prices, usually for high peak demands, which may enable more flexible contractual schemes but introduces other commercial risks. This differentiation directly affects revenue design, risk treatment, and the ability to structure contracts that support debt or service-payment schemes (Law 143, 1994).

Likewise, the subsidy and contribution regime established under Law 142 introduces a structural component for service sustainability in lower-income territories: it affects the effective revenue associated with basic or subsistence consumption, influences perceived payment capacity, and conditions the actual cash space available when the model seeks to leverage investment based on tariff savings. In energy communities, this relationship becomes particularly relevant because part of the project's "value" may materialize as savings, but such savings may be lower than suggested by aggregated averages if beneficiaries fall within subsidized ranges (Law 142, 1994).

Finally, the enabling framework for non-conventional renewable energy sources (FNCRE) constitutes the normative basis for integrating renewable technologies and distributed solutions into the national energy system. Law 1715 regulates the integration of non-conventional renewable energies, promoting their development and use, and incorporating elements such as storage, efficient energy use, and, in general, their participation both in the electricity market and in ZNI. Subsequently, Law 2099 amends and strengthens provisions associated with the energy transition, expanding scope and aligning the framework with efficiency and decarbonization objectives (Law 1715, 2014; Law 2099, 2021).

Taken together, this sectoral framework defines the "operability conditions" that any financeable energy community must resolve: alignment with system roles and rules (connection, metering, retailing), consistency of the revenue architecture with tariff and subsidy realities, and the feasibility of integrating FNCRE under rules that allow service continuity and flow traceability, which is particularly critical in rural and ZNI contexts.

[6] Regulated user: Consumers whose tariffs are set by CREG.
[7] Non-regulated user: large consumers (above 55 MWh/month) who negotiate directly in the wholesale market.

## II. Specific provisions for energy communities

**Purpose:** To summarize the legal instruments that formally define and regulate energy communities.

- Decree 2236 (2023) and Resolution 14136 (2024) establish requirements and create the RUCE registry
- CREG Resolution 101 072 (2025) sets operational rules for communities in both SIN and ZNI.

Article 235 of Law 2294 of 2023 (NDP 2022–2026) incorporates the figure of energy communities as an associative scheme that enables natural and legal persons, under public or private law, to develop projects oriented toward the generation, commercialization, and efficient use of energy through FNCRE, renewable fuels, and distributed energy resources (Congress of the Republic, 2023). This enabling provision defines a broad framework of action for initiatives with community participation; however, its practical application depends on its translation into technical and commercial modalities recognized within the electricity sector, as well as into specific sectoral procedures.

Decree 2236 of 2023 partially regulates this mandate and specifies objectives, principles, and operational conditions for its deployment (Office of the President, 2023). From a technical-regulatory perspective, the regulation articulates the operation of energy communities, among other pathways, through schemes such as collective self-generation (AC) and collective distributed generation (GDC), applicable within the SIN and in ZNI, as appropriate (Office of the President, 2023). Consequently, the figure of the energy community does not operate as an independent technical modality, but rather as an associative arrangement that must materialize through enabled technical schemes and through an architecture of responsibilities consistent with market roles and the prevailing regulatory framework.

With regard to participation, the framework allows the structuring of communities with a mixed composition of users and beneficiaries, including households, productive units, community organizations (for example, community action boards, associations, and cooperatives), non-profit organizations, and public entities. This breadth is conditioned on compliance with the rules set forth in Decree 2236 of 2023 and on the project being framed within the enabled technical schemes (AC or GDC) or other modalities recognized by the applicable regulation (Congress of the Republic, 2023; Office of the President, 2023; MME, 2024). As an interpretative aid, the Energy Communities ABC issued by the MME provides a dissemination-oriented reading that facilitates translating these definitions into operational language, particularly to understand the relationship between energy communities, collective self-consumption, and collective distributed generation (MME, n.d.).

The framework incorporates administrative instruments to formally recognize energy communities and, where applicable, to guide the prioritization of public resources. In this context, the MME administers the energy communities registry, operated by the Directorate of Electric Energy through its institutional portal (MME, 2024). Registration in the registry does not equate to technical or financial viability of the project; however, it functions as a regulatory enabler to access benefits and, in certain cases, as support for advancing procedures associated with connection or integration under schemes such as AC or GDC (MME, 2024).

The registry establishes a progression of statuses that differentiate initiatives in the initial phase from those in operation. Initial energy communities register basic information on the associative agreement and have twelve (12) months to complete commissioning support documentation, with the possibility of a one-time extension of up to six (6) months. Energy communities in operation submit the full set of required documents and certifications. The Directorate of Electric Energy validates the information provided in the form, issues the corresponding certificate, and assigns a Unique National Recognition and Identification Number (NURIN), intended for benefit management and monitoring, within the timeframe established by regulation (MME, 2024).

For initiatives seeking guidance or allocation of public resources, the regulation incorporates targeting and prioritization criteria and provides for inter-institutional instances aimed at validating criteria and recommending prioritizations, mainly within the framework of calls published by the Ministry (MME, 2024). The regulation also delineates the scope of such targeting and excludes certain government-based typologies (for example, energy municipalities or energy educational communities), without prejudice to the existence of other public intervention pathways for these initiatives (MME, 2024). In practice, these components are relevant because they organize access to programmatic support and, at the same time, increase the need for documentary traceability and procedural compliance from the structuring phase onward.

From a normative-operational perspective, registration requirements serve a dual function: establishing a minimum base of governance and traceability (composition, representation, decision-making rules, and administration of the solution) and reducing technical and compliance risks that directly affect project bankability (installed capacity, electrical safety, point of connection, and commissioning conditions) (MME, 2024). In particular, for energy communities based on efficient energy use, it is required to demonstrate a baseline and the achieved savings, reporting implemented technologies and the proportion of savings; under this modality, certificates of installed capacity, point of connection, or the Technical Regulation for Electrical Installations (RETIE) inspection reports are not required, and the Ministry provides specific formats and guidelines (MME, 2024). For projects with electrical infrastructure subject to verification, commissioning support or an inspection report in compliance with RETIE is required as evidence of electrical safety, with direct effects on operational risks, incidents, and failures that increase operation and maintenance costs (MME, 2024). Where grid connection exists, a certificate from the Network Operator (in the SIN) or from the distributor (in ZNI) is required to evidence the processing or granting of the point of connection; for off-grid projects, supporting materials and a commissioning report signed by the party responsible for administering, operating, and maintaining the solution are submitted (MME, 2024). A certificate of installed or nominal capacity (kW) issued by a qualified professional is also required, serving as a basis for traceability for sizing, energy projections, and regulatory verification; in photovoltaic systems, this corresponds to the sum of the nominal capacities of the alternating-current inverters (MME, 2024). The certificate of compliance with the Just Energy Transition School is also incorporated, applicable to communities constituted fully or partially with public resources and also to private-capital initiatives delivered to the community for administration and benefit, as evidence of minimum capacities and alignment with Ministry guidelines for community operation (MME, 2024). Finally, the associative contract or agreement is consolidated as a foundational document, as it defines purpose and objective, the number of users that make up the community (distinguishing natural and legal persons), the number of beneficiaries, and, where applicable, the associated productive or social activity; this instrument also becomes a baseline input for due diligence processes and financial structuring (MME, 2024).

The recent framework complements the above with additional administrative instruments: the Single Registry of Energy Communities (RUCE), created through Resolution MME 40136 of 2024, and the targeting criteria to guide public resources allocated to energy communities, defined by Resolution MME 40137 of 2024 (MME, 2024a; MME, 2024b). From an operational standpoint, these instruments affect the structuring timeline, eligibility requirements for support, and the traceability architecture required to mobilize public and blended resources, and therefore must be considered as constraints from the early stage of institutional and financial design.

## III. Subsidy schemes, tariffs and financial sustainability

**Purpose**: To explain how tariff structures and subsidies affect community viability.

- The stratum-based tariff system complicates collective arrangements that include households from different socioeconomic levels.
- Existing subsidies were designed for utility-managed service and may require adaptation for community-managed systems.

In Colombia, for users in the regulated market, the electricity tariff faced by the end user is published by the retailer or retailer–operator and is typically expressed in COP/kWh, complemented by a fixed charge per bill. The applicable tariff depends simultaneously on the type of user (residential versus non-residential), residential stratification (strata 1 to 6), contribution or exemption status for certain non-residential uses, and the relationship between monthly consumption and the subsistence consumption block. For energy communities, these variables are not ancillary: they determine the effective “avoided tariff” used to quantify the economic benefit of self-consumption and, therefore, define the actual cash space available to sustain operation and maintenance (O&M), asset replacement, and, where applicable, debt service or payments for use/service (Retailer/Operator, 2025; CREG, 2025).

From an operational standpoint, the financial design of energy communities connected to the SIN must recognize that savings are neither a single nor a constant concept. The marginal benefit of self-consumption changes according to the consumption block and the type of user. In addition, the published unit cost usually reflects a structure of regulated components (energy, transmission, distribution, retailing, losses/restrictions, and other associated charges), while the fixed charge remains even when part of consumption is displaced by on-site generation. For this reason, financial modeling requires disaggregating the "avoided benefit" into (i) the variable portion that is reduced through self-consumption and (ii) the costs that remain solely due to being connected and billed, avoiding overestimation of the savings available to finance CAPEX or OPEX (CREG, 2025; Retailer/Operator, 2025).

### A. Residential tariffs (by stratum) and consumption blocks

Colombia applies a differentiated residential tariff system based on a six-level socioeconomic stratification of households, whereby lower-income groups (strata 1–3) receive explicit subsidies on electricity consumption, middle-income households (stratum 4) pay tariffs that reflect the full cost of service, and higher-income groups (strata 5–6) face surcharges that contribute to cross-subsidizing the system.[8,9] Subsidies are limited to a defined subsistence consumption block, representing the portion of monthly demand considered essential, above which all households are charged significantly higher tariffs. This structure ensures a degree of affordability for basic energy services while preserving price signals for higher levels of consumption. A more detailed explanation of the scheme is given in the appendix.

### B. Non-residential rates (commercial/industrial, official, exempt, common areas)

In the non-residential segment, tariff categories (commercial/industrial, official, exempt, common areas, among others) usually face higher effective tariffs than subsidized residential users and, in many territories, exhibit relatively more stable collection behavior due to more predictable income flows or institutional payment mechanisms. For energy communities, this makes non-residential anchor loads a key financial element: they increase the marginal value of self-consumption and can better sustain recurring O&M and replacement costs, reducing the risk to service sustainability. In the cited tariff example (December 2025), non-residential categories relevant for community design are distinguished, including industrial and commercial; official and contribution-exempt; as well as common areas with and without contribution, showing that user classification directly affects the kWh value and, therefore, the bankability of the scheme when the model relies on savings or payments for energy service (Retailer/Operator, 2025; CREG, 2025).

### C. Unit Cost Structure and Fixed Charge (Relevant for Modeling)

The structure of the unit cost (UC) and the fixed charge are critical modeling variables because they determine which portion of electricity expenditure can be converted into effective savings

[8] Tariffs: the regulated per-kWh prices households pay for electricity
[9] Strata: Colombia's official socioeconomic classification of residential households

under collective self-consumption or distributed generation, and which portion remains unavoidable due to continued connection to the regulated market. A common modeling error is assuming that each self-generated kWh "equals" the total published UC, when in practice the bill combines components that behave differently and includes a fixed charge that persists even with significant reductions in grid purchases. This directly affects estimates of economic benefit, payment capacity, cash-flow bankability, and the sustainability of O&M and asset replacement.

The published UC is composed of several regulated components with different cost drivers: the energy procurement and retail component varies with consumption, while network use, losses, restrictions, and other recognized charges may not decline proportionally in the short term. From a conservative view, savings should therefore be estimated as marginal savings on the variable component effectively displaced, excluding residual costs that persist due to being a connected user. In collective schemes, small deviations in assumed unit savings are amplified over the number of users and the system's life cycle, often generating overestimated cash flows that later translate into O&M deficits, undercapitalized reserves, and pressure on community collection.

The fixed charge is a structural condition of cash flow. For energy communities, this means the "effective avoided tariff" is always lower than the published UC, since it equals variable savings minus fixed and administrative costs that persist. This distinction is central to financial design: it determines whether the project can rely on savings alone or requires complementary revenues (such as service charges, non-residential anchors, co-financing, or mitigation mechanisms) to sustain operations. It also affects internal payment structures, which must be calibrated against real net savings to avoid charges that exceed observable bill reductions, a frequent cause of arrears and governance deterioration.

Incorporating UC and fixed charges at this level of detail improves traceability and credibility with financial and regulatory actors. It explains why technically sound projects often fail to sustain debt or service-payment schemes when most consumption remains within subsidized blocks or when marginal savings are lower than expected. UC and fixed charges should therefore be treated as control parameters of the model: assumptions on avoidable components must be explicit, sensitivity scenarios included, and links established with design decisions such as user segmentation, anchor loads, and O&M and replacement reserves, ensuring that projected cash flows reflect actual billing behavior in the regulated market.

## IV. Regulatory implications for project design and operation

**Purpose:** To show how regulation shapes technical, financial, and governance decisions.

- Metering, settlement, and reporting procedures require further operational clarity for community arrangements.
- Community governance structures must align with commercial obligations under electricity market rules.

In the Colombian context, the regulatory and public policy framework associated with energy communities generates direct implications for how projects are designed, implemented, and sustained over time. These implications condition key structural decisions: the applicable technical and regulatory modality (and its compatibility with SIN or ZNI), the connection route and network operator requirements, the metering and billing scheme for collective arrangements, and the economic treatment of benefits (savings and, where applicable, surpluses). The framework also introduces procedural and traceability requirements that affect schedules, transaction costs, and eligibility for public support, and requires explicit and verifiable assignment of roles between the community, marketer, network operator, and O&M provider. When these definitions are not resolved, frictions concentrate in critical points: delays and cost overruns in connection, difficulties in settlement and benefit distribution, weakening of collection, and gaps in O&M and replenishment that affect service continuity. With this approach, the main implications are presented below, organized by blocks to translate regulation into operational criteria for technical design, institutional structuring, and financial sustainability.

### A. Regulatory and technical design decisions with impact on enforceability

The regulation applicable to energy communities operates as a set of enforceability conditions that must be verified from the structuring stage. This implies that the project must be defined not only as a technological solution, but as an energy service with verifiable responsibilities, flows, and rules. In SIN projects, the technical modality (self-generation or distributed generation, individual or collective) determines requirements for connection, operation, and treatment of surpluses, and conditions the design of measurement, billing, and benefit allocation. The design should therefore confirm the modality early, anticipate the connection point and network operator requirements, and integrate the metering and billing scheme as part of financial design. In collective contexts, benefit measurement and allocation are critical: when it is not clear who receives what and why, project legitimacy deteriorates and collection risk increases. Prefeasibility must therefore incorporate a traceable and operationally manageable allocation rule, with conservative assumptions about information availability, transaction costs, and local management capacity (CREG, 2025; MME, 2024).

### B. Operational interface with the grid operator and the marketer: typical frictions and mitigation

The operation of a network-connected community scheme depends on coordination with the grid operator and marketer, particularly in connection, access to metering information, billing, settlements, and fault management. In the diagnosis, the main frictions arise from interface management: underestimated connection times and costs, late technical requirements, limited access to timely data, and administrative burdens that raise transaction costs for actors with limited capacity. These frictions affect schedules, perceived profitability, and financial sustainability. Structuring must therefore provide for minimum operational agreements on information exchange, service protocols, conciliation mechanisms, and discrepancy resolution. When the model depends on surpluses or complex distribution rules, these needs intensify, increasing the importance of measurement and control solutions that reduce ambiguity and discretion (CREG, 2025; UPME, 2024).

### C. O&M contracting, traceability and social control as regulatory-financial mitigators

O&M contracting and traceability mechanisms function as regulatory-financial mitigators by translating governance and accountability into operational routines. Clear O&M arrangements, reporting obligations, and basic social control mechanisms reduce execution risk, improve compliance with service standards, and strengthen confidence among regulators, funders, and users. Where these elements are weak or absent, regulatory compliance becomes fragile, operational failures accumulate, and the project's eligibility for public or financial support is undermined.

As a complement, active transparency and operational traceability function as risk mitigators in collective schemes: repositories of minutes, periodic performance reports (production, availability, collection), and traceability between data, decisions, and execution. This approach reduces information asymmetries, strengthens legitimacy and payment discipline, and decreases the risk of internal conflict or decision capture. In energy communities, transparency is not only a good governance practice: it is a control mechanism that protects cash flow and reduces the likelihood of early operational deterioration (MME, 2024; GIZ, 2024).

The following are the operational eligibility criteria for an energy community:

1. **Regulatory eligibility**: applicable modality and territory (SIN/ZNI).
2. **Registration path**: procedural compliance and reportability.
3. **Access to public support**: targeting criteria and restrictions on use.
4. **Connectability**: feasibility, costs, timelines, and requirements of the RO/distributor.
5. **Measurement and settlement**: compatible scheme and defined surplus treatment.
6. **Contractual structure**: explicit responsibilities between RO, marketer, community, and O&M.
7. **Governance and transparency**: evidence of accountability and traceability.
8. **Collection risk**: collection architecture, expected default and mitigating factors.
9. **O&M sustainability**: plan, technical support and replenishment fund.

# FINANCIAL INSTRUMENTS AND CAPITAL MOBILIZATION MECHANISMS

**Purpose**: To map financing options and identify gaps affecting the bankability of energy communities.

- CAPEX financing is available through multiple national and international instruments, but O&M and risk-mitigation tools remain limited
- Financing conditions vary widely by instrument, scale, and territorial context.

**Key Message: There is a significant gap between available CAPEX (capital expenditure) financing and the lack of OPEX (operational expenditure) and risk-mitigation tools. Sustainability requires "blended finance" and dedicated O&M reserves.**

This section discusses access to financial instruments from a multi-stakeholder perspective, recognizing that mobilizing capital for energy communities does not fall solely on the community organization driving a project. In practice, the structuring and sustainability of these models depends on the articulation between communities, public entities in the territory, energy operators and developers, banks and development funds, and international cooperation, each with different capacities, restrictions and mandates to channel resources. The purpose of the chapter is to identify the available public, private and community tools, and to establish how viable they are in the Colombian context, under what conditions they operate and what structural barriers limit their effective use, with special emphasis on rural territories and ZNI.

In Colombia, the main obstacles to financing energy communities tend to be concentrated in the transition between formulation and actual disbursement. The challenge is not only the formal existence of instruments, but also their compatibility with eligibility, formalization and legal representation requirements, requirements for guarantees and counterparts, financial conditions (terms, currency and payment structure) and traceability and reporting standards for the use of resources. In addition to the above, there are risks that are decisive for funders and operators: stability of the collection scheme, clarity of contractual roles and responsibilities, operation and maintenance capacity, replacement of critical assets and management of conflicts or defaults. In rural contexts and ZNI, these restrictions tend to be intensified by higher logistics costs, lower institutional density, low banking penetration and higher transaction costs for communities and territorial entities.

The analysis is based on a diagnostic premise: the financial viability of an energy community is built through a process of institutional and financial assembly, in which the capital structure, incentives and risk mitigation mechanisms must be consistent with the real capacities of the territory. In this sense, there are more feasible financing routes when instruments are combined and responsibilities are aligned. Public resources and sectoral programs can cover pre-investment, co-financing, and technical assistance components; development banks and specialized funds can provide concessional conditions and risk mitigation mechanisms; operators and developers can structure execution and reduce technical and O&M risks; and community mechanisms, where they exist, can provide local anchorage and payment discipline if they are integrated into clear rules of administration, transparency and governance. This reading allows instruments to be evaluated not as isolated options, but as pieces that may or may not be integrated into implementable routes.

