GUIDELINES FOR ENERGY COMMUNITIES IN COLOMBIA

TECHNICAL REPORT

ACKNOWLEDGEMENTS

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This report has been produced by the Transactive Energy Colombia – https://www.transactive-energy.co/ –an initiative by EnergEIA research group at EIA University in Medellín, Colombia to promote the development of user-centered renewable energy systems in Colombia.

The guidelines were created interacting with various institutions, including government, business, academia, and social groups, in a pioneering joint effort. The collaborative work included 20 different institutions across government agencies, non-governmental organizations, universities, and energy companies.

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EXECUTIVE SUMMARY

Energy communities are getting increasing interest from researchers and policymakers worldwide as socially owned organizations that can bring potential benefits to a just energy transition, such as strengthening community bonds, empowering citizens, democratizing energy, improving energy access, and alleviating energy poverty. Energy communities can be a model that bridges the gap between renewable technologies deployment and local socioeconomic development.

However, community energy models are highly contextual, and scaling and replicating them across different regions and contexts can present significant challenges. Particularly in the Global South, there is a dearth of knowledge regarding the application of energy communities and their potential role in facilitating a just energy transition.

The current Colombian government's flagship policy is to carry out a Just Energy Transition in which energy communities will play an important role. There will be a need to mobilize significant financial resources considering non-commercial and socially oriented metrics to develop energy communities. The challenges ahead are evidenced by the La Estrecha Community, a pilot project between a university, energy companies, and 24 mid-income households in Medellín.

Critical barriers identified in this case study included high investment costs, complexities in grid connection procedures, lack of appropriate regulatory figures, and hefty legal prerequisites. La Estrecha community alone would not have been capable of implementing an energy community, and a growth model concluded that current conditions are insufficient for the widespread deployment of energy communities in the short-to-mid term. Practical and long-lasting implementation mechanisms and a suitable policy and regulatory environment are necessary to scale these energy models.

This document presents guidelines to promote the deployment and financing of energy communities in Colombia, considering that energy communities will probably require a significant flow of outside investment and support. As external entities are expected to play a significant role in supporting energy communities, theoretical frameworks are needed to aid developers in promoting energy community projects.

The objective of this document is three-fold. First, to analyze the potential of energy communities in the Colombian context. Second, to present guidelines and an assessment framework to evaluate energy communities' project feasibility. Third, to present a diagnosis of current funding alternatives and propose ways to improve them.

The guidelines were designed in collaboration with key stakeholders, including the developers of the La Estrecha energy community pilot, energy companies, and relevant NGOs and researchers. Five groups or dimensions of energy communities' planning were defined.

- **Community objectives:**
  As benefits or outcomes expected from the energy solution.
- **Social feasibility:**
  Understanding the social context, designing engagement and education strategies, and drafting community agreements.
- **Technical feasibility:**
  Planning and designing, installation, permitting, operation, management, maintenance, and risks.
- **Legal feasibility:**
  Legal association forms and how to participate in the electricity market as public utility companies or through a commercial representative.
- **Economic feasibility:**
  Initial investment, operation and maintenance costs, revenue sources, and financial indicators.

Furthermore, to pave the way for possible higher growth rates of energy communities' implementation in the country, a roadmap for improving funding options was established, mapping current alternatives for financing energy communities, identifying gaps, and recommending actionable steps to promote funding. These steps included creating dedicated energy community regulatory figures and funding mechanisms, increasing awareness, education, capacity building, technical assistance, and fostering partnerships and energy community networks.

This document ultimately aims to create competencies and inform Colombian policymakers and actors in the sector to promote energy communities. Especially, to support the different actors to implement the draft Decree that will regulate energy communities in Colombia recently published by the Ministry of Mines and Energy.

This document is organized as follows. Section 1 defines energy communities and describes the most common models used in European countries. Section 2 presents a diagnosis of the Colombian electricity system. Section 3 evaluates the potential role, challenges, and opportunities of energy communities in Colombia by analyzing the La Estrecha case study and conducting a growth projection. Section 4 presents a detailed description of the guidelines for energy community feasibility. Section 5 presents an assessment framework tool to support potential energy community developers in their decision-making and feasibility analysis. Finally, section 6 describes the roadmap for funding energy communities in the country.

Guidelines to promote energy communities in Colombia

1 **GUIDELINES AND ASSESSMENT FRAMEWORK**
Evaluate multi-dimensional feasibility factors to deploy energy communities

2 **ROADMAP TO ACCESS FUNDING**
Current funding alternatives, gaps, and recommended actionable steps to improve access to funding.

3 **BUILDING CAPACITIES**
Competencies for policymakers and actors in the sector to promote energy communities

1 ENERGY COMMUNITIES

Energy communities are organizations that arise from community interests. They are managed and owned by civil society actors who play an active role in the energy sector, meeting its demand and other energy-related services by adopting a cooperative approach.

Energy communities can potentially address some of the transition challenges by empowering energy end-users through cooperative structures [1]. Energy communities are organizations created, managed, and owned by civil society actors where citizens take an active role in the energy sector [2, 3]. Participants can cover their energy needs in energy communities by cooperating in diverse organizational and legal structures. These communities promote decentralization, decarbonization, and the active participation of citizens in the electricity system [4]. Several descriptions and definitions of energy communities can be found in the literature, and some governments have provided legal concepts. However, a commonly acknowledged definition is missing due to the diversity of organizational structures, regulatory mechanisms, and business models.

The European Commission defines energy communities as “entities that can take part in any stage of the energy supply chain ranging from energy generation and supply to the provision of other energy services while fulfilling a social and environmental purpose” [5]. The EU Renewable Energy Directive, Directive 2018/2001 (RED II) defines energy communities as:

> *Non-commercial legal entities based on the open and voluntary participation of their members, which can be households, public authorities, and small and medium-sized enterprises, provided that their main activity is not energy-related [...] Community members must be fully or partly involved in daily decision-making and operation control, and the potential revenues attained must be used to provide local services/benefits [6].*

RED II also differentiates between two types of energy communities: Renewable energy communities are geographically bounded (participants must be close to each other), promote the involvement of the community in "generation, trading, storage, and supply of energy from renewable sources," and are "fully controlled by small end-users aiming to benefit from renewable energy or to be deployed in partnership with commercial stakeholders or social entrepreneurs" [7, 8]. Citizen energy communities are not physically bound, but they share the characteristic of having environmental, economic, or social communal objectives rather than turning a profit.

Based on the European framework, energy communities are "bottom-up energy projects driven towards local needs, characterized by strong citizen participation, local ownership, and decision-making" [6]. This new perspective on energy ownership and participation implies the creation of new policies, market structures, and actors in the electricity sector. Some examples of these new actors are prosumers, energy cooperatives, specialized energy service companies, digital utilities, information, communication, and technology (ICT) providers, and energy crowdfunding investing [5]. Although terminologies vary, most agree that energy communities are groups of people interested in energy generation around active participation and democratic governance. Their main objective is to bring environmental, social, or economic benefits to the community through local and sustainable renewable energy generation [9].

Energy communities have a long history in European countries. Community business models emerged in the 1990s due to new renewable generation technologies and citizen participation in the energy sector. National and European Commission regulations have incentivized energy communities' development and encouraged climate actions to achieve the energy transition. Countries like Germany, Spain, Italy, Belgium, and Greece already have rules for energy communities, and their number is increasing.

Most of these projects are local cooperatives with economic, communitarian, social, and environmental objectives. Participation is usually open and voluntary, with bottom-up democratic governance. Generally, the community members control the operation, and external investors or collaborating companies have minimal influence in decision-making. In Europe, there are two main types of energy cooperatives: *Community Energy Producers and Self-consumption Communities.*

1.1. COMMUNITY ENERGY PRODUCERS

In this model, citizens can join an energy cooperative by investing and becoming shareholders and members. The cooperative uses the capital to fund renewable energy generation installations, and the profits from the energy systems go to the members. The energy systems may be installed in schools, town halls, hospitals, member’s houses, and other community-owned buildings and land. These cooperatives can usually grow to a considerable number of members and can build large-scale photovoltaic and wind projects. This model has a wide geographical scale, ranging from cities, regions, and even entire countries. Participation is always open and voluntary; governance is usually "one member, one vote," and decision-making is achieved through general assemblies. The cooperative usually hires professional engineering, management, social, and environmental services companies to ensure adequate operation.

An example of this model is Som Energia cooperative. This Spanish organization was formed to promote collective and sustainable production and consumption of renewable energy. Its functioning is based on the principles of citizen participation and energy democracy. Som Energia members join the cooperative by paying an entry fee and an annual membership fee, which grants them rights and benefits in decision-making and access to energy services. The cooperative is responsible for managing the contracting and supply of renewable energy, such as solar and wind energy, through agreements with green producers and suppliers. Members receive renewable electricity in their homes and businesses, contributing to reducing greenhouse gas emissions and the transition to a more sustainable energy model.

Additionally, the cooperative promotes energy efficiency and awareness of responsible consumption among its members. Decision-making in Som Energia is carried out democratically through assemblies and the active participation of the members. Furthermore, the cooperative tries to raise awareness, promote renewable energy, and advocate for policy changes to support a transition to cleaner energy sources.

In addition, cooperatives may fund social programs to tackle local energy poverty, create new projects, train local workers, and contribute to the local community's needs. In most cases, they work with other institutions or cooperatives to promote initiatives that are not necessarily linked to the energy transition but align with the community's sustainable development objectives.

An example is the cooperative Som Energía and La Ortiga alliance, a responsible consumption and agroecological cooperative. This alliance between the two cooperatives fosters the growth and strengthening of both parties by creating mutually beneficial commitments. Some examples of this agreement include: Som Energia members receive the same discounts as La Ortiga members when purchasing their products, and both cooperatives promote and advertise each other at their respective events and spaces, mediation in cases of non-payment and financial support, consumption of each other's services at their facilities and events, offering free advice to cooperative members on topics such as agroecological food production, renewable generation, and responsible energy consumption. Other examples of similar alliances include the cooperative Plymouth Energy Community and the community social housing organization Plymouth Community Homes.

1.2. SELF-CONSUMPTION COMMUNITIES

Self-consumption communities are a recent model enabled by distributed energy resources. Self-consumption communities operate differently from community energy producers. In this case, small communities of individuals with an energy need associate through an organizational entity (such as a municipality, a neighborhood council, or a production cooperative) and work together with third parties to install the generation equipment, make the connections, handle legal matters, or seek financing. Afterward, the community utilizes the generation equipment to consume their energy and benefit from that generation.

Self-consumption communities are localized models where participants generally know each other and share meeting spaces. These communities typically have limited participants and are bound to blocks, neighborhoods, and villages. The energy assets are usually located on community-owned land or rooftops. The local community institutions shape the energy community governance model. In this sense, established community organizations such as local councils can provide organizational and administrative capabilities, facilitating decision-making, communication, land procedures, and access to financing mechanisms. Self-consumption communities can struggle to access funds for the upfront investments required for the energy systems and often rely on subsidies and external financial aid.

Some European countries have devoted financial resources to support self-consuming energy communities within their energy transition and climate action programs.

1. Germany:
Germany has implemented support mechanisms, such as feed-in tariffs and incentives, to promote self-consumption and community energy projects. Programs like the Mieterstrom (tenant electricity) scheme provide financial support for renewable energy installations in multi-unit buildings.

2. Spain:
Spain has implemented a legal framework that supports self-consumption and energy communities. The country offers net metering and simplification of administrative procedures for self-consumption installations. Financial incentives, such as subsidies and tax exemptions, are available for community energy projects.

3. France:
France has implemented financial support mechanisms to encourage self-consumption and energy communities. The country offers feed-in tariffs, tax credits, and low-interest loans for renewable energy installations. Additionally, community energy projects can benefit from crowdfunding platforms and cooperative financing.

4. Netherlands:
Netherlands has introduced subsidies and grants for self-consumption and community energy initiatives. The SDE+ (Stimulation of Sustainable Energy Production) scheme provides financial support for renewable energy projects, including those developed by communities.

5. Belgium:
Belgium's federal and regional governments have implemented financial incentives for self-consumption and energy communities. These incentives include feed-in tariffs, tax benefits, and grants for renewable energy installations.

The specific financial resources and programs may vary within each country, and the level of support may evolve as countries adapt their policies to promote self-consumption and community energy in their energy transition and climate action plans. In some cases, municipal governments help communities with local grants or subsidies. However, it is generally advised that citizens have financial or non-financial contributions to encourage engagement and responsibility while developing the energy community.

An example of this energy community model is the case of Trespuentes, a town in northern Spain, where the municipality and residents, in collaboration with Comunidades Energéticas S.Coop., carried out a solar community project. In this case, the municipality reached out to Comunidades Energéticas S.Coop. to propose the idea to the residents, and it was received with enthusiasm. With the cooperative's guidance and other stakeholders' involvement, the solar panels were installed and put into operation to reduce the energy costs on the participants' bills.

Comparison of the two types of energy communities in Europe.

	Community Energy Producers	Self-Consumption Communities
Size	Medium-to-large scale. City, region, or country-wide cooperatives with numerous distributed members.	Small-to-medium scale. Blocks, neighborhoods, small villages, and businesses. Few members.
Structure	One member one vote with general assembly and expert committees.	The community's own governance is maintained. Municipalities and external companies may be involved.
Motivations	Savings on the energy bill and environmental concern are the main drivers to participate. Community engagement.	Savings on the energy bill and community engagement is often the main motivating factor followed by environmental concerns.
Generation	Mainly small to medium-sized photovoltaic, wind, mini-hydro and biomass plants for the generation and sale of energy.	Mainly photovoltaic located on community land or land provided by municipalities or other institutions.
Social Contribution	Financial earnings can be reinvested in community projects, both related to energy generation and the social fabric.	From internal community cooperation initiatives. It is the members themselves who take an active part in the development of activities within the community.
Interaction	Members generally collaborate through a digital platform or digital application and often do not have direct contact.	Members often have direct social contact and know each other.

1.3. ENERGY COMMUNITIES IN DIFFERENT CONTEXTS

"Citizen participation in the energy transition embodies the difference between something being imposed upon a community and something being chosen by the community; ensuring that citizens are at the center of the energy transition and are active participants and leaders of the transition is not only practically important but has ethical merits" [10].

Energy communities can potentially promote a just energy transition and local sustainability. Their positive impact goes beyond electricity generation because they transform how communities interact with energy and create a more sustainable future. Energy communities can strengthen the social fabric, empower citizens, democratize energy, improve energy access, alleviate energy poverty, and foster economic development.

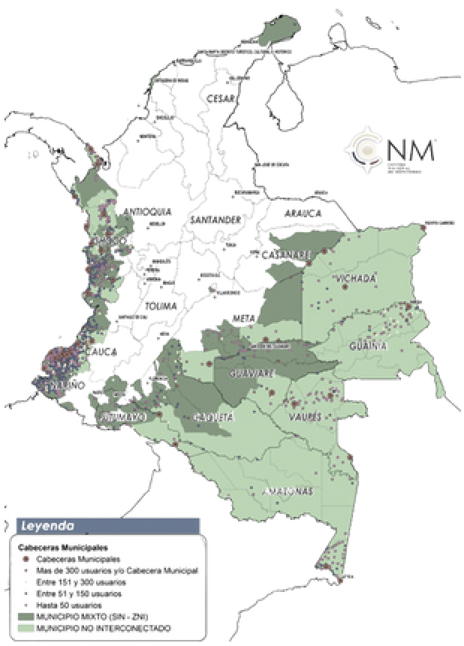
However, community energy models are highly contextual, and their benefits, barriers, and viability must be assessed considering the specific local technical, sociocultural, and legal conditions. Scaling up and replicating energy community models across different regions and contexts can be challenging. Each community has unique characteristics and needs and requires customized solutions and localized approaches. Furthermore, most of the existing projects and research around energy communities have occurred in developed countries, specifically Europe, North America, and Australia.

There is a lack of knowledge in applying these energy models in developing countries in the Global South and understanding their potential role in a just energy transition. The following section explains Colombia’s electricity sector and energy transition status as a reference framework to identify critical areas and stakeholders for developing energy communities in the country.

2 THE COLOMBIAN ELECTRICITY SYSTEM

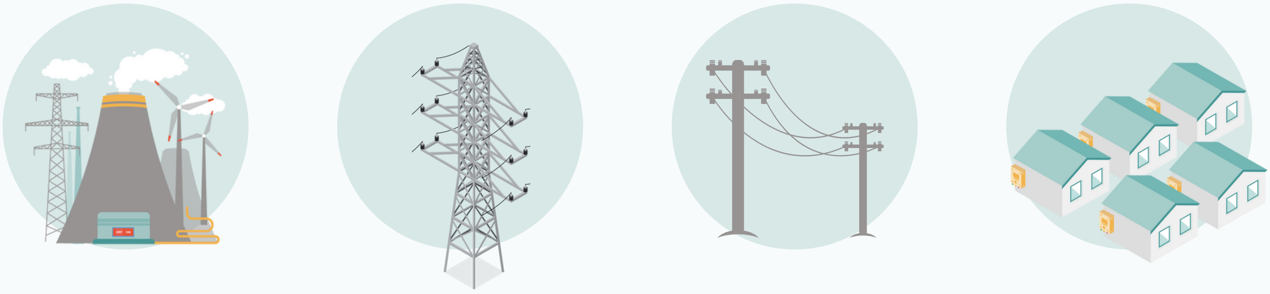
The Colombian electricity system comprises an interconnected national system, which covers 96% of the population and has 16,5 GW of installed generation capacity [11] and non-interconnected areas, representing 52% of the national territory and 4% of the population. In non-Interconnected areas, electricity is supplied by standalone systems, commonly powered by fossil fuels.

Interconnected national system [12]



Non-Interconnected areas [12]

The electricity system in Colombia comprises energy generation, transmission, distribution, and retailing activities, as well as state institutions in charge of regulation, control, and oversight [13].



Generation → Transmission Up 220 kW → Distribution Under 220 kW → Commercialization

Colombia's energy value chain

Ministry of Mines and Energy:
Highest authority, formulates and implements policies to ensure energy supply, and efficient use of natural resources.

Mining and Energy Planning Unit (UPME):
Plans and coordinates the energy sector's development expansion and modernization strategies.

Energy and Gas Regulatory Commission (CREG):
Oversees and regulates the electricity and gas sectors.

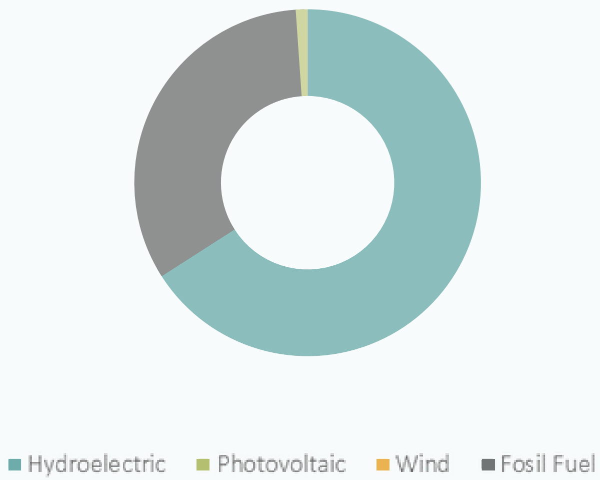
National Operation Council:
Coordinates and operates the national electricity system.

Commercialization Advisory Committee:
Guides and advises on prices, trading and market aspects of the energy sector.

Superintendency of Public Services:
oversees fair practices, service quality standards, consumer protection, well-being, and satisfaction.

XM:
Operates and manages the wholesale electricity market, the national interconnected system, and the international electricity transactions with neighboring countries.

2.1. GENERATION



Electricity generation installed capacity per source [11]

Colombia's installed capacity depends mainly on hydropower and relies on fossil fuel plants for back up and reliability. In 2022, the national interconnected system had 16,5 GW of installed capacity sourced from 55 power generation plants: 29 hydropower, 22 fossil-fuel power systems, three solar photovoltaic, and one wind farm [14] [1].

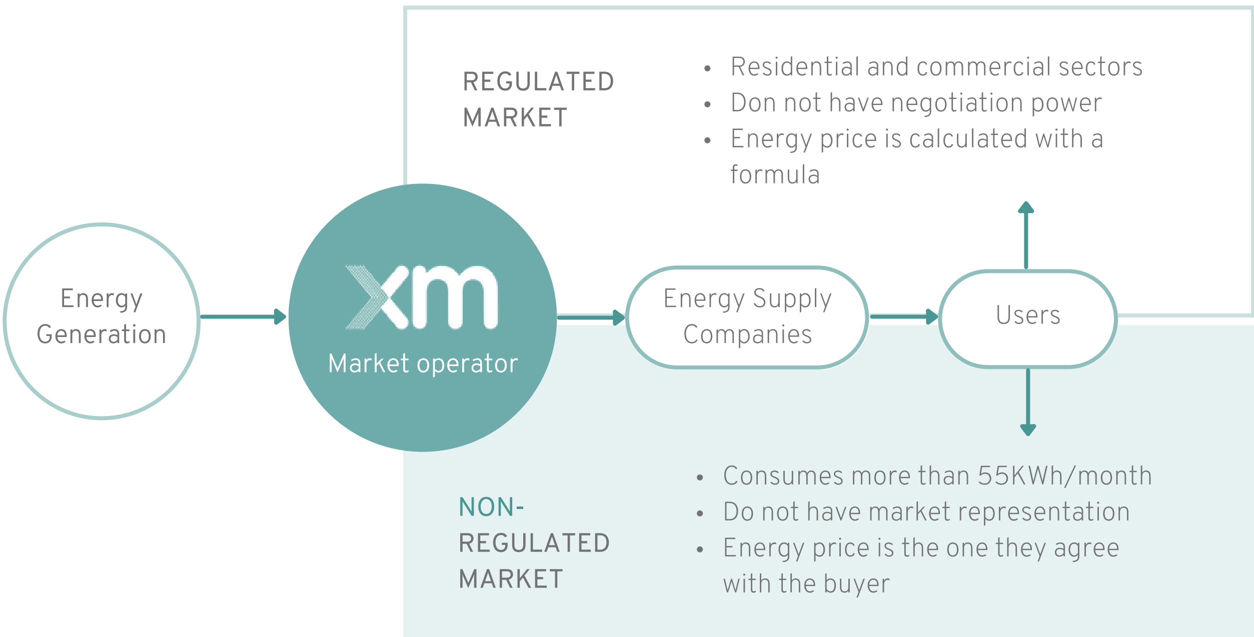
2.2. TRANSMISSION AND DISTRIBUTION

The transmission system connects generation plants to consumption centers through 28,126.35 km of high-voltage lines [11]. It comprises two levels, the national transmission system (STN), operating at voltages above 220 kV, and the regional transmission system (STR), operating at voltages between 57.5 and 220 kV. The transmission infrastructure is operated by 12 companies [15]; regulatory entities defined that this activity is economically more efficient when the service is provided by a reduced number of agents [16].

The distribution system comprises the electrical grid within consumption centers, and it is classified into single-phase, two-phase, and three-phase [16]. The distribution activity is determined by the areas in which a few companies provide the service. Distribution grids operate at voltages below 57.5 kV and are comprised of medium-voltage lines (voltage levels 2, between 1 and 30 kV, and 3, between 30 and 57.5 kV) and low-voltage lines (voltage level 1, below 1 kV).

2.3. RETAIL MARKET

Colombia's electricity market is divided into Regulated and Non-Regulated markets. In the Regulated Market (small-scale residential, commercial, and institutional customers), energy prices are fixed by the government to protect the end-users from fluctuations in the wholesale market. In the Non-regulated Market (users that consume more than 55,000 kWh/month or with a rated capacity higher than 100 kW), market actors buy and sell electricity through bilateral contracts or at wholesale market spot prices.



Colombian electricity market structure

In the Regulated Market, electricity prices depend on the unitary cost of electricity defined by CREG by adding generation, transmission, distribution, and retailing costs and including loses and restrictions charges [17, 18] [19]. The unitary cost is the standard price per kWh charged to Regulated market end-users. In addition to the unitary cost, Colombia has a cross-subsidy system where users pay an additional tax contribution or receive a subsidized discount depending on the following factors:

1. Colombia has a socioeconomic stratification system to classify sectors depending on various physical, social, and economic factors. The classification reflects citizens' wealth levels, ranging from stratum 1 (lowest wealth level) to stratum 6 (highest wealth level). In the electricity system cross-subsidy mechanism, end-users in strata 1, 2, and 3 receive a subsidy, while users in strata 5 and 6 pay an additional 20% contribution over their electricity bill. Stratum 4 is neutral and pays the unitary cost of electricity.

2.The subsidies for end-users in strata 1 to 3 are discounts applied to the unitary price (strata 1, 60%, strata 2, 50%, and strata 3, 15%). However, there is a monthly consumption limit, after which the discount does not apply further. This limit is the minimum subsistence amount and refers to a reasonable electricity quantity that a household requires in a month. Furthermore, the minimum subsistence amount varies depending on the household's location. This variable, measured in meters above the sea level (m.a.s.l.), is related to temperature and air conditioning needs. Hence, warmer regions have a higher minimum subsistence amount.

Electricity cross-subsidies parameters.

