From Vision to Action: Building Sustainable Energy Communities in Colombia

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Abstract

This study proposes sustainable variables for Colombian energy communities, inspired by European models. Key factors include social cohesion and financial support. Lessons from Europe inform above all local engagement and regulatory strategies for sustainability.

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1. Introduction

Energy communities (ECs) are gaining popularity as a response to the growing need for sustainable energy solutions amid global concerns such as energy security, climate change, and social inequalities within the energy sector (Lode et al. 2022). These communities enhance overall energy efficiency, promote the use of renewable energy sources, and empower end-users to actively participate in the energy market, contributing to government climate change mitigation goals (Bauwens et al. 2022). Policymakers, particularly in the European Union, recognize the potential of ECs to alleviate public resistance to renewable energy transitions, making them a focal point of attention. In the European Union, countries like Germany, Denmark, and Italy have a rich tradition of successful cooperative communities in the energy sector, emphasizing both top-down and bottom-up approaches. However, the concept of energy communities is gaining traction in Latin American countries, particularly in Colombia, as part of a socially just energy transition aimed at involving marginalized communities.

Colombian´s president Gustavo Petro is actively promoting the inclusion of energy communities in the national energy transition and development roadmaps, as evident in Law 2294 of 2023 with article 235 in which it is specifically created the figure of energy community,[1] followed by the decree 2236 of 2023 on the partial regulation of energy communities released by the Ministry of Mining and Energy.[2] The focus is on vulnerable population groups and the inclusion of minorities. The Colombian government acknowledges the importance of energy communities as a strategic element in its political agenda. By aiming to strengthen and empower local communities, improve energy access, address energy poverty, and contribute to the democratization and pacification of the country, energy communities represent a significant opportunity for positive change and development in Colombia.[3]

Despite their potential, establishing ECs face various challenges, including financial hurdles, complex organizational and administrative tasks, and the need for adept legal and operational approaches to ensure sustainability and efficiency. Specific factors unique to the Colombian context, such as a weak social fabric, high investment costs, grid connection complexities, lack of legal regulations, and the requirement for utility company status, pose additional hurdles (Energía y Equidad 2023).

These challenges need attention when trying to implement and scale EC in Colombia. Especially when it becomes evident that community energy research must consider social inclusivity alongside technical and financial aspects, especially concerning vulnerable populations (Belmar, Baptista, et Neves 2023).

The new Colombian government is ambitious in finding countermeasures, making it imperative for us to synthesize lessons from the European context and propose a holistic framework with sustainability parameters tailored to the Colombian case. For doing so, this paper adopts a New Institutional Economic perspective integrating debates on infrastructure provision effectiveness and implementation, while employing the Organizational Model Framework developed by the TU Berlin team to identify suitable sustainability variables (Beckers, Gizzi, et Jäkel 2012; Wealer et von Hirschhausen 2020; Heinemann 2023). It employs a three-step approach to construct the Organizational Model, initially based on the technical system, including assets, goods, value chain, and demand. Subsequently, tasks, roles, and relationships are identified to meet the requirements of the technical system, culminating in the establishment of actors and institutions necessary to complete the Organizational Model (cf. Figure 1). This framework prioritizes a bottom-up approach, empowering local communities in development processes, drawing inspiration from the insights of Hirschman (1958), Ostrom (1993) and Williamson (1994). Through a mixed-methodological approach, including an extensive literature review and empirical interviews tailored recommendations for Colombian policies were derived.

We find that a strong social component is critical to the success of energy communities, with community participation and cohesion being key factors. In addition, financing plays a critical role in enabling the success of these communities by supporting social efforts.

In the next section, we briefly introduce the Colombian context before discussing in detail the results of our literature review and interviews. The implications of these results for energy communities in Colombia are discussed then. From our analysis, we conclude that there are valuable lessons to be learned from Europe, particularly in terms of local community engagement, motivation, and the importance of a strong social fabric coupled with a tailored regulatory approach. Ultimately, sustainability in energy communities is multifaceted and requires a delicate balance between human well-being, social equity, and environmental considerations.