Based on this logic, the chapter is organized into four parts. First, it presents a mapping of national and international financial instruments relevant to energy communities, including subsidies and co-financing, concessional and commercial credit, development banking lines, guarantees, leasing, blended finance and first-loss, climate funds, trust schemes and community mechanisms. Second, it develops a benchmarking that allows these instruments to be ordered according to their alignment with the purpose, operational flexibility, enforceability, and financial sustainability. Third, it discusses the access conditions and market restrictions that explain why some instruments do not become usable in practice even though they are available. Finally, it consolidates a set of prioritized instruments and plausible combinations that serve as direct input for the analysis of enabling conditions and gaps, the construction of the decision tree, and the financial design in subsequent phases.

## I. Mapping of national and international financial instruments

**Purpose**: To catalog financing sources relevant to energy communities

- National tools include FAZNI, FENOGE, PRONE, the General Royalties System (SGR), and development bank credit line
- International sources include IDB, World Bank/ESMAP, KfW, the Green Climate Fund, and bilateral cooperation programs.

The mapping of financial instruments was developed as an applied characterization exercise to identify and order the mechanisms that can mobilize resources to energy communities in Colombia, recognizing that their financial viability usually depends on the articulation of complementary support and not on a single source. In operational terms, the mapping focuses on understanding how the instruments work in practice, what components of the project cycle they can cover, and what are the access conditions that determine their effective use. This approach makes it possible to distinguish between the "nominal" availability of an instrument and its actual applicability, particularly in projects with recurring challenges of eligibility, formalization, execution capacity, financial intermediation and transaction costs.

From the perspective of the Just Energy Transition, mapping plays a central technical role: it allows us to identify which instruments are best suited to contexts where banking penetration is low, logistics costs are high, and operational risk is concentrated in collection, operation and maintenance, and asset replacement. It also makes it easier to anticipate which instruments require institutional anchors and explicit risk mitigation schemes to become actionable, such as collateral-substitute guarantees, targeted public co-financing, management structures and traceability of resources, or disbursements conditional on verified results. In Colombia, this logic is connected to the enabling framework of energy communities, where registration and regulatory targeting are enablers for access to benefits and programmatic instruments, including the condition that the technical configuration is framed in figures such as Collective Self-Generator or Collective Distributed Generator.

The mapping was structured to produce a comparable and usable base, avoiding descriptive compilation. To do this, each instrument was analyzed with two simultaneous criteria: first, its financial function within a capital structure, and second, the most accessible access route according to the type of actor that can activate it. In practice, this distinction is decisive, because many instruments relevant to energy communities are not designed to be taken directly by a community organisation, but by territorial entities, real sector companies, developers, financial cooperatives or intermediaries.

*Table 16. Characterization variables*

| Variable | Characterization Content |
|---|---|
| **Nature** | Co-financing or subsidy, direct or intermediated credit, rediscount, guarantee, technical assistance, disbursements for results |
| **Admin & Channel** | Managing entity and method of access, directly or through a financial intermediary or partner |
| **Eligible Beneficiary** | Eligible actors and eligibility restrictions |
| **Eligible stage** | Pre-investment, CAPEX, start-up, OPEX, replenishment, expansion |
| **Eligible concepts** | Studies, engineering, equipment, works, working capital, O&M, strengthening, verification |
| **Conditions of access** | Technical and documentary requirements, limits on the age of the expenditure, counterparts, traceability |
| **Main operational friction** | Complexity of procedure, times, need for prior viability, monitoring and verification, transaction costs |

Based on the evidence collected, the instruments were grouped into a functional typology that allows the mapping to be translated into operational criteria for financial design. This typology is not constructed from the label of the instrument, but from its economic and operational function within the project cycle: what component it enables (preparation, investment, start-up, operation, replacement or expansion) and what risk it contributes to reducing or redistributing (development, performance, collection, collateral, financial cost, political-regulatory risk or institutional risk). In practice, this classification facilitates the comparison of heterogeneous mechanisms under a common framework and, critically, allows identifying which combinations are necessary to close specific gaps at each stage, particularly in community projects with small transactions, high fragmentation and access frictions.

International evidence on decentralized electrification and mini-grids shows that bankability is rarely achieved from a single source: schemes that mobilize capital in a sustained manner tend to be structured as packages of instruments that combine project preparation, non-reimbursable support or closing of the viability gap, concessional/intermediated debt, and explicit risk mitigation mechanisms (guarantees, insurance or first-loss tranches). This logic responds to an operational fact: the main risks that hinder financing are not only concentrated in CAPEX, but in the transition to sustainable operations (e.g. collection, O&M, replenishment and performance), especially in rural territories and ZNI. The global reference document compiled by the team also shows a growing trend of resource mobilization towards these models, with financing committed in the order of billions of dollars and an increase in the private component in the last decade, which reinforces the relevance of structuring "scalable" and standardizable mechanisms.

In order for the typology to be usable in the subsequent comparative analysis, each category is presented with four consistent elements: what it enables in practice, the stage of the project where it is most critical, the main risk it manages, and referential examples included in the mapping (national or international). This structure also makes it possible to avoid two common errors in financial diagnoses: assuming that an instrument "applies" just because it exists, or assuming that the community organization will always be the direct taker of the instrument.

*Table 17. Functions of mobilized capital*

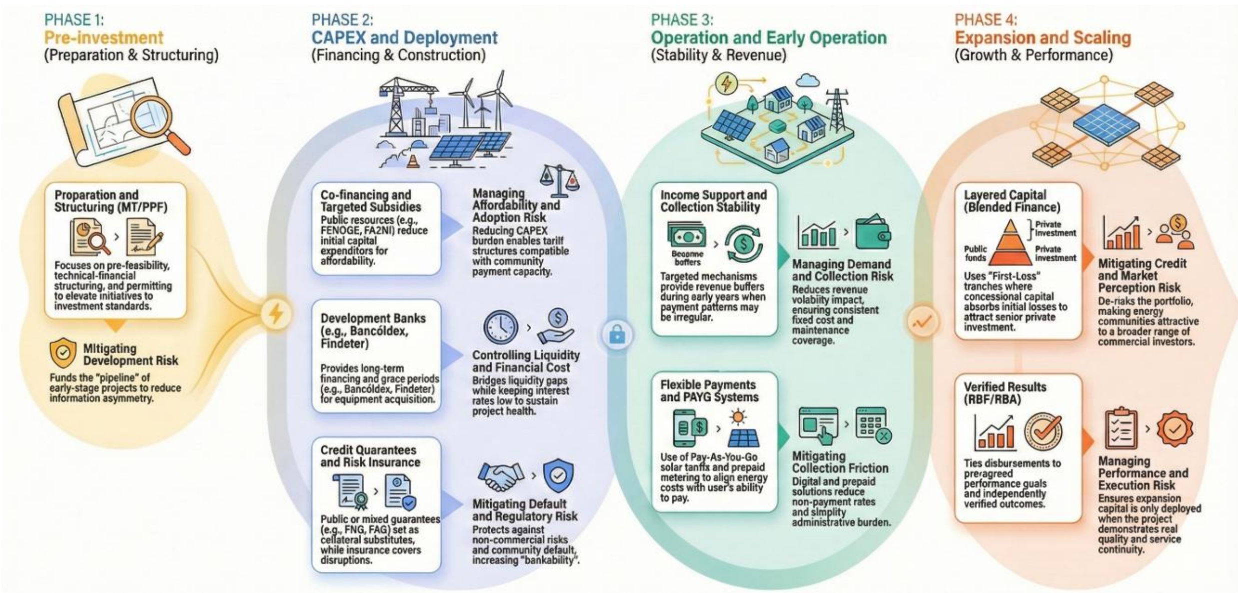
| Financial function | What it enables in practice | Main stage | Risk management | Examples |
|---|---|---|---|---|
| **Preparation and structuring (MT/PPF)** | Pre-feasibility and feasibility studies, technical-financial structuring, organizational strengthening, permitting and evaluation standards | Pre-investment | Development risk (pipeline) | GCF Project Preparation Facility; Energy Communities Facility (UE) for business plans and pre-development |

| Financial function | What it enables in practice | Main stage | Risk management | Examples |
|---|---|---|---|---|
| **Co-financing/subsidy (includes closing the viability gap)** | Reduced CAPEX and, in some cases, start-up costs; improved affordability and viability while maintaining TEJ-compliant tariffs | CAPEX and Bootstrapping | Affordability and adoption | EN-Community (FENOGE) and sectoral programmatic mechanisms |
| **Concessional and intermediated debt / rediscounting** | Investment financing and associated working capital with terms and grace more compatible with energy assets; Channeling through intermediaries | CAPEX and expansion | Financial cost and liquidity | Bancóldex Energía Solar is Reactivated; Findeter Energy and efficiency |
| **Leasing and asset finance** | It facilitates the acquisition of assets with payments associated with use; reduces initial investment barriers when there is a formal policyholder | CAPEX / Deployment | Liquidity constraint and initial CAPEX | Modalities enabled in products of financial institutions and second-tier entities according to eligibility |
| **Credit guarantees (public/mixed)** | Partial collateral substitution, reduction of expected loss and expansion of access to formal credit; Improvement of rate/term conditions | CAPEX and working capital | Default and collateral | FAG (Finagro); FNG (Business Guarantees) |
| **First-loss / layered structures (layered capital)** | It absorbs first losses to attract private capital and enable blended finance; Improved risk-return profile of the portfolio | CAPEX / Scaling | Credit and performance risk perceived by the market | Blended finance structures and climate funds that use concessional or first-loss tranches |

| Financial function | What it enables in practice | Main stage | Risk management | Examples |
|---|---|---|---|---|
| **Insurance and guarantees for political-regulatory risk** | Covers non-trade risks (regulatory changes, political events, contractual disruptions) and reduces uncertainty for investors | CAPEX / operation | Political/regulatory risk | International benchmarks used in infrastructure and decentralized electrification |
| **Verified Results (RBF/RBA/Performance Pays)** | Payments conditional on verifiable results and pre-agreed goals; strengthens execution and performance discipline, and can leverage co-investment | Deploy-ment / expansion | Performance and execution | ESMAP references on RBF/RBA in energy and decentralized electrification |
| **Income support / collection stability (selective)** | Mechanisms that reduce revenue volatility (e.g., on-demand support or payment continuity) when collection risk is dominant | Early Operation | Demand/Collection Risk | Schemes used in mini-grid portfolios (referential) |
| **Flexible payment and collection anchoring (PAYG / prepaid / smart metering)** | Align payments with consumption and ability to pay; reduces delinquency through control (prepayment/activation) and consumption traceability | Operation | Collection risk | PAYG as a mechanism widely used in off-grid and mini-grids, leveraged in digital payments and service control |

This typology allows the use of mapping to be oriented towards concrete decisions: which instruments are pipeline enablers (pre-investment), which close viability gaps (CAPEX/affordability), which reduce risks that block financing (collateral, performance, political-regulatory) and which stabilize the operation (e.g. collection and replenishment). In the framework of energy communities, the critical point is not only to "finance the asset", but to sustain the service over time; therefore, the subsequent analysis prioritizes combinations that integrate from the beginning elements of preparation, assignment of responsibilities and risk mitigation mechanisms.

*Figure 1. Stages of the Financial Lifecycle of energy communities*




## A. Relevant instruments and mechanisms for national energy communities

The national component of the mapping was organized by distinguishing between (i) enabling and programmatic mechanisms of the energy sector, which order eligibility and channel public resources for structuring and implementation, and (ii) non-exclusive financial mechanisms of energy communities that can be activated if access routes consistent with eligibility, execution capacity, and explicit risk allocation are structured. This distinction is relevant because, in practice, many of the instruments that could mobilize resources towards energy communities were not designed to be taken directly by a community organization.

In the first place, the enabling and targeting framework fulfills a practical function: to order the formal recognition, prioritization and traceability of projects, which directly affects the possibility of articulation with programmatic instruments. Resolution 40509 of 2024 is incorporated into the analysis as a central reference for the registration and targeting of energy communities, insofar as it defines criteria and procedures that condition access to public support and the technical-regulatory consistency of the solution. In parallel, programmatic instruments in the sector such as EN-Comunidad de FENOGE constitute non-reimbursable mechanisms aimed at strengthening capacities and closing structuring gaps, delimiting beneficiaries, documentation and requirements. This type of instrument is particularly relevant in the early phase, where the main constraint is usually the lack of sufficient technical, legal and financial structuring to meet evaluation standards and execute resources without disproportionately increasing transaction costs.

Secondly, intermediated and rediscount financing lines were characterized by their potential to finance energy investment with terms and grace periods more compatible with the nature of the assets. In these cases, the applicability to energy communities depends less on the existence of the financial product and more on the possibility of structuring an eligible entity with the capacity to manage flows, comply with requirements and manage operational risks. Therefore, in the diagnosis, plausible routes are considered those where the policyholder can be a territorial actor, a local private ally, an operator or a structured execution scheme that allows the typical restrictions of eligibility, support, age of expenditure and traceability to be resolved.

Third, mechanisms associated with rural financing and guarantees were incorporated because part of the potential of energy communities is anchored to rural productivity and productive uses that strengthen payment capacity. On this front, Finagro's Services Manual incorporates the destination of "Renewable Non-Conventional Energy Sources", which enables credit operations when there is an eligible rural subject and an intermediated channel. In addition, the guarantees of the Agricultural Guarantee Fund reduce collateral barriers for rural segments, while the National Guarantee Fund expands access routes for business policyholders (micro, small and medium-sized enterprises) through financial intermediaries. Taken together, these national routes reinforce a relevant diagnostic conclusion: effective capital mobilization tends to depend on the ability to structure "trigger paths" that align the instrument with an eligible policyholder, an executor with capabilities, and a operational scheme consistent with the market's perception of risk.

The mechanisms listed below represent a selection of national instruments identified through the mapping exercise as most relevant for energy communities, based on their functional alignment with Table 17 and their practical accessibility under current regulatory conditions. Based on this categorization, Table 18 summarizes the main national mechanisms identified as relevant for energy communities, together with their operational conditions.

*Table 18. Type of mechanisms*

Based on this categorization, Table 18 summarizes the main national mechanisms identified as relevant for energy communities, together with their operational conditions. The following corresponds to an exhaustive list of mechanisms applied in the context of energy communities in Colombia.

| Mechanism | Function | Administrator | Main stage | Operating condition[10] |
|---|---|---|---|---|
| **Register of Energy Communities (Res. 40509/2024)** | Preparation and structuring | MME | Pre-investment | Defines procedures and criteria, conditioning eligibility and articulation with programmatic instruments; requires technical-regulatory consistency when appropriate |
| **EN-Community** | Co-financing (non-repayable) | FENOGE | Pre-investment and CAPEX | Delimits beneficiaries and requirements; reduces structuring gap; Typical friction: document loading, evaluation times and execution traceability |
| **Solar Energy Reactivates** | Intermediated debt | Bancóldex | CAPEX | Deadlines and grace; Typical friction: need for an eligible policyholder, investment supports, limits on the age of expenditure and financial intermediation |
| **Energy and energy efficiency** | Rediscounting | Findeter | CAPEX and working capital | Deadlines and grace; typical friction: viability requirements, pre-structuring, intermediation and traceability; useful when there is an institutional anchor or executor with the capacity |

[10] Operating condition refers to the enabling factors to be considered when applying the referenced mechanism.

| Mechanism | Function | Administrator | Main stage | Operating condition[10] |
|---|---|---|---|---|
| **Destination FNCER (Finagro)** | Credit guarantees | Finagro | CAPEX | Enables credit for FNCER in rural areas; Typical friction: rural eligibility, intermediated channel, intermediary requirements and coherence with productive flow |
| **FAG Warranty** | Credit guarantees | Finagro | CAPEX and working capital | Reduces collateral barriers in rural segments; Typical friction: hedging rules, fees, eligibility, and articulation with the underlying credit |
| **Business Warranties** | Credit guarantees | FNG | CAPEX and working capital | Guarantees for MSMEs through intermediaries; Typical friction: conditional access to the intermediary's financial product, credit assessment and formalisation requirements |

### B. Transferable instruments and international operational references

The international component of the mapping is aimed at identifying operational references whose design logic has proven to be effective in mobilizing capital towards energy communities, mini-grids and decentralized electrification schemes. The criterion of transferability is not based on replicating specific institutional arrangements, but on capturing mechanisms that resolve recurring failures that are also observed in Colombia: insufficient technical and financial preparation to achieve investment standards; high uncertainty in early stages that prevents leveraging debt; high transaction costs for small and dispersed transactions; and dominant risks concentrated in collection, O&M, and asset replacement. From this perspective, the value of the international component is to provide a set of "pieces" that can be replicated by function, that is, by what they enable and by the risk they help to manage, rather than by their institutional label.

In the pre-investment stage, the most consistent international reference is the use of Project Preparation Facilities associated with climate and multilateral funds, which finance pre-feasibility and feasibility, technical and financial structuring, accompaniment for permits and capacity building to meet evaluation standards. These facilities serve an enabling function: they turn initiatives into bankable projects, reducing information asymmetry and development risk for funders. In this framework, the Green Climate Fund's Project Preparation Facility is used as a reference for its global role in supporting the preparation of climate projects before their approval, including technical and financial support for structuring. In addition, in Europe there are more focused and "light" instruments specifically aimed at energy communities, whose objective is to accelerate pre-development tasks and business plans, reducing transaction times and costs; an example is the Energy Communities Facility, conceived as a grant oriented to business plans and technical-legal components necessary to move towards implementation. The transferability of these references does not depend on replicating their governance, but on incorporating their logic: agile and standardized pre-investment financing, with clearly defined products that elevate projects to a comparable and assessable level.

In closing the viability gap and protecting affordability, international evidence reaffirms the relevance of viability gap funding mechanisms for community projects where the fee cannot fully reflect costs without affecting equity and access. The transferable element is not the exact figure of the subsidy, but its structure: clear eligibility rules, territorial prioritization criteria, traceability of the use of resources and a design that connects co-financing with conditions of operational sustainability to prevent the support from running out in the asset without guaranteeing continuity of service. In community projects, this co-financing usually operates as an anchor of bankability, allowing debt or co-investment to be structured on a reduced CAPEX and a more realistic income profile.

In risk mitigation, international references emphasize that mobilizing capital in decentralized electrification requires explicit de-risking instruments that act on risks that the private market does not assume efficiently. Three families of mechanisms stand out for their relevance to an applicable diagnosis: credit guarantees or partial risk hedges, which replace collateral and reduce expected losses, enabling debt conditions that are more compatible with energy assets; layered capital and first-loss structures, in which a concessional tranche absorbs first losses to improve the risk-return profile of senior capital and attract private co-investment; and insurance or guarantees for non-commercial risks (e.g., political-regulatory risk), used in infrastructure to reduce uncertainty in environments where rule stability and contractual compliance are determinants for investment. The main transferable lesson is methodological: it is not a matter of accumulating instruments, but of identifying the dominant risk of the project or portfolio and selecting the mechanism that effectively displaces it, ensuring that there is an anchor actor capable of activating it and managing its demands.