Municipality location	Subsidized electricity consumption limit	Stratum	Subsidized consumption
Warm temperatures Below 1000 m.a.s.l	173 kWh / month	1	60%
		2	50%
		3	15%
Moderate temperatures Over 1000 m.a.s.l	130 kWh / month	1	60%
		2	50%
		3	15%

2.5. COLOMBIA'S ENERGY TRANSITION

The Colombian electricity system faces numerous challenges, such as supplying an increasing energy demand, diversifying and decarbonizing power generation sources, modernizing aging infrastructure, and improving security, reliability, efficiency, affordability, and universal access to electricity [20]. Colombia is greatly dependent on hydropower; thus, during drought seasons like El Niño (ENSO), Colombia needs to change its generation mix drastically. During the last reported phenomenon in 2015, hydropower generation capacity dropped by 45%, and fossil power ramped up, implying high environmental and economic costs [21].

The hydropower vulnerability and reliance on fossil power plants are driving Colombia to diversify its generation sources, including non-conventional renewable alternatives. Policy and regulatory change started with the enactment of Law 1715 in 2014. This law promotes the development of non-conventional renewable energy sources in the national electricity system, i.e., biomass, small hydropower, wind, geothermal, solar, and marine. Law 1715 was updated with a recent National Energy Transition Law 2099 from 2021. This legislation intends to open the Colombian electricity market to new actors and technologies and to promote energy supply decarbonization, security, reliability, and sustainability [22]. Legal incentives for renewable energy sources have been mainly tax benefits and exemptions.
Currently, there are several renewable energy projects in the pipeline. Between 2023 and 2024, over 70 wind and solar PV projects are expected to start operating, increasing Colombia´s non-conventional renewable installed capacity from around 3% (early 2023) to 16%.

The social license to operate, community relationships, and acceptance have become crucial for new renewable energy project viability. There are recent cases where project developers canceled renewable energy infrastructure construction for social issues, especially in remote, vulnerable areas. Colombia has a history of violence and a lack of state presence in many regions, where the relationship between the government and the communities is fragmented. These regions usually lack access to basic public services and suffer from poverty and discrimination.

In response to the transition challenges, the current government is promoting a Just Energy Transition program as one of its more relevant policy proposals. The Ministry of Mines and Energy issued a roadmap for Colombia's just energy transition with several principles, including equity, ensuring the country's energy sovereignty and reliability, promoting education and research, and involving citizens to take part in the electricity value chain as consumers, as generators, as cooperatives, and as energy communities.

3 ENERGY COMMUNITIES IN COLOMBIA

Energy communities could positively impact Colombia's energy transition in various ways. In addition to diversifying its power generation mix, Colombia is committed to reducing GHG emissions by 51% by 2030 [23]. Electricity generation accounts for 8.5% of the total emissions, and the Ministry of Mines and Energy has a mitigation strategy promoting renewable energy sources, demand-response measures, and energy efficiency. Energy communities can be a tool for targeting those three objectives simultaneously.

Regarding energy access, 404.000 Colombian families do not have electricity access. These households are usually located in rural and remote areas with limited access to electrical infrastructure. Furthermore, approximately 29% of Colombian households reported difficulties paying for public utilities, including electricity [24]. Energy communities could provide sustainable energy sources to these areas and alleviate energy poverty. Furthermore, energy communities in Colombia can be a strategy to give citizens better electricity prices and greater control over their consumption and behavior. Community solutions may decrease dependence on large electric companies and provide a potential solution for replacing cross-subsidies in certain areas for more innovative support models.

Energy communities can become test labs for new technologies and business models using renewable energy and focusing on the end-user. Energy communities can help diversify and modernize the country's energy sector, making it more resilient and open to new actors and technologies. They can also help create better ways for communities to accept larger-scale renewable energy projects.

On the other hand, illegal grid connections and non-payment have been a widespread phenomenon in Colombia, especially in vulnerable neighborhoods. Energy communities can become a vehicle for distributed network operators and retailers to promote legal connections and improve the ability and willingness to pay. Besides increasing trust, energy communities can also strengthen participants' knowledge and energy awareness and promote efficient energy use.

Considering these positive impacts, energy communities are becoming increasingly popular in the political landscape; however, their development is still in its initial stages. This section presents a detailed diagnosis of the current situation of energy communities in Colombia. It describes the political and regulatory framework, key stakeholders, a case study of the first grid-connected energy community in the country, and, finally, an energy community growth analysis in the short-to mid-term under current conditions.

3.1. POLICY FRAMEWORK

The Ministry of Mines and Energy included energy communities in the Just Energy Transitions Roadmap as a solution to promote energy democracy, improve electricity provision in vulnerable areas, and achieve universal energy access [25]. Moreover, the Colombian government included energy communities in the National Development Plan 2022-2026 to regulate them as a legal figure for distributed generation.

3.2.1. DRAFT DECREE TO REGULATE ENERGY COMMUNITIES WITHIN THE FRAMEWORK OF A JUST ENERGY TRANSITION IN COLOMBIA

In early July 2023, the Ministry of Mines and Energy published for comments the draft Decree that will regulate energy communities in Colombia. At the time of publication of this guide the Decree is not yet sanctioned.

Among the most noteworthy provisions are:

- The possibility for energy communities to associate with each other and establish public-popular and private-popular alliances with third parties.
- The regulation of the figure of Community Public Utility Company (E.S.P.C.) by the Superintendence of Public Utilities.
- The establishment of Collective Self-Generation and Collective Distributed Generation as new activities in the chain of electric energy service provision in Colombia.
- Collective self-generation and collective distributed generation activities will have priority to use the assets of the Local Distribution System, right to build microgrids.
- The communities may be beneficiaries of public resources for the financing of energy communities if they belong to territorial structures of Indigenous Peoples and Communities' Own Government; peasant communities, and peasant communities formalized as peasant reserve zones; black, Afro-Colombian, Raizal and Palenquero communities.

The draft Decree proposes a differential and special treatment for energy communities in the Colombian electricity sector and these characteristics allow inferring that the government's vision on energy communities is mainly focused on vulnerable communities, with special interest in minority groups.

3.2. REGULATORY ALTERNATIVES

There are limited regulatory alternatives for the operation of energy communities in Colombia. Only two regulatory forms are available to connect distributed generation to the interconnected system: Small-Scale Self-Generators and Distributed Generators [27] [28] . The main difference is that the former is for prosumerism and feeding-back excess energy into the grid, while the latter enables selling all the electricity generated.

3.2.2. SMALL-SCALE SELF-GENERATORS

Small-scale self-generation is a single-user prosumerism figure. It provides attractive economic incentives for systems with an installed capacity of less than 100 kW. Small-scale self-generation operates through a net metering mechanism considering the user's monthly consumption. Each kWh of electricity exported to the grid is paid at the unitary cost minus retailing costs. This price applies when the sum of exported (surplus) energy is less than or equal to the imported or consumed energy. The additional surpluses beyond the self-consumption limit will be paid at the spot market price (significantly less than the unitary cost). This mechanism has been very successful in promoting prosumerism since the energy exported is paid at almost the same price as the energy consumed.

Electricity surpluses can be sold in the regulated or non-regulated market for small-scale self-generators larger than 100 kW and smaller than 1 MW. In the regulated market, if the export is equal to the import of energy, they are recognized at a price close to the unitary retail price. However, if surpluses exceed grid imports, they are paid at the hourly market price. In the non-regulated market, the price can be agreed directly with the energy retailer. Projects larger than 1 MW and up to 5 MW are considered large-scale self-generators.

Small-Scale Self-Generation is not ideal for energy communities since it is designed for single energy users, and the collective self-generation activity is not yet regulated, so there are no mechanisms available to share energy between small-scale self-generators and other consumers.

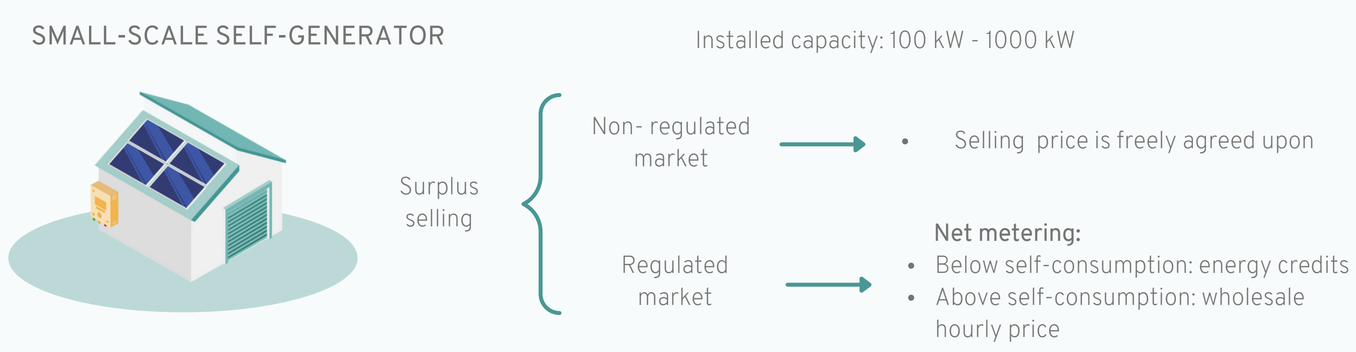
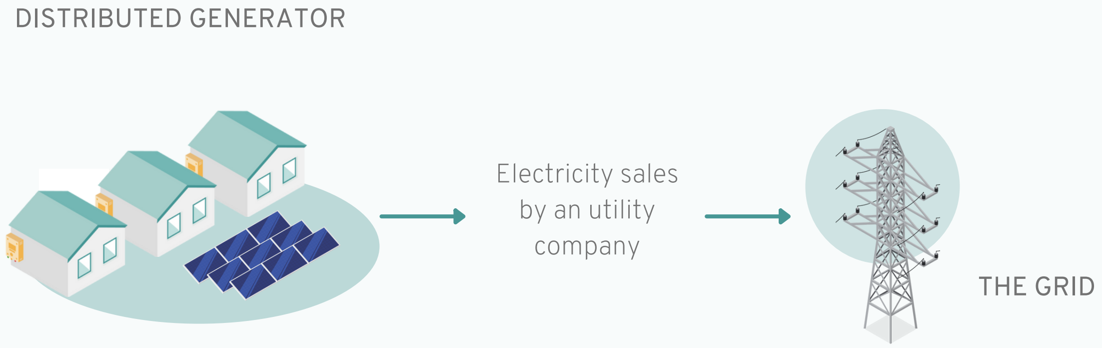


Figure 7. Small-scale self-generator surplus electricity sales
Surplus: Electricity fed back to the distribution grid by a self-generator, expressed in kWh.

3.2.3. DISTRIBUTED GENERATION

Distributed generators are generation plants with an installed capacity smaller than 1MW. They must be installed near consumption centers and connected to the local distribution network. Distributed generators must also be registered as a public utility company to sell electricity to the national interconnected system. In that sense, distributed generators are subject to the same regulations and oversight as traditional large-scale generators.



It is fundamental to emphasize that there is no self-consumption in distributed generation. The electricity generated is sold to the grid, and the revenues can be shared among participants. Distributed generation is currently the only viable way for energy users to co-own and co-share renewable energy installations. Therefore, distributed generation is the only viable mechanism for establishing energy communities (taking into account that the figures of collective self-generation and collective distributed generation are not yet regulated).

3.3. KEY STAKEHOLDERS

The participation of multiple stakeholders is essential for the success of energy communities. The following table presents the key Colombian stakeholders that may be impacted by and could promote the development of energy communities in the country.

Stakeholder	Type of institution	Importance to Energy Communities
Local communities	Civil society	Local citizens are the cornerstone of an energy community. They can participate as active members by consuming and generating electricity and sharing the community's benefits. They can also be involved in decision-making regarding energy management and usage, participating in assemblies and collaborating in the planning and execution of energy projects.
Municipal and departmental authorities	Local and regional government	Access to financing through municipal initiatives and synergies between energy communities and local productive activities. Benefiting from education strategies and local job creation.
Ministry of Mines and Energy of Colombia	Central government	Promote favourable policies and regulations that encourage the creation and operation of these communities. Provide financial incentives, subsidies, or financing schemes for community energy projects, facilitating access to necessary permits and licenses for project implementation.
CREG	Regulatory – independent authority	Oversees defining the concrete steps and conditions for an “energy community” legal figure. How will it affect tariffs, remuneration?
UPME	National planning authority	Consider how energy communities may increase distributed generation within consumption centers. How does that affect the expansion of the interconnected system
Energy Distribution companies	Private sector	How will energy communities affect the DN operation and maintenance. Could it be a good thing, balancing services, congestion relief.
Energy Retail companies	Private sector	Energy communities as a new service? How will the existence of energy communities affect tariffs in the regulated market, the role of technology and new digital offers.
Energy services, asset installation companies	Private sector	Installation, maintenance, and management of renewable energy generation and distribution systems.
XM – market operator	Wholesale market operator	Connection authorizations. Control of distributed resources. Bilateral contracts oversight.
Superintendency of Public Services	Customer protection	Billing users
NGOs	Civil society	Civil society organizations and NGOs are crucial in raising awareness, educating, and advocating for sustainable energy and energy communities. They can collaborate with local communities to provide training, technical advice, and support in implementing energy projects. Additionally, they can advocate for policies favourable to energy communities and work towards defending the energy rights of communities.
National and international financial institutions	Banks and development agencies	Provide funding for developing energy communities.

3.4. CASE STUDY: LA ESTRECHA SOLAR COMMUNITY IN MEDELLÍN, COLOMBIA

El Salvador is a neighborhood of around 4,000 households of primarily lower-to-middle-income families. La Estrecha (the narrow one) is a dead-end road surrounded by multifamily houses facing each other. In the La Estrecha energy community pilot, a university and energy companies cooperated with local citizens to create a PV solar community model. Twenty-four households agreed to join the pilot, mainly motivated by obtaining savings on their energy bills, becoming a pioneer community, installing a smart meter, accessing a digital application to monitor their consumption, and participating in workshops on energy-related issues [29].

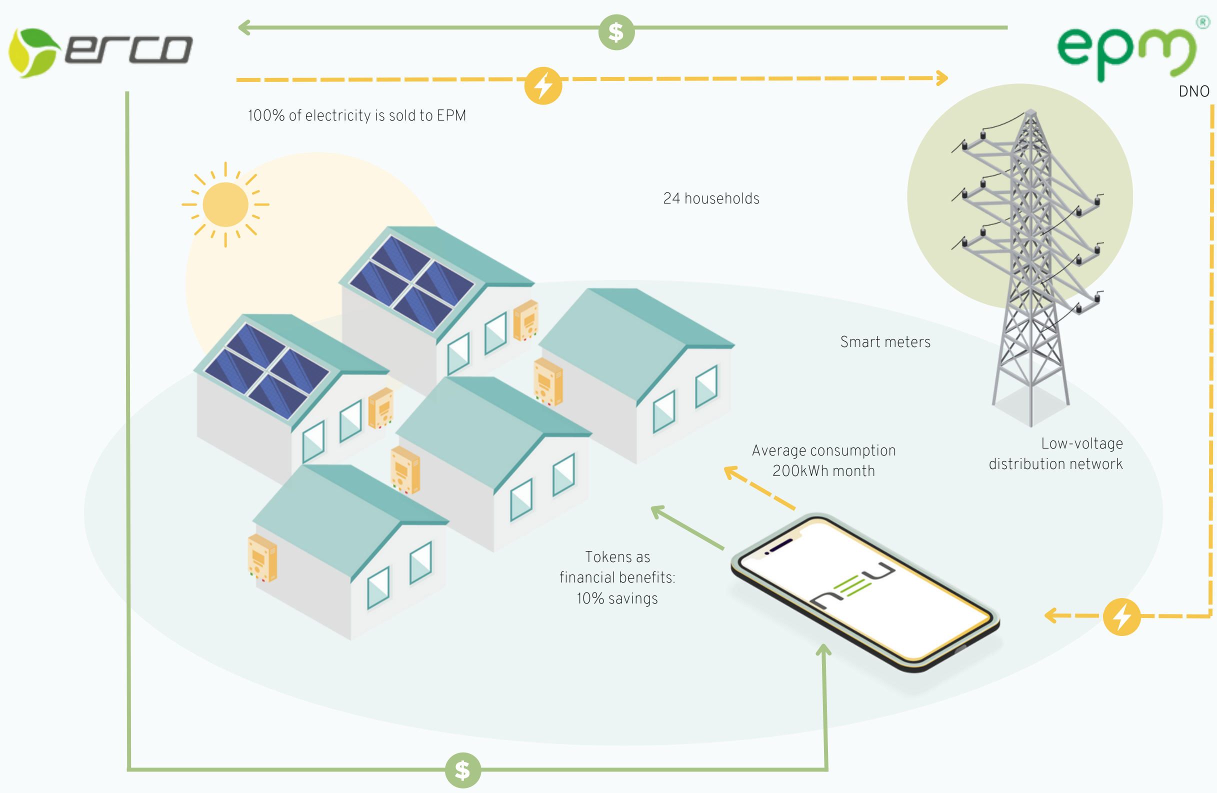
La Estrecha energy community: motivations and roles of project partners (retrieved from [29]).

Partner	Description	Motivations	Role
Transactive Energy Colombia – EIA University	Local academic institution	*Produce evidence for scaling energy communities in Colombia	*Project lead *Community interaction *Research, educational strategies, and result analysis.
EPM - Empresas Públicas de Medellín - Local utility company	Grid operator and incumbent energy retailer Local funder	*Improve relationships with customers. *Explore new possible business models and value proposals. *Corporate social responsibility	*Provide funding for assets. *Grid operator and energy buyer *Advice on grid requirements and legal connection procedures.
NEU	Technology company and digital energy retailer	*Test technology, UX/UI, smart metering management, and tokenization. *Learn new possible business models and value proposals	*Energy retailer for the users *ICT support: digital platform and application to monitor consumption and energy generation. *Distribute economic benefits through tokens.
ERCO	Distributed energy resources installer and power generation company	*Possible new market opportunities. *Learn new possible business models and value proposals.	*Design, install, operate, and maintain the PV systems. *Enable the electricity sale in the wholesale energy market.
UCL - University College London	International academic institution	*Learn from new contexts *Create new research collaborations and outreach	*Provide advice on research and methodological aspects.
UK Royal Academy of Engineering	International funder	*Promote sustainable development and collaboration with partner countries	*Provide funding for project management and research

An educational and engagement strategy was developed for the La Estrecha community to increase the community's knowledge of energy issues and create frequent discussion spaces for decision-making, answering questions, asking advice, and reporting on the project's progress.

Regarding the community's technical operation, a 20 kWp PV system was designed and divided into two 6 and 14 kWp systems installed on three communities' rooftops. The two systems were registered as Distributed generators. Since it was not feasible to register La Estrecha as a public utilities company to fulfill the Distributed generators requirement, ERCO registered the distributed generators to represent the community members.

100% of electricity is injected into the grid and sold to EPM (integrated retailer and grid operator) at wholesale market price (around 30% of the retail price users usually pay). ERCO transfers the money to NEU, the digital retailer, who transforms it into tokens and disburses them into each member's account. Then, the participants can use these tokens to pay their energy bills. There is no self-consumption in this energy model.



Costs were covered 100% by external funding, including the PV assets, designing, planning, project management, labor, workshops, and educational strategies. Most of the funds, covering project management and research costs, came from an international research grant by the UK's Royal Academy of Engineering. EPM covered the PV system installation costs (30% of the total project budget). The community participants did not make financial contributions to participate in the project.

In November 2021, ERCO installed the two PV systems on La Estrecha's rooftops. Still, the system took 16 months (until March 2023) to start operating. La Estrecha community had the first Distributed generators in the country, and this brought challenges regarding legalizing the connection because none of the involved institutions, including the relevant authorities, had standardized procedures for this type of connection. The process required multiple verifications from external companies and authorities. Institutional inexperience, procedure complexity, and long delays caused the community to remain on standby for over a year. The delays affected the relationship with the community because the benefits did not arrive timely as expected.

This pilot community is the first in Colombia and is expected to operate until 2024. The pilot developers are working to find ways for the community to continue and become self-sufficient. Community participants are expected to have savings around 10% of their regular monthly electricity bill.

3.5. POTENTIAL GROWTH OF ENERGY COMMUNITIES

After reviewing the conditions to develop energy communities in Colombia and the challenges faced by the La Estrecha trial, this section evaluates the potential growth and adoption rate of energy communities in the following decades based on the current landscape. The potential growth was estimated using the Bass diffusion model (see annex 1 for a detailed description of the model), which depends on three variables: m: market size of potential adopters, p: innovation coefficient, and q: imitation coefficient. p and q determine the diffusion speed of the new product in the market [30]. Only energy communities based on solar PV systems were considered for this analysis.

For energy communities, m was assumed as 20% of Colombian households (2,241,048)[2]. This assumption comes from a previous diffusion model on distributed energy installations [31]. p and q were estimated by a least squares method using historical data on small-scale self-generators in the Antioquia department[3]. In this case, small-scale self-generation adoption rates were used as a proxy variable as the closest user-centered energy model in the country. However, essential differences between small-scale self-generators and energy communities must be considered.

Completion time was used as the quantitative differentiating parameter between self-generators and energy communities. This parameter refers to the time required for a project to be completed and accounts for the differences in procedural and administrative challenges that energy communities have compared to self-generators. A small-scale self-generator's completion time is between 5 to 6 months. In contrast, an energy community using distributed generation takes around 15 months[4]. Considering this difference, energy communities' p and q were assumed to be 25% of the p and q values for small-scale self-generators in Antioquia.

A cities competitiveness index was used to extrapolate Antioquia's *p* and *q* values to the rest of the country's departments. This index measures a region's human capital, market efficiency, and innovation ecosystem [32]. Therefore, a multiplier factor was defined to adjust the p value for each department. q values remained constant across the country.

Finally, the *initial year* when the first household will join an energy community was determined based on the cities competitiveness index. According to these estimates, Antioquia and Bogotá (higher indexes) will have the first community by 2023. And the departments with lower indexes will have the first one by 2027. The country's potential growth for energy communities is determined by the sum of the department's adoption curves.

The Bass model was run to forecast three growth scenarios with varying p and q values depending on the completion time parameter used to measure the effectiveness of energy communities' installation, connection, and legalization processes.

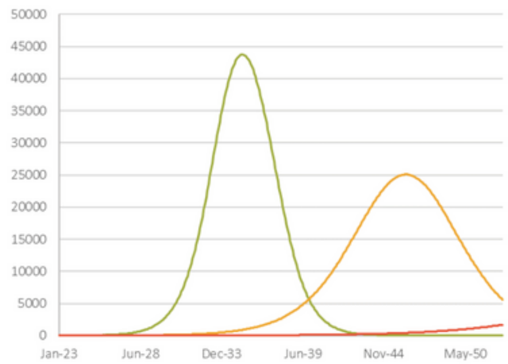
1. Current scenario:
The status quo continues, and energy communities' completion time remains around 15 months. In this scenario, there is no political willingness to deploy energy communities in the country. Policy and regulation remain stagnant with complex and lengthy processes. Under the current scenario, households participating in energy communities peak by December 2052 with 1,700 households. This implies that energy communities would only reach 3% of the potential adopters.

2. Moderate scenario:

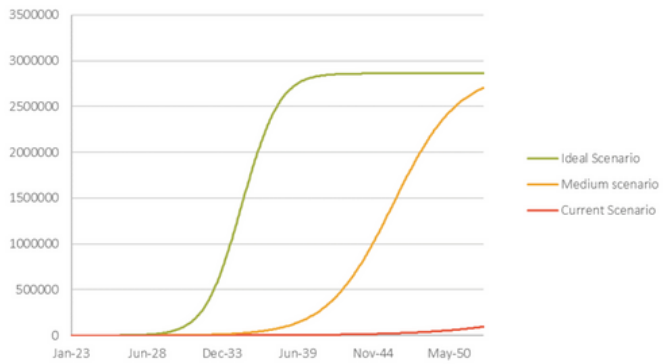
Completion time for energy communities decreases from 15 to 10 months. Some efforts are made to improve energy communities' development and make procedures more efficient. The number of adopters peaks by June 2046, with 25,088 households joining energy communities. Not all potential adopters are reached.

3. Ideal scenario:

The completion time of energy communities reaches the completion time of small-scale self-generators. In this scenario, policies and regulations make the processes for deploying energy communities simpler and faster. In this scenario, the number of households joining energy communities peaks by May 2035, with 43,747 households. From then on, the adoption rate diminishes as the market gets saturated until all potential adopters are reached by the middle of 2050.



n(t) Energy communities adoption curve



N(t) Cumulative number of adoptions

Figure 17. Energy communities' potential growth scenarios

The results from the growth model suggest that current conditions for deploying energy communities are insufficient for their massification. The diffusion model evidenced the impact of complex and lengthy procedures on the potential growth of energy communities. Under the current scenario, with completion times over ten months, it is unlikely that energy communities will develop in Colombia in the short-to-mid-term.

3.5. THE CHALLENGING LANDSCAPE FOR ENERGY COMMUNITIES IN COLOMBIA

Critical barriers to deploying energy communities were identified after reviewing the Colombian context and considering the lessons from La Estrecha Community.