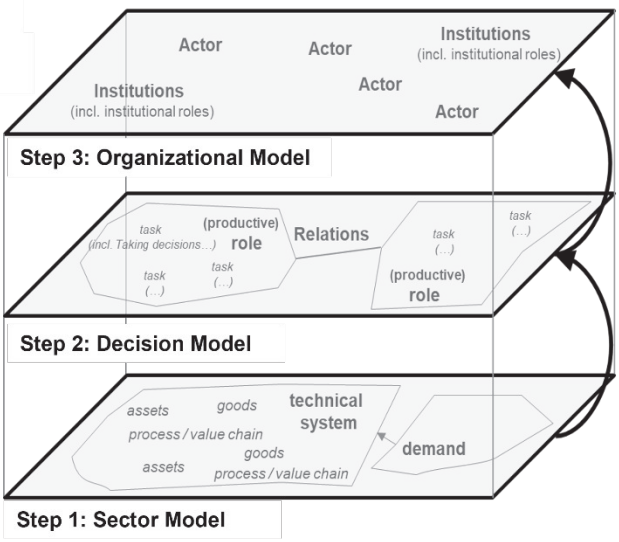


Figure 1: Research framework.
Source: Beckers et al. (2012).

2. Context Colombia and energy communities

Historically, energy communities have emerged in response to escalating energy costs, economic challenges, and a market dominated by multinational energy corporations (Hewitt et al. 2019). They are entities where citizens, along with other stakeholders, jointly invest, own, and participate in energy production. They can take various legal forms such as associations, cooperatives, or capital companies, often originating from pre-existing groups like municipalities or housing cooperatives (Eriksson Berggren et al. 2023). By granting more decision-making power to local communities, ECs foster inclusive and democratic energy environments (Hanke et Guyet 2023).

2.1 Energy Transition in Colombia

Colombia boasts significant renewable energy potential yet lags in energy sector innovation. Despite pledging ambitious emission reduction targets, challenges persist. Over 90% of the industrial sector relies on coal or fuel energy, necessitating innovation to optimize energy usage without compromising productivity. Enhanced collaboration between industry, research, and policy is crucial. The Ministry of Mines and Energy has devised strategies to expedite the transition to a low-carbon economy, addressing challenges such as over-reliance on hydropower and fossil fuels and inadequate infrastructure in remote regions. Decentralizing power generation through community-based technologies is a key strategy, albeit hindered by technological and entrepreneurial limitations (IEA 2023).

2.2 Status Quo of Energy Communities in Colombia

Only since recently, energy communities hold a prominent position in Colombia's political agenda, heralded as tools to empower local communities, broaden energy access, alleviate poverty, and bolster democracy. Aligned with the government's ambitious net-zero goals, ECs represent a crucial step towards sustainable energy infrastructure. President Gustavo Petro's administration is spearheading these efforts, integrating them into national policies and development plans, such as the National Energy Transition Roadmap [4] and the National Development Plan.[5] The Ministry of Mines and Energy's presents a decree on energy community regulation underscores inclusivity, especially for vulnerable populations and minorities. In this context, energy communities encompass groups of individuals or entities collectively owning, managing, and benefiting from non-conventional renewable energy projects, as outlined in Law 2294/2023, Article 235.[6] Colombia's energy policy regarding energy communities aims to advance renewable energy sources, decentralize energy production, and foster community participation in the energy sector. Before the officialization of the aforementioned law, the Energy and Mines Ministry issued decree 2236/2023 on December 22nd, mandating the establishment of a sustainable model for energy communities (Article 2.2.9.2.2).[7]

It is worth noting that specific details of Colombia's energy policy concerning energy communities are still evolving, awaiting technical regulations from regulatory bodies like CREG (Comisión de Regulación de Energía y Gas). This includes determining the maximum installed capacity for the energy planning unit (UPME) and outlining the supervision and control framework for the superintendent of public services.[8] Existing energy communities in Colombia primarily stem from top-down initiatives, often financed by development banks or government entities. To accelerate their proliferation, key challenges such as high investment costs, complex grid connections, legal barriers, and a lack of incentives or institutional support must be addressed. Bottom-up initiatives may play a vital role in combating energy poverty and fostering participation, necessitating knowledge transfer and supportive frameworks. Guidelines and evaluation tools are indispensable for facilitating feasibility studies and empowering community-led initiatives (Martínez et al. 2023).