In results-conditional financing, the international literature documents the use of results-based financing (RBF) and results-based aid (RBA) to align incentives and reduce performance risk through disbursements linked to pre-agreed and independently verified outcomes.[11,12] This approach is especially relevant when the critical risk is not only investing, but also executing with quality and sustaining operations, since it introduces performance discipline and can complement other instruments (e.g. co-financing or debt) by reducing uncertainty about the delivery of results. In this diagnosis, the work of ESMAP is incorporated as a reference, which systematizes designs and considerations for RBF/RBA in energy and decentralized electrification. The transferable element for Colombia is the contractual and verification logic: contingent payments associated with verifiable milestones, with a reliable payer and measurement mechanisms that minimize disputes.

Finally, for revenue and collection stabilization, the international experience of pay-as-you-go (PAYG) models and prepaid variants is recognized as operational mechanisms that can reduce delinquency by aligning payments with consumption and enabling service control through measurement and management. However, its transferability is selective: it requires measurement and control infrastructure, technological and commercial capabilities of the operator, functional payment channels and social acceptance of the scheme. Therefore, rather than presenting itself as a standard, PAYG is incorporated as a reference that may be relevant in specific contexts, particularly when collection is the dominant risk and there are capacities to operate a control and collection model.

Taken together, these international benchmarks strengthen the diagnosis by showing that capital mobilization for energy communities is typically achieved through composite financial arrangements: standardized preparedness to reduce development risk; co-financing to close viability gaps without compromising affordability; risk mitigation (guarantees, first-loss and non-commercial hedges) to attract debt and co-investment; and, when applicable, results-based schemes or operational mechanisms that stabilize the flow in operation. This international reading is used in the report as a framework to assess the actual applicability of instruments in Colombia, avoiding nominal approximations and focusing prioritization on implementable combinations that reduce access frictions and attack dominant risks in rurality and ZNI.

Based on this analysis, Table 19 summarizes the international operational references identified as most relevant for transferability to the Colombian context. The references include both concrete international facilities and more generic mechanism types, presented illustratively to highlight transferable design logics rather than specific instruments for direct replication.

*Table 19. Financing mechanisms*

[11] Results-based financing: Capital provided upfront by private or public actors with repayment contingent on verified performance results, shifting delivery risk to the implementer or investor.
[12] Results-based aid: Public or donor funds disbursed only after independently verified development outcomes are achieved,

| Reference/ mechanism | Main function | Main stage | Dominant Risk Management | Replicable element for design in Colombia |
|---|---|---|---|---|
| **GCF Project Preparation Facility** | Preparation and structuring | | Development risk (pipeline) | Financing pre-investment and structuring to raise initiatives to investment standards and reduce information asymmetries. |
| **Energy Communities Facility** | Preparation (business plan and pre-development ) | | Development risk and transaction costs | Agile instrument to bring communities to evaluable business plans, with standardized products and less operational friction. |
| **Viability Gap Funding / co-financing (referential)** | Closing the viability gap | | Affordability and bankability | Co-financing with eligibility criteria, territorial prioritization and traceability, connected to O&M sustainability and replenishment. |
| **Guarantees and partial risk coverage** | De-risking for debt | | Credit/Collateral | Collateral substitution and expected loss reduction to enable formal debt with conditions compatible with energy assets. |
| **First-loss / layered capital** | Blended finance and leverage | | Perceived risk by private equity | Concessional tranche that absorbs first losses, improves risk-return profile and attracts senior capital for portfolio scaling. |
| **Non-commercial risk insurance/guarantees** | Non-commercial coverages | | Political-regulatory/institutional | Mechanisms to reduce institutional and contractual uncertainty in infrastructure, improving investment appetite in critical phases. |
| **ESMAP RBF/RBA** | Performance payments | | Performance/Execution | Contingent payments to verifiable results to discipline execution and support expansion, with independent verification. |

| Reference/ mechanism | Main function | Main stage | Dominant Risk Management | Replicable element for design in Colombia |
|---|---|---|---|---|
| **PAYG / Prepaid (selective)** | Collection stabilization | | Demand/collection | Operational control and collection mechanism that stabilizes flows; requires measurement/control and operator operational capability. |

## II. Benchmarking of financial mechanisms and incentives

**Purpose**: To compare how different instruments support CAPEX, OPEX, and risk mitigation.

- Most instruments prioritize capital expenditure and offer limited support for O&M or lifecycle financing.
- Incentives differ in eligibility, scale, and applicability to community-based models.

The comparative evaluation was designed as an exercise in applied analysis that allows moving from a wide universe of potentially relevant mechanisms to a technical ordering based on their real usefulness to mobilize capital towards energy communities in Colombia. To this end, methodological references used in the field of development finance and blended finance were adopted, which recommend evaluating instruments not only by their "type" (subsidy, credit or guarantee), but also by their ability to correct market failures, generate additionality and unblock transactions that would not occur under standard commercial conditions. In this approach, concessionality is understood as a strategic resource that must be allocated in a focused manner: the higher the level of risk or the greater the affordability gap, the greater the need for concessional or mitigation mechanisms; And as the project matures and risk is reduced, the structure should allow for a transition to financing with greater commercial equity participation.

In addition, the methodology incorporates the principle of "efficient risk allocation" typical of the design of financial structures and public-private partnerships: each risk must be managed by the actor that has the greatest capacity to control or mitigate it at the lowest cost, avoiding transferring risks that are inherently institutional, technological or financial to the community or the end user. This logic is particularly relevant in energy communities, where bankability is often affected by dominant risks such as collection and revenue, operation and maintenance, asset replacement, and regulatory stability. Consequently, the analysis prioritizes mechanisms that explicitly shift or redistribute these risks, rather than mechanisms that only provide resources without modifying the underlying risk structure.

On this basis, the comparison is structured in two complementary layers. The first corresponds to a stakeholder classification exercise, which makes it possible to identify who can really activate each mechanism and under what institutional architecture it can operate. This layer distinguishes between the anchor actor or eligible taker (who meets formal and contractual requirements), the implementing actor (who executes CAPEX and is accountable for performance), and the flow manager (who ensures traceability, custody, and disbursement rules when applicable). The goal is to avoid a nominal reading of availability and instead build plausible routes of access that reflect mandates, capacities, and constraints of ecosystem actors.

*Table 20. Stakeholder classification matrix*

| Variable | Assessment Content |
|---|---|
| **Anchor Actor (Eligible Taker)** | Who can request and receive the resource by complying with formal eligibility and contractual capacity (for example: territorial entity, energy services company, financial cooperative, sectoral public entity, fund, operator). |
| **Implementing actor** | Who executes CAPEX and is accountable for technical deliverables or operational performance (e.g., developer, operator, installation company, community organization with technical support). |
| **Flow and traceability manager** | Who has custody, orders disbursements or ensures reportability (for example: autonomous assets, trust, executing public entity, financial intermediary). |
| **Dominant Risk Shifting** | The main risk that the mechanism reduces or redistributes (development, credit/collateral, performance and O&M, demand/collection, regulatory, foreign exchange). |
| **Minimum Qualifying Condition** | Requirement without which the mechanism is not activatable (e.g.: project preparation, O&M contracts, measurement and control, registration/targeting criteria, verification). |

The second layer corresponds to an operational qualification matrix that translates the previous framework into comparable criteria of applicability. The assessment considers, in particular, implementability (probability of reaching disbursement under real conditions of documentation, times and transactional load), effectiveness in risk mitigation (degree to which the instrument reduces the dominant risk that slows down bankability), scalability and standardization (potential to operate through portfolios with lower transaction costs) and consistency with Just Energy Transition objectives (affordability protection, territorial equity and operational sustainability).

Based on the functional typology used in the mapping (preparation and structuring; co-financing; concessional/intermediated debt; guarantees and hedges; disbursements by results; operational collection mechanisms), the evaluation allows mechanisms to be ordered not by their financial label, but by their **transactional function** within the project cycle and by their most plausible activation route. This makes it easier to derive concrete implications: what combinations are necessary to close gaps in pre-investment, CAPEX, start-up and operation, and which instruments should be treated as pre-enablers rather than as main sources.

The result of this comparison is expressed as a diagnostic prioritization by levels, understood as an initial ordering (e.g., risk appetite, deal breakers, times and real constraints), without altering the logic of the framework. Prioritization emphasizes mechanisms with greater capacity to enable pipeline, reduce dominant risks, and facilitate escalation. Interviews in the appendix section further expand and contribute to the defined prioritization levels.

*Table 22. Prioritization matrix*

| Functional typology of the mechanism | Priority Level | Main justification in the diagnosis |
|---|---|---|
| **Preparation and structuring (TA, PPF)** | High priority | Enabling condition to convert initiatives into bankable projects; reduces development risk and transaction costs; improves eligibility against debt, guarantees and co-financing. |
| **Co-financing and closing the viability gap (targeted subsidies, co-financing)** | High priority | A determining factor in making CAPEX compatible with affordability and TEJ; it allows models where the tariff does not cover costs to be made viable without affecting access; It must be connected to operational sustainability. |
| **Guarantees and partial risk coverage** | High priority | Efficient instrument to mobilize credit by substituting collateral and reducing expected loss; displaces risks that the market tends not to assume; relevant to enable intermediated debt. (OECD) |
| **Concessional or intermediated debt (development banking, rediscounting, DFIs)** | Medium-high priority | It works when there is an eligible policyholder with clear flows and a credible collection and O&M structure; Their performance depends critically on prior preparation and risk mitigation. |
| **Disbursements conditional on results (RBF/RBA)** | Medium priority | Useful for execution discipline and verifiable expansion; more suitable as a complement to co-financing and debt, especially when the main risk is performance and not just CAPEX. |

| Functional typology of the mechanism | Priority Level | Main justification in the diagnosis |
|---|---|---|
| **Income stabilization mechanisms (income supports, minimum income guarantees)** | Selective Priority | Powerful in the face of demand and collection risk, but they require contractual capacity and institutional clarity; Applicable in schemas with robust roles and flow management. |
| **Flexible payment models (PAYG and variants)** | Selective Priority | They can reduce arrears, but they require measurement and control, technological and operational capabilities; its applicability depends on the context and the operator, it is not universal. |

In interpretative terms, the evaluation suggests that the most implementable routes tend to be structured as "sequences" rather than as isolated instruments: preparation to elevate the project to an investment standard; co-financing to ensure affordability and close viability gaps; and guarantees or hedging to enable debt and co-investment under an explicit allocation of risks. This sequence is consistent with guidelines that recommend using blended finance to correct market failures, minimize concessionality where possible, and favor instruments with mobilization capacity, such as guarantees, particularly relevant for their leverage efficiency and their role in unlocking credit in riskier markets.

## III. Access conditions and market restrictions

**Purpose**: To identify constraints that limit communities' ability to access financing.

- Small project size and high transaction costs reduce bankability and limit access to credit.
- Many communities lack formal credit history, organizational structure, or collateral.

The availability of financial instruments does not automatically translate into effective access. In energy communities, the "market constraint" usually manifests itself as a gap between mechanisms that exist in the institutional design and the real capacity to activate them in specific projects under conditions of eligibility, transaction costs and risk management. This gap is particularly relevant in rural territories and ZNI, where geographic dispersion, lower institutional density, and operational limitations for collection, operation, and maintenance intensify. In this diagnosis, access conditions are addressed as a set of enabling requirements that determine whether an instrument can move from intention to disbursement and, subsequently, to operational sustainability.

First, access is conditioned by the existence of an eligible subject with legal, financial and contractual capacity. Many instruments, especially intermediated ones (credit, rediscount, guarantees), presuppose a policyholder who can meet documentary requirements, assume obligations, manage reports and support control and traceability schemes. In community models, this condition is rarely fulfilled directly in the community organization, and usually requires an anchor actor (territorial entity, operator/developer, energy services company, financial cooperative or other ally) capable of signing, executing and responding for performance. This need generates a central friction: if the actor who can assume the financial obligation is not the one who controls the operational risk (e.g. collection, O&M, replenishment), the transaction is exposed to asymmetries that are difficult to cover. In practice, these asymmetries are only corrected when the structure explicitly defines roles, responsibilities and control mechanisms, including clear flow management rules and verifiable performance criteria.

Second, instrument activation depends on the level of project readiness and its ability to meet technical and financial evaluation standards. Frequently, the main bottleneck appears before disbursement: absence of solid information on demand and ability to pay, conceptual and detailed engineering, estimation of life cycle costs (e.g. CAPEX, O&M, replenishment), definition of asset ownership scheme, responsible operator, critical contracts and a traceable financial model that explains how costs will be covered over time. In programmatic and co-financing instruments, this translates into documentary burdens, prioritization criteria and administrative times that require technical capacities to respond. In debt instruments, lack of preparation is expressed as an inability to demonstrate a source of repayment, stability of income and adequacy of the operating arrangement.

Third, access is highly determined by the transaction economy. Many community projects are located in size ranges where the costs of structuring, monitoring, verification, and reporting may be disproportionate to the amount funded, even if the rate or term is favorable. This friction is aggravated in dispersed territories by the cost of technical visits, installation logistics, supply of spare parts and maintenance management, as well as by the need for social and institutional support to sustain community agreements. Therefore, the mechanisms most likely to be activated are those that reduce friction through document standardization, templates, simplified processes, technical support, or that allow operating under programmatic or portfolio logic to capture economies of scale.

Fourth, the market "selects" instruments according to the way in which the dominant risks in operation are managed, which are the ones that determine real bankability. In energy communities, these risks tend to be concentrated in: (i) collection and revenue, especially where there is low banking penetration, informality in payments or absence of measurement and control; (ii) operational performance and O&M continuity, including local technical capacity, spare parts availability and failure response; (iii) replacement of critical assets, which requires reserves or explicit replacement mechanisms; and (iv) institutional stability and coordination, where the breach of roles or contractual ambiguity increases the perception of risk. If these elements are not mitigated by concrete mechanisms (e.g. flow management, O&M contracts, replacement reserves, guarantees, verification), the cost of capital increases or financing does not occur, regardless of whether there is a formally available instrument.

Fifthly, the traceability and governance of resources becomes a cross-cutting condition of access. Both in public resources and in concessional financing and cooperation programs, the demand for reporting, verifiability and control is usually high.[13] This introduces a practical tension: robust control mechanisms increase trust and reduce fiduciary risk, but they also raise transaction costs and demand administrative capacities that may not exist in the territory. The solution is not only to make requirements more flexible, but also to design flow management architectures that reduce friction without losing control, for example through experienced resource managers, fiduciary schemes or executing units with proven capabilities, especially when the instrument requires milestones, verification or periodic reports.

The following matrix summarises the typical constraints observable in the activation of instruments for energy communities and their operational implication:

*Table 23. Financing constraints matrix*

| Constraint dimension | Typical manifestation | Effect on access |
|---|---|---|
| **Eligibility and Contractual Capacity** | Policyholder does not meet requirements, weakness of legal representation, low administrative capacity | It forces the structuring of an anchor actor; without this, intermediated instruments lose applicability |
| **Project maturity** | Lack of studies, engineering, lifecycle model, critical contracts, definition of roles | Delays or blocks disbursement; limits debt and reduces the effectiveness of co-financing |
| **Transaction costs** | High processing, supervision, verification, and reporting for the size of the project | It penalizes isolated projects; Favors portfolios and standardization |

[13] Concessional financing: loans provided at below-market interest rates, often by development banks or government programs, to support projects with social or environmental benefits.

| Constraint dimension | Typical manifestation | Effect on access |
|---|---|---|
| **Collection and revenue risk** | Uncertainty in payments, low banking penetration, absence of measurement and control | Perceived risk increases; requires clear flow management and payment mechanisms |
| **O&M and Replenishment Risk** | Undefined operator, weak technical capabilities, absence of replacement reserves | Reduces bankability; requires explicit contracts and provisions |
| **Traceability and governance** | Difficulty demonstrating resource use and compliance | Increases friction; Favors flow managers with controllability |

In addition, the relevance of each constraint changes depending on the stage of the project cycle. In pre-investment, preparation dominates; in CAPEX, eligibility and risk structure dominate; and in operation, the stability of income and O&M capacity dominates, where repayment and continuity of service materialize.

*Table 24. Financing stages*

| Stage | Most decisive restrictions | Practical involvement |
|---|---|---|
| **Pre-investment** | Technical-financial preparation, contractual definitions, transaction costs | Without minimum standards, there is no step to evaluation or disbursement |
| **CAPEX and Bootstrapping** | Policyholder Eligibility, Collateral/Collateral, Traceability, Schedules, and Counterparties | Disbursement slows down even with available instruments |
| **Operation and replacement** | Collection, O&M continuity, provision for replenishment, conflict management | Determines sustainability and real bankability, beyond CAPEX |
| **Expansion / Scaling** | Standardization, replicability, institutional capacities and economies of scale | Requires programmatic logic to lower transaction costs and mobilize capital |

## IV. Prioritized instrument groups

**Purpose**: To highlight the instruments most relevant for scaling energy communities.

- Grants and concessional financing are particularly important for ZNI and low-income contexts.

- Blended finance and risk-sharing tools are needed to complement existing CAPEX-focused mechanisms.

The prioritization of instruments is built for implementability, identifying mechanisms that, in Colombia, are more likely to become disbursements and be sustained, either because they have clear access channels, because they can be activated by actors with contractual and execution capacity, or because they directly reduce the risks that typically block bankability in energy communities. Consequently, prioritization is not presented as a "list of sources", but as a set of pieces that allow for the construction of routes of capital mobilization. Four prioritized groups of instruments are included: pre-investment and structuring enablers, co-financing and closing the viability gap, intermediated debt and rediscounting for CAPEX with compatible conditions, and risk mitigators and operational sustainability mechanisms.

A cross-cutting finding is that the most relevant instruments for energy communities in rural areas and ZNI are those that resolve the transition between formulation, disbursement and sustainable operation. This means prioritizing mechanisms that finance readiness (to elevate projects to evaluation standards), reduce CAPEX without compromising affordability, substitute collateral to enable debt, and ensure that O&M and replenishment are explicitly covered by verifiable arrangements. Under this logic, prioritization is expressed in two complementary levels: prioritization by instrument and a prioritization by "recommended configurations" (instrument packages) according to the type of project and anchor actor.