- High investment costs for energy assets and expert labor.
- The complexity of the connection to the grid procedures.
- Lack of appropriate regulatory figures on collective self-consumption.
- Legal prerequisite of being a public utilities company to set up distributed generators.
- Lack of incentives or institutional support to motivate communities to develop energy communities.

In the La Estrecha case (that can be expanded to similar communities in the country), the community's participation, autonomy, and decision-making were limited, and the implementation relied on expert intermediaries. The main conclusion is that the La Estrecha community would not have been able to implement an energy community by itself. Furthermore, the potential growth analysis shows that current conditions are insufficient for massively deploying energy communities in the short-to-mid-term.

In the Colombian context, it is critical to differentiate between two types of energy communities. *Bottom-up* energy communities are initiated and funded by citizens without substantial intervention from external parties, and the benefits stay within the community. In contrast, *top-down* energy communities are initiated by external institutions and are funded by development banks or government funds. Top-down communities want to achieve community welfare, tackle energy poverty, and bring development to vulnerable areas. However, the processes and decision-making shift to the hands of external entities [29].

In Colombia, top-down communities will likely be more the rule than the exception; hence it is crucial from this point on to define two distinct actors:

Energy community members are the residents where the energy community will be installed. They are the primary beneficiaries of the energy solution and constitute the group of users that co-own, co-manage or co-share the energy assets themselves or the benefits from the assets.

Energy community developers are external institutions and actors that support the community members to deploy the energy community. The support may come from funding, technical assistance, social guidance, education, and training. These external institutions include governmental authorities, development banks, energy companies (DNO, Retailers), and NGOs.

Depending on each case, energy community members can assume a larger role as community developers. In the European context described in Section 1, energy community members are, by definition, the developers of the energy solution. Given the challenges identified in Colombia, it is probable that energy community developers will be external entities and will provide significant economic and technical support to community members.

In this complex environment and considering the novelty and few implementation rates in the country, there is a need for guidelines and assessment frameworks that support developers in conducting preliminary feasibility studies for energy community projects.

4 GUIDELINES FOR ENERGY COMMUNITIES IN COLOMBIA

This section presents guidelines for potential energy community developers to evaluate multi-dimensional feasibility factors to deploy energy communities in Colombia. The guidelines are grouped into community objectives, social, technical, legal, and economic feasibility. The guidelines were designed in collaboration with key stakeholders, including the developers of the la Estrecha energy community pilot, energy companies, and relevant NGOs and researchers (see annex 4.5 for the interview transcripts).

Relevant note:
Energy communities can use various technologies, such as wind, solar PV, biomass, micro-hydro, and batteries. Solar PV systems are becoming increasingly affordable, efficient, and the most widespread technology used for energy communities. For the scope of this work, only energy communities based on solar PV systems were considered for Colombia. Hence, the technical, economic, and legal aspects of energy communities will refer only to solar PV system-based energy communities.

4.1. COMMUNITY OBJECTIVES

Energy community developers must address the question: what benefits or outcomes are expected from the energy solution? What does the community intend to achieve? The local population needs to define the energy community's objectives. While low-income areas may be primarily concerned with meeting basic energy needs, high-income areas might prioritize energy bill savings and environmental responsibility.

Energy communities' objectives	
Economic savings and additional income sources	Community-owned energy systems can benefit participants through savings in their energy bills associated with self-consuming renewable energy and decreasing grid imports. Additional income can come from electricity sales or other services such as storage and demand response.
Socioeconomic community development	Installing and maintaining local renewable energy systems and businesses involve acquiring technical knowledge and energy-related skills, which can foster job opportunities and economic growth.
Environmental impact	Reduce dependency on fossil fuels, decarbonize power generation, and promote climate action. Increased environmental awareness.
Improve government – communities relationship	Increased potential to facilitate trust-building processes where communities obtain tangible benefits and take part in ownership and decision-making in the energy sector.
Strengthening community bonds	Enhancing local collaboration, common goals, and shared decision-making. Fostering a sense of belonging and cooperation within the community.
Empowering citizens	Stop being passive consumers, gain control over their energy consumption, generation, and environmental footprint, and reduce their reliance on traditional actors in the energy sector.
Energy democracy	Citizens and communities increase their ability to participate, engage in public debates, and make informed and collective decisions while planning and managing local energy projects.
Grid benefits	Positive impacts on the distribution networks and the overall grid by locally balancing supply and demand and reducing transmission and distribution losses.
Improving energy access and energy poverty	Providing access to decentralized, clean, and affordable electricity from grid-connected and standalone community microgrids can be a solution for areas without access to electricity and households in energy poverty.
Energy efficiency and sustainable behavior	Energy community members can learn about optimizing energy consumption and adopting sustainable practices, enhancing energy education, and behavioral changes at individual and collective levels.
Tourist attraction	The local community can become a site of interest for sustainable development, culture, and urbanism.
Synergistic impacts	By bringing people together around a common goal and fostering collaboration, an environment is created to address other local challenges (sustainable mobility, energy efficiency, waste management, access to clean water, and diverse local economic activities).

4.2. SOCIAL FEASIBILITY

Energy community models originated mainly in high-income population segments in developed countries. Therefore, when introducing energy communities in Colombia, it is important to adapt to local realities, priorities, and requirements. Active citizen participation is vital at all stages of the process. Moreover, energy communities must account for Colombia's geographical and climatic conditions and existing infrastructure to ensure practical and sustainable energy solutions.

Societal norms, cultural factors, and resistance to change can present barriers to establishing energy communities. Community engagement, acceptance, and collaboration are crucial, especially considering socioeconomic inequalities and vulnerable communities. An energy community's social feasibility consists of a socioeconomic diagnosis of the local population, defining engagement and education strategies, and creating community agreements amongst participants and project developers.

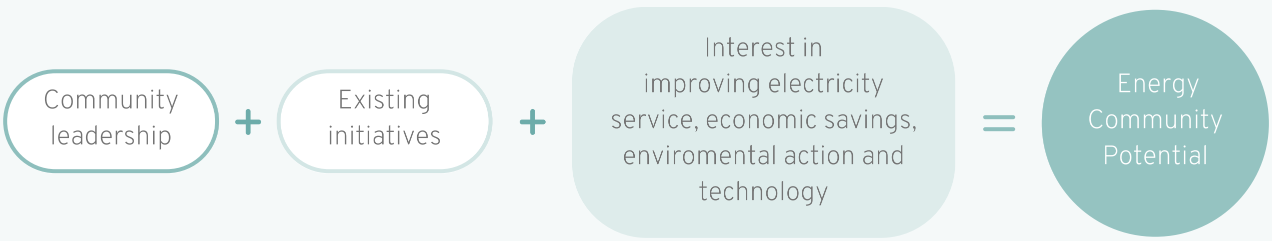
4.2.1. UNDERSTANDING THE SOCIAL CONTEXT

The local context includes its culture, traditions, history, community initiatives, and networks. Energy community developers must consider the participant’s cultural diversity and identity. It is essential to foster intercultural dialogue, respect, and inclusion among all participants. The following is a list of relevant aspects of the social context to develop an energy community.

- Basic socioeconomic assessment: number of households, household size, multi-family or single-family households, gender, age, occupation, education level, income, and socioeconomic stratum.
- Dwellings’ ownership status (house-owners or tenants).
- Existing community leadership and institutions (i.e., Communal Action Assemblies[5]).
- Existing community projects and initiatives.
- Attitude towards new digital and renewable energy technology.
- Environmental awareness and concern.
- Trust in public and private institutions (energy companies, national and local government). Especially relevant for communities that have suffered government abandonment.
- History of illegal grid connections and non-payment.
- Time available for volunteering activities.

A previous study conducted in Medellín revealed a distinct population segment willing to pay more for energy attributes related to peer-to-peer electricity exchanges, such as renewable energy, local energy, and social impact. This segment represented energy users between 30 to 60 years old, household owners in socioeconomic strata 2 to 4 with above-average technical education, a median household income ($USD 250–2200), high environmental and social awareness, and high technological affinity [33]. These characteristics can inform potential developers regarding which population segments would be more open to participating in energy communities. However, research and evidence are still significantly scarce in Colombia.

From the findings in the La Estrecha energy community pilot, it can be generalized that a local group has the potential to create energy communities if there are previous community leadership and initiatives in place and if individuals are aware and interested in improving their electricity service, economic savings, environmental action, and technology. Active collaboration with existing leadership structures is critical to understanding the local context and encouraging citizens to implement energy solutions in their territory.



4.2.2. EFFECTIVE ENGAGEMENT

Community engagement is critical for energy communities. Members should maintain active participation and fulfill their responsibilities within the community. Participants' commitment must be long-term and involve their initiative to solve potential problems. Not all members will be equally involved, so it is essential to establish clear minimum obligations and maintain the participant's interest, trust bonds, and involvement. Some strategies for effective engagement in energy communities are:

Strategies for effective engagement in energy communities:

- **Defining an advisory group:**
Establish a community advisory group composed of community representatives and project stakeholders. These groups can serve as a platform for ongoing dialogue and tap into the capacities of existing leadership, information exchange, and collaboration throughout the project.

- **Early and transparent communication:**
From the early stages of the project, open and transparent communication must be maintained. Communication channels must provide transparent information about the project's progress, operation, decision-making, and potential problems. Communication should be tailored to ensure inclusivity and participation from all community members. The main goals for community members must occupy the center of discussions, interactions, and decision-making to maintain motivation over time, especially during setbacks and difficulties.

- **Inclusive stakeholder meetings:**
It is essential to hold frequent in-person meetings with the community to discuss the project's progress. Stakeholder meetings and workshops must involve community members, local organizations, and other stakeholders in decision-making. Meetings should be a safe and inclusive space for dialogue where all voices are heard and respected. Attendance and participation in meetings, events, and community activities must be prioritized for strengthening community bonds and fostering collaborative work.

- **Encouraging a sense of ownership:**
Community members must be empowered to genuinely feel responsibility and ownership over the project rather than feel it is a service provided by external agents. Participants should have clearly defined responsibilities in the project to empower the community. Delegating duties to local community members (e.g., leading and arranging gatherings) increases the sense of ownership and accountability. Furthermore, the community must be actively involved in planning to contribute with their insights, local knowledge, and priorities.

- **Long-term engagement and monitoring:**
Engagement strategies should be continued during the project's lifetime. Communication and meetings must continue during operation and monitoring even after the project is implemented. The project developer must continuously seek community feedback, address concerns, and assess the project's social impacts over time.

4.2.3. EMPOWERING EDUCATION

Educational campaigns and strategies are necessary to inform the community about renewable energy, energy efficiency, and related topics. Project developers should provide opportunities for learning and capacity building for community members to participate in the project actively. Education is a fundamental component of communities' acceptability to have energy solutions in their territories and as an empowering tool to take control of the energy solution and decrease reliance on external entities.

Education and training strategies, programs, workshops, and skill-building activities should provide community members from different age groups with energy and sustainability knowledge, especially about the technologies and energy solutions they benefit from. In that sense, energy communities provide an excellent educational platform to learn about energy efficiency, responsible consumption, conscious and healthy behaviors, sustainability, just energy transitions, renewable energies, entrepreneurship, and local, sustainable development.

An example of workshop design is studying the electricity bill. Community members bring their bills, and experts help them understand how it is calculated and the variables that affect the amount they need to pay. The goal is for community members to understand their role as electricity end-users and how participating in an energy community shifts that role to a more active one.

Another educational strategy is a practical demonstration showcasing the functioning and benefits of renewable energy solutions with solar chargers or small-scale solar vehicles. Workshops should engage the community, allowing them to experience and understand the advantages firsthand and build confidence in the larger-scale implementation. Ideally, educational strategies should not be limited to knowledge sharing. Education programs should become practical skills that may eventually become job creation and social entrepreneurship. Finally, educational strategies must have clear success indicators. Social impact assessments should be conducted to identify the effects of the strategy on knowledge and skills creation.

4.2.4. COMMUNITY AGREEMENTS

Community decision-making must be registered in community agreements. Various significant agreements must be clearly defined before an energy community project begins. These agreements will be between the project developers and the community members.

Willingness to participate agreement:
It typically involves an informed consent document where local community members officially accept to participate in the project in collaboration with the external project developers. The third-party developers ensure that all stakeholders (community members, private companies, and public institutions) are informed about the project and have given their consent. This agreement should be written to ensure all participants fully understand the information. Regarding the content, this agreement should explicitly state the project definition, goals, and each actor's role. It should also clarify the basic aspects of all the conditions for participation.

Asset ownership agreement:
A clear statement of who owns the energy assets and if they are supposed to be transferred to community members or other entities during the operation of the energy community.

Benefit distribution agreement:
Rules and mechanisms to distribute benefits. In the Colombian case, with energy communities based on distributed generation, it means distributing profits from electricity sales. This agreement should clarify if the profits should be divided equally among all participants or if other considerations, such as a higher share going to the rooftop lenders, are to be included. Other options include setting up a community investment fund to manage the energy community’s income. Concerning the external project developers, the agreement should determine if the community’s income must cover some operational or maintenance costs.

Rights and duties agreement:
Community members can be entitled to rights such as savings on the energy bill, installation of a smart energy meter, guaranteed participation in educational and skill-building workshops, and the right to vote and express an opinion on community issues. Duties may include signing a consent form, participating in meetings and decision-making, switching energy retailers, and supporting the energy equipment’s installation (i.e., lending the rooftop for the PV installation and allowing technical visits).

4.3. TECHNICAL FEASIBILITY

This guide does not aim to comprehensively explain the technical design and implementation of solar PV systems. However, it intends to highlight key design criteria for solar projects in general and their potential impact on energy community models.

4.3.1. PLANNING AND DESIGN

Solar resource assessment
Historical solar irradiance data can be used to estimate the energy generation potential of a solar system available in the area.

Installation area
Community developers, community members, and the chosen solar PV contractor must define adequate rooftop or ground surfaces for installing the solar PV system. The installation area is a critical discussion point in the planning phase and determines the energy community's viability. Available rooftops or ground surfaces must be approved by community members and be technically viable for installation.

Rooftops must be structurally robust and capable of supporting the weight of the solar panels and withstand various weather conditions. There should be enough unobstructed rooftop space to accommodate the PV system. Additionally, the orientation and tilt of the rooftop or land area are relevant for solar energy capture.

Ground-mounted PV systems must consider factors such as wind and rain, seismic activity, and soil conditions. The mounting system should securely attach to the ground, allow for adjustable tilt angles, and provide easy maintenance access. Ground-mounted designs pose additional procedures related to land use, vegetation, forestry removal, construction permits, soil and inundation studies, and land use. These permits depend on each municipality and independent regional environmental authority[6].

For both installation modes, shading from nearby objects is an essential factor that can significantly impact the system's energy generation. It is necessary to analyze the shading patterns throughout the day and seasons.

System design and size

The design and size of a solar PV system depend on various factors. Appropriate system size is essential, considering factors such as available roof or land area, energy consumption, and capacity limits (1MW for distributed generation). Sizing is crucial to account for the community's energy requirements, available space, and budget. Component selection refers to choosing high-quality solar PV modules, inverters, mounting structures, and system components that meet performance and reliability standards. Usually, a PV contractor company decides on the components, and energy communities' developers should get quotes from multiple suppliers[7].

Electrical considerations

The electrical design involves the configuration of solar modules, wiring, and electrical protection devices, such as breakers and fuses. The inverter capacity must be properly sized to match the system size and expected power output. Electrical safety requires adequate grounding, surge protection, and isolation mechanisms to safeguard the system, occupants, and workers. Moreover, it is necessary to evaluate the building's electrical infrastructure to ensure it can accommodate the additional electrical load from the solar PV system.

Another important consideration is the electrical connection infrastructure required to connect the solar system to the interconnected grid. In Colombia, distributed generators must perform a simplified electrical connection study and be connected to the distribution grid.

Load assessment

As explained earlier, community self-consumption is currently not possible in Colombia. However, determining the community's energy consumption and load profile helps design a system that meets the community's specific energy needs, even if it is indirectly shared through energy sales. In addition, load assessments can help understand peak energy demands, consumption patterns, and seasonal variations to identify energy-saving opportunities and implement effective load management strategies.

4.3.2. INSTALLATION

The installation phase is the physical placement and connection of the PV system. The solar panels are mounted on the rooftop or ground-mounted structures. Depending on the system design, single or multiple micro-inverters may be installed.

The inverters are typically placed near the electrical panel. The electrical wiring, connectors, and junction boxes connect the solar panels, inverters, and electrical panels. Breakers, fuses, grounding conductors, and other protection devices are installed to ensure safety and protection against potential electrical hazards.

The installation phase is a significantly involves the community members. There are technical visits, equipment installation, and minor risks of damaging the participants' property. Delays can be expected and will probably affect the relationship with the community and the project developers. During the installation phase, communication channels, engagement, and education strategies are critical to keep the participants involved and motivated.

4.3.2. PERMITTING REQUIREMENTS AND CONNECTION TO THE DISTRIBUTION GRID

Includes obtaining necessary building and electrical permits. Feasibility also depends on the availability of a grid connection and net metering policies, enabling excess electricity to be exported back to the grid. Compliance with grid connection requirements, including safety protocols, metering, and agreements with the utility company, must be ensured. The solar PV system and the location's electrical wiring must comply with the Colombian Technical Regulation of Electrical Installations[8]. This requirement may challenge energy communities since many buildings have informal construction and wiring, especially in low-income areas.

In terms of grid connection, as explained earlier, the only viable alternative for grid-connected energy communities is distributed generation. The aggregated installed capacity of distributed generators may not exceed 50% of the nominal capacity of the local distribution network circuit. This rule limits the amount of distributed generation deployed in a determined area.

The grid connection process for a Distributed Generator has two general steps: obtaining the connection permit from the distributed network operator and registering in the Colombian electricity market at XM.

Connection permit and legalization to the DNO:

1. A grid connection request is sent to the network operator. After submitting the relevant documentation, the grid operator approves the community's PV system installation.
2. PV system installation.
3. The grid operator visits the site to verify the system and the connection.
4. An external verifier visits the site to validate that the system and the connection comply with the grid operator conditions.
5. The grid operator visits the site to verify that the generator can start feeding power into the grid.

Registering in the Colombian electricity market:
For the community to sell energy, it must register with XM, the market operator. This process consists of the following steps:

1. Collect the information to request registration and access to XM´s platform.
2. Upload the technical information and approvals to the platform.
3. Activation of the commercial frontier to sell energy in the National Interconnected System.
4. Registration of the energy sales contract with the energy retailer.
5. Billing of energy sold.

Currently, there are no established response times for distributed generators, and the process can take up to three months. Finally, when the distributed generator comes into operation, the electricity sold from the distributed generator is settled through XM.

4.3.4. OPERATION AND MANAGEMENT

Once the system is legally connected and feeds energy into the grid, the operation and management of an energy community have two main components, capturing and distributing the benefits. The type of capture and distribution mechanisms are highly dependent on the energy community's legal figure (subsection 4.4) and will fundamentally define the economic feasibility (subsection 4.5).

Capturing the benefits

Solar PV systems have two potential income sources: self-consumption and electricity sales. Self-consumption refers to savings in the overall community electricity costs by decreasing grid imports and consuming directly from the community solar system. There is no available regulatory figure for community self-consumption. Therefore, electricity sales via distributed generators are the only income source for energy communities (revenue sources for energy communities are discussed in more detail in subsection 4.5).

Distributing the benefits

Distributing the benefits consists of sharing the profits or energy savings from the communal energy solution. Usually, benefit distribution involves digital platforms where participants can monitor their consumption and generation, and there is transparency about benefit distribution.

The community agreements must define the distribution mechanism before starting the operation. A community could determine, for instance, that participants lending their rooftops or ground surfaces for the solar PV system should receive a larger share of the benefits. Other considerations involve each household's consumption patterns and volume and distributing the savings accordingly.

For distributed generators, there is a monthly income from electricity sales. In the La Estrecha case study, this income is transformed directly into equal savings to each participant’s energy bill since the retailing company also enables the distributed generator sales. However, in other energy communities, the distribution could be handing out cash payments, creating a community fund, or other mechanisms for managing the community's profits.

4.3.5. MAINTENANCE AND RISKS

Maintenance and accessibility are relevant aspects of solar PV systems. The PV modules require periodic cleaning and inspection, requiring safe access to the rooftop or ground surface. Fire safety considerations and protection from environmental factors, such as wind, rain, and extreme weather conditions, should be considered. Furthermore, security measures like perimeter fencing, surveillance cameras, or alarms should be considered to deter theft or vandalism.

Rooftop PV systems may carry minor risks for participants, such as leaks or rooftop damage during installation and operation. These risks must be explained and discussed with the participants.

The maintenance and security of the energy systems pose an opportunity to involve the community members. A potential benefit of energy communities is to create employment by maintaining and protecting the community's energy assets. However, the involvement of community members in technical tasks is highly dependent on the type of educational and training programs conducted and the level of commitment that community members can have within the community. Some questions about the maintenance and the energy community are who will maintain the panels, and how often? How will the cleaning and maintenance costs be covered? And what will be the remuneration scheme for participants?

4.4. LEGAL FEASIBILITY

The two primary legal considerations for energy communities are to establish the community under a legal form and register as a Public Utilities Company (Empresa de Servicios Públicos - E.S.P).

In the new draft Decree that seeks to regulate energy communities in Colombia, one of the most important provisions is the possibility for energy communities to associate with each other to carry out joint projects. Likewise, they will be able to establish public-popular and private-popular alliances with third parties, which will allow collaboration between public and private entities and the communities.

On the other hand, the energy communities or associations must be constituted as legal entities to participate in the commercialization of energy and the Superintendence of Public Utilities will regulate the figure of Community Public Utility Company (E.S.P.C.) and will determine the cases in which the energy communities must be constituted as such.

4.4.1. LEGAL ASSOCIATION FORMS

Energy communities must be constituted under a legal form. With legal representation, energy communities may sign contracts, distribute money among members, and participate in the electricity system. Currently, no legal figures are explicitly defined for energy communities, and, except for La Estrecha, no energy communities are operating under the currently available forms. There is a significant challenge regarding how citizen-driven communities can navigate the procedures' complexities and assume economic and legal responsibilities.

There are some critical questions for energy community developers and participants regarding the legal registration of the community. What are the obligations of participants? How can new members join? What happens if members breach their commitments or wish to leave the community? Who will cover the financial expenses related to the legal registration of the community?

The following table presents some options in Colombia that energy communities can use to register legally and operate in the sector. The table below compares different legal forms that energy communities can use.

Legal form	Description
Cooperative	A group of people with common interests associate to satisfy their economic, social, or cultural needs democratically.
Non-profit organizations	A non-profit entity allocates resources to carry out activities of general interest, such as education, health, culture, or social development.
Association	Allows the grouping of individuals with a common purpose, whether social, cultural, educational, sports-related, or others.
Simplified Stock Company (SAS)	Business companies with a flexible and simplified structure require at least two shareholders.
Public Limited Company (S.A.)	Capital is divided into shares, and the liability of the shareholders is limited to their shareholding.
Limited Liability Company (SRL)	The liability of the partners is limited to the amount of their capital contribution, and the company's capital is divided into participation units.

Cooperatives and simplified joint stock companies are energy communities' most viable legal alternatives. Below there is a brief guide to their required procedures. According to Law 454 of 1998, cooperatives are Non-Profit Entities created to produce, distribute, and consume goods and services to satisfy the needs of their members jointly and efficiently.

4.4.2. REGISTRATION AS A PUBLIC UTILITIES COMPANY

As explained earlier, only Public Utilities Companies can sell energy to the grid from distributed generators. Therefore, an energy community can only be viable if it also registers as a Public Utilities Company in addition to establishing as a legal form presented in the last section.

In the new draft Decree that seeks to regulate energy communities in Colombia, the creation of a new figure of Community Public Utility Company (E.S.P.C.) is proposed, which will potentially have special considerations for community projects. However, this figure is not yet regulated in the country.

Colombian National Law 142 of 1994 stipulates the requirements for registering as a Public Utility Company and the obligations, prohibitions, and tax regime. The registration process takes around ten working days. Once registered, Public Utilities Companies must report their activities to the Public Utilities Superintendency. Power generation companies must report yearly on commercial, technical, and financial information.

A community is likely unable to register under a legal form and as a utility company. In that case, similarly to the La Estrecha case, an external company can serve as a commercial representative of the community. The commercial representative will represent the community-owned distributed generator in the electricity market and be responsible for technical and regulatory compliance. It is also in charge of delivering the money for the sale of energy to the users of the energy community.

4.4. ECONOMIC FEASIBILITY

The most critical challenge for energy communities is economic viability. High upfront costs, limited capital availability, and difficulties securing funding are barriers to implementing community-based energy projects. Currently, most energy communities rely on low-risk solar PV economic models to meet their customers' needs and mobilize capital at feasible conditions.

This subsection presents the general guidelines for understanding an energy community's economic feasibility based on an integrated financial planning approach. This approach consists of understanding the upfront investments, cost structure, revenue streams, and financial indicators that determine if the project is economically viable. While this subsection focuses on the main economic aspects of energy communities, Section 6 describes different ways of accessing funding in Colombia.