*Table 25. Prioritization of instruments*

| Instrument group | Main function | Most plausible activation route | Cycle stage | Dominant Risk Manageme nt | Expected contributio n | Plausible Finance Sources |
|---|---|---|---|---|---|---|
| **Preparation and structuring** | Elevate projects to investment standards | Cooperation /multilaterals, sectoral public funds, | Pre-investment | Developme nt risk | Reduces pre-disburseme nt failures and enables financing | Public Funds, Internationa l Cooperation , |

| Instrument group | Main function | Most plausible activation route | Cycle stage | Dominant Risk Management | Expected contribution | Plausible Finance Sources |
|---|---|---|---|---|---|---|
| **Targeted sectoral co-financing** | Reducing the viability gap and protecting affordability | Public funds / programs with territorial prioritization and eligibility criteria | CAPEX and Bootstrapping | Affordability and adoption | Reduces CAPEX and facilitates TEJ-compliant rates | Concessional Finance, Development Banking |
| **Second-tier debt / rediscount** | Fund CAPEX and, where applicable, associated working capital | Development and rediscount banks via intermediaries; Eligible Policyholder | CAPEX / expansion | Financial cost and liquidity | Provides compatible terms and grace; requires credible collection/O&M structure | Concessional Finance, Private capital |
| **Guarantees** | Replace collateral and reduce expected loss to enable credit | Guarantee funds via intermediaries; Defined eligible subject | CAPEX / Working Capital | Credit/Collateral | It denied access to formal debt in contexts with guarantee restrictions | Public Funds, development banking |
| **Flow management and traceability structures** | Ensure disbursement rules, resource control, supplier payments, and O&M | Resource manager agreed upon by actors | CAPEX and operation | Fiduciary and coordination risk | Reduces traceability friction and improves funder/payer confidence | Private Banking |

| Instrument group | Main function | Most plausible activation route | Cycle stage | Dominant Risk Management | Expected contribution | Plausible Finance Sources |
|---|---|---|---|---|---|---|
| **O&M and Replenishment Reserves and Provisions** | Ensure service sustainability beyond CAPEX | Incorporated into financial structure, rates and/or flow management rules | Operation/Replenishment | O&M and Replenishment | Avoids failures due to unfunded replacement; Improved continuity and bankability | Private Banking, |
| **Performance-conditional instruments** | Align incentives and discipline verifiable execution/expansion | Cooperation or public sector as payer; Independent verification | Deployment/Expansion | Performance/Execution | Complement for expansion and quality; does not replace base CAPEX | Private Banking, development banking |

Prioritization is best applied as configurations, because each instrument group covers a different part of the problem. Below are three prioritized configurations that represent capital mobilization routes, differentiated by the type of anchor actor and the nature of the dominant risk.

*Table 26. Prioritized configurations*

| Settings | When it applies | Typical anchor actor | Minimum instrument package | Expected Result |
|---|---|---|---|---|
| **Public-programmatic route with a focus on affordability** | High viability gap and territorial priority where the tariff cannot cover CAPEX | Sectoral fund / programme and/or territorial entity with execution capacity | Preparation, targeted co-financing, flow management, O&M provision/replenishment | Executable disbursement with traceability and operational sustainability |

| Settings | When it applies | Typical anchor actor | Minimum instrument package | Expected Result |
|---|---|---|---|---|
| **Blended route to enable debt (leverage)** | Bankable subject and the possibility of stable flow | Eligible partner (operator/developer/service company), with territorial support | Prep, collateral, intermediated debt / rediscounting, flow management, O&M provisioning / replenishment | Reduce perceived collateral; enable deadlines; mobilize added capital |
| **Performance Path for Expansion and Quality** | Expansion phase, where main challenge is execution and verifiable performance | Public payer / cooperation, executor with technical capacity | Preparation, financing basis, performance disbursements, verification | Improve quality and expansion with performance linked payments |

Understanding the instruments and application configurations, in terms of immediate applicability, the following are prioritized as the "core" of the Colombian package: first, programmatic and sectoral mechanisms of focused co-financing that allow closing the viability gap without transferring incompatible costs to the end user; second, development and rediscount financing lines with compatible terms/grace periods to finance CAPEX when there is an eligible policyholder; third, guarantees to replace collateral and enable credit; and fourth, the O&M/Replenishment flow and provision management schemes incorporated from the design, as a condition of sustainability and bankability. In addition, transferable international references (preparation facilities and performance mechanisms) are prioritized as design pieces that can strengthen the pipeline and discipline expansion when there is payer and verification.

Table 27 below synthesizes the conclusions from the prioritization analysis by categorizing instrument groups according to their implementation necessity. Core instrument groups are the minimum viable financing stack essential for any implementable energy community project path. These include pre-investment support, co-financing to close viability gaps, debt access mechanisms, and basic risk mitigation instruments. Add-on instrument groups provide enhanced sustainability, scalability, or risk coverage, but may be selectively applied based on specific project characteristics, available resources, and contextual requirements.

*Table 27. Instruments prioritized by role*

| Category | Instrument groups | Role in an Implementable Path |
|---|---|---|
| **Core (High Priority)** | Preparation/structuring; targeted co-financing; guarantees; intermediated/rediscounted debt; flow management; O&M provision/replenishment | It makes it possible to move from an initiative to a bankable, disbursable and sustainable project |
| **Add-on (Selective priority)** | RBF/RBA and performance disbursements; PAYG/flexible (selective) payment; specific coverage according to risk | Useful under strict enabling conditions (metering, operator, reliable payer, verification) |

Prioritization proposes a capital mobilization approach based on combinations of instruments: preparation and structuring to ensure the quality and bankability of the project; co-financing to maintain affordability and close viability gaps; collateral and debt to leverage CAPEX on terms compatible with the model's flows; and resource management mechanisms, along with provisions for O&M and replenishment, to ensure continuity of service. This logic makes it possible to convert the diagnosis into implementable financing routes, especially in rural territories and ZNI, where the market restriction is structural and requires designs that reduce access frictions and assign risks in an explicit and verifiable way.

# ENABLING CONDITIONS AND GAPS

**Purpose**: To synthesize enabling factors and structural gaps across regulatory, institutional, financial, and community dimensions.

- Colombia now has a legal framework and emerging financing tools that support energy communities.
- Major gaps include limited OPEX financing, underdeveloped risk-sharing instruments, and fragmented institutional processes.

**Key Message: Successful implementation is blocked by "transactional friction" high administrative burdens that exceed local community capacities. The most critical gap is the underestimation of the project lifecycle, leading to "operational death" when batteries or inverters fail without replacement funds.**

This chapter synthesizes and deepens the diagnostic findings from previous sections, translating the observed patterns in energy community implementation and consolidating the key determinants of success and failure into a structured framework for policy and project design.
This section consolidates a diagnostic reading of the factors that explain the operational and financial success of energy communities and, at the same time, of the limits that condition their replication in other territories. The starting point is to recognize that the performance of these models does not depend solely on an adequate technical solution, but on the coherence between multiple dimensions that must work in a coordinated manner: regulatory and contractual clarity, governance arrangement, collection and profit allocation architecture, O&M and replenishment provision, and institutional capacity to sustain decisions and operational discipline over time. In practice, the results are explained by the ability to "close" these pieces in a consistent and verifiable way, so that the project can operate as a continuous service and not as a one-off intervention.

In Colombia, success factors are particularly relevant because many initiatives face recurring obstacles in the transition between formulation, entry into operation and sustainability. The challenge is not only to identify what works in general terms, but to understand why it works, what risk it reduces and what minimum conditions enable that outcome. The elements that usually make the difference are concentrated in the actual execution: the explicit assignment of roles, the reduction of ambiguities about measurement and benefits, the existence of operational mechanisms to sustain collection, and the incorporation of a life cycle approach that ensures operation, maintenance and replacement. In rural territories and ZNI, these demands are intensified by logistical constraints, lower institutional density, higher transaction costs, and fragility of payment channels, making success even more dependent on simple, robust, and sustainable arrangements.

The analysis is based on a methodological premise: "success factors" are not interpreted as isolated good practices, but as combinations of enabling conditions that reduce dominant risks throughout the project cycle. Consequently, those elements are identified that, when present simultaneously, increase the probability of entry into operation, stabilize cash flow and sustain the legitimacy of the scheme before users and financiers. At the same time, the limits of transferability are analyzed as the set of constraints that prevent models from being transferred directly between contexts, either due to regulatory differences, the absence of institutional capacities, tariff and subsidy structures, demand constraints, or the impossibility of replicating operating arrangements without significantly increasing transaction costs.

Based on this logic, the section is organized into two complementary blocks. First, it identifies the success factors that explain the sustained performance of energy communities in comparative experiences, explicitly connecting them with the type of risk they help manage and with the moment in the project cycle in which they are decisive. Second, it delimits the limits of transferability and the minimum conditions necessary to adapt these factors to the Colombian context, distinguishing between elements that can be replicated with operational adjustments and those that require reforms, specific instruments or institutional anchors to become implementable, especially in rural areas and ZNI.

## I. Enabling conditions by dimension of analysis

**Purpose**: To summarize supportive conditions across key dimensions.

- The legal and institutional framework provides a foundation for community participation and distributed generation.
- Community governance structures can strengthen legitimacy and improve operational outcomes.

Enabling conditions are understood as the minimum set of capabilities, arrangements and definitions that allow moving from a conceptual design to an operating unit with financial sustainability and functional governance. In practice, an energy community is implementable when, in addition to the technical solution, there is clarity about the applicable regulatory modality, the institutional and contractual arrangement, the mechanism for capturing benefits (savings and revenues) and the operation and maintenance route with a defined source of payment. Under this approach, these conditions operate as a practical threshold: if any piece is not resolved, it increases the probability that the project will stagnate in formulation, not reach evaluation standards to access resources, or deteriorate early due to failures in collection, maintenance, or replacement.

**Regulatory authorization** depends on the design incorporating the applicable modality and its operational translation from the beginning. This includes defining the configuration of the project (self-generation or distributed generation, individual or collective), its relationship with the grid operator and the marketer, and compliance with technical and commercial requirements associated with connection, metering, billing and treatment of surpluses. In addition, it has the capacity to support, when applicable, the formalization and registration route, with registration, updating and reporting processes, as well as the availability of minimum evidence that reduces regulatory uncertainty before third parties. Ambiguity in the regulatory fit usually materializes in schedule risks, unforeseen costs and restrictions to monetize the economic value of the project.

**Institutional articulation and territorial coordination** work as enablers when they allow the construction of a realistic route of permits, authorizations and operational agreements, aligned with the times and requirements of the project. The lack of coordination between key counterparties tends to result in delays, design rework and cost overruns, which directly increases the perceived risk of funders and operators. In this framework, evidence such as minutes of agreement, letters of intent and preliminary agreements contribute to reducing the risk of execution and strengthen the credibility of the project, especially in rural areas and ZNI, where lower institutional density increases transaction costs.

**Community governance and capacities** enable implementability when there is a minimum viable scheme of decision-making, representation, and accountability. This involves defining who represents the community, how commitments and expenses are approved, how resources are managed, how conflicts are resolved, and how project benefits are distributed, whether through savings, income, or improvements in quality and continuity of service. The sustainability of the collection depends on the legitimacy of these arrangements, so simple and consistent mechanisms of active transparency, such as minutes, periodic reports and traceability of decisions and execution, operate as practical enablers for continuity and to reduce management risks before third parties.

**Technical and operational robustness** requires a minimum characterization of the demand and the physical context that supports the pre-feasibility engineering and allows the system to be sized with realistic criteria. In projects connected to the SIN, this implies anticipating connectability restrictions and conditions required by the network operator, including connection point, protections, studies, deadlines and associated costs. In ZNI, where continuity depends to a greater extent on logistics, spare parts and local operation, the critical enabler is to incorporate from the beginning a robust maintenance and replacement scheme consistent with the capabilities of the territory. In both cases, the identification of critical loads, time variability, expected growth and site constraints determines service continuity and conditions the economic performance of the project.

The **commercial, tariff, and revenue definition** enables the model when it establishes precisely how economic value is realized and how that value is converted into operating flow. This requires deciding whether the scheme is mainly based on savings from self-consumption, income from surpluses, payment for energy service or a mixed model, ensuring compatibility with metering and billing rules. Based on this definition, there must be an operational collection architecture, with a responsible party, periodicity, monitoring mechanisms and treatment of arrears. In contexts with subsidies and subsistence consumption, the effective avoided rate may be lower than the average unit cost, reducing the cash margin to pay for investment when the model depends only on savings; therefore, segmenting users and incorporating anchor loads or productive uses is usually decisive to strengthen bankability.

The **financial enablement** is consolidated when the project has a complete cost structure and an explicit mechanism to sustain operation, maintenance and replacement during the life cycle. This requires modeling recurring OPEX, management, insurance, monitoring, measurement and control costs, and also transaction costs associated with the relationship with the grid operator and the marketer when applicable. In addition, a clear rule for the provision and capitalization of an O&M and replenishment fund is required, along with a financing structure consistent with the risk profile and with the capacities of the territory, incorporating explicit risk allocation and operational mitigators. Under this framework, a project becomes bankable when its assumptions are traceable, conservative, and executable, and when the source of payment for O&M and replenishment is verifiable.

**Socio-territorial adoption** acts as an enabler when the energy service is aligned with the real needs of the territory, with clear access rules and with a value proposition perceived as legitimate by users. In contexts of volatile or informal income, adoption and payment discipline are strengthened when the project is integrated into relevant uses, such as community services or productive activities, as long as demand is not overestimated and the operating arrangement can respond to local conditions.

As a control and monitoring instrument, it is recommended to consolidate these enabling conditions in a traffic light-type verification matrix, associating for each condition a verifiable indicator, the minimum evidence required, the associated risk if it is not met and a corrective action with the person responsible. This tool facilitates the prioritization of gaps, feeds the decision tree and allows the definition of technical assistance and financial support packages differentiated by type of energy community, ensuring that the implementation path is based on verifiable enabling conditions and not only on conceptual designs.

## II. Critical gaps and structural bottlenecks

**Purpose**: To identify obstacles that hinder scalability and sustainability.

- OPEX financing, risk-mitigation tools, and operational clarity remain limited across the ecosystem.
- Institutional fragmentation and limited local capacity create persistent bottlenecks.

Critical gaps correspond to recurring failures that appear in the transition between the formulation and effective operation of energy communities and that, if not addressed from early stages, become bottlenecks for the schedule, cash flow stability and continuity of service. They are considered structural because they are not solved only with technical investment: their closure requires clear institutional arrangements, minimum local capacities, verifiable operating rules and a financial design consistent with the reality of the territory. In practical terms, these gaps concentrate the dominant risk of the project (execution, collection, operational performance, governance or regulatory risk) and determine the difference between initiatives that manage to enter into operation with sustainability and those that remain as pilots without the ability to scale.

A first critical gap is the operational and contractual **ambiguity regarding roles and responsibilities** between the community, the territorial entity when it participates, the network operator and/or marketer, the developer, and the operation and maintenance provider. This ambiguity translates into essential tasks without an explicit "owner": who manages the relationship with OR and marketer, who is responsible for measurement and data quality, who attends to failures, who manages collection, who defines and applies measures in the event of arrears, and who authorizes maintenance and replacement expenses. In practice, this gap generates unbudgeted costs, delays due to rework and disputes over obligations, increasing the risk of execution and performance. The bottleneck appears particularly strongly when the project moves from "installation" to "service": without service level agreements, information protocols and decision mechanisms, the operation becomes discretionary and fragile.

A second recurring gap is the **measurement, allocation of benefits and traceability of economic value in collective schemes**. When there is no clarity about how consumption and generation are measured, how savings or income are distributed, and how the real benefit per user or group is verified, the legitimacy of the model deteriorates and collection loses discipline. In community settings, the perception of inequity often quickly translates into reluctance to pay, internal disputes, and erosion of social support. This gap is not only technical: its impact is financial and governance, because the stability of the flow depends on users perceiving a tangible, verifiable benefit allocated under consistent rules. Consequently, projects that do not resolve this dimension from the beginning tend to "spend governance" on disputes over distribution, instead of consolidating operational capacities.

A third critical gap is the **systematic underestimation of O&M and asset replenishment** under a life-cycle approach. It is common to be able to close CAPEX with public support or cooperation, but without a robust solution to cover recurring OPEX and replacement of critical components (e.g., batteries, inverters, protections, meters, and control equipment). The result is predictable: degradation of availability, fall in savings or expected income, increase in complaints, loss of confidence and deterioration of collection, until reaching the "operational death" of the project. This gap is intensified in ZNI due to logistics and response times, and is aggravated when there are no minimum inventories of spare parts, preventive maintenance protocols, or a reserve fund to ensure response to failures.

A fourth structural gap is the **fragility of collection and the limited capacity to effectively pay**, especially in territories with high informality, seasonal income, and consumption concentrated in subsidizable or subsistence ranges. In these contexts, the "cash space" available to finance investment via savings may be lower than estimated, and collection is usually irregular if there is no simple, legitimate and verifiable operating mechanism. This gap directly affects bankability: without predictable income, debt becomes unviable and sustainability depends on continuous transfers or subsidies. In addition, when internal rules of payment discipline and transparency of resource use are not incorporated, arrears can become a socially accepted phenomenon, weakening the model from within.

A fifth gap is related to **unrealistic schedules and underestimated costs in the transition to entry into operation**, which are manifested in a differentiated way between SIN and ZNI. In projects connected to the SIN, connection times and costs, studies, adaptations and procedures can be decisive, and the absence of early pre-feasibility usually leads to delays and cost overruns. At ZNI, the bottleneck is concentrated in logistics, availability of technical support, equipment transportation, and operational continuity under complex territorial conditions. In both cases, the risk is similar: projects that do not come into operation within the expected period lose political and financial windows, become more expensive, and can be trapped between resources executed and service not provided.

A sixth critical gap is the **weakness of governance and the low social legitimacy of the organizational arrangement**, particularly when there are dynamics of capture by few actors, lack of transparency or unmanaged internal conflicts. This gap has operational and financial effects: it increases delinquency, reduces asset care, increases the risk of vandalism or abandonment, and limits the sustainability of the O&M scheme. In terms of diagnosis, weak governance usually manifests itself with early signs: absence of decision-making and control rules, low access to information, recurrent conflicts over benefits, and lack of accountability mechanisms. When these signals are not corrected, the project can be sustained only as long as there is external support, but it does not achieve autonomy.

A seventh gap, transversal to the previous ones, is the **high transactional friction to access financial and programmatic instruments**, derived from eligibility, formalization, documentation and reporting capacity requirements that exceed the capacities of community organizations or territorial entities with operational restrictions. This gap is expressed in long times to achieve disbursement, high transaction costs (studies, procedures, structuring), and institutional dependencies that are not always aligned with the project schedule. As a result, even when instruments are available, their activation may be unlikely in real conditions without technical assistance, standardization and anchor actor-based paths.

To consolidate these gaps as an operational input, a diagnostic matrix is then organized that connects gap, manifestation, associated risk and implication for implementability, facilitating traceability to corrective actions and to the report's decision tree.

*Table 28. Gap analysis*

| Critical gap | Typical manifestation | Dominant risk | Practical involvement |
|---|---|---|---|
| **Ambiguous roles and responsibilities** | Critical tasks without an owner, operational disputes | Execution, performance | Delays, cost overruns, discretionary operation and deterioration of service |
| **Unresolved Profit Measurement and Allocation** | Inequitable or unverifiable benefits, internal disputes | Collection, governance | Increase in arrears, loss of legitimacy and fall in financial sustainability |
| **Underestimated O&M and Replenishment** | Closed CAPEX with no provision for OPEX and replacement of critical assets | Performance, continuity | Early degradation, recurrent failures, "operational death" of the project |
| **Fragile payment and collection capacity** | Irregular income, normalized arrears, low banking penetration or weak payment channels | Revenue, bankability | Debt unviability, transfer dependence, unstable continuity |
| **Underestimated start-up schedules and costs** | SIN connection with unanticipated procedures/studies; ZNI logistics not considered | Execution | Non-entry into operation, loss of financial/political window, cost overruns |
| **Weak governance and low legitimacy** | Capture, unmanaged conflicts, lack of transparency and accountability | Governance, assets | Arrears, abandonment, vandalism, unsustainable operation without external support |
| **Transactional friction for resource access** | Requirements, reports and formalization that exceed local capacities | Access to capital | "Existing" but not activatable instruments; Delays and high transaction costs |

Consequently, the identification of these gaps is not proposed as a descriptive exercise, but as a basis to guide design and prioritization decisions in subsequent phases. Each gap signals a condition that must be closed with concrete instruments (contractual arrangements, operating protocols, profit measurement and allocation schemes, collection mechanisms, and O&M and replenishment provisions) before scaling or replicating initiatives. This approach makes it possible to move from isolated projects to implementable, comparable and bankable routes, focusing efforts on the points where risk is concentrated and where early intervention has the greatest effect on entry into operation, flow stability and continuity of service.

## III. Success factors and transferability limits

**Purpose**: To define the conditions required for successful replication and scaling.

- Success requires governance clarity, realistic tariffs, strong O&M, and sustained support.
- Transferability depends on territorial conditions, regulatory constraints, and financing availability.

While enabling conditions are structural prerequisites for feasibility, success factors are operational elements that determine long-term sustainability. They are understood as combinations of enabling conditions that, when present simultaneously, reduce dominant risks and allow an energy community to move from a pilot to a sustainable and replicable service. In the diagnosis, these factors are treated not as isolated "good practices," but as levers explaining why some models enter operation, maintain collection, meet performance standards, and sustain legitimacy over time. At the same time, transferability is limited: what works in one context cannot always be replicated elsewhere, since portability depends on minimum regulatory, institutional, territorial, and financial conditions, and on the ability to reproduce operational arrangements without increasing transaction costs or creating permanent external dependencies.

A first success factor is the **clarity and stability of the operational arrangement**, with explicit and traceable roles and responsibilities. Models that work tend to solve "who does what" from the beginning. This clarity is reinforced when there are service level agreements, reporting protocols, and decision-making mechanisms that do not depend on specific individuals, but on known and sustained rules. The limit of transferability appears when these arrangements are based on institutional capacities that do not exist in territories with low state presence or with operators without accompaniment capacity; In these cases, replicating the same arrangement requires contractual simplification or the incorporation of an anchor actor that assumes critical functions.

A second success factor is the **traceability of the economic benefit and its translation into payment discipline**. Sustainable collective schemes often have simple rules for allocating benefits, access to basic information to verify results, and transparency mechanisms that sustain legitimacy. When users understand how savings or service materialize, and can observe it on a regular basis, compliance is strengthened and the risk of conflict is reduced. The transferability limit arises when the metering and allocation architecture requires infrastructure, connectivity, or data management capabilities that are not available, or when the local tariff structure reduces the monetizable value of the savings. In these scenarios, replication demands adjustments towards simpler service models or the incorporation of anchor loads that stabilize the flow.

A third success factor is the lifecycle approach: **financing and operating with explicit O&M provisions and replenishment** from start-up. The most robust experiences internalize that sustainability does not depend on installing assets, but on availability and continuity, which requires preventive maintenance, critical spare parts, response times and a standalone replacement fund. The limit of transferability manifests itself when the supply chain is fragile, the territory is difficult to access, or there is no local capacity for basic operation; replicating the model involves designing more fault-tolerant solutions, strengthening logistics and, in some cases, structuring regionalized or portfolio O&M contracts to reduce costs.

A fourth success factor is **bankability built by assembly: combining instruments and explicitly allocating risks**. Models that scale rarely rely on a single source; they usually integrate preparation support to achieve evaluation standards, co-financing to protect affordability, risk mitigation and concessional or intermediated financing for CAPEX, in addition to operational mechanisms that stabilize revenues. This approach works when the institutional architecture allows instruments to be activated with eligible actors and when transaction costs are reduced through standardization or portfolio approaches. The limit of transferability appears when the structure depends on specific programmatic windows, non-recurring cooperation, or levels of reporting that are difficult to sustain; In such cases, adjustment requires simplifying the financial stack or institutionalizing permanent mechanisms.

A fifth success factor is **regulatory fit by design**, with reduced uncertainty for the actual operation. Stronger experiences integrate connection, metering, billing, and overage requirements from pre-feasibility, avoiding late redesigns and delays. This is especially critical in SIN connected projects, but it also applies in ZNI with specific rules on service provision or subsidies. The limit of transferability arises when the regulatory framework changes, when there are grey areas in the application of collective figures or when the procedures are not homogeneous; In these contexts, replication requires greater articulation work and an explicit regulatory management strategy.

A sixth success factor is **social legitimacy and alignment with territorial needs**, particularly through relevant uses and demand anchors. Energy communities that are sustained tend to connect service to visible needs (quality of service, reduction of interruptions, community services) and, when possible, to productive uses or anchor loads that stabilize incomes and improve payment capacity. The limit of transferability appears when productive demand is insufficient or seasonal, when income is highly volatile or when the socio-organizational structure does not allow for long-term agreements; Replicating the model involves adapting sizing, prioritizing critical loads, and designing payment mechanisms compatible with real capacity.

Together, these success factors and transferability limits allow the comparative experience to be interpreted without automatic extrapolations. Effective transferability depends on identifying which component of the model explains the outcome (governance, measurement, O&M, collection, financing, regulation) and what minimum conditions must exist to replicate it without increasing risks or transaction costs. This reading directly feeds the construction of typologies and the decision tree, by distinguishing implementable routes under real conditions of the territory and by guiding the selection of intervention packages to close gaps before scaling.

# TYPES OF ENERGY COMMUNITIES AND DECISION TOOL

**Purpose**: To define the conditions required for successful replication and scaling.

- Success requires governance clarity, realistic tariffs, strong O&M, and sustained support.
- Transferability depends on territorial conditions, regulatory constraints, and financing availability.

**Key Message: Implementation must be guided by a structured decision tree that begins with territory classification (SIN vs. ZNI) and proceeds through community capacity and technical configuration.**

This section presents the framework of typologies of energy communities and the decision tool that organises, in an operational way, the criteria that determine their viability and implementation route. As a starting point, the classification defined by the MME is adopted, as it constitutes the official reference to guide the registration, targeting and articulation of these initiatives with sectoral public policy.[14] However, the purpose of the chapter is not to replicate a normative categorization in a descriptive way, but to translate it into a functional scheme that allows identifying concrete implications for the technical structuring, institutional arrangement, financial sustainability, and enabling conditions associated with each typology.

In practice, typologies are useful when they allow answering an essential implementation question: under what regulatory, institutional and financial configuration a project can operate as a continuous service in a specific territory. For this reason, the classification is read in the light of dimensions that usually determine the real viability of a community model: the relationship with the system (SIN or ZNI), the mode of generation and use (self-generation or distributed generation, individual or collective), the structure of demand and benefits (savings, income from surpluses, payment for service), the governance scheme and assignment of responsibilities, and the ability to sustain O&M and replenishment under a life-cycle approach. In addition, the ability to receive and manage public resources is incorporated as an operational dimension, since this decision introduces verifiable requirements of traceability, active transparency, accountability and social control mechanisms that must be reflected from the institutional design and flow architecture.

[14] MME classifies energy communities by: (i) service type (generation, distribution, integrated); (ii) grid connection (SIN vs ZNI); (iii) governance model.

From this framework, a decision tool is developed that organizes the regulatory, institutional, technical, and financial criteria identified in the diagnosis. The tool is structured as a decision tree that helps to determine the applicable typology and, at the same time, to identify the enabling conditions that must be closed before advancing to investment and operation phases. The tree is not intended to replace the official framework, but to complement it with an implementation logic: it allows us to distinguish scenarios where the main bottleneck is regulatory, where the dominant thing is the risk of collection or O&M, or where the main constraint is on the eligibility of actors to mobilize capital. Overall, this section serves as a bridge between the diagnosis and the subsequent phases, providing a clear framework to characterize initiatives, prioritize interventions, and build realistic escalation routes, especially in rural territories and ZNI.

## I. Characterization Framework and Classification Criteria

**Purpose**: To define the criteria used to categorize energy communities.

- Classification considers SIN/ZNI location, governance capacity, demand characteristics, and technical configuration.
- These criteria help determine which implementation pathways are viable.

The characterization framework defines the operational criteria with which the energy communities will be described and classified, taking as a reference the typology of the MME, but translating it into verifiable variables that allow comparing initiatives and anticipating implementation implications. The usefulness of a classification, in a scalability-oriented diagnosis, is not in the name of the category but in its ability to guide decisions: what figure applies in regulatory terms, what it requires in measurement and marketing, who can operate and respond for the service, how O&M and replenishment are sustained, and what capital mobilization routes are activated with real actors. Therefore, the framework does not seek to build a parallel taxonomy, but to establish a common language and a minimum set of evidence to place each case within the official typology and, at the same time, link it to enabling conditions and dominant risks.

The framework is organized into criteria that include the determinants that, in the evidence analyzed, explain the operational and financial viability: relationship with the system and the territory (SIN or ZNI), eligibility and institutional capacity to manage public resources, configuration modality and use of energy in practical terms, technical architecture of the system, demand structure and anchor loads, economic value capture mechanism (savings, revenues, payment for service or combination), institutional arrangement and governance, assignment of operational responsibilities, O&M and replenishment scheme under a life cycle approach, and financing structure with identification of the eligible policyholder and the flow manager when applicable.

*Table 29. Classification criteria*

| Characterization criteria | Operational definition | Minimum verifiable evidence | Direct involvement for implementation |
|---|---|---|---|
| **Territory condition** | Define whether the model operates connected to the SIN or in ZNI, type of interaction required with OR/marketer or with a local provider. | SIN/ZNI location and condition; identification of OR/marketer or provider; connection point when applicable. | Determines connection, measurement, marketing and schedule requirements; in ZNI it conditions logistics, spare parts and continuity. |
| **Ability to receive and manage public resources** | Verifies whether initiative is eligible for public resources and has capacity to manage with traceability, active transparency, social control, and accountability, | Target entity / program / call; resource destination; role of the executor and the administrator of the resource; minimum mechanisms of active transparency, and formal channels of attention and follow-up | Defines whether route can be used on public resources without increasing execution risk; may require anchor / executor actors, traceable resource management, periodic reports transaction costs |
| **Configuration and use mode** | Identify how energy is used, and how transactions and associated responsibilities are structured. | Configuration description; basic parameters of capacity and use; cases of self-consumption/surpluses. | Defines billing scheme, benefit allocation, income eligibility, and technical/business requirements. |
| **Technical system architecture** | Describes the technical solution that ensures continuity adjusted to the territory. | Technical scheme; installed capacity; presence of storage/backup; Sizing criteria. | Impact CAPEX/OPEX costs, O&M and replacement criticality, and performance risk; conditions technical support requirements. |
| **Demand and user structure** | Characterizes beneficiaries, consumption pattern, critical loads and potential for anchor loads or productive uses. | Estimation of demand; segmentation; identification of critical loads/anchor; expected growth. | Determines flow stability and bankability; guides sizing and structure of payments; affects collection risk. |

| Characterization criteria | Operational definition | Minimum verifiable evidence | Direct involvement for implementation |
|---|---|---|---|
| **Capture and Allocation of Economic Value** | It defines how value is materialized and how it is distributed among beneficiaries. | Allocation rule; collection mechanism; measurement/tracking support; tariff assumptions. | Conditions legitimacy, payment discipline and sustainability; reduces disputes and deterioration of collection if traceable |
| **Governance and representation** | Defines who represents, how decisions are made, how resources are managed, and how conflicts are resolved; includes anchor entity. | Bylaws/minutes; representation structure; rules for approving expenditures; accountability mechanisms. | Reduces risk of capture and conflict; enables contractual and financial management; it increases the confidence of funders and allies. |
| **Operational responsibilities** | Assign responsibility for measurement, billing, collection, customer service, O&M, replenishment and data management. | Matrix of responsibilities; agreements/contracts; operation and reporting protocols. | Reduces operational ambiguity and cost overruns; improved performance and continuity; strengthens traceability. |
| **O&M and Replenishment** | Establishes how availability is ensured: maintenance, critical spare parts, response times and replenishment fund. | O&M Plan; OPEX budget; reserve fund scheme; performance indicators. | Central condition of sustainability; it reduces the risk of early degradation and loss of legitimacy and revenue. |
| **Financing structure and activatable route** | It defines how CAPEX/OPEX is covered and who can be an eligible policyholder and flow manager. | Intended sources; contribution and debt scheme; policyholder eligibility; Flow traceability. | Determines actual implementability; Identifies eligibility gaps and need for risk mitigation to mobilize capital. |

This framework allows the MME classification to be applied consistently and, at the same time, to produce a comparable characterization between cases, with minimal evidence and with clear consequences on the implementation path. In addition, the criteria are designed to directly feed into the decision tool: each one can become a verification node or an enabling condition that, if not met, significantly increases the risk of execution, performance, or financial operation of the model, and therefore defines specific needs for technical assistance, institutional strengthening, or risk mitigation mechanisms before moving forward to investment and scaling.

## II. Operational typologies and differentiation criteria

**Purpose**: To present the main operational types of energy communities.

- Typologies vary by grid connection, organizational maturity, and energy use patterns.
- Each type implies distinct technical, financial, and governance requirements.

The operational typologies allow the classification of the MME to be translated into differentiated implementation routes, recognizing that two initiatives may share the general label of "energy community" and, however, require completely different regulatory, technical and financial arrangements to be sustainable. Operational differentiation is not built solely by technology, but by the combination of four determinants that directly affect design and bankability; the relationship with the system and the territory (SIN or ZNI), the mode of use and transaction of energy (self-consumption and/or surpluses, individual or collective), the mechanism through which the economic value is materialized (savings, income or payment for service) and the institutional arrangement that assumes critical responsibilities (contractual management, collection, O&M and replacement). In a complementary way, a cross-cutting determinant is incorporated: the ability to access and manage public resources, given that when a route depends on public co-financing or budget allocations, the design must integrate from the beginning verifiable requirements of traceability of flows, active transparency, accountability and social control, as well as the associated transaction costs (monitoring, reports and mechanisms of attention). Under this logic, the official typology is interpreted through criteria that make it possible to distinguish which risks dominate in each case and what minimum conditions must exist to move towards investment and continuous operation.

### A. Relationship with the system and the territory (SIN and ZNI)

The first operational differentiation corresponds to the condition of operation in the SIN or in ZNI, because it defines the type of interaction required with system actors, the nature of the restrictions and the dominant risk of the model. In the SIN, the implementation route is strongly conditioned by requirements for connection, metering, billing, allocation of consumption in collective schemes and treatment of surpluses, in interaction with the network operator and the marketer. At ZNI, sustainability depends less on business integration into the system and more on operational continuity in contexts with complex logistics, technical support limitations, and higher transaction costs. This difference has direct implications on the design: while in SIN the bottleneck is usually located in regulatory-commercial consistency and in connection times and costs, in ZNI the risk is concentrated in sustained technical performance, supply of spare parts, and availability of resources for O&M and replacement from the first year of operation.

### B. Mode of use and allocation of benefits

The second differentiation is located in the way energy is used and translates into economic benefits for the participants. In individual schemes, profit traceability is usually more straightforward, but the scale can be limited and transaction costs per user can rise. In collective schemes, the main challenge is not generation itself, but the definition of operable and legitimate rules for the allocation of benefits, accompanied by measurement and reporting mechanisms that avoid discretion. In addition, the nature of the economic value is decisive: when the model is based on savings from self-consumption, its sustainability depends on the magnitude of the effective savings and the ability to convert it into stable cash flow to cover OPEX and replacement; when surpluses are incorporated, the priority is technical and commercial consistency that allows their treatment and settlement; and when it is structured as payment for energy service, the key is a robust and socially accepted collection scheme. In all cases, the operational typology depends on the benefit being traceable, verifiable and compatible with the collection scheme.

### C. Institutional arrangement and allocation of responsibilities

The third differentiation corresponds to who explicitly assumes responsibility for critical functions: representation and decision-making, contracting and execution of CAPEX, flow management, operation and maintenance, replacement of assets, management of arrears and customer service. In many territories, the community cannot and should not bear all these functions alone, especially when there are gaps in formalization, administrative capacities or technical expertise. Therefore, the operational typology is largely defined by the institutional architecture that makes execution and sustainability possible: whether there is an anchor actor (territorial entity, developer or operator, service company, financial cooperative or fiduciary scheme) that can enter into contracts, manage resources with traceability and sustain operating standards. This criterion is decisive because it conditions the eligibility to activate financial instruments, the way of allocating risks and the credibility of the project before funders and counterparties.

### D. Demand profile, critical loads and economic anchors

The fourth differentiation relates to the demand structure and its ability to sustain stable cash flow. Models with dispersed demand, small consumption, and high dependence on subsidies tend to have less room to finance CAPEX through savings and face greater collection vulnerability, so they more frequently require co-financing, concessional conditions, and mechanisms that protect affordability. In contrast, when there are critical loads or economic anchors (essential community services or productive uses), the model can improve flow stability and increase the viability of provisions for O&M and replenishment. However, these anchors only fulfill their role when their participation is contractually defined and when the allocation of benefits and responsibilities avoids conflicts with residential users. In diagnostic terms, this criterion makes it possible to differentiate typologies with financial scaling potential from those that, due to their demand profile, will need a more intensive design in subsidies, technical assistance and risk mitigation.

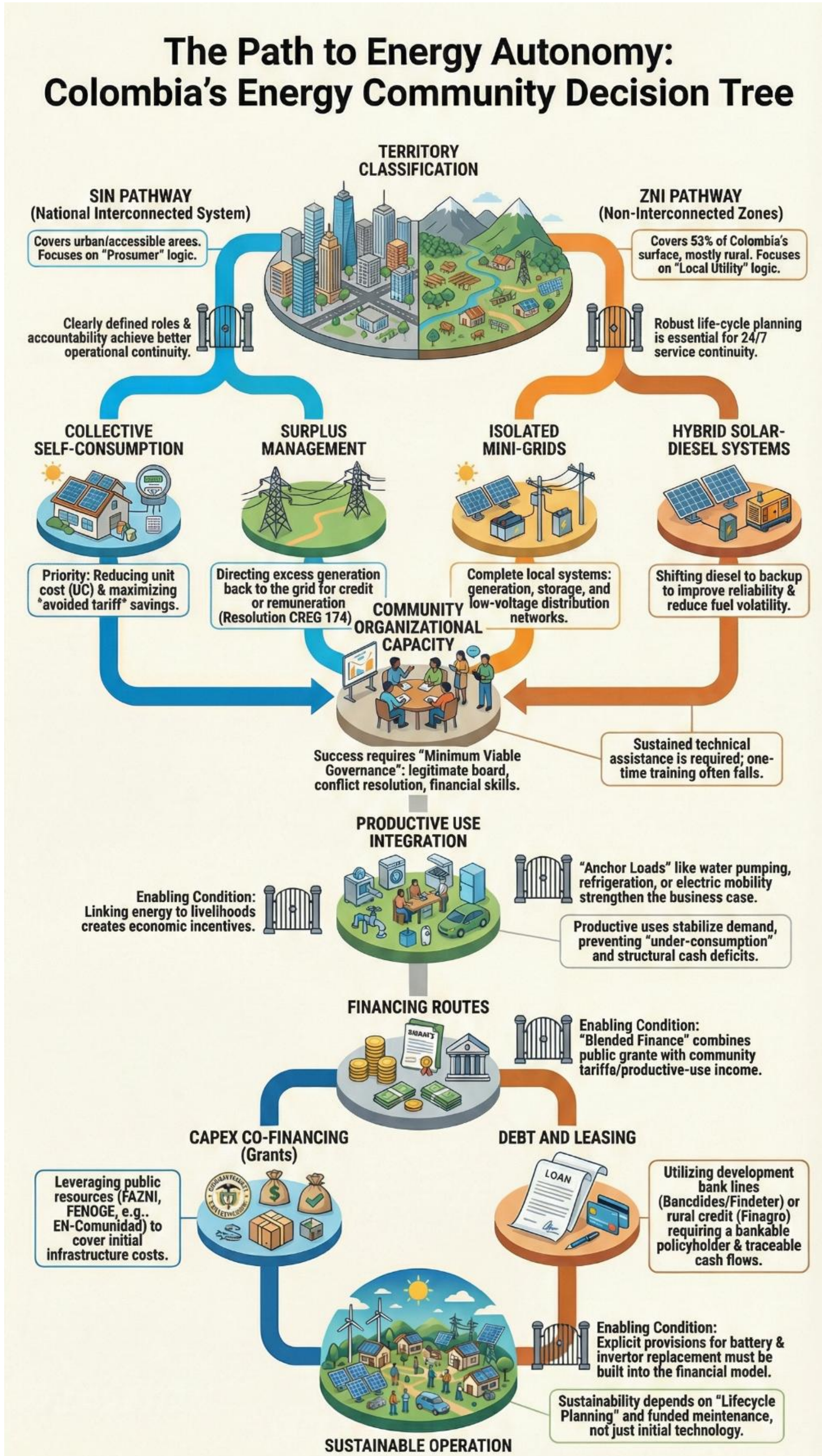
With these four sub-sections, the Ministry's classification becomes actionable: each initiative can be located within the official typology and, at the same time, be characterized by variables that determine its implementation route, its dominant risks and the minimum requirements to be sustainable. On routes with public resources, these minimum requirements also include traceable administration and accountability mechanisms, without which execution often faces institutional friction and operational sustainability risks.