It is essential to mention that economic feasibility depends on the objectives and structure of the community. For instance, in the La Estrecha Community case, the project developers funded and operated the community. In other cases, project developers may expect a return on their investment or a minimum cost recoup, in which case the expected financial indicators change. Another case can be an energy community financing and operating their energy solution without substantial external help or funding.

4.5.1. INITIAL INVESTMENT

Capital expenditures are the upfront costs, including equipment, installation, engineering, procurement, and construction expenses. Solar PV system costs have sharply declined over the past decades. For instance, the turnkey system costs of Solar PV dropped from 4600 USD/KWp in 2010 to 1000 USD in 2019[9]. However, the upfront investments are still considerably high for most of the Colombian population, with prices ranging 3.200.000 to 3.500.000 COP/kWp.

The initial investment is directly related to the size of the solar PV system and its generation capacity described in the Technical Feasibility subsection. The system's size should be optimized according to the community's energy demand. It is essential to have enough installed capacity to create a viable economic model and strike a balance between meeting the energy needs and avoiding excessive oversizing.

A crucial factor related to the initial investment is the cost of debt. The project revenues must cover the debt interests depending on how the project's capital is sourced (cash contributions by members, equity, debt providers, fund raising, crowdfunding). In addition, the project must include insurance policies to protect the energy assets.

4.5.2. OPERATION AND MAINTENANCE COSTS

Operational expenditures include ongoing maintenance, repairs, monitoring, insurance, and administrative expenses. As mentioned in the Technical Feasibility subsection, the community agreements must explicitly state who covers the operating and maintenance costs and how.

The long-term economic feasibility is highly dependent on the expected lifecycle of the solar PV system. The lifespan of the components, warranties, and degradation rates is crucial for considering an adequate time horizon for the financial modeling. For solar PV projects, the time horizon is between 20 and 25 years.

4.5.3. REVENUE SOURCES

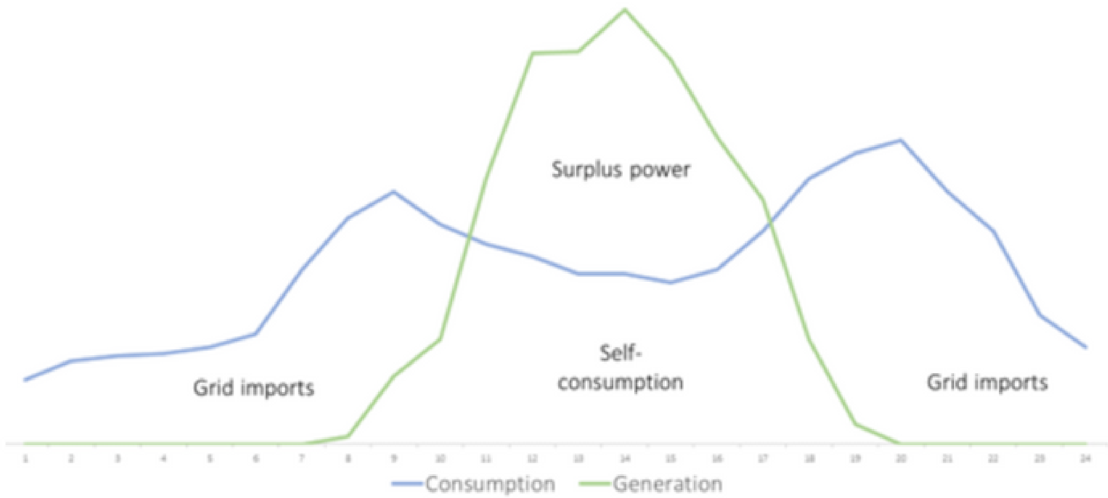
Energy communities' revenue alternatives can be grouped into the following categories:

- Savings on energy bills

In collective self-consumption, community participants collectively use the electricity generated to cover part of their energy consumption. The primary source of income for energy communities comes from these savings by displacing grid imports with electricity from the solar system. Savings depend on the community households' load profiles and how well they fit into the generation profile of the solar system.

The graph below depicts a typical daily load curve and a solar PV generation profile. Self-consumption is the demand share covered by solar generation. Surplus power occurs when generation exceeds demand, and the excess energy is fed back to the grid.

However, as noted earlier, collective self-consumption is still impossible under Colombian regulations.



Typical daily load curve and a solar PV generation profile

- Electricity sales

A critical economic factor is the electricity price per kWh the community will receive for its sales. Communities can sell their surplus power after self-consumption or the whole amount of electricity produced, as in the case of distributed generators in Colombia.

Electricity injected into the local distribution network can be subject to net metering, feed-in tariffs, or other support mechanisms. For net metering, excess electricity is used to offset future grid consumption or is paid directly to the customer. Feed-in tariffs are government incentive programs that offer fixed, premium rates for renewable electricity. In bilateral contracts, the community agrees with a purchaser on a buying price for the generation. In addition, electricity can be sold in the wholesale market. The projected price per kWh is critical to ensure a stable revenue stream for solar PV projects.

For distributed generators in Colombia, the alternatives for selling electricity are:

1. Selling electricity to an energy retailing company that supplies to users in the Regulated Market (CREG resolution 096 of 2019) [34].
2. Selling electricity at freely agreed on prices to an energy generation or retailing company supplies to users in the Non-regulated Market.
3. Selling electricity to an energy retailer integrated into a distribution grid operator. In this case, the company must purchase the electricity fed to the grid by a registered Distributed Generator. The purchase price is calculated considering the benefits to the local distribution grid. It is based on the wholesale spot price ($/kWh) (see the detailed equation in Annex B).

- Renewable energy certificates

The environmental attributes of renewable energy generation can be sold separately from the electricity produced, providing additional revenue streams.

- Additional revenues

From electricity usage in productive activities (machinery, agriculture, small businesses, e-mobility car sharing) and providing flexibility services.

4.5.4. FINANCIAL MODELLING AND PERFORMANCE INDICATORS

Financial modeling calculates performance indicators to determine if an investment or business is profitable. The financial indicators allow an investor to foresee the financial gains an investment could yield during its lifetime. This subsection does not provide a detailed explanation of energy assets' financial modeling but describes general concepts relevant to energy communities in Colombia.

- Basic financial modelling concepts

Future cash flows include inflows (electricity sales, renewable energy certificates) and outflows (initial investment, cost of debt, operating and maintenance costs). Discounting the cash flows derives the net present value of the expected future cash flows using a discount rate, during a determined period of time.

The investor determines the discount rate representing the cost of capital, the required rate of return, the time value of money and the associated risk. The discount rate usually reflects the opportunity cost for alternative investment options.

A positive net present value indicates that the project will yield a larger return than the required expected discount rate during the defined time horizon. Therefore, the project is attractive to the investor. The higher the net present value, the more attractive the project.

A zero net present value occurs when the returns are equal to the required discount rate. This means the investor will get the minimum expected return from the investment.

A negative value means that the project will not deliver the minimum return on investment considering the time horizon and the expected discount rate.

Some related indicators include the project's internal rate of return, the discount rate that makes the net present value equal to zero, and the payback period, the length of time it takes for an investment to reach the break-even point (i.e., when the net present value is zero).

- The importance of the levelized cost of electricity (LCOE)

LCOE represents the average net present cost per unit of electricity required to pay the expenses of implementing and operating the energy solution over the project's lifespan. It is determined by dividing the total discounted electricity production by all the costs. LCOE provides a standardized way to compare different energy generation technologies on an equal basis, considering all costs. The LCOE measures the competitiveness of an energy solution.

- Energy communities' financial performance

As energy communities in Colombia will require significant external support and funding, there may be a range of possible agreements and collaborations between communities and project developers. This collaboration implies different community configurations, participation models, capital structures, and economic models.

For instance, in the La Estrecha case study, the project developers fully funded the energy assets and operation, transferring all the revenue benefits to the community. The project developers had no interest in receiving a return on their investment. The assets, labor, and operating expenses were donated to the community. In the La Estrecha case, the project developers had research and innovation motivations rather than economic interests.

If energy communities are to be deployed massively in the country, viable economic models will be required, and financial analysis is a crucial tool for energy community developers to set clear objectives and analyze potential projects. The following scenarios explain how energy communities' conditions and financial expectations can change depending on the capital sources and the project developers´ goals and expectations.

- No external economic support

The energy community financial model needs to comply with business-as-usual financial standards. Project developers must recoup their investment in a reasonable time and expect a minimum return on investment. Whether the project developer is an external company or the community members themselves, the energy solution economic model must satisfy standard indicators.

For instance, typical financial indicators for solar PV distributed generators (less than 1 MWac) have internal rates of return over 30 years of a minimum of 11% and payback periods between 9 and 11 years. Distributed generators typically require LCOEs between COP$270 and COP$320 to be competitive in the Colombian sector.

- Economic support through capital donation and volunteering labor

The project developer provides funding for the upfront costs of the community. Therefore, the initial investment is removed from the financial analysis, improving the probability of having an economically viable model that accounts for operation, maintenance, and providing sufficient benefits to the community.

On the other hand, project developers can define a mixed structure where the energy community model must recoup part of the capital costs, and the external funder assumes others. Other ways of support include providing volunteer labor for operation, maintenance, and technical support. In this scenario, the external developer helps decrease the energy community expenses.

- Economic support through better purchasing prices and additional income

External community developers can provide economic support by improving the income flows for the community. Improved revenues can be achieved by securing bilateral contracts with prices per community generated-kWh larger than the community's LCOE. Other income sources can be renewable energy certificates. In this scenario, the community model revenue streams are improved to increase the probability of covering the costs at a reasonable discount rate.

Energy community planning checklist		
	Identify the potential community objectives	✓
Social feasibility	**Context evaluation**	
	Conduct a basic socioeconomic assessment	✓
	Conduct an attitude assessment: environmental awareness, technological affinity, trust in institutions	✓
	Identify and link with existing community leadership and initiatives	✓
	Identify previous cases of illegal grid connections and non-payment	✓
	Assess time available and willingness for volunteering activities.	✓
	Engagement	
	Design a communication strategy	✓
	Design an engagement strategy	✓
	Education	
	Design an education strategy	✓
	Community agreements	
	Draft a willingness to participate agreement	✓
	Draft an ownership agreement	✓
	Draft a benefit distribution agreement	✓
	Draft a rights and duties agreement	✓
Technical feasibility	**Solar resource assessment**	
	Estimate the generation potential of a solar system in the area.	✓
	Installation area	
	Identify prelimary viable areas for installation (determine if they are rooftops or ground surfaces)	✓
	System size	
	Conduct preliminary engineering studies to determine the optimal installed capacity	✓
	Electrical installations	
	Identify the potential connection point with the local distribution grid	✓
	Load assessment	
	Understand the energy consumption and billings of participants	✓
Legal feasibility	**Legal representation**	
	Determine the legal representation of the community to perform in the energy sector.	✓
Economic feasibility	**Economic interests and support**	
	Define clear economic interests and capabilities from developers and community members	✓
	Capital structure and potential financial sources	
	Define a preliminary capital structure and potential sources of funding	✓
	Economic model	
	Define the financial plan and business model under which the community will operate	✓
	Conduct the financial analysis and calculate financial indicators for decision-making	✓

5 ASSESSMENT FRAMEWORK

5.1. COMMUNITY'S OUTCOMES RANKING

The community's outcome ranking consists of determining the most significant community objectives. The indicators came from the benefits described earlier and were validated through a public survey asking citizens for their preferred benefits for participating in an energy community (complete survey data in annex 3).

The outcomes ranking is an essential exercise between the community and the project developers. The most relevant outcomes will inform the planning and implementation of the energy community. They will be at the center of the engagement and education strategies. They also determine the degree of motivation, alignment of interests between stakeholders, and willingness to participate and develop the energy community.

Potential community objectives	Ranking
Economic savings and additional income	/ 12
Environmental impact	/ 12
Socioeconomic community development	/ 12
Improve government – communities relationship	/ 12
Strengthening community bonds	/ 12
Empowering citizens	/ 12
Synergistic impacts (local economic activities)	/ 12
Tourist attraction	/ 12
Improving energy access and energy poverty	/ 12
Grid benefits	/ 12
Energy democracy	/ 12
Energy efficiency and sustainable behavior	/ 12

5.2. MULTICRITERIA DECISION ANALYSIS

A multicriteria decision analysis was used to evaluate the key feasibility factors. Multi-criteria decision was chosen as a helpful tool for decision-making in complex problem-solving. The multicriteria analysis was created following existing literature [35, 36] and expert interviews.

The multicriteria analysis was designed to help potential energy community developers to have an integrated planning framework to evaluate the potential of a community project. The analysis intends to motivate energy community developers to consider all dimensions of deploying an energy community. The following list describes the main steps for developing the multicriteria assessment:

- *Decision problem*: determine the preliminary feasibility of an energy community project.
- *Criteria selection*: based on the potential community goals and the feasibility guidelines described in section 4, five dimensions for the multicriteria assessment were defined: community objectives and motivation and social, technical, legal, and economic feasibility.
- *Criteria weighting*: criteria weights were determined based on their relative importance to the feasibility of an energy community. The weight values were determined based on the La Estrecha case study, results from the survey (See Annex) and expert interviews (Annex).
- *Alternative evaluation*: the La Estrecha energy community was evaluated as an example on how to use the multicriteria assessment.
- *Normalization and aggregation*: the criteria scores were normalized and aggregated to arrive at an overall feasibility value for the energy community.

Energy community feasibility assessment framework					
Objectives and motivation	Are community members and project developers clear about the energy community objectives and there is alignment of interests, motivation, and willingness to participate?				
	Score levels	Condition	Factor Score	Factor weight	Performance value
	5	Excellent clarity, alignment, motivation and willingness to participate			
	4	Good clarity, alignment, motivation and willingness to participate			
	3	Acceptable clarity, alignment, motivation and willingness to participate		4%	0.00%
	2	Poor clarity, alignment, motivation and willingness to participate			
	1	Very Poor clarity, alignment, motivation and willingness to participate			
Social feasibility	Are potentially viable rooftops or ground surfaces owned by community members?				
	Score levels	Condition	Factor Score	Factor weight	Performance value
	5	All potentially viable spaces			
	4	Most potentially viable spaces			
	3	About half potentially viable spaces		4%	0.00%
	2	Few potentially viable spaces			
	1	None potentially viable spaces			
	Are there existing leadership structures in the community?				
	Score levels	Condition	Factor Score	Factor weight	Performance value
	5	Excellent - Consolidated leadership over several years			
	4	Good - Strong leadership			
	3	Acceptable - Occasional and informal leadership		6%	0.00%
	2	Poor - Rare leadership on few occasions			
	1	Very Poor - Nonexistent leadership			

<table>
<tr><td rowspan="42">Social feasibility</td><td colspan="5">Are there previous community initiatives?</td></tr>
<tr><td>Score levels</td><td>Condition</td><td>Factor Score</td><td>Factor weight</td><td>Performance value</td></tr>
<tr><td>5</td><td>A Great Deal - various established initiatives sustained over time</td><td rowspan="5"></td><td rowspan="5">4%</td><td rowspan="5">0.00%</td></tr>
<tr><td>4</td><td>Much - established initiatives</td></tr>
<tr><td>3</td><td>Somewhat - some initiatives</td></tr>
<tr><td>2</td><td>Little - few attempts to develop initiatives</td></tr>
<tr><td>1</td><td>Never - no initiatives in the community</td></tr>
<tr><td colspan="5">Community members' environmental awareness</td></tr>
<tr><td>Score levels</td><td>Condition</td><td>Factor Score</td><td>Factor weight</td><td>Performance value</td></tr>
<tr><td>5</td><td>Very Important</td><td rowspan="5"></td><td rowspan="5">2%</td><td rowspan="5">0.00%</td></tr>
<tr><td>4</td><td>Important</td></tr>
<tr><td>3</td><td>Moderately Important</td></tr>
<tr><td>2</td><td>Of Little Importance</td></tr>
<tr><td>1</td><td>Unimportant</td></tr>
<tr><td colspan="5">Community members' technological affinity</td></tr>
<tr><td>Score levels</td><td>Condition</td><td>Factor Score</td><td>Factor weight</td><td>Performance value</td></tr>
<tr><td>5</td><td>Excellent</td><td rowspan="5"></td><td rowspan="5">2%</td><td rowspan="5">0.00%</td></tr>
<tr><td>4</td><td>Good</td></tr>
<tr><td>3</td><td>Acceptable</td></tr>
<tr><td>2</td><td>Poor</td></tr>
<tr><td>1</td><td>Very Poor</td></tr>
<tr><td colspan="5">How is the relationship between community members and relevant public and private institutions?</td></tr>
<tr><td>Score levels</td><td>Condition</td><td>Factor Score</td><td>Factor weight</td><td>Performance value</td></tr>
<tr><td>5</td><td>Excellent</td><td rowspan="5"></td><td rowspan="5">1%</td><td rowspan="5">0.00%</td></tr>
<tr><td>4</td><td>Good</td></tr>
<tr><td>3</td><td>Acceptable</td></tr>
<tr><td>2</td><td>Poor</td></tr>
<tr><td>1</td><td>Very Poor</td></tr>
<tr><td colspan="5">Are community members willing to invest time in volunteering community activities?</td></tr>
<tr><td>Score levels</td><td>Condition</td><td>Factor Score</td><td>Factor weight</td><td>Performance value</td></tr>
<tr><td>5</td><td>A Great Deal</td><td rowspan="5"></td><td rowspan="5">2%</td><td rowspan="5">0.00%</td></tr>
<tr><td>4</td><td>Much</td></tr>
<tr><td>3</td><td>Somewhat</td></tr>
<tr><td>2</td><td>Little</td></tr>
<tr><td>1</td><td>Never</td></tr>
<tr><td colspan="5">Do community members pay their utilities bill in time?</td></tr>
<tr><td>Score levels</td><td>Condition</td><td>Factor Score</td><td>Factor weight</td><td>Performance value</td></tr>
<tr><td>5</td><td>Always</td><td rowspan="5"></td><td rowspan="5">1%</td><td rowspan="5">0.00%</td></tr>
<tr><td>4</td><td>Usually</td></tr>
<tr><td>3</td><td>About Half the Time</td></tr>
<tr><td>2</td><td>Seldom</td></tr>
<tr><td>1</td><td>Never</td></tr>
</table>

Technical feasibility	How is the solar irradiance in the area?				
	Score levels	Condition	Factor Score	Factor weight	Performance value
	5	Excellent		10%	0.00%
	4	Good			
	3	Acceptable			
	2	Poor			
	1	Very Poor			
	Are there potentially viable installation rooftops or ground surfaces?				
	Score levels	Condition	Factor Score	Factor weight	Performance value
	5	A great deal of potentially viable spaces		11%	0.00%
	4	Several potentially viable spaces			
	3	Some potentially viable spaces			
	2	Few potentially viable spaces			
	1	None potentially viable spaces			
	How close are the potential spaces to distribution grid lines?				
	Score levels	Condition	Factor Score	Factor weight	Performance value
	5	Less than 10 meters		2%	0.00%
	4	10 - 15 meters			
	3	15 - 20 meters			
	2	20 - 25 meters			
	1	Over 25 meters			
	Is there available capacity in the local distribution circuit for the estimated generation capacity? (50% limit)				
	Score levels	Condition	Factor Score	Factor weight	Performance value
	5	Yes		5%	0.00%
	3	No, but the DNO may increase the limit			
	1	No			
Legal feasibility	Is the community registered under a legal figure or has a legal representative?				
	Score levels	Condition	Factor Score	Factor weight	Performance value
	5	Definitely: Yes, it is registered with a legal form or has a legal representative		8%	0.00%
	4	Very likely: No, but is very likely that it can register			
	3	Likely: No, but it is likely it can register			
	2	Unlikely: No and it is unlikely it can register			
	1	Very unlikely: No and it is very unlikely it can register			
	Is there an external institution willing to represent the community?				
	Score levels	Condition	Factor Score	Factor weight	Performance value
	5	Definitely		7%	0.00%
	4	Very likely			
	3	Likely			
	2	Unlikely			
	1	Very unlikely			

Economic feasibility	Community members' capacity and willingness to fund the project				
	Score levels	Condition	Factor Score	Factor weight	Performance value
	5	Very high			
	4	High			
	3	Moderate		7%	0.00%
	2	Low			
	1	Very low			
	Percentage of capital costs covered by donations and external support				
	Score levels	Condition	Factor Score	Factor weight	Performance value
	5	75 - 100%			
	4	50 - 75%			
	3	25 - 50%		8%	0.00%
	2	0 - 25%			
	1	0			
	Level of external experts volunteering labor and technical support				
	Score levels	Condition	Factor Score	Factor weight	Performance scores
	5	Very high			
	4	High			
	3	Moderate		6%	0.00%
	2	Low			
	1	Very low			
	Likelihood of accessing better purchasing prices and additional income				
	Score levels	Condition	Factor Score	Factor weight	Performance value
	5	Very high			
	4	High			
	3	Moderate		5%	0.00%
	2	Low			
	1	Very low			
	Viable alternative funding sources identified				
	Score levels	Condition	Factor Score	Factor weight	Performance value
	5	A great deal of viable funding sources			
	4	Several viable funding sources			
	3	Some viable funding sources		5%	0.00%
	2	Few viable funding sources			
	1	Nonviable funding sources			

Dimension	Factor weight	Performance value	Result
Objectives and motivation	4%	0%	0%
Social feasibility	22%	0%	0%
Technical feasibility	28%	0%	0%
Legal feasibility	15%	0%	0%
Economic feasibility	31%	0%	0%
Total	100%	0%	0%

Score	Relevance	Explanation
80 - 100 %		Very high feasibility
60 - 80 %		High feasibility
40 - 60 %		Moderate feasibility
20 - 40 %		Low feasibility
0 - 20 %		Very low feasibility

A note on limitations

The feasibility analysis was built considering there is only the option of Distributed Generators in the Colombian context presently. Potentially, there will soon be new policy and regulatory updates to accelerate energy communities' development. Furthermore, the multi-criteria must be used considering each independent case and decision problem.

6 ROADMAP TO ACCESS FUNDING

Energy communities encounter financial challenges due to the substantial upfront costs required for acquiring and installing energy assets. Funding from banks or investors can be difficult to access, as these initiatives are often perceived as risky. Limited favorable financing options and government incentives adds to the financial hurdles. Additionally, the lack of financial expertise within community members can hinder effective project management. Overcoming these obstacles requires innovative financing models, supportive policies, and capacity-building efforts. This section describes the current financial mechanisms to access solar PV systems that energy communities may use, identifies financial access gaps, and recommends ways to facilitate access to funding in the Colombian context.

6.1. CURRENT FINANCING ALTERNATIVES

This section presents various financing alternatives for solar PV systems in Colombia. The financing alternatives can be loans, power purchase agreements, or community-based crowdfunding models supplied by traditional financial entities such as banks, financial cooperatives, energy companies, new financial technology companies (Fintechs), and the government.

FINANCING ALTERNATIVES FOR SOLAR PV SYSTEMS

DEBT FINANCING	FINANCIAL LEASING	POWER PURCHASE AGREEMENTS	CROWDFUNDING	GOVERNMENT
Specialized credits Free investment credit	Monthly fee Purchase option	Monthly fee Purchase option	Numerous investors Digital platforms	Tax incentives Government funds

6.1.1. DEBT FINANCING

Community project developers can borrow money through debt financing to cover project costs. Commercial banks, development banks, and specialized renewable energy financing institutions are common sources of debt financing. For accessing debt financing, it is crucial that community developers have an appropriate credit rating, and it is foreseeable that many small-scale energy systems and community groups will struggle to qualify for bank loans at reasonable rates.

In Colombia, traditional financial institutions such as banks and financial cooperatives generally provide two financing options: free investment and specialized loans. The debt financing options are similar and subject to the same regulation, but they differ in the interest rates. In 2022 there were 20 banking institutions with financial products available for solar PV systems.

6.1.1.1. FREE INVESTMENT LOANS

The free investment loan provides cash that the user can use freely. It is usually the most accessible credit in financing systems because it does not require a co-signer or any real estate as security. Generally, they are small loans, but they can go up to COP 850.000.000 with terms of up to 96 months. A fixed interest rate with an average year of 30.86% is commonly used.

6.1.1.3. SPECIALIZED LOANS

Specialized loans are those programs specific design for investing in renewable energy systems. There are 49 programs of specialized loans offered by six entities. The capital, project requirements, and interest rates vary considerably, with some of them with interest yearly rates as high as 55% [37].

6.1.2. FINANCIAL LEASING

Funding a solar PV system through financial leasing means that a third-party (bank, energy company, or other financial entity) acquires the energy assets, and the recipient pays a monthly fee for a determined period. The lease agreement enables the community to fully use the assets (operation, electricity consumption, and sales). The leasing contract involves the transfer of the energy assets to the community by the end of the lease contract.

This model is attractive since it represents zero investment costs, and the recipient becomes the legal owner of the assets for the lease period, including some risks related to maintenance and possible damage. The monthly fee is fixed without relation to energy consumption. The typical duration is ten years and is commonly restricted to companies [38]. In leasing models, the tax benefits associated with renewable energy technology go to the recipient if a selling contract is in place. A crucial question is whether energy communities could have legal and tax figures to take advantage of these benefits effectively.

The most relevant of this business model is the green line (Línea Verde) of Bancolombia bank. This leasing product is part of its sustainable leasing program, with a term of up to 60 months and an amount of up to 30.000 million COP [39]. However, it is restricted to enterprises with a relevant credit history.