## III. Decision tree for enabling conditions and deployment paths

**Purpose**: To provide a structured tool that guides project design based on contextual factors.

- The first branch distinguishes SIN versus ZNI, shaping regulatory and financial options.
- Subsequent branches incorporate community capacity, technical needs, and financing pathways.

*Figure 2. Decision Tree*



The decision tree organizes, in a sequential and verifiable way, the criteria that determine the implementation route of an energy community and the enabling conditions that must be closed before advancing to investment and operation. Its function is not to "classify by name", but to turn the official typology of the MME into a practical tool to: (i) locate an initiative within the set of applicable configurations, (ii) identify the dominant risk that blocks its viability (regulatory-commercial, collection/revenue, O&M/replenishment, financial eligibility or governance), and (iii) derive an implementation path with milestones and minimum packages of technical preparation, institutional and financial. The tree is built under a logic of "gates" or gates: a verifiable condition is defined in each node; if it is not met, the route does not advance and a corrective action or a prior requirement is activated, preventing the project from being structured on unclosed assumptions that then translate into delays, cost overruns or operational deterioration. Immediately after defining the SIN/ZNI condition, the tree incorporates a specific node to verify the capacity and convenience of receiving public resources, since this decision introduces additional requirements of traceability, active transparency, accountability and social control mechanisms that affect the institutional arrangement, flow management and operational architecture from the beginning.

The tool operates on a central diagnostic principle: implementability depends on aligning three elements in the same design. First, the regulatory and commercial framework that determines how it is connected, how it is measured and how profits or surpluses are settled. Second, the institutional arrangement that defines who is responsible for execution, flow management, operation and maintenance. Third, life-cycle financial sustainability, which requires ensuring the provision of O&M and replenishment from the outset, as well as a traceable collection or value capture architecture. Consequently, the tree is not limited to technical variables; It includes institutional and financial nodes that reflect the reality of access to capital: who is an eligible borrower, which vehicle manages resources, and which mitigators reduce the dominant risk for funders and allies. On routes with public resources, this logic is reinforced: before advancing to investment, the institutional capacity to manage the resource with traceability and reporting must be closed, as well as the minimum package of active transparency and accountability, to avoid late redesigns during execution.

In operational terms, the tree produces two main outputs: first, the identification of the applicable operational typology (combination of territory/system, mode of use, benefit structure, and institutional arrangement), and second, a recommended implementation route with minimum enabling conditions, required evidence, and associated risk mitigation mechanisms. This output is designed to support prioritization processes and downstream financial design: it allows initiatives to be grouped along similar paths, standardize requirements, and reduce transactional friction through repeatable preparation and structuring packages.

*Table 30. Use of the decision tree*

| Operational decision | Minimum verifiable evidence | If the condition is not closed | Enabling Result |
|---|---|---|---|
| **Territory condition** | Location, characterization of the area, identification of OR/marketer or ZNI provider | Determine condition: SIN path requires connection / measurement management; ZNI route requires robust O&M and logistics continuity design | SIN or ZNI Base Path Selection |
| **Ability to receive and manage public resources** | Intended source, destination of resource, role of executor and administrator; transparency mechanisms decision traceability; formal service/follow-up channels | Reconfigure scheme (anchor actor/executor), incorporate a traceable management mechanism, switch to route without public resources adjusting financial and operational design. | Governance, reporting, active transparency, social control for resource management. |
| **Configuration and use mode** | Description of the planned configuration, beneficiary users, self-consumption assumptions and surpluses | Rethinking the benefits model to ensure traceability and operational compatibility | Definition of benefits and transaction architecture |
| **Regulatory-commercial feasibility** | Metering, billing, profit allocation, interaction with RO/marketer, treatment of surpluses when applicable | Configuration adjustment, simplification of rules, closure of technical and commercial requirements | Reducing regulatory and commercial uncertainty |
| **Demand profile and stability of economic value** | Estimation of demand, critical loads, possibility of anchor loads or productive uses, consumption pattern | Resizing, incorporation of anchor loads, adjustment of the revenue model (savings vs. service) | Consistency between system size and payment capacity |
| **Anchor Institution and Responsible Arrangement** | Evidence of representation, preliminary agreements, definition of roles | Definition of anchor actor, fiduciary scheme or traceable management mechanism | Responsibilities and traceability of resources |

| Operational decision | Minimum verifiable evidence | If the condition is not closed | Enabling Result |
|---|---|---|---|
| **Scheme for the collection and allocation of benefits** | Simple and verifiable rule of allocation, collection periodicity, monitoring mechanisms, treatment of arrears | Redesign to reduce conflict and discretion; Strengthening Active Transparency | Stable flow for OPEX and provisions |
| **O&M and replenishment** | O&M plan, OPEX budget, replenishment provision/fund, critical spare parts and response times | Design of mandatory provisions, O&M contracting, definition of KPIs and SLAs | Operational continuity and service protection |
| **Activatable financing route** | Identification of eligible policyholder, expected capital structure, need for collateral/co-financing/TA | Reconfiguration of the vehicle or anchor; incorporation of mitigants | Bankability Shutdown and Capital Mobilization |

From this sequence, the tree allows you to group deployment paths into profiles that are often repeated in practice. In the SIN, the routes tend to bifurcate according to whether the model depends predominantly on savings from self-consumption or whether it incorporates surpluses as a relevant component, and according to the degree of complexity of the allocation of benefits in collective schemes. In ZNI, the critical differentiation is usually between service models with assured continuity (where the provision of O&M and replenishment is closed) and models that depend on diffuse savings without a robust collection structure, which typically require stronger institutional anchors and concessional schemes to sustain operations. In both cases, the tree makes explicit that the "fast route" is not the one that reduces readiness, but the one that closes early the enabling conditions that prevent late redesigns: roles, collection, O&M/replenishment, and financial eligibility.

For implementation purposes, the tool is applied as a verification matrix linked to the tree: each node is marked with available evidence and a closure status (closed/in process/not closed), with an associated risk if it is not met and a standard corrective action. This approach improves consistency between initiatives, facilitates prioritization and allows technical assistance packages and financial instruments to be structured by route, reducing transaction costs and increasing the probability of effective execution in rural territories and ZNI, where constraints are structural and require designs that explicitly and assign risks.

## IV. Application of the tree in financial and operational design

**Purpose**: To show how the decision tree informs financial modeling and implementation planning.

- Each pathway leads to differentiated CAPEX/OPEX assumptions, risk parameters, and collection scenarios.
- The tool ensures financial models reflect real territorial and community conditions.

The application of the tree in financial and operational design consists of translating each implementation path into decisions, instruments and responsibilities that make the project executable and sustainable. The tree is used as a design mechanism to ensure coherence between the regulatory framework, the contractual architecture, the capital structure, and the operation and maintenance scheme. This coherence is critical because energy communities tend to fail when CAPEX is financed without closing the governance of flows, collection and replenishment, or when a commercial scheme is designed that cannot be implemented with real actors in the territory. Under this logic, the application of the tree generates two operational products: (i) a "financial path" that defines which instruments can be activated and in what sequence, according to eligible policyholder and dominant risk; and (ii) an "operational roadmap" that defines who executes, who manages resources, how O&M is secured, and how breaches are managed. The expected result is a design that reduces transactional friction, makes risk allocation explicit, and allows standardizing requirements for scaling by portfolio.

In practice, the application is performed as a calibration exercise between nodes of the tree and design components. Each activated node determines a set of necessary choices and, equivalently, discards combinations that are not consistent with the conditions of the territory. For example, if the route is in ZNI with high exposure to logistics and performance, the operational design requires an outsourced or hybrid O&M scheme with service standards, critical spare parts, and a replacement fund, while the financial design must prioritize mechanisms that protect continuity (co-financing for CAPEX, mandatory lifecycle provisions, and, when feasible, income support or payments conditional on performance). In the SIN, on the other hand, consistency is concentrated in the regulatory-commercial closure (measurement, invoicing, treatment of surpluses) and in the ability to convert economic benefit into stable cash flow to cover OPEX and replenishment, which usually requires flow management structures, clear allocation rules and, depending on the anchor actor, debt or leasing instruments with risk mitigators.

To operationalize this approach, the tree becomes a design board with three layers that are completed consecutively. The first layer defines the "value architecture": whether the model is mainly based on savings from self-consumption, income from surpluses, or payment for service, and what are the conservative assumptions that convert this value capture into cash. The second layer defines the "institutional and flow architecture": who is the eligible borrower, who executes CAPEX, who manages resources and collection, and which agreements ensure traceability, including spending prioritization rules (O&M and replenishment before distributions). The third layer defines the "capital and mitigation architecture": how much of the CAPEX is covered by co-financing, how much by debt or leasing, what collateral or mitigators are needed, and how the O&M and replenishment fund is capitalized with verifiable rules. This sequence requires that the financial design be a consequence of operational design, which is especially important in ZNI.

Based on this logic, four reference combinations are proposed that usually cover most of the paths observable when applying the tree. They are not "unique models", but base configurations that are adjusted by territory, anchor actor and collection capacity. In all cases, the selection criterion is the same: attack the dominant risk that blocks execution and continuity, minimizing transaction costs through standardization and, when possible, portfolio structuring.

*Table 31. Decision tree path*

| Route derived from the tree | Minimal operational design | Minimal Financial Design | Mitigating factors and sustainability rules |
|---|---|---|---|
| **SIN – Self-consumption with traceable profit** | Simple allocation rules, verifiable measurement and reporting, clear admin and collection responsibility | Focused co-financing, debt/leasing for CAPEX when there is an eligible policyholder | Flow management with traceability; mandatory O&M/replenishment provision; service level agreements for O&M; Rules for the treatment of arrears |
| **SIN – Relevant surpluses or mixed scheme (savings + surpluses)** | Regulatory-commercial closing, clear contract/role with RO/marketer | Debt/leasing + mitigating factors for income uncertainty | Document standardization; verification and reporting mechanisms; income buffers; O&M prioritization / replenishment in the payments cascade |
| **ZNI – Energy Service with Priority Continuity** | Delivery with defined O&M, critical spare parts, response protocols, service governance | CAPEX co-financing + concessional structure to reduce tariff/affordability + lifecycle provisions | Replenishment fund and O&M; availability KPIs; performance clauses; resource traceability and social control |
| **ZNI – Model with productive uses / anchor load** | Contractual incorporation of anchor cargo, robust collection scheme and demand risk management | Co-financing + concessional debt when the flow is more stable + guarantees where applicable | Stable collection; rules for assigning and prioritizing the service; managing Flows with separate accounts for O&M / replenishment |

These combinations allow us to move from a diagnostic reading to a replicable design as a guide for structuring portfolios with homogeneous requirements. To scale, each route is associated with a set of minimal evidence and closed decisions. In operation, this reduces the cost of preparing projects, facilitates evaluation by public entities, development or cooperation banks, and allows for packaging technical assistance and financing with less friction. In financial terms, it makes explicit that bankability does not depend only on "obtaining resources", but on demonstrating that the project has a stable value capture mechanism, an anchor responsible with execution capacity, and a continuity structure (O&M and replenishment) protected by verifiable rules.

Applied consistently, the tree also allows for realistic funding sequences to be designed. Before seeking debt or leverage instruments, the typical route requires closing pre-investment and structuring, and establishing flow management mechanisms. Only when the collection node and the O&M/replenishment node are closed does it become reasonable to incorporate debt, leasing or guarantees, because the dominant risk ceases to be "uncontrolled operation" and becomes "mitigable financial". In this sequence, co-financing and technical assistance are not complements: they are enablers to reduce development risk and ensure affordability, allowing market instruments to enter without compromising the social sustainability of the service.

Finally, the application of the tree in the financial and operational design directly feeds into the next phase of the work: the construction of scenarios and the financial model. Each path defines differentiated cost assumptions, risk profiles, replacement provision needs, payment structure and instrument mix. This allows for consistent and comparable scenarios to be modeled, and avoids using a single model for different realities. In this way, the tree becomes the methodological bridge between diagnosis and design: it transforms evidence and gaps into implementable routes, with explicit, verifiable decisions.

# CONCLUSIONS AND RECOMMENDATIONS

## I. Conclusions

Colombia's early experience aligns with global patterns. Energy communities often require external support to meet equity goals. Community participation improves outcomes but requires sustained capacity building. Governance is only effective if it is backed by clear rules and accountability mechanisms. In practice, technological solutions tend to converge towards solar and hybrid schemes when reliability is the main criterion. Consequently, Colombia's challenges in operation and maintenance, financing, and technical and administrative capacity gaps are comparable to those observed in other regions.

At the same time, it is essential to recognize structural differences between Europe and emerging countries such as Colombia. In Europe, many models are built on more robust networks, greater local institutional capacity, mature energy markets, and greater financial depth, facilitating more sophisticated prosumer schemes, aggregation, and value capture mechanisms. In Colombia, especially in ZNI and dispersed rural territories, models must prioritize continuity of service, operational sustainability, and prolonged technical support, with a more decisive role for the State and cooperation to close initial gaps and reduce risks.

One of the critical challenges is to consolidate a clear and shared understanding in public policy about what an energy community is, what objectives it pursues, and what are the implementation routes according to the territory. This clarity must be translated into explicit incentives for the participation of the different actors. Without an alignment of incentives, projects tend to rely on isolated efforts, fragment, or remain as pilots without scale, limiting their impact.

In a complementary way, the enabling framework must strengthen the perception of security and guarantees for stakeholders. This implies reducing regulatory and operational uncertainty through stable and understandable rules, guidelines on ownership, operation and responsibilities, clarity on access to and use of public resources, consistent criteria for tariffs or cost recovery when applicable, and practical mechanisms for inter-institutional articulation. In complex territories, this security must be legal, technical and operational, so that there is clarity about who responds to failures, how the replacement of equipment is financed, how the continuity of the service is ensured and how accountability processes are sustained.

In terms of design, Colombia has a differential opportunity to leverage its territorial energy potentials derived from geographical and climatic conditions. Favourable solar radiation over large areas and the possibility of configuring hybrid solutions with storage make it possible to adapt the energy supply to different demand profiles. This reinforces the need for a territorial approach, where the technological criterion responds to the expected service and the local reality, avoiding unique solutions for heterogeneous contexts.

Therefore, the viability of energy communities is not uniform. It depends on the regulatory context, the community management capacity, the associated productive potential and the real possibility of leveraging resources with a coherent implementation route. The most robust models combine initial investment with public or concessional resources, operational sustainability with realistic management and collection schemes when appropriate, and an explicit strategy for replacement, maintenance, and renovation. At the same time, community and municipal institutional strengthening must be assumed as an asset as important as infrastructure, because without capacities to manage, operate and be accountable, technical and governance risks increase.

Finally, international evidence and national analysis converge that energy communities are a viable way to move towards universal access and energy resilience in remote areas, but they are not an automatic solution. Its success requires careful planning, sustainability over time and continuous improvement. Well designed, they can deliver not only electricity, but also social empowerment and local economic opportunities. In summary, Colombia is well positioned to consolidate a specific framework for energy communities, and the decisive challenge will be to turn it into an enabling environment with clear incentives, credible guarantees for actors, effective institutional coordination, and a territorial approach that leverages the energy potential of each region to ensure lasting impacts on historically lagging communities.

## II. Recommendations

The next step of the project consists of the construction of a financial model based on the decision tree, which allows for a consistent assessment of the financial viability of energy communities in Colombia under different territorial, regulatory and operational conditions. This model must translate the criteria of the tree into quantifiable assumptions and comparable financial routes, so that it is possible to estimate, for each typology and context, the total cost of the project, its sustainability in operation, its financing gap and the realistic alternatives to close it.

The model must incorporate the logic of segmentation of the tree, differentiating at least between SIN and ZNI contexts, levels of organizational and operational capacity of the community, possibility of access to public resources and conditions of institutional articulation. Based on these branches, the model must parameterize the technological dimensioning and the scope of the accompaniment, as well as the main determinants of cost and risk. The expected result is not a single "average" case, but a set of standard scenarios that represent the most likely paths of implementation and allow comparing which combinations of conditions make the project viable and which require design adjustments, greater support or changes in the financing structure.

To reflect the reality of the lifecycle, the model should be structured with a CAPEX and OPEX approach throughout the project horizon, including equipment replacement, preventive and corrective maintenance, logistics, insurance where applicable, and capacity building and governance costs. Similarly, it must incorporate assumptions of demand and quality of service, evolution of consumption, technical and non-technical losses, and, when appropriate, cost recovery alternatives such as tariffs, community contributions or other mechanisms compatible with the regulatory framework and with affordability criteria.

A central component of the next step is to estimate the financing capacity of each typology. This involves identifying, for each path in the tree, which sources are plausible and in what proportion. The model must map public resources, cooperation, territorial contributions, subsidy or incentive mechanisms, and, when feasible, private equity participation or concessional financing. It is not just a matter of listing sources, but of evaluating their fit with the nature of the project, the expected flows and the risks perceived by each actor. With this, the model must quantify the financing gap, propose combinations of instruments and show minimum conditions for the structure to be bankable, including guarantee requirements, institutional stability and clarity on who assumes responsibilities for operation and replacement.

In coherence with the project methodology, this step must be developed in an iterative manner, combining technical construction of the model with territorial and institutional validation. A phase of defining assumptions and structure of the model is recommended, followed by a calibration with reference cases and observed costs, and then a validation with key actors to adjust critical assumptions. The model must allow sensitivities on variables of greater impact, such as logistics costs in ZNI, useful life and replacement of batteries, level of support required, quality of community management, and effective availability of public resources. The final product should facilitate decision-making, transparently showing what factors enable sustainability and what bottlenecks need to be resolved before scaling.