6.1.3. POWER PURCHASE AGREEMENTS

In power purchase agreements (PPAs), an external entity acquires the solar system, and the recipient pays for the electricity generated by the system over a determined period. PPA's contracts can be based on the energy generated by the system, or the energy consumed by the community. The agreement period ranges between 10 to 20 years. PPAs are usually offered by energy companies that fund, operate, and keep ownership of the solar PV system. PPAs can help energy communities to kickstart a community solar PV system with no initial investment.

6.1.4. CROWDFUNDING

Crowdfunding is an increasingly attractive option to finance energy communities. Crowdfunding collects small sums of money from numerous individuals to fund an energy community. It leverages the convenience of social media and crowdfunding platforms to connect energy community developers with potential funders [40].

Crowdfunding is usually mediated by Fintecs, companies in the financial sector that utilize technology to improve or automate financial services and operations. Fintecs aim to be innovative financial services providers, add value to existing financial services, simplify financial processes, make financial products more accessible and transparent, and provide better solutions to people through technological capabilities.

Collaborative capital raising has considerable potential for energy communities since the investors' return on investment expectations may vary significantly, and the funds can be contributions, prizes, shares, royalties, or loans. In Colombia, the company Unergy provides a pioneer crowdfunding platform for distributed solar PV systems, which could be adapted to fund energy communities in the future [41].

6.1.5. GOVERNMENT INCENTIVES AND FUNDING ALTERNATIVES

Government policy support incentives, such as tax credits, grants, or subsidies, can significantly affect solar PV systems' financial viability. Assessing the availability and applicability of such financial support is crucial to offset the initial investment and improve the system's overall return on investment. In Colombia, tax Incentives for renewable energy sources have been mainly tax benefits, exemptions, and accelerated depreciation. These incentives were defined by laws 1715 of 2014 and 2099 of 2021.

TAX BENEFITS

from law 1715 of 2014 modified by law 2099 of 2021

1.

INCOME

Discount of a 50% of the investment on FNCER* and Smart metering projects distributed on a period of 15 years from the first taxable

*Non-Convencional Renewable Energy Sources

2.

ACCELERATED DEPRECIATION

Defines thet the maximum annual depreciation rate is 33.33%. This expensive is deductible from the income tax

3.

IVA* EXCLUSION

For actions and measures of efficient energy management

For renewable energy generation asses and services

For smart meeting asses

*Value added tax

4.

TARIFF CHARGES

Exception of importation tariff charges to equipment, asses, materials for FNCER and energy efficiency projects that are not produced by the national industry

Additionally, the Colombian government provides funding alternatives through FENOGE, the Fund for Non-Conventional Energies and Efficient Energy Management. Its role is to fund, administer, and carry out plans, programs, and projects to improve energy efficiency and use non-conventional energy sources in the country. FENOGE offers non-reimbursable capital, a financing option where the initial capital source is not subject to reimbursement, payment, return, or restitution by the applicant [42].

6.2. FINANCING GAPS AND CHALLENGES

The access to funding mechanisms for renewable energy systems suitable for energy communities in Colombia faces several gaps. These gaps refer to challenges and limitations that hinder the availability and accessibility of financial resources for renewable energy projects in the country. The main gaps were identified through interviews with financing experts from banks, cooperatives, start-ups, and the government.

- The lack of regulatory figures on energy communities, collective self-consumption, and self-generation creates uncertainty regarding the performance and profitability of energy community schemes and can make investors hesitant to support such projects.
- Insufficient financial instruments and funding opportunities specifically tailored for community energy projects.
- Difficulty for energy communities to access traditional financial instruments. Obtaining funding can be complex, burdensome, and time-consuming. Furthermore, energy communities as emergent social organizations would, in most circumstances, be unable to provide adequate credit scores and collateral to sustain traditional debts.
- Limited awareness and understanding of renewable energy options and their potential benefits among the general public and local communities in Colombia.
- High perceived risks regarding social issues and profitability uncertainty associated with energy communities can deter potential investors and financial institutions from providing funding.

6.3. ACTIONABLE PLAN TO FACILITATE AND SIMPLIFY FINANCING ACCESS

Addressing the identified gaps requires a multi-faceted approach that involves raising awareness about renewable energy, developing dedicated regulatory figures and funding mechanisms, streamlining bureaucratic processes, and mitigating perceived risks associated with renewable energy projects. By bridging these gaps, energy communities in Colombia can have improved access to funding mechanisms for renewable energy systems. The following list presents the Colombian energy sector authorities with four actionable steps to facilitate and simplify funding access for energy communities in Colombia:

1. Create dedicated energy community regulatory figures.

The government needs to define regulatory figures for energy communities, collective self-consumption, and self-generation, ensuring that energy communities can have a viable business model and access preferential tariffs (above regular wholesale market prices). This step is crucial to mitigate potential funders' concerns regarding the performance and profitability of energy community projects. In addition, the government can offer guarantees or insurance schemes to protect investors against potential losses and uncertainties associated with energy community projects to incentivize investments.

2. Establish dedicated funding mechanisms.

Establish dedicated funding programs targeting energy communities with government agencies, financial institutions, and international organizations. The funding mechanisms must have clear guidelines, eligibility criteria, and streamlined application processes tailored to the needs of energy communities. The government should collaborate with local banks and financial institutions to create specialized loan products or financial instruments with favorable terms and conditions for renewable energy projects in energy communities.

3. Increase awareness, education, capacity building and technical assistance.

Firstly, collaborate with local educational institutions, NGOs, and community organizations to conduct workshops, seminars, and awareness campaigns to educate energy communities about the benefits of renewable energy systems and the available funding mechanisms. Secondly, design capacity-building programs to empower communities to develop bankable project proposals. Support spaces with local and international experts to provide training and guidance on project development, financing strategies, and accessing funding opportunities.

4. Foster partnerships and energy community networks.

Create collaboration spaces between energy communities, renewable energy developers, financial institutions, and investors through networking events, forums, and matchmaking sessions. Facilitate access to expert advice for communities though institutional programs where experienced renewable energy project developers or consultants can guide in securing funding and project implementation. Develop collaboration platforms that connect energy communities with potential investors, crowdfunding platforms, and impact investment funds interested in supporting renewable energy projects. Furthermore, provide a platform to monitor and measure the impact of ongoing funding initiatives and share success stories and best practices to inspire and motivate other energy communities to pursue renewable energy projects and access funding.

7 ANNEXES

1. ENERGY COMMUNITIES' POTENTIAL GROWTH: TECHNICAL REPORT

The Bass model is an analytical approach to evaluate a product's diffusion over its lifecycle: launch, growth, maturity, and decline [30]. In its early stages, the Bass model was implemented to evaluate the diffusion of durable goods, such as electric refrigerators, freezers, TVs, air-conditioners, clothes dryers, and coffee makers [30].

The Bass model has recently been used to understand renewable energy technologies' diffusion in different countries. Some of its applications include forecasting the diffusion of Hybrid Electric Vehicles in the USA [43], wind power in Pakistan [44], cross-country solar PV [45], solar PV and solar water heater systems in Japan [46], wind power in China [47] and solar PV market in Brazil [48].

In Colombia, the Bass model was applied to analyze the diffusion of photovoltaic systems and the influence of support schemes in Medellín [49] and to simulate the effect of the Pay-as-you-go scheme for solar energy diffusion in off-grid regions [50].

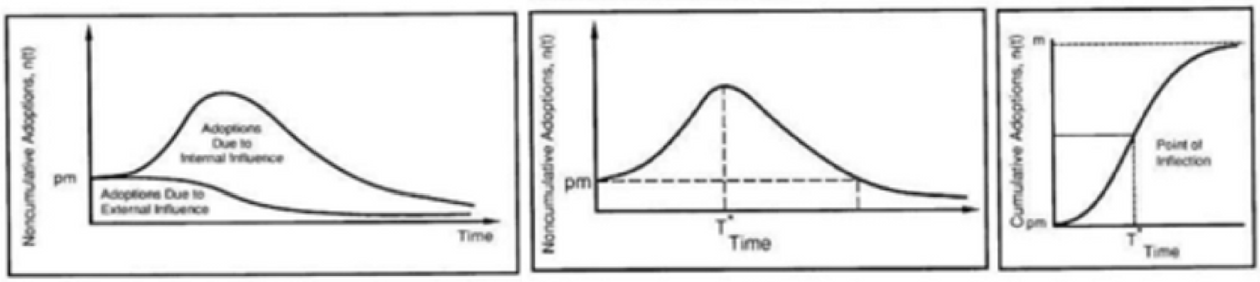
The Bass model focuses on how information about the new product is communicated to society; therefore, it assumes that there are two types of adopters: the innovators, influenced by mass media, and the imitators, influenced by word of mouth. This premise is transformed into the first-order differential equation shown below, in which p, the innovation coefficient, is the probability of initial adoption, and q, the imitation coefficient, represents the imitative behavior of the market [30].

$$n(t) = \frac{dN(t)}{dt} = p(m - N(t)) + \frac{q}{m} N(t)(m - N(t))$$

Where:

- n(t) is the number of adopters in a time t.
- N(t) is the cumulative number of adopters by t time.
- m is the market size and represents the number of potential adopters.
- p is the innovation coefficient.
- q is the imitation coefficient.

The function of adoption of the innovation n(t) follows a bell-shaped curve. While the cumulative number of adoptions, N(t), follows an S-shaped curve, as shown in the figure below [30]. This curve represents the lifecycle of the technology in three different growth stages: a slow take-up stage, followed by accelerated growth as the technology becomes widespread, and finally, slow growth when the market gets saturated [51].



Bass model n(t) and N(t) curves. Taken from [30].

As can be noticed in the formula, the Bass model depends on three parameters p, q, and m; p and q determine the diffusion speed of the new product in the market; therefore, high values of these parameters imply fast product development [30].

The literature accepts different p and q values. Some have referred p-values between 0.00007 and 0.03 [52], with higher values for Europe than for the U.S. [53]. And q values between 0.38 and 0.53 [52]. Nevertheless, in a forecast of the diffusion of Hybrid Electric Vehicles in the USA, based on monthly vehicle registrations, researchers estimated monthly p and q-values as 0.0000515 and 0.0728, respectively [43]. These values validate the p and q-values obtained for AGPE in Antioquia, which are 0.00000407 and 0.0744, respectively. P value is lower than the one obtained in the research mentioned before. Still, since values tend to be higher in Europe than in the United States, it is very likely that in Latin America, they are even lower [51].

p	0.00000407
q	0.0744

Table 3. Parameter estimation for AGPE in Antioquia.

Department	Multiplier factor	P value
Cundinamarca	110%	0.0000045
Antioquia	100%	0.0000041
Boyacá	91%	0.0000037
Valle del cauca	90%	0.0000037
Santander	90%	0.0000036
Caldas	89%	0.0000036
Atlántico	84%	0.0000034
Risaralda	83%	0.0000034
Quindío	81%	0.0000033
Cauca	80%	0.0000033
Tolima	79%	0.0000032
Bolívar	79%	0.0000032
Nariño	78%	0.0000032
Huila	77%	0.0000031
Magdalena	70%	0.0000029
Norte de Santander	68%	0.0000028
Córdoba	68%	0.0000028
Casanare	65%	0.0000027
Meta	65%	0.0000027
Sucre	65%	0.0000026
Arch. San Andrés y Providencia	64%	0.0000026
Cesar	63%	0.0000026
Caquetá	62%	0.0000025
La Guajira	56%	0.0000023
Arauca	54%	0.0000022
Putumayo	53%	0.0000022
Chocó	52%	0.0000021
Guaviare	49%	0.0000020
Amazonas	41%	0.0000017
Vichada	40%	0.0000016
Guainía	35%	0.0000014
Vaupés	32%	0.0000013

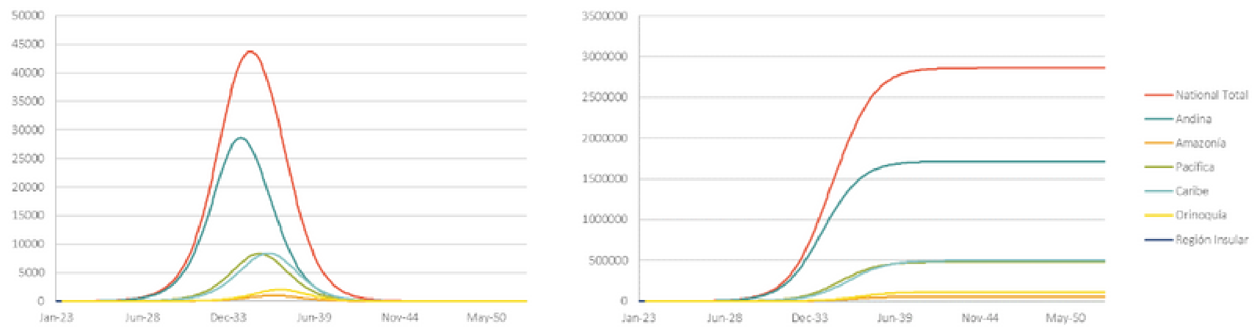
Table 4. P multiplier factor based on the Cities Competitiveness Index and p values.

Finally, it is essential to define the model's general limitations and assumptions [54]:

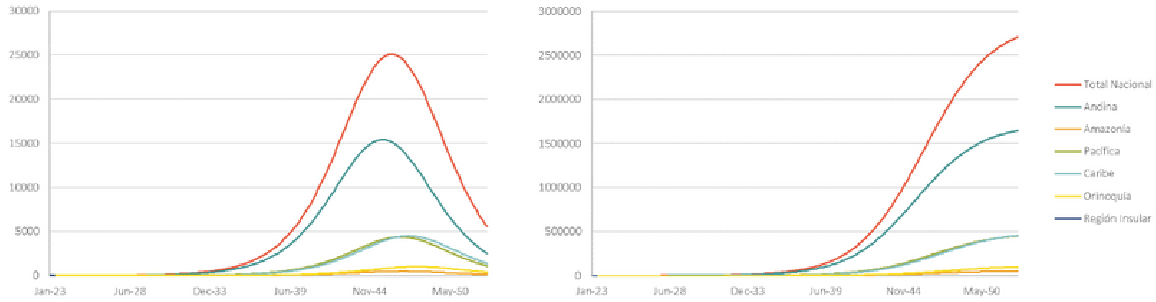
1. Consumers can be influenced only by advertising, educational campaigns, or interpersonal relationships.
2. Innovation and imitation coefficients remain constant over time.
3. The market's potential size is constant over time; population growth is not considered.
4. The diffusion process of other innovations does not influence the diffusion process.
5. There are no supply limitations.

COMPREHENSIVE GROWTH POTENTIAL ANALYSIS PER REGION

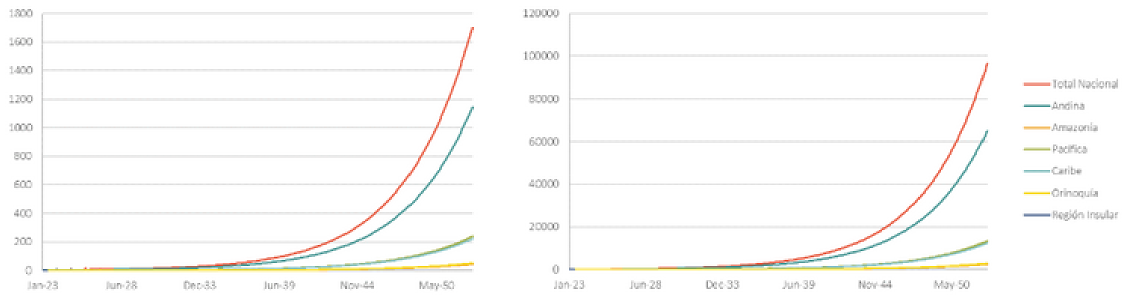
In the graphs bellow, Colombian departments were grouped by regions to facilitate a more comprehensive analysis. Andina Region groups the departments of Antioquia (in which Medellín is located), Boyacá, Caldas, Cundinamarca (in which Bogotá, the capital, is located), Huila, Norte de Santander, Quindio, Risaralda, Santander and Tolima. Amazonía Region groups the departments Amazonas, Caquetá, Guainia, Guaviare, Putumayo and Vaupés. Caribe Region groups Atlántico (in which Barranquilla is located), Bolivar, Cesar, Córdoba, La Guajira, Magdalena and Sucre. Pacifico Region includes the departments of Cauca, Chocó, Nariño and Valle del Cauca (in which Cali is located). Orinoquía Region groups Arauca Casanare Meta and Vichada. And finally, Insular Region is considered as the San Andrés and Providencia archipelago.



National ideal scenario of EC growth by regions (in the left n(t) and in the right N(t)).

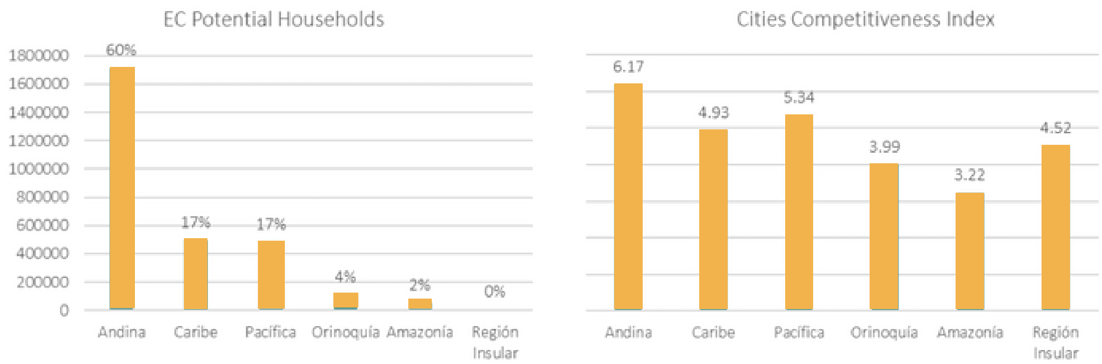


National medium scenario of EC growth by regions (in the left n(t) and in the right N(t)).

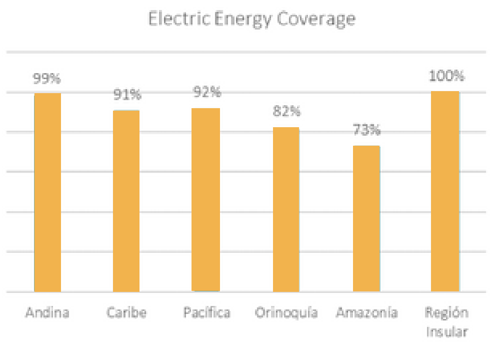


National current scenario of EC growth by regions (in the left n(t) and in the right N(t)).

The Andina region shows the higher EC growth in the three scenarios, not only because it has the highest p and q but because it has the highest m value since it houses 60% of the country's population. The Insular Region is the less developed since it has the lowest population. And is followed by the Amazonía and Orinoquía, which population represents around 6% of Colombia's population and have the lowest Cities Development Index, of 3.22 and 3.99, respectively.



Potential households and average Cities Competitiveness Index by regions.



Average Electric Energy Coverage percentage by region.

Orinoquía and Amazonía are the regions in Colombia with the lowest electric energy coverage, with departments of Vichada, Vaupés, and Guanía, having 48%, 53%, and 69% of electricity coverage. These departments also have the three lowest Cities Innovation Index, with values of 2.27, 2.83, and 2.49, respectively. In Amazonía and Orinoquía, under the ideal scenario, EC could potentially cover the electric energy coverage gap.

2. ELECTRICITY SALES PRICE FOR DISTRIBUTED GENERATORS

A distributed generator can sell directly to the retailer integrated with the network operator. In this case, the retailer is obliged to buy the energy from the distributed generator and the sale price of the energy delivered to the network will be calculated by applying the following expression:

$$PVgd_{h,m,n,i,j} = Pbolsa_{h,m} + Beneficios$$

$$Beneficios = 0.5 \times P_{n,m-1,i,j}$$

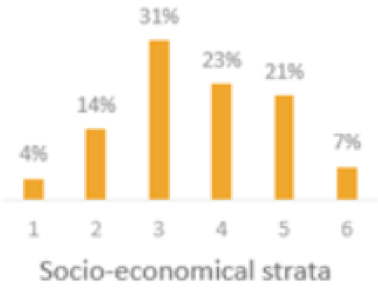
$PVgd_{h,m,n,i,j}$:	Sell price of distributed generation on hour h of month m on the tension level n to de energy supplier i on the market j, in \$/kWh.
$Pbolsa_{h,m}$:	The market price on the hour h of month m, in \$/KWh. When the market price is higher than the scarcity activation defined in resolution CREG 071 of 2006 or the one that replaces it; the energy price mustn't exceed the scarcity price.
$P_{n,m-1,i,j}$:	Is the value of technical system losses of the Grid Operator j, cumulated until the tension level n: $P_{n,m-1,i,j} = \frac{G_{m-1,i,j} * PRTe_{n,j,t}}{1 - PRTe_{n,j,t}}$ Where PRTen,j,t is calculated as: Gm,i,j: Energy buying cost (\$/kWh) for the month m, of the minor commercialization i, in the market j, determined as established by chapter III of Resolution CREG 119 of 2007.
Benefits to distributed network	Value is recognized by the benefits that bring distributed generation to the local distribution grid.

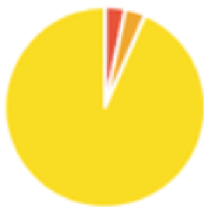
3. VALIDATION SURVEY SUMMARY

Benefit perceived for Energy Communities in Colombia

We conducted a survey to determine people's perceived value of the most significant benefits of energy communities. The survey is **representative of the most populated regions of the country and all socio-economic strata.**

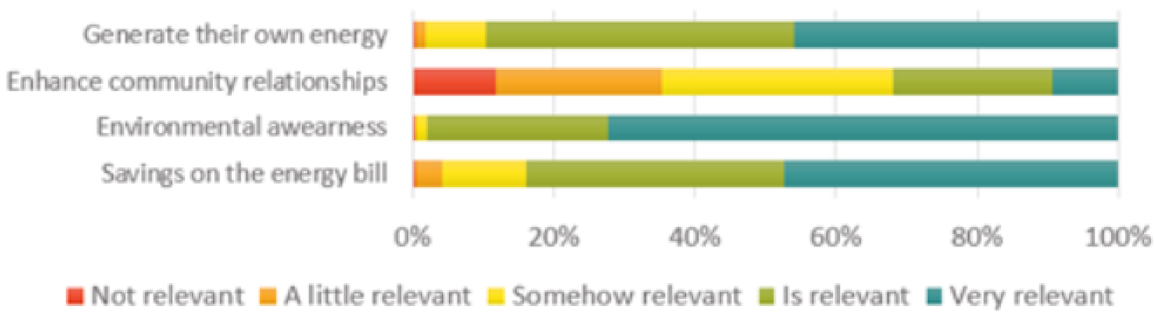
213 surveys
from people in 13 departments





94% are willing to participate in an EC, while 3% are not interested. The other **3%** would want to learn more about them.

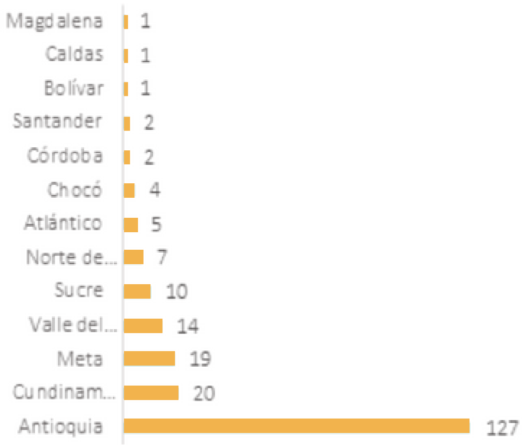
How important would each of these criteria be to you when deciding whether or not to join an Energy Community?



The benefit perceived as the most significant is the environment, people say that helping the environment is very relevant for them. When looking at the results segregated by stratum, we find that all of them have a similar trend

For further information, contact us in https://www.transactive-energy.co/ or by email at ana.ramirezz68@eia.edu.co

We ran a survey to determine the value people perceive from the most significant benefits of energy communities. The survey had 213 answers from people in 13, distributed as shown below.



Geographical representativeness

The survey has representativeness from the most populated regions in the country and from every socio-economic stratum, even though Colombian population stratification distribution is slightly different from the survey strata distribution. In Colombia 21% of the population is strata 1; 32%, strata 2; 29%, strata 3; 11%, strata 4; and 7%, strata 5 and 6 [55].

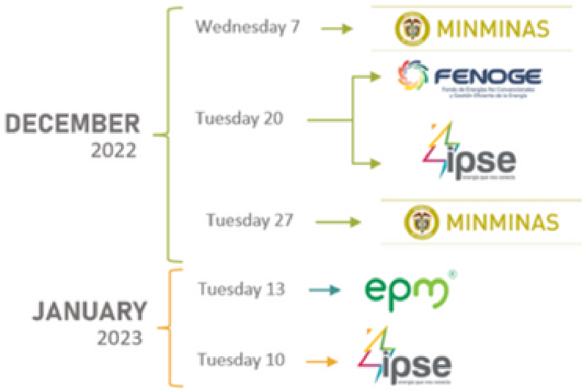
In the survey we asked people to choose how relevant was each potential benefit in the process of deciding if they wanted to participate in an energy community. The benefit perceived as the most significant is the environment, people say that helping the environment is very relevant for them; the second most relevant was savings on the energy bill, followed by the generation of their own energy. The least relevant is the enhancement of social relationships. When looking at the results segregated by strata, we find that all of them have a similar trend.

Benefit interest comparison between strata

4. PROJECT MEMORIES AND SUPPORT MATERIAL

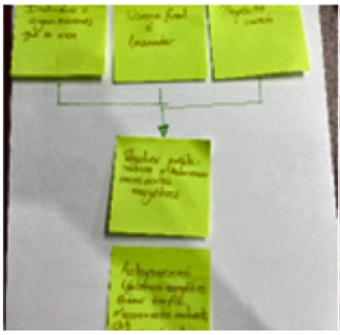
4.1. WORKSHOPS AND OUTREACH ACTIVITIES

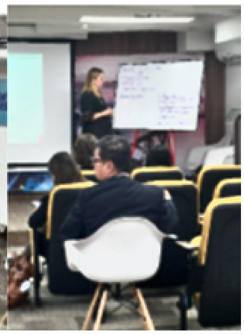
More than 16 meetings were held to socialize and discuss the project advance. The most relevant were during December 2022 and January 2023.



The teaching and learning materials were development by an inclusive process of co-creation, four workshops were made during the project with the different public, from government entities, academics, and energy businesses.

MINISTRY OF MINES AND ENERGY



[SP] Tittle	Areneras regulatorias para comunidades energéticas
Date	October 2022
Public	Officials of the Colombian Ministry of Mines and Energy ([SP] Ministerio de Minas y Energía)
Objective	Identify the regulatory and social barriers to the implementation of energy communities as a territorial development strategy in the energy transition.

MINING-ENERGY PLANNING UNIT



[SP] Tittle	Taller de exploratorio de comunidades energéticas
Date	October 2022
Public	Officials of the UPME (Mining-Energy Planning Unit, [SP] Unidad de Planeación Minero Energética) Colombia
Objective	Determine the catalysts, delays, and energy community implementation strategy. Generate a discussion on public policy guidelines for the fulfillment of sustainable development objectives.

ENERGY AND SUSTAINABILITY CLUSTER OF THE ANTIOQUIA CHAMBER OF COMMERCE


[SP] Tittle	Comunidades energéticas ¿qué disrupciones y oportunidades vienen para las empresas?
Date	February 2023
Public	[SP] Clúster de energía y sostenibilidad de la Cámara de Comercio de Antioquia. [EG] Energy and sustainability cluster of the Antioquia Chamber of Commerce
Objective	Suggest a concept of energy communities that may be matched with government and social development aims. Assess hazards associated with the implementation of energy communities in Colombia's electrical industry, as well as potential for enterprises involved with the cluster.

MAGDALENA UNIVERSITY

[SP] Tittle	Comunidades en la transición minero-energética
Date	March 2023
Public	[SP] Diplomado de Transición Minero-Energética justa en el Caribe colombiano, Universidad del Magdalena. [EG] Diploma on Fair Mining-Energy Transition in the Colombian Caribbean, Universidad del Magdalena
Objective	Case studies of energy communities as a territorial governance instrument for socioeconomic change, as well as co-creation of concepts for implementation in the Caribbean area, are presented.

TECHNICAL MISSION TO BRAZIL

Brazil in one of the countries in Latin America that has widely developed EC as Energy Cooperatives. For this reason, and for its similarity with the Colombian context, a visit was made to two different energy cooperatives in Rio de Janeiro and Campinas with the DGRV Brazil.

Percila e Lucio cooperative in the Babilonia and Chapeu Mangueira favelas in Rio de Janeiro was founded on January 16 of 2021 and is the first solar energy cooperative in the favelas of Brazil. This cooperative emerged as a response to the vertiginous energy price increase from 2011 to 2015, and as a result, 34 families benefit from a 26 kWp solar plant, that was financed by the foundation Revolusolar. The cooperative operates as follows: Revolusolar owns the energy assets, but the cooperative has a contract for the use of the plant; energy is produced, and the community gets a benefit as energy credits, which are reflected in savings on the bill; finally, the members pay a monthly payment to the cooperative, which corresponds to half of the savings they obtained. With this money the plant is kept in operation and savings are built up to expand the installed capacity in the future. The cooperative's operations include monthly meetings with members to discuss relevant training topics; it also has a sustainability committee and a board of directors in charge of administrative and organizational processes. In addition to generating energy, the cooperative also carries out other projects of community interest.

These cooperatives have some challenges that energy communities in Colombia have also faced. Some of them are:

- Energy generation plant legalization: procedures take a lot of time and effort.
- Energy metering and accounting: they have had problems metering the energy consumed, the energy generated and the energy credits.
- Members motivation: the cooperative members are mostly motivated by energy prices, but they don't recognize the social and environmental benefits. This causes them not to take ownership of the project.
- Education: these projects need to come with an education program for people, companies, and the government.
- Financing: it has been a common barrier, science these kinds of projects don't have a high profit. The financial model must be built for every case, and it is recommended for the project to be linked to a productive process.
- Regulation: they have encountered regulatory barriers.

Unlike Colombia, in Brazil the cooperative scheme is widely used for different purposes. According to the director of DGRV Sao Paulo, cooperatives usually arise from a problem whose solution is not interesting for the market, but for the communities, because they do not bring economic benefits, but environmental and/or social benefits.

4.2. BUSINESS LEADERS WORKSHOP REPORT FEBRUARY 2022

On February 9, the Transactive Energy Colombia group of EIA University, in collaboration with the Sustainable Energy Cluster of the Medellin Chamber of Commerce, held a co-creation workshop on the risks, challenges and opportunities of energy communities within the framework of Colombia's energy transition. This workshop was attended by various companies that are part of the energy sector, in each of the stages of the energy value chain.

RISKS AND CHALLENGES

The implementation of these disruptive energy schemes where the prosumer has a collective role of greater impact, the following risks are identified for the electric system and the actors that are currently part of it:

- Power limits to define market rules: not having a power limit could cause energy communities to be instrumentalized by companies that can benefit from regulation, making unequal competition to traditional household utilities. At the same time, a very low power limit could restrict the development of communities in favor of incumbent companies. It is important to analyze the limits carefully.
- Monopoly in non-interconnected areas and in specific sectors, governance, and participants' rights conflicts: although governance is the autonomy of energy communities, service provision by minorities within these schemes could eventually be violated.
- Low service quality, poor operation, and physical risks: The lack of experience in management, operation and maintenance of energy sources may pose a risk to service provision. Likewise, regular operation and inadequate maintenance represent physical damage not only to the infrastructure, but also to people's integrity.
- Political context, continuity, lack of legal stability and regulatory barriers: despite the interest shown in the draft National Development Plan 2022-2026, the political instability of future government plans predisposes a risk in the regulation of these schemes, in addition to the existing regulatory barriers.
- Risks of costs, tariffs and macroeconomic indicators given the variability of the electricity market due to macroeconomic indicators and the high costs of technologies, there is a risk associated with the financial behavior of these investments in the medium term, especially in financial sustainability and their ability to survive without subsidies.
- Registration and visibility, lack of information: in the event of massive implementations, the market operator's capacity to have a record of all the capacity installed in the country by distributed generation schemes such as energy communities is at risk.
- Money laundering and illegality: due to local economies that are difficult to inspect and monitor, they could be used for money laundering and other types of illegalities.
- Other risks: obligations of individuals; exclusion of interest groups; lack of and errors in information on territories; limited access.

Mitigation of these risks and deep business concerns about the sustainability of these community initiatives can be achieved by developing ideas that emerge from cross-sectoral dialogues, such as implementation strategies and regulations specific to the Colombian context.

OPPORTUNITIES

- Establishment and strengthening of community participation mechanisms: the alternative of being able to supply their own energy demand with the energy resources of their territory becomes a driver of social cohesion to the extent that energy communities emerge autonomously, voluntarily and maintain their governance.
- Improved service and coverage: the main objective of these schemes is distributed generation. Providing mechanisms so that the service can be provided by the community itself facilitates coverage and is a motivator for improving service quality and local infrastructure.
- Social training that generates economic development: community members are required to assume specific roles such as administration and maintenance of generation or storage systems, which implies technical training in different disciplines, offering job opportunities, local and economic development derived from energy.
- New investment mechanisms: the potential social benefit of these schemes becomes attractive for access to international financing sources and the innovation of financing mechanisms designed for the specific characteristics of vulnerable communities that cannot access traditional investment schemes.
- Deep decarbonization: promoting alternatives in the decarbonization of energy, such as these emerging distributed schemes, represents a direct impact on the reduction of greenhouse gas emissions.
- New markets with valuable products: energy generated renewably, on a small scale and by rural communities can offer added value in products or services, also the issuance and sale of CO2 credits.
- Other opportunities: Demand for new services in excluded geographic areas; opportunities for the grid operator; improved quality of multidimensional information.

CONCLUSIONS

From the electricity sector in all its components: generation, transmission, distribution and commercialization, there is a positive interest in the implementation of these community distributed schemes that can help in the task of electrifying the national territory, improving the quality of service, reducing costs and, above all, generating social welfare by closing gaps. However, the current government proposal represented in the National Development Plan 2022-2016 sets alarm bells ringing about the sustainability of these projects, both financially and socially, especially in the medium and long term. The development of ideas and specific regulations is needed to reach the implementation of energy communities in Colombia.

The implementation of disruptive schemes in systems such as energy can represent uncertainties not only for the market itself, but also for the users or participants of them. Such uncertainties, which have been previously described as risks, represent an opportunity to modernize the Colombian energy system, based on a fair and sustainable transition. As well as potentiating the opportunities that are identified, of special importance within the development of current public policy.

However, the implementation of energy communities as autonomous and voluntary user-centered systems, which will move from a passive to an active role in the regulated electricity market, requires greater precision in the roles and responsibilities of the new agents, incentive schemes, training and education campaigns and, of course, a clear and consistent regulation (defining both prices for users and the process of connection to the system) in order to send signals to the market and design attractive solutions for people to achieve the adoption of these schemes.

4.3. GOVERMENT WORKSHOPS REPORT OCTOBER 2022

On October 12 and 13, the Energy Democratization team of the TRAJECTS Transnational Center, formed by institutional partners headed by researcher Ana Maria Ramirez of TRANSACTIVE ENERGY COLOMBIA-EIA, had the opportunity to share two workshops on energy communities with representatives of organizations, institutions and processes involved with transactive energies in the country. The first workshop was held at the Ministry of Mines with the support of Carolina Garzón, Advisor of the International Affairs Group, and the second took place at the Mining-Energy Planning Unit UPME in cooperation with the Deputy Director of Demand Lina Escobar.

WORKSHOP 1: REGULATORY SANDBOXES FOR ENERGY COMMUNITIES IN COLOMBIA

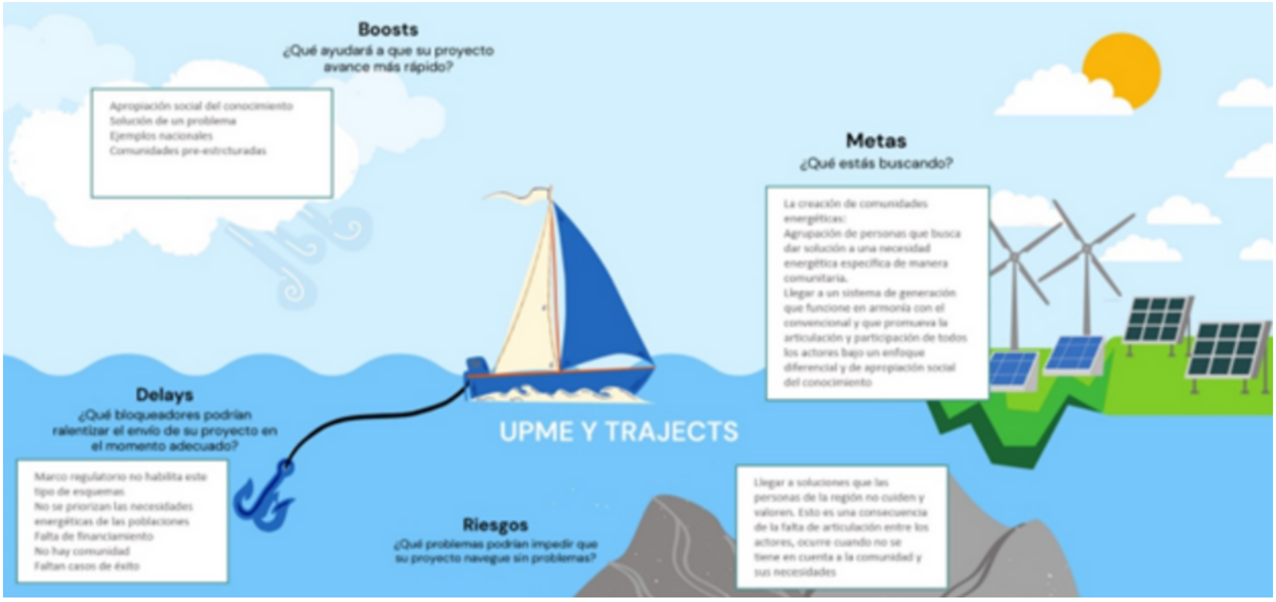
Facilitated by Carolina Garzón of the internationalization project of the Ministry of Mines and Energy, call made by the Ministry's network. The objective of a co-creation workshop to map and promote Colombia's energy communities was achieved. The methodology proposed the creation of working groups with different actors who carried out the mapping of their communities. As part of the results, it was established that:

- Communities involve the participation of diverse actors and include consideration of the different spatial and contextual characteristics of the participants.
- In that sense, not all energy communities are the same,
- And each community needs a particular tailor-made design.
- The principles for establishing the direct and indirect regulatory framework were cemented, but it is important to continue the co-creation process.

It was also identified that it is necessary to continue fostering meetings with diverse participants to broaden the limited and isolated vision that some institutions, such as the Ministry of Mines and Energy, have in relation to what an energy community is. Given that user-centered energy systems, and especially energy community schemes, involve complex elements where the social fabric is as fundamental a factor as the technical, technological, and financial aspects associated with the development of autonomous and self-regulated energy models.

WORKSHOP 2: UPME – "BOAT EXERCISE"

In this meeting, held at UPME's facilities with the support of Lina Escobar, an approach to the concept of energy communities was made, based on the identification and establishment of some of the main goals and barriers for the development of these systems. A ship exercise was carried out with the following conclusions:



The conversation made it possible to establish that having problems of access to energy or its low quality, as well as the possibility of achieving productive purposes through the community energy scheme are factors that promote the possibility of establishing an energy community in a territory, while having to address even more basic emergencies such as malnutrition or water shortages, as well as the lack of legal regulation of transactional schemes and the absence of financing are factors that discourage the emergence of energy communities.

CONCLUSIONS

An energy community is a group of people that seeks to solve a specific energy need in a communal manner. The group may include actors from the residential, commercial, and industrial sectors in areas connected to the SIN or ZNI. The problem it seeks to solve can range from supplying the community with electricity, to saving on the electricity bill, which allows the development of schemes where users can organize themselves to not only consume energy but also play decisive roles in terms of generation, storage, aggregation, or demand response, among others.

In any of the cases, the solution proposed by the articulated actors must have an ethnic and differential approach that adjusts to the specific context of the region, its needs, and its energy resources. The community must have a cooperation structure with defined rules, clear roles, and an equitable scheme for the distribution of benefits, including the creation of an oversight body to supervise its operation. Finally, for energy communities to develop, it is necessary to have a flexible regulatory framework and a financial scheme that promotes them both inside and outside the SIN.

When creating energy communities, it is important to take into account the social appropriation of knowledge, community participation must be reflected in the design of the community so that the solution does solve the particular needs of the territory during the design it is necessary to define who is designing and for whom, and it must provide a solution to a particular problem or have a common problem.

NEXT STEPS

To build two parallel regulatory frameworks, taking into account that there is a difference between interconnected and non-interconnected zones and to create a framework for the implementation of energy communities. Therefore, it is justified the need to propose a second workshop with the same participants convened by the Ministry on October 12 to co-create the particularities of these schemes and policies, in order to promote energy democratization from point zero, that is, from the planning itself.

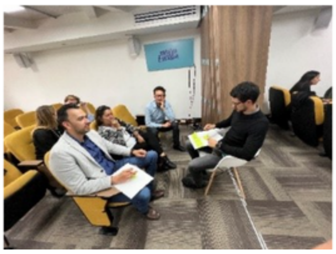
Likewise, the team has the challenge of reviewing public policy, current laws, and the legislative route in terms of energy, as well as the framework and scope of action of the CREG, in order to effectively guide the creation of regulatory frameworks of energy communities for Colombia and dialogue with government entities to overcome the barriers that may currently present the national regulations for the implementation of these transactive strategies.

Expand the number and capacity of the energy community pilots existing to date in Colombia, currently the Salvador pilot is limited to 66 people in 24 families. For new pilots, inter-institutional support and financing is vital. EIA's Transactive Colombia initiative offers its technical team and experience for the development of new energy community pilots where the inclusion of rural models is required.

Articulate the social, technical, and financial components in future meetings to favor the promotion of energy communities as a viable scenario that, in addition to the political and economic implications it may have, generates a positive impact on the environment, as interconnection and energy democratization can avoid deforestation and the creation of large sacrifice zones created by schemes such as solar or wind farms.








4.4. INFORMATIVE BULLETINS

As part of the diffusion strategy of this research, “Energia Pura” was the social media account used. Instagram posts were published. Also, the previous Workshop reports were shared by email, LinkedIn, and the page of Transactive Energy Colombia, to cover more interested public.

In parallel, a working paper titled "Regulatory Barriers for the Implementation of Energy Communities in Colombia" was published in collaboration with several members of the Transactive Energy Colombia team. [56]

4.5. INTERVIEWS

We recognized the importance of gathering insights and feedback from relevant stakeholders at every stage. To achieve this, we conducted interviews with stakeholders from diverse backgrounds and with varying levels of involvement in the electric energy sector. In the first stage, identify the key factors for ECs development, we interviewed ERCO and NEU, companies that helped with the development of an EC in Medellín, and other stakeholders from the energy sector such as EPM, BIA and UNERGY; a renewable energy foundation, RE4.

To define the financial model and the financing mechanisms we interviewed private and public entities, such as FENOGE, Bancolombia, and CFA Foundation. And to have a comprehensive approach to the social component of EC we interviewed an anthropologist and different members of DGRV. We used this information to guide the development of the project and ensure that we were focusing on the most relevant aspects under the Colombian context.

Project interaction and partners

DER INSTALLER - ERCO

Date: July 8th of 2022
People: Silvia Castro and Andrés Pineda.

They think that the most interesting thing about the pilot is that communities can generate their clean energy by investing as a community in a project that they could not afford on their own. From their perspective, the biggest barriers to the project have been the regulatory ones, due to energy communities being complex at the financial and legal levels. The challenges they have had can be categorized into four dimensions, people, technical, technology and regulation.

1. People: the first pilot, in *Comuna 13*, went down due to the relationship with the community, their history, values and beliefs. It is not easy to get people to understand what is all this about, because they don't have a technical background. The most important thing for projects to work is that the community sees the added value of renewable energies because if the money and savings are the main drivers (and in most cases they are), they could lose interest when difficulties appear. In the second pilot, a problem they had with people was that some of them owed EPM, so they could not change the meter until that bill was settled.
2. Technical: EPM did not have technical guidelines to establish a distributed generator system, so they had to build it from scratch. They even had to design the cabinet and they had to define how was the RETIE because this is an uncommon metering scheme, the first one of its kind.
3. Technology: the energy metering system that they used in this pilot required advanced technological development, without which this pilot would never have been possible.
4. Regulation: regulation for this procedure is so general that it leaves space for every stakeholder to interpret it differently. ERCO perceives that a change in the regulatory framework could boost the deployment of energy communities.

By experience, ERCO knows that a community on its own cannot implement a solar community, they need someone with technical knowledge to design the system and to guide them along all the administrative procedures. Solar communities are a viable business model for ERCO due to their expertise is to design and assembling solar systems and registering them, in this case, as distributed energy generators. ERCO thinks that solar communities could be a new business model for NEU and that it would be interesting for people in the communities to be able to exchange energy between them, something that NEU's system allows.

DIGITAL RETAILER - NEU

Interviewer: Laura Duque
Interviewee: Juan Esteban Hincapié Company – CEO - NEU
Date: July 11, 2022

- **What was the biggest difficulty and how did you deal with it?**

They state that the management of the communities is the most complex point for the implementation of these projects. They especially remember the event with the change of the meter that generated an additional charge, so the people of the community were very upset and did not talk to them.

Network operators are not accustomed to changes of retailer, therefore, they are slow processes. There is no regulatory incentive, and they (the ROs) are reluctant to this type of scheme.

The way to overcome these challenges is through open dialogue and working together.
NEUgets are not very well received, they are not seen as real money. For now, they can only be used to pay for energy, but some agreement could be made for them to have the money indirectly as some point of point in trade.

- **Do you think this Energy Community could be replicable?**

"With the current regulation, it is difficult to negotiate the price of energy for NEU."
At small scales of kW peak a system is very expensive, that lowers the viability of it; if they are larger, greater than 100 kWp or 200, maybe 50 or 70 houses, we could achieve a better return.

Currently the exchange price is not attractive to the sale of surplus for the user because it is too cheap and not for NEU because it would be too expensive; NEU needs to have contracted energy and not buy at the exchange price because that makes the company vulnerable.

- **How do you think energy communities can be implemented in other parts of the country?**

That the purchase prices can be transferred to the regulated market and that they can be freely traded, that they can be freely traded on the stock exchange.

- **How does EPM project itself with respect to this issue?**

NEU is seen in energy communities under other forms that enable liquidity.

DIGITAL RETAILER - BIA

IInterviewer: Ana María Ramírez Tovar
Interviewee: Leonardo Velásquez
Date: August 2, 2022

AMRT: What role do you play, or would you like to play as a company in the energy transition in Colombia?

LV: Ready. So, BIA is in phase one, because you will be seeing different phases of BIA as time goes by, but phase one of BIA is as a digital energy trading company, where essentially, we represent the users in a market that is highly regulated and complete and we become the interface to provide, to provide the best energy experience in the most human way. So we will be serving users from a platform, a platform that essentially replaces the little piece of paper that arrives monthly to all homes, a little piece of paper that is confusing that nobody really ever reads, and that those who have read it are really very few who understand it, and there we will be translating it into a much more human language, more understandable, with better energy prices, that is also something vital that we will be giving cashback on all energy transactions, we will be giving more data. And that's it, that's like phase one of BIA. Later on, I will be able to tell you more about other verticals that we are already working on launching.

LV: What role do we want to play? We want to play the role that is closest to the users. What we have seen in this sector is that much has been developed within the complete value chain, much has been developed and optimized from the user backwards; so there have been improvements in the distribution networks, improvements in the transmission network and improvements in the way in which energy is generated with different technologies.

That, there are great minds in the world working on it and we have seen good progress, relatively speaking, on those in those 3 components.

But as far as the user is concerned, we feel that everything is still to be done and an example of this is, users are not really getting a transparent service, most of the times when there is an anomalous consumption in a user, the retailers charge by average, they do not warn the user that they are charging by average, and we have just.... a little anecdote... we just hired our BPO Sales last Monday and then we were doing the onboarding, last Wednesday, and she took her invoice to the office and told me “Come here, Leo, explain this thing to me".

So, I started to explain to her a little bit about how to interpret an energy bill. Then she grabbed me and said: "Leo, come here, what happened? because in June I was out of my house for 3 and a half weeks, why did I get the same consumption as last month, if I was not there the whole month?

We started to analyze and, indeed, he was being charged on average. This is a typical case, what happens is that not everybody realizes it, of the people who realize it, not everybody complains, and of those who complain, very few are successful in actually charging them what they should be.

So, there are many, I think there is a lot of lack of transparency, many users who are being violated in an unfair way and do not know it and that is what we want to do: we want to be the interface to the user that provides the best possible service, with the best possible price with the best possible fares and that's it.

AMRT: Of course, what you are telling us about, we have also seen some situations in the pilot project of the solar community in Salvador, which we have in Medellin, because when changing the operator, sorry, the retailer, the meters have been changed from analog to digital and there has arisen new information, including charges for reagents, for reactive energy. So, this whole issue is not only new, but it also generates some controversy between the companies and the user. Also, because we know very little about how we consume our energy, so there are cases of people who say: "but I disconnected the equipment, but it still reached consumption".

So, there are always quite a few differences between what one believes, or the way in which one believes that one consumes energy, and the way in which one is charged for it. We would also like to know a little about the regulatory framework that you may need, or in the regulatory framework in which we are currently operating, do you think it is sufficient to promote distributed energy systems and, for example, to involve citizens more actively?
LV: No, there are some changes that have to be made. The example you just mentioned about reactive energy is just a sample of that. Then it is very ironic how a couple of years ago a first, I think it was a first decree that talked about AMI, but it was not regulated yet. Then in January the resolution came out that already says "I don't know what, by 2030 70% of the connections have to have an AMI system associated".