As a result, the decision tree-based financial model will become an operational tool to guide prioritization and design. It will make it possible to compare routes, justify investment and support decisions, and propose guidelines for public policy aimed at reducing uncertainty and improving the "bankability" of projects. Ultimately, this next step must provide not only numbers, but a clear reading of feasibility and support needs by typology, enabling a realistic implementation agenda for energy communities in different territories of the country.

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# APPENDIX

## 1. Summary normative matrix (SIN vs ZNI)

| Standard | Year | Entity | Theme | What it enables | What it requires | Practical involvement for energy communities | Observations (SIN vs ZNI) |
|---|---|---|---|---|---|---|---|
| Law 142 | 1994 | Congress | Public services; Solidarity | Benefit and solidarity regime | Billing, subsidies/contributions | Define collection logic and sustainability of O&M | General applies; Impact varies by territory |
| Law 143 | 1994 | Congress | Electricity regime | Sector Structure (G-T-D-C) | Sectoral competences and rules | Determines counterparties (RO/marketer) and contractual structure | General base; ZNI is complemented by specific rules |
| Law 1715 | 2014 | Congress | FNCER | FNCER Integration and Incentives | Promotion conditions/instruments | Enables typical technologies for CE | General; Implementation depends on the scheme |
| Law 2099 | 2021 | Congress | Energy transition | Strengthens transition and efficiency | Additional provisions | Reinforces FNCER/efficiency enablers | Complements Law 1715 |
| Law 2294 (Art. 235) | 2023 | Congress | Energy communities | EC legal framework | General Guidelines | Legal basis for EC | Apply SIN and ZNI |
| Decree 2236 | 2023 | Mines/Presidency | EC Regulation | Operational Guidelines | Requirements/Implementation | General Operational Path for CE | Apply SIN and ZNI |
| Res. 40136 | 2024 | MinMinas | RUCE | Create Record | Enrollment/Update | Eligibility and traceability | General Applies |
| Res. 40137 | 2024 | MinMinas | Targeting | Criteria for targeting resources | Prioritization/Eligibility | Access to public support by program | Relevant in prioritized territories |

| Standard | Year | Entity | Theme | What it enables | What it requires | Practical involvement for energy communities | Observations (SIN vs ZNI) |
|---|---|---|---|---|---|---|---|
| Res. 40165 | 2024 | MinMinas | Active transparency | Transparency and Data Guidelines | Proactive Publication and Traceability | Supports trust and caution | General Applies |
| Res. CREG 030 | 2018 | CREG | AGPE/GD | Integration into SIN | Connection/Operation | Connection and design costs/timelines | WITHOUT |
| Res. CREG 174 | 2021 | CREG | AGPE/GD | Settings; Surpluses | Technical/Commercial Requirements | Savings Cash/Surpluses; Transaction Costs | WITHOUT |

## 2. Tariff summary (example of tariff publication, December 2025)

The table below summarises published values for LV/Tier 1 (COP/kWh) and subsistence consumption ranges, for reference purposes for financial modelling. Values may vary by market/trader and must be verified in official publications of the relevant broker.[18]

| Category | Block | Tariff (COP/kWh) | Observations |
|---|---|---|---|
| **Residential Stratum 1** | 0–CS | 402,83 / 390,35 / 377,88 | BT/Level 1. Three property configurations. |
| **Residential Stratum 1** | >CS | 859,19 / 824,84 / 790,49 | Full rate above CS. |
| **Residential Stratum 2** | 0–CS | 503,53 / 487,94 / 472,35 | |
| **Residential Stratum 2** | >CS | 859,19 / 824,84 / 790,49 | |
| **Residential Estrato 3** | 0–CS | 730,31 / 701,11 / 671,92 | |
| **Residential Estrato 3** | >CS | 859,19 / 824,84 / 790,49 | |
| **Residential Estrato 4** | All | 859,19 / 824,84 / 790,49 | |

| Category | Block | Tariff (COP/kWh) | Observations |
|---|---|---|---|
| **Residential Strata 5–6** | All | 1031,03 / 989,81 / 948,59 | Includes contribution. |
| **Industrial & Commercial** | N/A | 1031,03 / 989,81 / 948,59 | |
| **Official and Exempt** | N/A | 859,19 / 824,84 / 790,49 | |
| **Subsistence consumption** | Altitude ≥ 1,000 meters above sea level | 0–130 kWh/month | Subsidized range. |
| **Subsistence consumption** | Altitude < 1,000 meters above sea level | 0–173 kWh/month | Subsidized range. |

Source: Publication of rates (December 2025).

## 3. Interview Memoirs

### GGGI

### 1. General Information and Characterization

| Item | Information |
|---|---|
| Date | **January 29, 2026** |
| Mode | **Virtual** |
| Entity / Organization | **GGGI** |
| Name | **Juan Fernando Higuita Peña** |
| Post | **Sustainable Energy Senior Officer** |
| Type of actor | **The Global Green Growth Institute (GGGI) is an international cooperation organization that supports governments and territories in their transition to green growth models through technical assistance, public policy development, the structuring of financial instruments, and the strengthening of institutional and community capacities. Within the energy communities ecosystem, it acts as a strategic enabler, supporting awareness-raising processes, business model design, the structuring of financing mechanisms, and the transfer of assets to communities. It promotes sustainable schemes where energy is managed as an economically viable service. Its role is to ensure that these projects do not depend exclusively on subsidies, but rather evolve into self-sustaining models with community participation, private investment, and collaboration with stakeholders in the energy system.** |
| Consulting team | **Antonio Jaramillo, Valentina Jiménez and Erika Diaz** |

### 2. Purpose of the Interview

The interview aimed to gather lessons learned, best practices, and challenges identified by a technical expert in the energy sector with experience in clean energy solutions and distributed generation, in order to understand what factors facilitate or limit the implementation of energy communities in different regions. Based on their work in structuring financial instruments, strengthening community capacities, and transferring energy assets, the interview sought to identify how these projects can evolve into self-sustaining business models, avoiding dependence on subsidies and promoting the effective participation of communities, the private sector, and public entities.

### 3. Experience or General Perspective on Energy Communities

| Aspects | Comments |
|---|---|
| Role of the entity in the ecosystem | GGGI acts as a strategic enabler and facilitator in the development of energy communities, providing technical assistance, structuring financial instruments, and |

| | |
|---|---|
| | strengthening capacities to ensure project sustainability. Its role includes supporting community awareness processes, designing business models for the operation of energy assets, facilitating the participation of investors and financial institutions, and promoting schemes where the community is a partner in the energy system. It also fosters collaboration among local governments, the private sector, and communities to ensure that projects operate as sustainable businesses and do not depend exclusively on subsidies. |
| Level of progress observed (international / national) | Internationally, energy communities are moving towards models where users are partners in the system, with the participation of investors, specialized operators, and financial mechanisms that ensure long-term sustainability. In Colombia, the model is still in an early stage of development, with an emphasis on subsidies and the transfer of assets to communities without sufficient capacity to operate them as businesses. There is a clear need to transition to market-based schemes, with charges based on energy consumption, designated operators, and financial participation from public and private actors to guarantee the model's sustainability. |
| Main opportunities identified | • Positioning communities as partners in the energy model, strengthening their sense of belonging.<br>• Develop financial instruments that allow projects to scale up and attract investors.<br>• Participation of international cooperation as a technical and financial enabler.<br>• Involvement of local governments as co-investors in vulnerable areas.<br>• Implementation in non-interconnected areas and communities of strata 1 and 2 with high social impact.<br>• Creation of sustainable business models with investment horizons of 10 to 15 years.<br>• Improved quality of life through continuous access to energy and economic development opportunities. |
| Main challenges identified | • Lack of technical, administrative and business capabilities in communities to operate energy systems as sustainable businesses.<br>• Dependence on initial subsidies hinders the transition to self-sustaining models over time.<br>• Handing over assets without a clear model for operation, maintenance, and governance can turn them into liabilities for the community. |

| | |
|---|---|
| | • Lack of a culture of paying for energy services, associated with the perception that community energy should be free.<br>• Difficulty in structuring clear agreements between community, companies and investors on roles, responsibilities and distribution of benefits.<br>• Limited knowledge of the energy sector by communities, which affects informed decision-making.<br>• The need for guarantees or collateral to access financing restricts the participation of vulnerable communities.<br>• Challenges in the articulation between public, private and financial actors to consolidate viable business models.<br>• Risk of financial sustainability if charging schemes per kWh and responsible system operators are not established. |

### 4. Contributions of the Interviewee

| Topic covered | Main comments |
|---|---|
| Overview of energy communities | Energy communities should be conceived as socio-business models where the community participates as a partner in energy generation and management, rather than as a passive recipient of subsidies. These schemes aim to guarantee access to reliable energy, promote local economic development, and strengthen community governance. For their sustainability, they must operate under principles of financial viability, charge based on consumption, and professional asset management, avoiding the perception of free energy and fostering a culture of shared responsibility. |
| Relevant experiences or references | The experience in Bahía Málaga was highlighted, where a process of approximately 60 months was supported, including community awareness-raising, the transfer of energy assets, and the development of financial instruments to boost the local economy. This experience demonstrated that transferring assets without capacity building can create operational difficulties, and that energy systems must be managed as community businesses to ensure their long-term sustainability. |
| Conditions necessary for its development | • Awareness-raising and community capacity-building processes prior to the delivery of assets.<br>• Clear business models that allow energy systems to operate sustainably.<br>• Participation of companies in the energy sector as investors or operators. |

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|---|---|
| | • Community agreements that define roles, responsibilities and distribution of benefits.<br>• Energy consumption billing schemes that ensure income for operation and maintenance.<br>• Collaboration between government, private sector, international cooperation and communities.<br>• Access to financing with guarantees or alternative mechanisms adapted to the community context. |
| Financial considerations | Energy communities should be structured under sustainable financial models, with investment horizons of 10 to 15 years similar to PPA schemes. It is essential to establish charges per kWh consumed, even when the energy comes from community systems, to cover operation, maintenance, and asset replacement. Subsidies can act as initial enablers, but should not replace system revenues. The participation of financial institutions, intermediaries, and public-private co-investment schemes can facilitate access to capital, provided that guarantees or risk mitigation mechanisms are in place. |
| Risks and possible solutions | **Risks:**<br>• Dependence on subsidies that compromises the sustainability of the model.<br>• Community inability to operate energy assets as businesses.<br>• Perception of free energy that affects the culture of payment.<br>• Lack of guarantees to access financing.<br>• Disarticulation between key actors in the ecosystem.<br>**Possible solutions:**<br>• Strengthening business and energy capacities in the community.<br>• Implementation of consumption-based pricing schemes and financial education.<br>• Design of guarantee mechanisms adapted to community contexts.<br>• Participation of specialized operators to ensure technical sustainability.<br>• Governance models that integrate community, businesses and the public sector. |
| Recommendations for Colombia | • Transitioning from welfare models towards self-sustaining energy schemes.<br>• Strengthening community capacities to manage energy assets as businesses. |

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| | • Design financial instruments adapted to energy communities.<br>• Promote co-investment between the public sector, private sector and international cooperation.<br>• Establish clear guidelines on governance, consumption charges and operation.<br>• Prioritize projects in non-interconnected areas and vulnerable communities with a productive focus.<br>• Integrate energy communities as an engine of local economic development, not just as an energy solution. |

**5. Key Elements Highlighted**

| Aspect | observations |
|---|---|
| Critical factors for success | • To conceive of energy communities as sustainable business models, not as welfare projects.<br>• Strengthening community capacities for the technical, administrative and financial management of the systems.<br>• Establishment of energy consumption charge schemes that guarantee income for operation and maintenance.<br>• Participation of specialized operators to ensure the technical sustainability of the system.<br>• Clear governance agreements between community, businesses and public institutions.<br>• Effective coordination between ecosystem actors (government, private sector, financing and cooperation).<br>• Awareness processes that promote ownership and a sense of community belonging. |
| Aspects that require strengthening | • Energy and financial education to promote a culture of payment and system sustainability.<br>• Community business capabilities to operate assets as productive units.<br>• Design of guarantee mechanisms that allow access to financing.<br>• Language and communication that facilitate the understanding of the model by the communities.<br>• Regulatory frameworks and operational guidelines adapted to community contexts.<br>• Strategies to reduce dependence on subsidies in the long term. |

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| Strategic actors | • Communities organized as partners and managers of the energy system.<br>• Companies in the energy sector as investors, operators or technical partners.<br>• Local and national governments as enablers, co-investors, and regulators.<br>• Financial institutions and intermediaries that structure adapted credit mechanisms.<br>• International cooperation as a technical and financial facilitator.<br>• Network operators for integration into the electrical system and surplus management. |

**6. Summary of the Consulting Team**

| Element | Observations |
|---|---|
| Connection with other interviewees | GGGI provides the systemic and financial approach that articulates the perspectives of the other stakeholders. Its proposals on sustainable business models, financial instruments, and community governance complement the technical expertise of Enel Técnico, the social appropriation strategies of Enel Sostenibilidad, and the operational challenges identified by B2CLEAN. GGGI connects these elements by emphasizing that energy communities must operate as sustainable businesses with community participation, private investment, and institutional support. |
| Implications for the final diagnosis | • The model should be designed as a sustainable business, not as a welfare scheme.<br>• Financial instruments adapted to the community context are required.<br>• The community must be a partner in the system, not just a beneficiary.<br>• It is key to avoid dependence on subsidies to ensure sustainability.<br>• The diagnosis must integrate governance, financing, and community capacities. |

**ENEL - Sustainability**

## 1. General Information and Characterization

| Item | Information |
|---|---|
| Date | **February 11, 2026** |
| Mode | **Virtual** |
| Entity / Organization | **ENEL - Sustainability** |
| Name | **Cesar Mejia** |
| Post | **Technical Manager Enel** |
| Type of actor | **Enel Colombia, through its technical division, participates in the development of energy communities as a system developer and operator. It is responsible for designing, implementing, and commissioning distributed generation infrastructure, as well as managing its integration with the electrical grid and ensuring regulatory compliance. Its role includes the technical and regulatory structuring of the model, the initial operation of the system, the definition of benefit distribution mechanisms, and the progressive transfer of capabilities to the community for its ownership and sustainability. Within the ecosystem, it acts as a key player, translating the regulatory framework into operational solutions, mitigating technical risks, and facilitating the transition from traditional schemes to energy community models.** |
| Consulting team | **Antonio Jaramillo, Valentina Jiménez** |

## 2. Purpose of the Interview

The interview aimed to understand the technical, operational, and regulatory lessons learned from the design and implementation of one of the first energy communities in Paratebueno, in order to identify the factors that facilitate or hinder the transition from distributed generation schemes to sustainable energy community models. Drawing on Enel's experience in structuring, initial operation, regulatory compliance, and the progressive transfer of the system to the community, the study sought to analyze mechanisms for benefit distribution, integration with the electrical grid, and strategies to ensure the technical and financial sustainability of the model in rural contexts.

## 3. Experience or General Perspective on Energy Communities

| Aspects | Comments |
|---|---|
| Role of the entity in the ecosystem | Enel, through its technical division, acts as the initial developer and operator of energy communities, handling the design, implementation, and commissioning of distributed generation infrastructure, as well as its integration with the electrical grid and compliance with regulatory requirements. Its role includes structuring the |

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| | technical and regulatory model, managing injection accounts and billing, defining mechanisms for distributing energy benefits, and progressively transferring ownership and operation of the system to the community. Furthermore, it facilitates collaborative agreements with community organizations and ensures operational sustainability through maintenance schemes and the provision of resources for future upgrades. |
| Level of progress observed (international / national) | At the national level, the Paratebueno project stands out as one of the first officially designed and operational energy communities in Colombia, demonstrating progress in the transition from distributed generation schemes to community-based models. However, the process has taken longer than anticipated due to regulatory adjustments, certifications, and construction permits, reflecting a lack of regulatory clarity and the early stage of the model in the country. Experience shows that, while infrastructure and technical capacity exist, regulatory definitions and operational mechanisms that would allow for more agile replication of the model are still being consolidated. |
| Main opportunities identified | • Use of existing infrastructure to transition to energy community models.<br>• Generating economic benefits for users through injection accounts and reducing the bill by up to 50%.<br>• Creation of community funds for future maintenance of the system.<br>• Progressive transfer of ownership and management of the system to the community.<br>• A replicable model in rural areas with difficulties connecting to the network.<br>• Proportional distribution of benefits based on actual consumption patterns.<br>• Strengthening the relationship between the community and the energy operator. |
| Main challenges identified | • Lack of regulatory clarity and definitions regarding energy communities.<br>• Lack of awareness of the concept on the part of communities and institutional actors.<br>• Prolonged times for compliance with certifications, registrations and legal requirements.<br>• Logistical difficulties in isolated rural areas (access, climate, transport of supplies). |

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| | • Initial dependence on the operator for structuring and sustainability of the model.<br>• Need to establish clear governance mechanisms before transferring ownership to the community.<br>• Sustainability risk if resources are not consolidated for future maintenance.<br>• Complexity in the equitable management of benefits without generating positive balances that affect the operation. |

**4. Contributions of the Interviewee**

| Topic covered | Main comments |
|---|---|
| Overview of energy communities | Energy communities are understood as an evolution of distributed generation, where electrical infrastructure is collectively managed to generate economic and operational benefits for users. Beyond the installation of solar systems, the model involves integration with the electrical grid, management of feed-in accounts, and the proportional distribution of benefits based on consumption. Its sustainability depends on regulatory compliance, the clear definition of governance mechanisms, and the progressive transfer of responsibilities to the community. |
| Relevant experiences or references | The Paratebueno case represents one of the first officially designed and operational energy communities in Colombia, built upon a pre-existing 22 kW mini-grid solar infrastructure that supplied 21 homes and a school in a remote rural area. Building on this foundation, Enel spearheaded the transition to the energy community model, supporting its structuring, regulatory compliance, and commissioning for three years. The project includes 72 solar panels, a feed-in account to generate economic benefits, and community agreements for the future transfer of ownership of the system. |
| Conditions necessary for its development | • Regulatory and normative clarity that facilitates the implementation of the model.<br>• Adequate technical infrastructure adapted to isolated rural contexts.<br>• Community agreements that define governance, benefits, and responsibilities.<br>• Profit distribution models based on actual consumption to facilitate management.<br>• Creation of community funds for maintenance and future sustainability.<br>• Initial technical support to ensure proper system operation.<br>• Strategies for the progressive transfer of ownership and management to the community. |

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| Financial considerations | The model offers economic benefits to users by reducing their electricity bills by up to 50%, derived from the energy injection account. Part of these benefits is allocated to a community fund for future maintenance, ensuring operational sustainability. The community made no initial financial contributions, which facilitated implementation, while Enel assumed the initial investment and support. Additionally, costs associated with land lease and the need for future resources for system replacement and maintenance are taken into account. |
| Risks and possible solutions | **Risks:**<br>• Lack of regulatory clarity that delays implementation.<br>• Initial dependence of the operator for the sustainability of the system.<br>• Logistical difficulties in isolated rural areas (climate, access, transport).<br>• Possible lack of resources for future maintenance if the community fund is not managed properly.<br>• Lack of awareness of the model on the part of the community and institutional actors.<br>**Possible solutions:**<br>• Strengthen clear regulatory guidelines for energy communities.<br>• Establish community financial mechanisms for maintenance and replacement.<br>• Design technical models adapted to rural and climatic conditions.<br>• Progressive technical support with capacity transfer.<br>• Socialization processes to strengthen understanding and appropriation of the model. |
| Recommendations for Colombia | • Accelerate the normative and regulatory definition for energy communities.<br>• Promote the transition from distributed generation to sustainable community models.<br>• Establish clear mechanisms for the distribution of energy benefits.<br>• Integrate community funds for maintenance from the project design stage.<br>• Prioritize projects in isolated rural areas where the model generates greater value. |