Perfect, then it is said that the nation wants to go that way, but when it comes to implementing it, we find things like the ones you just mentioned, where there, I don't know what to call it, maybe it is like unfair competition, an inconsistency in the framework, I don't know what we want to call it, but what you just noticed happens: A user changes, has a much more intelligent meter and it turns out that, due to the way the regulation is structured, for the incumbent operators that are naturally serving the users, when you change them, you have to start measuring things that before the operator did not have to measure and, therefore, did not charge them; now when you change them a new equipment, which is more technological, now you have to charge them, you have to charge them in this case reactive energy.

In the end, this is an inconsistency, because if we want to move towards a smarter network, but when we pass it on, users will be negatively affected, what is the real reason for users to switch, if in the end they may even end up paying more than what they were paying to switch? So, there will definitely be things that need to be fine-tuned in the current regulatory framework.

AMRT: In addition to this barrier that we see in the regulatory framework, do you find any other barriers to the promotion of these systems?

LV: Well, there are complexities from the commercialization of energy, from the commercialization of energy there are important complexities with respect to the issuance of guarantees, which is a deeper and more particular issue of commercialization, but there is an enormous cash requirement, which acts as an entry barrier, because, unfortunately, we raised an important amount of capital, but if this had not been the case, the growth capacity would be very restricted by the amount of guarantees that one has to be issuing according to the energy that is being traced in the market. That is a very important barrier. What else? Apart from the reagents, it is very important, there is a third huge barrier that we are finding and the operational capacity of the network operators, so we have some, on average what we are finding is that each network operator has the capacity to schedule 3 changes of retailer per day. That is nothing. If we have 10 customers that we want to change in a day and Codensa has already told us that on average it can sustain 3, Encali has already told us that on average it can sustain 3, sometimes 2.

We are going to hit that wall and we will have to. We will have to solve it somehow, but we are already finding that, if we want to make massive changes of users to provide a better service, at a lower price, we will only be able to do it, badly counted, with three users per day. From there it seems difficult to increase, when we get to that point, we will surely have to start generating noise; it does not make much sense that one is limited to 3 users per day, it is crazy but that is another barrier.

AMRT: And with these 3 users per day, have you found great interest from the market to switch or, so far, do you see it as something that is just starting and maybe it is not so well received? How do you see that?

LV: The 2, both are true because we are really just starting up, we launched last week, the first changes will be made next week, but at the moment we have a waiting list I think it is more or less 350 users that are on hold. And actually, we launched very recently, we are not yet doing... or rather, as we have just launched, we are adjusting a lot of things, but despite the fact that we have just launched, there are already 300 or so users on standby. What I think is that there is going to be an important demand, because the alternative, which is what the users want, is very bad today. The alternative is a paper that is charging you, often unfairly, they are not going to tell you and they charge you dearly, that is the alternative, there is nothing else, almost anything is better than that.

AMRT: Regarding other types of strategies that can be implemented in this whole energy transition, solar communities, which is what we previously told you about, are systems where communities group together to generate energy and that also gives them a more active role as, not only as users, but also as a distributed generator in the system.

Have you perhaps explored working with that? We were able to identify previously that one of the problems is precisely the commercialization of the distributed energy that is generated. We would like to know if you have explored those alternatives, have you perhaps reviewed some proposals, do you have any interest?

LV: We have not reviewed, at this moment we do not have a materialized proposal to really review; however, we are working on the solar vertical to launch it and we would also love to be able to participate, I believe that there are two types of solar communities: let's say decentralized solar communities, like the pilot that you have done; but there is another type of category called Shared Solar or Community Solar, which is when it is more centralized and it is a specific community that owns a piece of a park, well obviously it is more specialized and you have to pay a fee, but that has also worked relatively well in Brazil, for example.

And yes, yes we would like, I think that from the, well, applying good technological tools it should not be very difficult to balance all the energy that is coming in and going out for each one of the users, what happens is that at the end it is a matrix and the regulation has to be adapted so that they have benefits and not the other way around. I imagine that at this moment it must be... it must be complex to implement it and it must require a lot of effort, a great deal of work to be done to have a small community, because it is, I think it is normal when one is starting up, and in this case it is the first pilot, but of course it has to continue advancing.

AMRT: What strategy could you implement, or we could implement, let's say jointly, to promote these new strategies of digitalization, distributed generation, all of this, in order to change the paradigm of how we have the relationship of the energy chain for the users, to focus on the user, what strategy could we propose?

LV: The strategies will depend on who is promoting them, obviously one thing is us, and we have a number of strategies, but the other one is you, the other one, I don't know, where is the question going? Are you as a transactive energy group or, are you asking me what strategy are we following?

AMRT: No, we are looking for a way to propose to the Ministry of Mines and Energy a regulation... a regulatory sandbox where these systems can be promoted and where all these regulatory barriers that already exist are considered, not only in digital commercialization, but also in distributed generation. But then, the question is focused, is there any other item that we did not manage to talk about right now in this half hour, that we could consider relevant as a promotion strategy, not to execute it ourselves, maybe I did not manage to explain the question well, but the intention is if we propose it to entities such as the Ministry, what could we propose, in addition to what we have already talked about or would you like to emphasize in some particular of those that we have already talked about?

LV: I would think that for now the most important thing is that the regulation should be modified so that the implementation of AMI and digitization of energy and more technology and so on, does not end up harming users, which is the reality of today and that is something central for this type of programs to move forward. I would think that this is the highest priority at the moment.

DIGITAL RETAILER - UNERGY

Interviewer: Ana María Ramírez Tovar
Interviewee: Eduardo Ospina
Date: August 2, 2022

EO: Unergy wants to play a very relevant role in the transition, mostly motivated by the dream we had when we talked about democratizing and massifying clean energy. We are closely related to communities, because Unergy is a platform that helps ordinary people to invest in clean energy projects and also to finance projects in industry, associations and even grid connection, right. In that sense, the role we want to play and the role we believe we will play very soon is that Unergy will allow the massification of projects, not necessarily in two 500 MW projects, but in many small projects that can add up to more than 1 GW installed.

This means that we want millions of people to be able to invest in these projects not only in Colombia, but all over the world, and that these financed projects can help generate cleaner, cheaper energy without investment costs, both for Colombian industry and the Colombian electricity grid, as well as for Brazilian industry and the Brazilian electricity grid and some other Latin American countries, right.

What is our medium-term goal? This year we have a goal of helping to finance about 20 million dollars in projects; Today we have more than 1300 investors that are part of a community of investors that invest in clean energy projects and the most relevant role that this plays in the minds of these investors is that they are investors that today begin to invest in clean energy from one million pesos, but many have made the decision, after seeing the results of the Unergy platform in terms of profitability and technological compliance, they make the decision to put their solar energy project in their home or make the decision to start buying an electric bicycle, an electric car, an electric motorcycle, to start recycling.

The fact that you have the possibility of understanding what you can contribute to the environment also allows the community itself to start empowering itself and making other decisions in this regard. We have had cases of investors who at some point entered for a net profitability reason, that is, I as an investor invested 20 million in Unergy because I wanted profitability and because Unergy offered me an interesting profitability and then they began to wonder and ended up putting their solar energy system.

I believe that the relevant role is to allow millions of people around the world to invest in clean energy and people who could not invest and that many companies and the electricity grid can be financed, which previously could not be financed due to debt problems and many other reasons. We hope to reach more than one million dollars soon, but there is a long way to go, and I believe that if we succeed, we will play a leading role in the energy transition in Colombia and Brazil.

AMRT: I think that it is not only interesting, but also very accurate because it is in line with some of the diagnoses we have already identified, which is that the lack of participation of people in Colombia is due to two factors, one is also a lack of knowledge of the ways in which they can participate in the energy transition and the other is the lack of access to capital that would allow them to be part of it.

And in this regard, connecting it also with a little of all the intentions we have seen in recent years, both for the government and for private enterprise, the decentralization of energy through these distributed generation schemes seems to be a very interesting bet.
Already, for example, law 1715 back in 2014 already proposed some incentives; recently the CREG resolution 174 of last year already uses even some arrangements for small-scale self-generation, distributed energy; but nevertheless, it is almost a decade since 1715 and also the concept of self-generation is not really new because it appears in law 143 of 1994, almost 30 years, so, in this regard I would like to ask you what is your opinion of the regulatory framework? Do you think it is sufficient for the promotion of these distributed generation systems?

EO: Definitely, no, and I think it will never be enough, that is, I do not think it is bad either, it has really been quite good, and it has been fast, but the regulatory framework must always be changing, it must always be improving. Well, 1715 at the time generated some problems, such as, for example, the difficulty for a household or a residential system to have tax benefits, then that was improved by the 2019 national development plan; CREG 030 regulated the sale of surpluses, which had a number of problems in its process; or for example, if the user was an independent energy supplier, that supplier could refuse to receive the energy surpluses because CREG 030 allowed it.

The 174 changed many things; single window, which has not yet been implemented or as far as I know, has not been implemented. Definitely, there will always be something important to improve, I think that now what can be improved more than anything else, are the energy commercialization schemes, I think that nobody cares about the surpluses, nobody wants to receive surpluses, because the way the system remunerates them or defines that remuneration I think is quite unfair, especially the type two surpluses. And that has to change, it has to change also that today it is not allowed to centralize the measurement of a building to put solar energy to the whole building.

Soon there will be a regulatory sandbox that will allow testing and, let's say, doing things that are not regulated within this sandbox. But definitely there is always, always, always an opportunity to improve and I believe that at this time it has to change again or new resolutions that make the market to improve and open other market niches such as small buildings of one to five floors that nobody attends and if we remove the individualized measurement of each of the apartments and centralize them in the same one and we could put a single solar energy system, it would be much more viable, these are just some examples, but there are many things that can change.

AMRT: Sure, and what other barriers besides the regulatory issue and the way in which energy is being commercialized on a small scale have you found to be barriers to implementing this type of strategy?

EO: I think that the biggest barrier always and I think that, well, I hope that Unergy will help to stop it from existing is the financial barrier. I mean, Latin America does not really have solar energy on a massive scale because we do not have enough liquidity to massively install solar panels. I think that countries like England have a radiation well below the average of Colombia, European countries that have been installing solar energy in a very massive way, today Switzerland, for example, or Europe because with this energy situation almost all homes are starting to have panels, but not because they have liquidity. On the one hand, they have the liquidity, but on the other hand, the per capita consumption of electricity there is better, so the project is big enough to be more viable.
AMRT: Are they bigger?

EO: Yes, they are larger on average. Here an average household project can be between two and five kW and there it can be between 10, 20, 25 kW. It is because seasonality has some larger ones, but I think the answer concretely is what? It is financing, which is what Unergy wants to provide.

AMRT: In that sense do you see interest in the market for accessing these types of systems, assuming, let's say this financing is achieved? Do you see that interest in people?
EO: Absolutely, I think there is an important interest, I think there are also problems, I think that the industry today is, for the most part, I would say that 80% of the projects that are signed today in the industry are or tend to be PPAs, that is to say, projects that are already financed from the outset. Well, I correct this, 80% of projects, and this is a super estimate, may be between PPAs and leasing, which are projects that come with financing in the industry.

In residential there is a problem and that is that in residential it is difficult to finance through PPAs due to multiple factors and the banks, sometimes, or sometimes not, most of them, do not have lines dedicated to clean energy projects, so in residential, although credit is made, they are not credits that are oriented to a clean energy project. I do not know much about residential; I think Juan Manuel knows more about it because our sector has been more in commercial and industrial, but I definitely think that the market is accepted and adopted financing solutions.

In residential there is a problem and that is that in residential it is difficult to finance through PPAs due to multiple factors and the banks, sometimes, or sometimes not, most of them, do not have lines dedicated to clean energy projects, so in residential, although credit is made, they are not credits that are oriented to a clean energy project. I do not know much about residential; I think Juan Manuel knows more about it because our sector has been more in commercial and industrial, but I definitely think that the market is accepted and adopted financing solutions.

AMRT: Regarding the interior of the market, one thing is the interest let's say individual to put in, you say in industry or if we look at it in the residential, to put in my house or let's say in my property, but facing the response of the community to be able to associate with my neighbor or with more people, let's say 15, 30 people to install a joint system that does not necessarily supply us 100% of the demand of those of us who are associated but in some percentage well, This would have more of a scheme of energy communities or solar communities, where the user is also given more power in the chain, because he/she not only plays the role of user, but also participates as an energy generator and with respect to this feasibility or this execution of projects in this community aspect, have you explored anything about it, have you found interest or do you see a problem in the execution that it is not going to be an individual consumption, but a community one?

EO: Yes totally the biggest problem is what I mentioned to you that energy, that today you in a building cannot put a centralized measure for the entire building because that is called aggregating or grouping border, since 2011 if I am not wrong I think there was a regulation that prohibited this, I think the experiences of Switzerland and Spain is that this was removed as long as there is a solar energy project so that community projects could be given, I think that Colombia should pay attention to this and one of the objectives that Unergy has soon is and well, if we can share this with the EIA, I think we could propose within the Sandbox, which hopefully will come out, is style projects, we already have an approved project like this, that is, we did the whole process with a building, it was approved, we were going to do something interesting and it was to implement a technology called SolShare.

SolShare is an equipment that allows to put a centralized system and divide the energy in 13 apartments, if I am not wrong, no, I think 10 apartments; however, after they had approved it, after everything was fine, we verified that SolShare did not have a very adequate equipment to what is the Colombian network capacity.

In that sense, I believe that the biggest problem we have for there to be physical community energy, that is, sharing electrons between one neighbor and the other, is that there are not enough benefits because in the middle you always have to put a network operator or a retailer. That is the biggest problem there is, because even if I am an independent retailer, I will not be able to bring benefits to the neighbor who invested with the other neighbor, because I also have to, the benefits are not very clear and the energy is not distributed very efficiently, I think the biggest problem is that restriction of aggregate borders.

AMRT: Could one, somehow, then propose mechanisms where the small generator is allowed to sell the power directly? Is that like what you would be proposing?

EO: No, what I would be proposing is that there should be a way for me as a building to say: "come on EPM, I don't want you to put a meter in each of the apartments, because I am going to put a solar system for all the apartments and I need a means for everything and I am going to put a centralized system".

That, if that were allowed, that is not allowed, right. If that were allowed, the system, per unit, in each of the sections, would be cheaper. It has a very big challenge and that is how to manage energy privately, communally among all the neighbors, and there are the applications, because there are a lot of digital technologies, Smart meters and all that, but the biggest problem is that today I cannot say in my 5-story building, "I am going to remove the meter of all the appliances and I am going to put a single meter for everything, with a single solar system".

If I were the government, I wanted to say it, now that makes sense and has a logic, why can't I do that? because what did people do before? they would come and several companies would get together and buy very cheap energy with a 30% discount, but it was really because they arrived at an industrial park and charged everyone, but he bought the energy at 300 pesos and then charged the others 400 pesos, then he was making an unfair sale of energy to the others, because he was making money where he did not have to make it, since energy is a public service.

Now, I would allow this, as long as there is a solar energy project that supplies, at least, I do not know, 10 or 20% of the total consumption, so that this unbundling of borders can take place, then, yes, it should be kept as a restriction until there is no solar energy project. I believe that the solar energy project is what breaks the scheme so that it can take place in a correct way.

AMRT: I see what you mean. And, finally, Eduardo, I would like to know, suddenly, what strategy could be implemented to promote these schemes, in addition to the financing that we have talked about the channels, have you come up with, suddenly, any other strategy that could be implemented at the national level for the promotion of distributed energy generation systems?

EO: Yes, I believe that if we somehow manage to interconnect the information of all the systems that are being generated privately in the country, many important alternatives could be generated, for example, I could take all the surpluses of type two, I do not know of 100 users and combine them so that this could become a virtual energy farm and those surpluses could have certain benefits with respect to other surpluses, right? or with respect to other generation.

In the end, I believe that what allows people to unite in the same community, finally ends up being the "skin", that is, that everyone has skin, that everyone has skin and benefits, so there must be a way for those people who invest, and that investment is skin, to share information to generate benefits in a community, I believe that is the key, in my opinion, to the issue. And that is the big challenge to be solved.

It is not the same when you generate a community of a social project, where nobody invested, as when you generate a community project, a project where people put something of their part. That is putting skin in the game. And it is not the same when you generate that, if they get together, they generate benefits, that is the key: that there is investment or skin put in and that there are benefits, through getting together, that is the point.

I want to give you an example of this, and that is that today in Unergy there are more than 1300 people, investors, more than 13000 users that are on the platform and when we do events, usually more people arrive than we expect and there is an interest to share, there is an interest to talk and there is even a strong resistance to the bad, that is, we have had complicated situations with some projects and people understand that they come together to help solve and even help us to solve, then, but they have skin and have benefits of being together. That is the point.

JME: Eduardo, thank you very much and whenever you want we can sit down to invent that sandbox, so that we can get our heads around it, I think we have a good regulatory background and also we have a very good input with the Ministry that we have been working with for a while now, although we will wait to see what happens now with August 7, but also with CREG and UPME we are very close and they have told us that whatever we invent, well-grounded and well thought out, is welcome in those instances.

EO: Juan Manuel, yes look, I think this is worthwhile because I do not know if you saw that there is a regulation in draft that puts the sandbox, if we manage to force the issue of allowing us to make installation by removing the borders of the apartments and centralizing them in one, I believe that this would make viable a market quantity that does not exist today, those buildings of one to five floors, with a terrace and between 10 and 13 apartments, right, so we are also interested in it, we have a building already tested, which is the curious and funny thing, it is waiting for this to come out.

JME: Yeah, great. A question that I think I saw somewhere or if you told Santi, are you a retailing company or are you on the way to becoming one? Are you already a retailing company?

EO: We are already retailers, this energy from this Unergy interview.
JME: Very good, very important because that also makes things a little bit easier when proposing these models.

EO: It allows a broader view of the market. I believe that today there are more challenges in commercialization than even in self-generation. Marketing challenges to positively impact self-generation, I think there are many challenges there.

VERTICALLY INTEGRATED UTILITY - EPM 1

Interviewer: Ana María Ramírez Tovar - Laura Duque
Interviewee: Eugenia Duque
Date: August 9, 2022

LD: We would like to hear a little bit about your experience, EPM's experience with the pilot, what lessons have you learned and what challenges have you encountered?

ED: EPM since it began to join efforts with Erco University and, finally, also with NEU because we are using the NEU platform, although the effort and the agreement was made between the Antioquia School of Engineering, EPM and Erco. From the beginning it was because we saw an attractive project, that is why we accepted to present ourselves, to opt for external resources, for funds, to put funds for the project. We believe that these solar energy solutions in communities, with the issue of distributed generation, let's say, are something that points to the future in new forms of energy commercialization and, let's say, that is precisely why we saw it as a potential to bet on this. We, from the innovation development management, know that pilot projects, when they involve customers, end customers, have some very big challenges, because we are not doing this project within the framework of what is known as a regulatory sandbox, but we are doing it within the existing regulation, so the first thing we have to evaluate is that the project is feasible to carry out within the existing regulation and that, even so, it can give us valid results to then make decisions regarding new commercial offers.

ED: There are 3 actors here and each one may have different interests and so do the users. Although we have some common interests, it is true, let's say we are the established operator in the area, the one that has more presence in low-income users' strata 1, 2 and 3; the project is being carried out precisely in stratum 3, in residential users, in the same billing cycle. But there are many challenges, for example, the Colombian regulation requires that in order for a user to be able to change supplier, he must be in good standing.

The simple fact of the challenge of the relationship with the community and explaining to them what the project is, what benefits it can have, but that it also implies changing retailer; changing from traditional metering to hourly metering, with an AMI meter; that this implies, let's say, being present at some moments, going to some workshops; that there will come a time when in the same month they will receive two invoices, one from the EPM supplier and another from the new supplier; explaining to them why EPM's billing and metering cycle is different from the new supplier's cycle; why we cannot do it with a platform, let's say of EPM energy marketing, but with NEU's, and so on.

And it has already been quite a challenge, even to meet the requests and complaints of these users, because we have been presented with things that sometimes even, we ourselves, who are part of the organization, had not foreseen, let's say, we had not foreseen, right. That is to say, even though it is a pilot, we have to pay for the visit to change the meter, so those are, let's say, 70,000 COP. The users are guaranteed that participating in the pilot does not have a cost, but it does have a commitment, so that commitment implies their presence in many moments, to be in good standing in some moments; Some of them had overdue accounts and deferred accounts due to COVID, COVID made that in Colombia there was a regulation and users of certain strata had their accounts deferred in some cases, without interest, in others with very low interest, then, let's say, users have shown so much interest, that in some cases, they have been updated in overdue or deferred accounts, just to be able to continue participating in the pilot.

ED: This has also given us some kind of early findings, yes, in other words, the issue is attractive to them, because they are capable of making that effort; one might also wonder at times, I mean, maybe they have a payment habit, but they could pay in full, because why am I late, if I have enough money to pay? However, there is still a long way to go to reach the moment of truth of the project, which is to look at the end and see if they are going to make, let's say, in some way, an effort and find a way to stay in a solar community, because today, let's say many, let's say, distributed generation is provided with resources from the project, which are basically cash money that EPM put in to buy the equipment, Erco put in the whole issue of the installation of the equipment, the certification has been paid, the verification, the whole process has been carried out, let's say, that the regulation has established for the installation and connection, however the distributed generation is still not in service, we are just this week in the visit for the commissioning, that has also made the management very difficult, as let's say, of the community, so that they understand that they are going to have the benefit, but it has been delayed. I do not know if that answered you a little bit.

LD: The idea at the end of the pilot would be that the community buys the system from EPM?

ED: In the Colombian regulation, a distributed generator must be represented by a utility company, that is what CREG Resolution 174 says, taking this into account, anyone who owns those distributed generation assets, must be represented by one of these companies, in this case if it were not EPM, which is already an ESP, but any community that owns its assets, it would still have to get someone to represent it before the system. As long as it is EPM, let us say, and within the framework of the pilot, Erco Generación SP is representing that distributed generation, but the money resulting from that generation is going, let us say, to be converted into a kind of points or virtual currency, called NEUgets, which will generate benefits to that community for the payment of the bill, what will happen? There is a moment of truth at the end of the project, that is, they will be able to evaluate, let's say, the benefits and decide to keep that system and by keeping them, they may do it through some kind of acquisition proposal, financed or cash, depending on the purchasing power, or on the financing sources with third parties, or the financing source of EPM itself, right, or Erco Generación SP may be interested in keeping it and also buy it.

We don't know yet, I mean, this project is, let's say, precisely about that, that is, we have to, at the end, know what the users' willingness is to stay in this, in a solar community as it is, depending on the benefits they perceive. And if, and that will say how viable is also an offer of this kind in the market, for a market like this, it does not mean that the fact that they, for example, finally do not manage to stay organized as a solar community, cannot mean that there is no space for solar communities in Colombia either, because we already see very attractive that there would be a solution of this kind, at least for non-interconnected areas.

Today the regulation for non-interconnected areas is favoring individual solutions rather than collective solutions. So, for example, we at EPM have a project we call the Coverage Project, which I am not going to talk much about because I am not the expert, but I do know that in the project we are oriented to provide individual solutions, so we offer, for example, a solar solution for a family, where it will have so many hours of energy per day to power this type of appliances and it will comply with the regulation for that, and it will have access to some resources that the ministry guarantees for such solutions, in that way.

But from my point of view, and we all know that when you install more generation capacity the kWh can be cheaper and you can share that, let's say, among a group of users that are relatively close, it could make sense, not even necessarily for the... that is, we would have to look at the distance between one and the other, it would make sense to have distributed generation solutions, right, outside the national interconnected system. So it could be that this could be solutions for certain islands, for example, or for certain areas within the departments that are farther away than where the SIN does not reach and that through this type of solutions, it could be possible to provide coverage with electric energy to some communities.

Within the system, let's say, interconnected, we believe there are many different types of solar communities. We are testing one, but there are some that could occur between customers who are far away from each other, because the digital platform allows it, I could have a solar community as offered by other companies in Spain, for example, there are solar communities offered by companies, I will not say names to avoid advertising, but I know two companies, one of them has a presence in Colombia, and they offer two alternatives. You can propose to create a new solar community to participate in an existing one, if you want, I will give you links where you can see what they propose. And then, for example, they have like all the propaganda, the publicity, "Do you want to join the new community? So, there is a community, I don't know, in Madrid, in any state of Spain, in any region, and you join it, even if you don't live in that neighborhood, because through the digital platform, let's say, they share the energy produced in a distributed generation way, among several customers. The service provider runs the risk of the demand and guarantees a service where the supply has to have enough account executives to guarantee that if someone leaves the community after a year or two years, a new demand will replace him, which he will be able to obtain through the commercialization of that energy. And if people go there, it is because it is cheaper than the energy of the national interconnected system.

LD: But then that system would be more like a Peer-to-Peer?

ED: No, it is distributed generation. Look, you put, for example, a distributed generation system, I don't know, suppose you put it in Guajira, but in a point that is still interconnected; you have to be in an interconnected point and you own, to say something... there are different models, there is an investment model, where different people, each one can own a panel and I get 100 panels and I assemble them, something like that, and I represent the owners of those 100 panels and where are the panels? I don't know, in the Guajira, in the Tatacoa desert, in a point in Córdoba, in a point with good solar radiation, where it is possible to generate well and the benefits of that generation, which are received by an energy company, are transmitted to those who are part of that solar community, from the same investment, through what? The energy that they pay for is given to the clients in the form of resources that they will use to pay for the energy they obtain from the national system, that energy in any case, normally there is a retailer that is associated with that generator that represents it and is the one that sells them the energy, so this facilitates the crossing of accounts between the generator and the retailer.

There is another way, which is not by investing, but simply by the one who makes the investment, which is a generator, who is the owner of the distributed generation, offering the service to the customers and selling them, from the beginning, part of that distributed generation to a few customers. I set up, to say something, 1 MW of power, but I have half of that MW of power already sold to some customers and the rest, I try to get them to join that community. This can be done, no matter where the client is in Colombia, all of them are sharing this distributed generation, theoretically. This can be done even today we can do it within the national regulation, with the markets as they are today, but if you have technological platforms that can do it, like what we are doing in the solar community of El Salvador.

AMRT: Yes, that's exactly what I was going to ask you, you know if that was not precisely the scheme that existed in El Salvador, because the.... you see, let's say, that energy is generated in some roofs, it is sold and then those profits from the sale are the ones that are distributed in the community, then that scheme as it is, could it exist in Colombia, because please correct me if I am wrong, the same for NEU, which would be their retailer, there is no need for them to be close, the users, but it is generated at a point, it is sold and that sale is the one that is distributed as profit by the NEUgets?

ED: Okay, let's say that for the purposes of the pilot, we chose the nearby clients, because in order to carry out the workshops, because we have to define, for example, the rules of how the NEUgets are distributed among the different users. I could have defined that the one who puts the roof, for example, has a higher percentage of the energy or the benefit than the one who does not put it, of course, that can be defined by the community, or it can be defined that it does not matter if he puts the roof or not, he will have the same benefit. For example, the possibility of having an extra user who accumulates NEUgets like all the others and that those NEUgets would then be used as a saving by the community for, let us say, maintenance of the system or for other things, was raised. So, these kinds of things that are defined with the community, like community rules, are easier to manage in a pilot like these that the community is around. But we believe that when this becomes a mature commercial offering, we could have different kinds of communities, with different kinds of rules, shaped for different kinds of markets and offer them for whoever wants to join that. There could be a type of solar community aimed at high-strata buildings, or middle-strata homes, or for example, universities, and a university with its campus and students from that campus could benefit from the same solar community.

So we have thought about different schemes and then, let's say, whoever makes the offer must have the possibility of, based on the data they have, the knowledge of their market, of the needs, of how much they are paying for the price of energy, how the competition for the market is at a given moment, let's say, and, taking into account that in the regulated market one has to treat all regulated market customers equally in Colombia, that's right. Each retailer has an approved tariff for the regulated market that will depend on its energy basket, on how it buys energy and, let us say, on its marketing expenses, depending on the type of market it serves. Then we would also have to look at which are the retailers that are, let us say, due to a series of characteristics, depending on that basket they have and the market they serve, let us say that they could have a certain competitive position that favors them to offer these energy communities, or not, to be able to compete with an established company in certain markets, for example, or to avoid competition from an incumbent.

LD: EPM, which has such a large market, is already considering this type of schemes, that is, would you like to start implementing them?

Let's see, we are exploring. We have a very strong commitment with solar energy, we know we have a very good energy basket and we believe we have a good kWh price that is competitive, obviously, in certain markets; we also believe we are covered, we have a tariff that is very well covered because we are not very exposed to the stock market price, which is also another thing to look at, there are energy retailers that have a great exposure to the stock market price and if a residential user is served by an energy retailer of that type, his electric energy tariff can be very variable from month to month, depending on how much the stock market varies. So, let us say that this is an issue that must be looked at with a magnifying glass, it is true that there are many issues: exposure to a stock exchange price, what I said, the energy basket, the issues of active energy, reactive energy, customers' ability to pay, willingness to acquire a system or to join an energy community that will soon have already established rules...

What is clear is that in Colombia there is no regulation as in other countries for energy communities as such or the so-called energy cooperatives, in other parts, so it is clear that here it is not being promoted that it is not a public utility company, for example, that represents the generation of energy, and we think this is very good. In other words, let us say, this has a degree of complexity that does not make it easy for any community to take charge of representing energy generation.

LD: Knowing that EPM is a generator, that it is also a retailer, why in this case did they decide to change to NEU and not continue with EPM?

ED: EPM has an innovation program called Ventures EPM, this program has invested, it has several activities, one of the activities is to invest in companies, let's say, young companies, in Startups, with certain characteristics. This program is registered... or has 2 private equity funds, which have an investment regulation registered with the superfinancial institution, and let's say, one of these funds has invested in several companies, among them Erco, so more than 50% of Erco is owned by this fund, and NEU is a subsidiary of Erco, which, where Erco has about 33%, or something like that. The point is that, let's say, in a way, we have an interest in them doing well and they also have an interest in us doing well.

We allied ourselves to participate in this and we believe that they are like the spearhead in marketing issues because, let's say, they have been our ally in the integrated solar energy solutions that we provide. They were our partner, for example, in the Guatapé floating solar energy pilot, they are our partner for many of the solar solutions that we provide to our customers, Erco. And Erco's digital platform, let's say, is currently adapted to manage this first solar community, the idea is that, in the future, if we are going to have to decide how we are going to do it, right, if we are going to continue providing solar communities based on that platform, if there are going to be new platforms, if EPM is going to have its own, that is still not clear, but at least for the pilot we decided to do it because we believe that we add more this way, than doing it separately, It was also more difficult for them to reach clients, let's say, of this type of profile and if we had not approached them together and with the university, let's say that the project would not, possibly would not go, let's say, with a balanced and articulated development, where we are looking from the academic, from the perspective of an operator, well, like us, who are both generator, retailer and distributor, and hand in hand with our ally in solar energy issues, which has been Erco.

Another retailer we would not see it so easy to make that kind of alliance, here we have, well, a different position.

LD: If we wanted to do something more grounded in reality, where the community would invest in the photovoltaic system, where all the companies involved could have a profit, do you think that the alliance would still work? or how would you think that a community could work in the best way?

ED: And that, you are talking about an additional step, which is the step of structuring a commercial offer, right. Here we have different actors that participate in this project within the organization, so there are people from household offers, there are people from commercial intelligence strategy, there are people from innovation and, apart from that, there are people from our external allies, right, from the engineering school and Erco. Let's say that the pilot is going to provide inputs from the qualitative point of view, from the social management, from the relationship with the community, from the data we collect, etc., to make a kind of pre-feasibility of the offer, and the feasibility of the projects and reach this kind of... the answer to the questions you are asking... I mean, I think that giving this answer now is going to be very difficult because we do not have the elements to do it, well, with arguments.

I do believe that in the future we are going to have solar community offers and that they will start where it is most viable, according to what the market tells us, this pilot and others that we are doing; also with the signals that the regulation is giving, because, for example, in these coverage issues we have been doing it today so that not only individual solutions are favored, but also collective ones, in the coverage issues, well, coverage issues. So there may be, let us say, opportunities that we are not seeing as viable today, anyway we believe that this is the type of projects where we have to bet and learn and that we can only learn by being there, I cannot imagine how the community is going to behave, how a user is going to perceive? that is to say, there are very big challenges for the users, because they also have to go from a service center, or via a telephone channel, to a totally digital service from the customer service, to the payment of the bill, to the reception of the bill. The truth is that, I believe that the more digital, the more avant-garde to digital a customer is, the easier it is for them to take this step.

On the other hand, there are other issues that may favor a stratum, let's say, higher than the one that is benefited because they do not have subsidies, but rather they pay contributions; then, since they have a higher rate, it makes more sense for them to benefit from a rate that can be obtained with a solar system, than for a user who, in itself, has a subsidy and whose rate is not so high.

AMRT: Understanding the regulatory scheme, not the supply let's say that could be generated around the communities, wouldn't a change of retailer be required then, this is to give a function to the pilot, well, knowing what were the advantages of making this change, but not because legally this change is going to be made, because let's say that according to the regulatory framework, EPM could continue being the retailer of our community, of those people enrolled in the distributed generation and they as generators sell the energy, of the different mechanisms they have as a generator, is that correct or am I confused?

ED: No, that is correct, I mean, EPM could say "no, I am going to set up my own platform", let's say, of digital commercialization of energy, with settlement and billing of the energy that comes from that distributed generator and I am going to grant the benefits through that platform and the customers will remain in the commercialized EPM, true, but let's say that we did not make the agreement that way, true. And to do that, let's say that, let's see, we are trained to serve, well, a very large market, right, so, sometimes it is more difficult to take out, well, like a little bit of customers to give them a different service, when you have so many customers, right. In other words, it is easier to serve 50 customers among 1000 customers in a different way, than to serve 50 customers among, I do not know, 2 million or 3 million customers; in other words, the complexity of making the pilot also implies, well, differentiated processes, which would have to be differentiated in everything for us, while there are retailers, like the one we are allied with at the moment, that already have the appropriate processes to serve all their customers in this way, so let us say that the corporate effort is different, also in view of the management of this pilot within the organization.

LD: And that was the same reason why Erco is the company that represents generation? because it could also have been EPM.

ED: Well, let's say, that is a major discussion that requires a great knowledge of energy trading in Colombia, because a retailer does not... that is, the rules for selling energy when it is directed to the regulated market are different than when it is not. So when it is directed to the regulated market, that is over there, I do not remember if it is in 174, in 030, or in which resolution, but we could look at it calmly, but I cannot sell directly the energy from a generator to a retailer so that he can sell it to the regulated market, if it is not through an offer.... that is to say, he has to make a bid and there is a platform that XM has in which he has to register this, and this has to be through a competitive bid, because the idea is that the energy for the regulated market comes out as cheap as possible.

If I, as a retailer, am going to sell energy to the regulated market, I have to guarantee that I buy it from the one that can sell it to me the cheapest, right, and then let's say that, since the energy for a pilot is so little, it makes no sense to go through a very big procedure, to register it in a platform and start looking at what other generators offer you and then start competing with others to be able to guarantee that the energy that NEU is going to buy is effectively that of that distributed generator that another company set up, which in this case is representing Erco Generación SP. In addition, there are no "pay-as-you-generate" contracts enabled for that market, so when I buy energy for the regulated market, I have to buy an amount of energy, it cannot be: "I will buy what you generate", no. So, there is a... there is a paragraph of a regulation that allows or obliges the established operator, the RO, which is associated to that retailer, to buy the energy generated by the generator to distribute and that is why we went that way.

Well, I mean, that is a very big watermark, if you want, well, I mean, we will have to go into the detail that in paragraph such and such, in article such and such, in literal such and such, there is that, and we went that way, but we did all those analyses. This has also been another challenge of the pilot: to understand how to better commercialize the energy of this distributed generator so that it benefits the customers.

VERTICALLY INTEGRATED UTILITY - EPM 2

Interviewer: Laura Duque Restrepo
Interviewee: John Restrepo Giraldo
Date: August 17, 2022

LD: What services does EPM provide?

JR: EPM, in electric energy, provides generation, transmission, distribution and commercialization services; in gas, it provides distribution services; in water, it provides water and sewage services; and in waste, it provides solid waste collection services.

LD: How is EPM adapting to the changes of the energy transition for end users in the regulated market? Do you believe that the current regulatory framework is sufficient for the promotion of distributed generation systems?

JR: No, the regulatory framework is not enough. What happens is that the energy market today is based on an equity scheme, that is why we have the whole issue of tariffs. And here there are many gaps, for example, because then how will the subsidy be given to users of strata 1, 2 and 3, on the total consumption or the net consumption of the network? It is also necessary to implement nodal energy tariffs, which means that a supply and demand formula would be applied to each node of the network to calculate the price. This way of calculating the price of electricity can modify the behavior of users, because then they begin to consume energy at times when it is cheaper, that is, during the day, when there is a lot of solar energy production.

LD: What have been the barriers that your company has encountered for such promotion?
JR: In the regulated market, for example for self-generation solar communities, a very important barrier that I consider is that most of the people in the country live in strata that are subsidized, i.e. strata one 2 and 3, if my memory serves me correctly, only 6% of the 15 million households in the country are strata 5 and 6 and more or less 80% of the households are strata one 2 and 3, and this has important implications. One is households that do not have money to make investments in self-generation infrastructure and there are some important difficulties on how to make the charges, because they are strata that receive subsidies so the subsidy should be applied on the net amount of energy they consume, and not on the total of what they consumed when they self-generate. If you consume 100, but generate 80, should the subsidy be on the 100 or on the 20? And there are some important regulatory gaps on how to calculate those tariffs and so on. Who owns the assets is important, but also the infrastructure where it is installed, so the infrastructure requires that the roofs are structurally robust, what happens if the house is not owned by that owner, what is going to happen when he sells it, or what is going to happen when the tenant leaves?

Eugenia is a better person to answer this question, but what we have learned in the community that is being set up in El Salvador, for example, and what was done in commune 13, is that there are some very important challenges because we have a low associative capacity. That is, if we compare ourselves, for example, with a country with a very high associative capacity, for example Germany, where everything works with cooperatives, it is very easy, but here it is very difficult to get a group of neighbors to agree to formalize and create a cooperative and that together they are the owners of the property of the assets, that this is managed in a proper way and so on, because as a country, in a cultural way, we have a very low associative capacity and the whole solidarity sector, which is the cooperative sector and others in Colombia, is in a deep crisis because of that.

Getting the neighbors, and I am talking about the regulated market in the lower strata, which is where the pilots are being carried out at the moment, to associate and organize themselves so that they can manage their own generation resources is difficult and this is not a regulatory barrier but a cultural and market structure barrier. It is possible that the users, who are finally the ones who pay, are not the owners of the houses because a high percentage of people live in rented houses, and it is difficult to organize these communities around associative models such as cooperatives or others and that makes them very difficult to implement. Again, barriers that are not regulatory. Now in the market that is not regulated in a market that is not residential, but industrial, for example, the barriers are almost always investment barriers.

LD: But these investment barriers would still be in the regulated market only they are not the main problem?

JR: Yes, they are also barriers in the regulated market.

LD: From EPM's experience with these pilots, and I also understand that at some point you ran a survey on a related topic, do you find interest in the market and the authorities in the implementation of these energy community schemes?

JR: I think that this has not been sufficiently explored, I believe that regulators are interested in seeing what happens. But the issue of energy communities is very new in the world, it is not even new in Colombia, it is new in the world, there are very few examples of energy communities that are well structured and are working in the world. And, in fact, most of them are pilots, they are projects that have a scale that does not allow us to see the impact that this may have, for example, on the market, because this will inevitably have an impact on the market.

Our market structure is a structure that seeks equity. The whole scheme of subsidies, for example, is a scheme that seeks equity, that is to say, that people with lower incomes can have access to energy at reference prices, versus people with higher incomes. So, I think that the regulator has an interest in seeing in which direction it moves, but I am also sure that the regulator has to take care of the market structure. An important portion of the tariff we pay, the value per hour we pay, is destined, for example, to attend the needs of those areas that have low energy coverage, for example, all the expansion of the network for the areas that are not interconnected and others, is financed with the tariff of the users. If the users start to self-generate, a very important portion, then this starts to go against the principle of equity, because then the service companies are left without resources to expand the network and provide service to the people who still do not have it. And, additionally, it is possible that a portion may be lost, especially if those who pass, which is what I feel is happening and probably the first thing that will happen if those who pass are the higher strata. Then, with what money are we going to pay the subsidies? Because strata 4 pay the full rate, do not pay subsidies, and do not receive subsidies, but strata 5 and 6 pay subsidies and with that additional money paid by the higher strata, subsidies are given to the lower strata which would be strata 1, 2 and 3.

The issue of self-generation has an associated risk and that is that it may be lost or modified, if that becomes an important percentage of the generation, I think it will be a long time before that happens, if it is going to happen, and it is not clear how we are going to solve the issue of subsidies. So the regulator has a moderate interest in watching what happens, but I know of absolutely nothing that is being worked on regulatory issues to ensure or facilitate that that happens.

And from the market point of view, I think that this changes in some strata and in some particular users. I am interested, but the current economic model does not allow this to close financially, that is, I make an investment in solar panels, and I spend 20 million pesos, I save half of the bill which is 50,000 COP per month, how long will it take me to recover that investment? Almost that is done with altruistic purposes and with the purpose of contributing to the improvement of the environment, but I do not see in the regulated market, at least, a high motivation for a significant number of users to switch to self-generation systems and/or solar communities. in the industrial market it is different because the rates are much higher than in the residential market so if there is an incentive and if there is a mechanism that allows the financial closure of these projects faster.

LD: How viable do you think these community solar schemes are?

JR: I don't see them as very viable.

Because of everything I have just explained. Because of regulatory barriers, because the market structure is complex, because of the issue of subsidies, because our capacity to associate or create associative models or solidarity economy is very low. I see that there are a lot of difficulties and challenges for these community projects to be viable on a significant scale in the short term, but I am sure that projects will begin to appear in this city. And in this city they may have 10, 15, 20, 20, 50 users, but there are 15 million households and almost all of them are in the lower strata, so I see that if there is no change in the market structure, in the regulation and in the associative capacity, it is very difficult for solar communities to grow fast enough to become a relevant actor within the energy matrix.

LD: What interest does EPM have in the implementation of energy communities? Do you have interest in continuing to develop pilots?

JR: At EPM we are interested in exploring and studying all technological and regulatory developments associated with our energy businesses.

LD: How would you propose a promotion strategy for distributed generation at the national level?

JR: For distributed generation, I think we have to correct the defects of the current regulation, specifically the 030, in relation to distributed generation. Because it unnecessarily restricts the possibilities of energy transactions between peers, which, in fact, was the first part of the solar communities' project, which was the transactive energy project; therefore, for distributed generation I believe that we must correct the regulatory defects that exist, in order to encourage distributed generation. Two: there is a limit, it is not infinite, and it is because the grids are designed for a certain generation and consumption capacity. At this moment the regulation says that I can charge a new generator to the grid up to 15% of its design capacity, with non-conventional renewables. What happens if that 15% is exceeded? What happens if all the houses in the plot where I live decide to install solar panels? Then 15 are installed and there are 80. What happens to the rest because the design limit of the grid has already been reached? There is an urgent need to modernize the grids to accommodate distributed generation. And this also happens with other things. Imagine that a building where you live, for example, 50 people buy electric cars. And what happens if 50 users in your building, and others in the next building, and others in the next building, change their electric cars? Already the network of the whole neighborhood has to be changed. The energy transition will also require huge investments in infrastructure, so how can this be promoted? We have to make a regulatory change that facilitates energy transactions between peers, and we have to make regulatory changes to facilitate the modernization of infrastructure.

And the other part, which is very important for solar communities, is to solve the cultural issues associated with these economic models of association or solidarity economy that I was talking about earlier. Because, without that, it is very difficult to reach an agreement with a community to organize and make some investments and mount their panels and share the profits. Think about it: we all put a million pesos each for the system to work, but there is a house that consumes 150 kWh, and the others consume 100, that could be seen as very inequitable, so how do we do it? the problems that exist are very difficult to solve.

NON-PROFIT NGO - RE4

Interviewer: Ana María Ramírez Tovar
Interviewee: Yuri Ulianov López C, director Renewable Energy For All - RE4
Date: August 25, 2022

At the beginning of the interview, the project is presented, as well as its objectives. An invitation is made to participate in the research in order to be able to advance a guide for the promotion of solar communities in Colombia. Then follows a discussion of the points described below:

The foundation's work has focused on isolated areas, where the most relevant factor for community work is the bonds of trust between the parties.

They suggest a multidimensional analysis of the design of any community solution to achieve social appropriation of technologies, specifically a multi-criteria design.

In the conversation, they share with us a four-part strategy for approaching the research project:

1. Approach process with the community. We must start with a dialogue of knowledge, get to know the community, their preferences and above all ask if they are interested in having an electric power system (it is contradictory as engineers to see that some people do not want it).

Here it is important to identify the internal hierarchy of the community, even if at first instance a person is identified as the leader, it is necessary to make a field visit and corroborate these power relationships within the community, if there are other factions, positions, or leaders; not doing so could generate great inconveniences in the development of the project.

In this first approach phase it is also important to explain both the advantages and disadvantages of the project, the installation process, and the dates on which the execution could take place.

A proposal should be presented, but indicate that it is not an imposition, nor a single solution, but on the contrary a space where they (the community) will be able to give their opinion, complain, propose or express any matter of concern.

2. Communication strategies. Communication is a critical factor given the heterogeneous nature of the communities. Although it cannot be homogenized as a single route, it is necessary to consider the idiosyncrasy of the place where it is located. With a working group of the foundation, they have advanced work where they have determined that the communication channels can be very diverse, some people will prefer the information by radio or audiovisual channels, others by written documents, presentations or others.

They highlight here the importance of having a defined communication strategy and knowing how to reach the community.
3. Interdisciplinary team: it is important to know the points of view of other stakeholders, especially those who will be decision-makers; likewise, public-private alliances where not only technical collaborations are presented, but also some other type of material or service support.

4. Project developers: it is not only important to know the community with whom the project is going to work, but also that the team developing the project has a clear idea of why and for what purpose it is being done, this will facilitate the communication channels and simplify the work by being efficiently directed to an objective.

On financial matters

On the financial side, the foundation's experience highlights that it is important for people to have access not only to financing options but also to subsidies. It is not possible for a family with a monthly income of between 400 or 700 thousand COP to pay for a solar photovoltaic system, not even because it has financing can guarantee that a family in these conditions can access them.

They share with us that, in a previous study framed in the Engineering Doctorate of the Universidad Autónoma de Occidente, they identified that Bancamía, Bancoomeva and Banco de la Mujer are the Colombian entities where there could be a greater possibility of financing because they have microcredit schemes. However, he expresses his great concern about the impossibility for some people to access them because they are considered by the financial entities as "unbankable", given that they do not have any type of credit history.

They suggest reviewing financing models that have been used in Africa, in which the installer "entrusts" the system to the users, who pay in small installments. However, it is a system that can bankrupt small installers because users do not always pay on time and these in turn (the installers) have received financing from another large company or financier that is completely unaware of the unstable payment dynamics of the market.

INTERNATIONAL NGO - VALENTINA HERRERA

Interviewer: Laura Duque
Interviewee: Valentina Herrera - Coordinator of the diploma course on fair mining-energy transition in the Colombian Caribbean. Researcher of the TRAJECTS network.
Date: February 3, 2023.

- It is necessary to get close to the territory and map the stakeholders.
- Identify the internal organizations in the territory and see which projects that have community action boards are useful because they have bylaws.
- Indigenous communities also have organizational figures.
- We work with all the organizations, I come to do a job, these are my proposals, and if you want to be part of the project, great.
- It is not about forming communities; it is about taking the communities that already exist and encouraging them to implement small-scale energy solutions.
- You can propose a project, but people must have participation, voice, and vote. People need to understand what the project is for. In projects as long as the energy communities, it is important that people do not lose interest, it is necessary to build trust with the community. It is important to go at least once a month and that they do not feel that we are doing academic extractivism.
- In order to approach the community, you have to talk to the leaders. The proposal is presented to the leaders and then a kind of hearing is held, in which the project is presented to the community. The leaders are the ones who facilitate the spaces. People's concerns are answered, and everything is taken note of.
- Informed consent must be given so that people are fully aware of what is going to be done.
- The boards are not the ideal figure, because they have a high turnover of people, the idea is for the community to adopt another figure in which they are an organization and assemblies can be held.
- Recovering the social fabric is very complicated. Because the relationships that people have with the state are complicated and even more so when there is no investment in the territory by the state. Projects that have a social component can help restore these relationships. For the construction of the social fabric, we can rely on the social projection of the schools.
- When the project is financed by the state, it must be clear to people that it is financed by the state, that it is mediated by the university, for example, but that the people are the ones who make the decisions. They have to feel that they participate in the project. As long as they feel important and loved, people work.

- Informed consent: here we tell people what we are going to do, where, why, it must be made clear that people are not going to receive money in exchange, what are the hypotheses of what we think we are going to find. Everything must be very explicit and colloquial.
- The project must be based on a community need.
- Paternalistic projects are so because they do not consider the reality of the people and actors of the territory. So, they have to go with an educational process.
- The projects in which people have to put part of the assets would have to be in strata 3 and 4, which have greater purchasing power. The most vulnerable people are not going to put money. The upper strata are not very interested because they have no real need, they have economic and intellectual capital.
- In order for the project to be consolidated, we need to do a lot of pedagogy and train people in a certified manner. Because the idea is that the project will last 10 years or more. EIA could give the certificates. For the project to really last, training should be done by age ranges, so that many people are left with the knowledge. Children, youth, and adults.
- We have to follow up a couple of times a year, like calling and asking, sending them some details. The university could be in charge of the follow-up because they have long-term processes. We could also evaluate the possibility of leveraging mining and energy companies, such as Ecopetrol.
- Let the people be in charge of overseeing the company as a citizen watchdog.
- It must be considered that these are very long processes.
- La Jagua. La Guajira is going to be an energy exporter, the republic of energy banana plantations.
- "We were never modern" - recommended text.

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