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| | • Design replicable schemes based on pilot experiences like Paratebueno.<br>• Strengthen the coordination between operators, communities and regulatory entities. |

**5. Key Elements Highlighted**

| Aspect | observations |
|---|---|
| Critical factors for success | • Clarity in the regulatory framework and regulatory compliance from the project design stage.<br>• Adequate technical infrastructure adapted to rural and difficult access conditions.<br>• Sustained initial technical support to ensure proper commissioning.<br>• Transparent mechanisms for distributing benefits based on actual consumption.<br>• Creation of community funds for maintenance and future sustainability.<br>• Formal collaboration agreements with the community that define roles and responsibilities.<br>• Progressive transfer of ownership and management to strengthen community ownership. |
| Aspects that require strengthening | • Clear regulatory definitions on energy communities and their operation.<br>• Community capacities for the technical and administrative management of the system.<br>• Governance mechanisms that ensure sustainability after the operator's departure.<br>• Strategies to ensure sufficient resources for long-term maintenance.<br>• Socialization processes that strengthen the understanding of the energy model.<br>• Institutional coordination to expedite certifications, registrations, and permits. |
| Strategic actors | • Enel as developer, initial operator and technical facilitator of the model.<br>• Communities organized as future owners and managers of the system.<br>• Regulatory entities that define guidelines for energy communities. |

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| | • Network operators that enable the integration and management of injected energy.<br>• Local governments as institutional facilitators and potential co-funders.<br>• Landowners who enable the installation of energy infrastructure. |

### 6. Summary of the Consulting Team

| Element | Observations |
|---|---|
| Connection with other interviewees | Enel's technical team contributes the regulatory, operational, and grid integration perspective, complementing the social (Enel Sustainability), financial (GGGI), and operational (B2CLEAN) perspectives. Their experience highlights the regulatory challenges, certification timelines, and the need for clear benefit-sharing mechanisms, connecting with the governance concerns raised by GGGI and the operational challenges identified by B2CLEAN. Furthermore, it reinforces the importance of community ownership promoted by Enel Sustainability through the progressive transfer of ownership. |
| Implications for the final diagnosis | • Regulatory clarity will be a determining factor for the viability of the model.<br>• Transparent mechanisms for distributing energy benefits are required.<br>• The progressive transfer of ownership can strengthen community sustainability.<br>• The design must consider timelines and regulatory requirements from the outset.<br>• The diagnosis must integrate the technical-regulatory dimension as a structural axis. |

## ENEL – Energy

### 1. General Information and Characterization

| Item | Information |
|---|---|
| Date | **February 11, 2026** |
| Mode | **Virtual** |
| Entity / Organization | **ENEL - Energy** |
| Name | **Cesar Mejia** |
| Post | **Technical Manager Enel** |
| Type of actor | **Enel Colombia, through its technical division, participates in the development of energy communities as a system developer and operator. It is responsible for designing, implementing, and commissioning distributed generation infrastructure, as well as managing its integration with the electrical grid and ensuring regulatory compliance. Its role includes the technical and regulatory structuring of the model, the initial operation of the system, the definition of benefit distribution mechanisms, and the progressive transfer of capabilities to the community for its ownership and sustainability. Within the ecosystem, it acts as a key player, translating the regulatory framework into operational solutions, mitigating technical risks, and facilitating the transition from traditional schemes to energy community models.** |
| Consulting team | **Antonio Jaramillo, Valentina Jiménez** |

### 2. Purpose of the Interview

The interview aimed to understand the technical, operational, and regulatory lessons learned from the design and implementation of one of the first energy communities in Paratebueno, in order to identify the factors that facilitate or hinder the transition from distributed generation schemes to sustainable energy community models. Drawing on Enel's experience in structuring, initial operation, regulatory compliance, and the progressive transfer of the system to the community, the study sought to analyze mechanisms for benefit distribution, integration with the electrical grid, and strategies to ensure the technical and financial sustainability of the model in rural contexts.

### 3. Experience or General Perspective on Energy Communities

| Aspects | Comments |
|---|---|
| Role of the entity in the ecosystem | Enel, through its technical division, acts as the initial developer and operator of energy communities, handling the design, implementation, and commissioning of distributed generation infrastructure, as well as its integration with the electrical grid and compliance with regulatory requirements. Its role includes structuring the |

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| | technical and regulatory model, managing injection accounts and billing, defining mechanisms for distributing energy benefits, and progressively transferring ownership and operation of the system to the community. Furthermore, it facilitates collaborative agreements with community organizations and ensures operational sustainability through maintenance schemes and the provision of resources for future upgrades. |
| Level of progress observed (international / national) | At the national level, the Paratebueno project stands out as one of the first officially designed and operational energy communities in Colombia, demonstrating progress in the transition from distributed generation schemes to community-based models. However, the process has taken longer than anticipated due to regulatory adjustments, certifications, and construction permits, reflecting a lack of regulatory clarity and the early stage of the model in the country. Experience shows that, while infrastructure and technical capacity exist, regulatory definitions and operational mechanisms that would allow for more agile replication of the model are still being consolidated. |
| Main opportunities identified | • Use of existing infrastructure to transition to energy community models.<br>• Generating economic benefits for users through injection accounts and reducing the bill by up to 50%.<br>• Creation of community funds for future maintenance of the system.<br>• Progressive transfer of ownership and management of the system to the community.<br>• A replicable model in rural areas with difficulties connecting to the network.<br>• Proportional distribution of benefits based on actual consumption patterns.<br>• Strengthening the relationship between the community and the energy operator. |
| Main challenges identified | • Lack of regulatory clarity and definitions regarding energy communities.<br>• Lack of awareness of the concept on the part of communities and institutional actors.<br>• Prolonged times for compliance with certifications, registrations and legal requirements.<br>• Logistical difficulties in isolated rural areas (access, climate, transport of supplies). |

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| | • Initial dependence on the operator for structuring and sustainability of the model.<br>• Need to establish clear governance mechanisms before transferring ownership to the community.<br>• Sustainability risk if resources are not consolidated for future maintenance.<br>• Complexity in the equitable management of benefits without generating positive balances that affect the operation. |

**4. Contributions of the Interviewee**

| Topic covered | Main comments |
|---|---|
| Overview of energy communities | Energy communities are understood as an evolution of distributed generation, where electrical infrastructure is collectively managed to generate economic and operational benefits for users. Beyond the installation of solar systems, the model involves integration with the electrical grid, management of feed-in accounts, and the proportional distribution of benefits based on consumption. Its sustainability depends on regulatory compliance, the clear definition of governance mechanisms, and the progressive transfer of responsibilities to the community. |
| Relevant experiences or references | The Paratebueno case represents one of the first officially designed and operational energy communities in Colombia, built upon a pre-existing 22 kW mini-grid solar infrastructure that supplied 21 homes and a school in a remote rural area. Building on this foundation, Enel spearheaded the transition to the energy community model, supporting its structuring, regulatory compliance, and commissioning for three years. The project includes 72 solar panels, a feed-in account to generate economic benefits, and community agreements for the future transfer of ownership of the system. |
| Conditions necessary for its development | • Regulatory and normative clarity that facilitates the implementation of the model.<br>• Adequate technical infrastructure adapted to isolated rural contexts.<br>• Community agreements that define governance, benefits, and responsibilities.<br>• Profit distribution models based on actual consumption to facilitate management.<br>• Creation of community funds for maintenance and future sustainability.<br>• Initial technical support to ensure proper system operation.<br>• Strategies for the progressive transfer of ownership and management to the community. |

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| Financial considerations | The model offers economic benefits to users by reducing their electricity bills by up to 50%, derived from the energy injection account. Part of these benefits is allocated to a community fund for future maintenance, ensuring operational sustainability. The community made no initial financial contributions, which facilitated implementation, while Enel assumed the initial investment and support. Additionally, costs associated with land lease and the need for future resources for system replacement and maintenance are taken into account. |
| Risks and possible solutions | **Risks:**<br>• Lack of regulatory clarity that delays implementation.<br>• Initial dependence of the operator for the sustainability of the system.<br>• Logistical difficulties in isolated rural areas (climate, access, transport).<br>• Possible lack of resources for future maintenance if the community fund is not managed properly.<br>• Lack of awareness of the model on the part of the community and institutional actors.<br>**Possible solutions:**<br>• Strengthen clear regulatory guidelines for energy communities.<br>• Establish community financial mechanisms for maintenance and replacement.<br>• Design technical models adapted to rural and climatic conditions.<br>• Progressive technical support with capacity transfer.<br>• Socialization processes to strengthen understanding and appropriation of the model. |
| Recommendations for Colombia | • Accelerate the normative and regulatory definition for energy communities.<br>• Promote the transition from distributed generation to sustainable community models.<br>• Establish clear mechanisms for the distribution of energy benefits.<br>• Integrate community funds for maintenance from the project design stage.<br>• Prioritize projects in isolated rural areas where the model generates greater value. |

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| | • Design replicable schemes based on pilot experiences like Paratebueno.<br>• Strengthen the coordination between operators, communities and regulatory entities. |

**5. Key Elements Highlighted**

| Aspect | observations |
|---|---|
| Critical factors for success | • Clarity in the regulatory framework and regulatory compliance from the project design stage.<br>• Adequate technical infrastructure adapted to rural and difficult access conditions.<br>• Sustained initial technical support to ensure proper commissioning.<br>• Transparent mechanisms for distributing benefits based on actual consumption.<br>• Creation of community funds for maintenance and future sustainability.<br>• Formal collaboration agreements with the community that define roles and responsibilities.<br>• Progressive transfer of ownership and management to strengthen community ownership. |
| Aspects that require strengthening | • Clear regulatory definitions on energy communities and their operation.<br>• Community capacities for the technical and administrative management of the system.<br>• Governance mechanisms that ensure sustainability after the operator's departure.<br>• Strategies to ensure sufficient resources for long-term maintenance.<br>• Socialization processes that strengthen the understanding of the energy model.<br>• Institutional coordination to expedite certifications, registrations, and permits. |
| Strategic actors | • Enel as developer, initial operator and technical facilitator of the model.<br>• Communities organized as future owners and managers of the system.<br>• Regulatory entities that define guidelines for energy communities. |

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| | • Network operators that enable the integration and management of injected energy.<br>• Local governments as institutional facilitators and potential co-funders.<br>• Landowners who enable the installation of energy infrastructure. |

### 6. Summary of the Consulting Team

| Element | Observations |
|---|---|
| Connection with other interviewees | Enel's technical team contributes the regulatory, operational, and grid integration perspective, complementing the social (Enel Sustainability), financial (GGGI), and operational (B2CLEAN) perspectives. Their experience highlights the regulatory challenges, certification timelines, and the need for clear benefit-sharing mechanisms, connecting with the governance concerns raised by GGGI and the operational challenges identified by B2CLEAN. Furthermore, it reinforces the importance of community ownership promoted by Enel Sustainability through the progressive transfer of ownership. |
| Implications for the final diagnosis | • Regulatory clarity will be a determining factor for the viability of the model.<br>• Transparent mechanisms for distributing energy benefits are required.<br>• The progressive transfer of ownership can strengthen community sustainability.<br>• The design must consider timelines and regulatory requirements from the outset.<br>• The diagnosis must integrate the technical-regulatory dimension as a structural axis. |

**B2CLEAN SAS**

## 1. General Information and Characterization

| Item | Information |
|---|---|
| Date | **January 28, 2026** |
| Mode | **Virtual** |
| Entity / Organization | **B2CLEAN SAS** |
| Name | **Juan Pablo VallSerra** |
| Post | **Founder & Manager** |
| Type of actor | **B2CLEAN SAS is a Colombian company focused on providing comprehensive clean energy solutions, including photovoltaic solar systems, energy efficiency solutions, distributed generation and self-consumption, sustainable energy business models, as well as technical support and project structuring. Its approach combines environmental sustainability with financial viability, facilitating the adoption of renewable energy by businesses and communities. Within the energy ecosystem, it positions itself as a key technical and operational player that designs, implements, and structures sustainable energy projects, translating regulations into viable initiatives and enabling the energy transition in various regions through schemes such as collective self-consumption and the development of energy communities.** |
| Consulting team | **Antonio Jaramillo, Valentina Jiménez and Erika Diaz** |

## 2. Purpose of the Interview

The interview aimed to gather lessons learned, best practices, and challenges identified by a technical expert in the energy sector with experience in clean energy solutions and distributed generation, in order to understand which factors facilitate or limit the implementation of energy communities in different regions. Based on their experience in the design, structuring, and operation of sustainable energy projects, the interview sought to identify key elements of technical, regulatory, financial, and social viability that can strengthen future energy community models and guide project decision-making.

## 3. Experience or General Perspective on Energy Communities

| Aspects | Comments |
|---|---|
| Role of the entity in the ecosystem | A technical and operational actor providing operation and maintenance (O&M) services for distributed generation projects and energy communities, as well as participating in the structuring and implementation of solar installations in various locations, including solar farms and residential systems. Their role focuses on ensuring the efficient operation of the systems, managing maintenance costs, |

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| | and contributing technical expertise to the viability and sustainability of the projects. |
| Level of progress observed (international / national) | At the national level, energy communities are being promoted primarily by local public entities, such as municipalities, through subsidized programs for low-income households. However, these projects still face challenges in their implementation and operational sustainability, demonstrating an incipient level of maturity. Experience shows adjustments to the initial design due to actual costs, difficulties in managing surplus energy, and challenges in community coordination, indicating that the model is in a learning and adaptation phase in Colombia. |
| Main opportunities identified | • Institutional impetus: support from local governments facilitates implementation in vulnerable communities.<br>• Distributed generation: allows income from selling surplus energy to the electricity grid.<br>• Community organization: the existence of community leaders facilitates the articulation of the project.<br>• System lifespan: Solar panels with an operational horizon of 20–25 years allow for long-term benefit planning.<br>• Centralized operation: managing multiple systems as a single facility can optimize operating costs.<br>• Local energy transition: an opportunity to reduce energy costs and improve access to clean energy in territories. |
| Main challenges identified | • High operating and maintenance costs, especially for cleaning and managing multiple installation points.<br>• Difficulty in coordinating community agreements, especially in the distribution of economic surpluses.<br>• Financial adjustments to the project due to underestimation of actual costs.<br>• Logistical complexity due to geographical dispersion and distances between facilities.<br>• Environmental factors such as pollution and dirt increase the frequency of maintenance.<br>• Risks of vandalism and damage to solar panels.<br>• The systems do not cover 100% of energy consumption, so users continue to receive bills.<br>• Complexity in grid connection and in the management of surplus energy. |

**4. Contributions of the Interviewee**

| Topic covered | Main comments |
|---|---|
| Overview of energy communities | Energy communities are understood as distributed generation schemes where multiple users produce energy, primarily solar, for self-consumption and potentially sell surpluses to the grid. While they represent an opportunity to improve access to clean energy and reduce costs, their implementation is complex due to technical, financial, and community governance challenges, especially in low-income contexts. |
| Relevant experiences or references | The experience promoted by the Cali Mayor's Office in a low-income neighborhood was highlighted, where the goal was to install subsidized residential solar systems. The project was scaled back from an initial proposal of 200 panels to 60 installations of 4 panels per home due to actual costs. The contracted EPC (Engineering, Procurement, and Construction) company operated the installations as an integrated system, assuming both the investment and maintenance. This experience revealed challenges in operating costs, community coordination, and financial sustainability. |
| Conditions necessary for its development | • Institutional support and initial subsidies for low-income communities.<br>• Existence of community leadership that facilitates organization and decision-making.<br>• Appropriate technical design according to location, pollution levels and distances.<br>• Clear operating and maintenance models with realistic costs.<br>• Transparent agreements on the distribution of profits and surpluses.<br>• Financial structuring that takes into account the useful life of the system (20–25 years). |
| Financial considerations | Solar projects are structured with a 20- to 25-year timeframe, corresponding to the lifespan of the panels. However, operating and maintenance costs—especially in dispersed installations—can impact profitability. Regular cleaning (at least twice a year) and the distances between installation points increase costs. Furthermore, the systems do not completely eliminate electricity bills, which can create unrealistic expectations among users. |
| Risks and possible solutions | **Risks:**<br>• Vandalism and damage to the panels.<br>• Community conflicts over the distribution of benefits.<br>• Increased operating costs due to geographical dispersion.<br>• Unrealistic expectations about a total reduction in the energy bill. |

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| | **Possible solutions:**<br>• Community ownership programs and energy education.<br>• Centralized operation to optimize costs.<br>• Technical designs adapted to the environmental and territorial context.<br>• Clear governance models for surplus management. |
| Recommendations for Colombia | • Strengthen technical and financial guidelines for energy communities.<br>• Promote pilot models with continuous technical support.<br>• Include energy education and community management strategies.<br>• Design sustainable operation and maintenance schemes from the outset.<br>• Consider location, dispersion, and environmental conditions in the design.<br>• Establish clear and transparent mechanisms for the distribution of benefits. |

**5. Key Elements Highlighted**

| Aspect | observations |
|---|---|
| Critical factors for success | • Institutional support and subsidy schemes that facilitate initial investment.<br>• Strong community leadership that brings families together and manages agreements.<br>• Technical design appropriate to the territorial context (location, pollution, distances).<br>• Clear operating and maintenance models with realistic costs from the outset.<br>• Transparent governance for the distribution of benefits and surpluses.<br>• Community ownership of the project to reduce vandalism and ensure sustainability. |
| Aspects that require strengthening | • Energy education to adjust expectations about saving and covering consumption.<br>• Community capacities for collective decision-making and conflict resolution. |

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| | • Financial structuring that incorporates real O&M costs in dispersed systems.<br>• Security protocols and protection of equipment against vandalism.<br>• Tariff models and clear mechanisms for the distribution of surpluses. |
| Strategic actors | • Local governments (municipalities) as promoters and facilitators of subsidies.<br>• EPC companies and technical operators responsible for installation, operation and maintenance.<br>• Energy companies and network operators for connection and surplus management.<br>• Community leaders as social articulators of the project.<br>• Funding or cooperating entities that support initial investment and community strengthening. |

**6. Summary of the Consulting Team**

| Element | Observations |
|---|---|
| Connection with other interviewees | B2CLEAN's experience connects with the other stakeholders by providing a technical and operational perspective on the real costs, maintenance complexity, and logistical challenges of energy communities. Its findings on operation and maintenance complement Enel Sostenibilidad's social approach, the financial structuring promoted by GGGI, and Enel Técnico's technical and regulatory expertise. While B2CLEAN highlights the practical challenges of operating multiple distributed systems, the other stakeholders contribute solutions from the perspectives of governance, financing, and regulation, demonstrating the need for a comprehensive approach. |
| Implications for the final diagnosis | • The sustainability of the model in Necoclí will depend on designing realistic operation and maintenance schemes.<br>• Operation and maintenance costs can be a critical barrier if they are not centralized or optimized.<br>• Geographical dispersion and environmental conditions must be considered from the design stage.<br>• Clarity in the distribution of benefits is required to avoid community conflicts.<br>• The diagnosis must incorporate operational feasibility as the central axis of the model. |