3. Results from the literature review

3.1 Framework conditions for energy communities

Energy communities, established since the 20th century, focus on decentralization, ecological sustainability, and corporate independence, with a common emphasis on local governance and collective benefits (Klemisch 2014; Drewing 2020). These communities aim for collective management, ownership, and participation, supported by regulations for secure energy access (Rogers et al. 2008; Hargreaves et al. 2013; Yildiz et al. 2015). Essential attributes of cooperatives include "self-help, self-accountability, self-administration, democratic governance, and the convergence of ownership and utility among stakeholders" (Drewing 2020, 1). The European Commission as well as the German law provide exemplary frameworks for energy communities (*Erneuerbare Energie Gesetz, EEG* 2023, §3; European Commission et al. 2020; *Genossenschaftsgesetz, GenG* 2022). The formation of a cooperative involves board establishment, member recruitment, and project planning focused on environmental and financial sustainability (Klemisch 2014; Bauwens 2016; Ruggiero et al. 2019). Research indicates that the connection between social capital, civic behavior, environmental concerns, and interpersonal trust influences members' decision to join and support energy communities (Bauwens 2016). ECs sustainability and resilience to insolvency stem from their ability to maintain self-sustained economic viability. Economic empowerment and resilience against (external) financial and economic challenges are crucial, with energy communities operating on principles of identity, aiming for deprivatization and leveraging democratic governance for climate goals (Klemisch 2014; Drewing 2020). The social innovation potential of these communities enables energy consumers, regardless of financial standing, to integrate into decentralized energy systems. These features makes energy communities less susceptible to global economic crises compared to fossil fuel-based systems reliant on imported energy sources (Walker et Devine-Wright 2008; Koirala et al. 2018; Caramizaru et Uihlein 2020).

3.2 Insights from German energy communities

Energy communities have played a transformative role in Germany's journey towards renewable energy adoption, originating in the 1990s but gaining significant traction in the 2000s. This growth coincided with Germany's intensified focus on alternative energy sources, driven by mounting environmental concerns and a strategic shift away from fossil fuels. The implementation of the Renewable Energy Sources Act (EEG) in 2000 served as a catalyst for the proliferation of energy communities by introducing a feed-in tariff policy that provided financial incentives for renewable energy producers, thereby encouraging local communities, citizens, and businesses to participate in decentralized energy production (Klemisch 2014; Drewing 2020).

As of 2022, Germany boasts a diverse landscape of over a thousand energy communities, ranging from grassroots initiatives to more established entities. These communities have become instrumental in decentralizing energy production, fostering community engagement, and promoting the acceptance of renewable energy projects at the local level. Moreover, they have generated economic opportunities, created jobs, and contributed significantly to Germany's renewable energy targets, thereby aiding in the reduction of the country's carbon footprint and facilitating a transition towards a more sustainable energy ecosystem (Energieagentur Rheinland-Pfalz GmbH 2016; DGRV 2023). Despite their successes, energy communities encounter challenges such as financing issues, regulatory uncertainties, and the need for professional management. Overcoming these challenges is crucial to sustaining their growth and impact, as they continue to serve as key agents of change in Germany's energy transition, embodying the principles of Energiewende and advocating for a more sustainable and inclusive energy future (Pfister et al. 2015; DGRV 2023; Kajimura 2023).

3.3 Insights from other energy communities in Europe

The European Union (EU) spearheads the development of Energy Communities (ECs), boasting over 1,900 projects involving more than 1.2 million citizens, particularly prominent in Germany and Denmark. These initiatives, leveraging various technologies like solar panels and windmills, provide a rich context for understanding the potential and challenges of ECs (Yildiz et al. 2015; Caramizaru et Uihlein 2020; Tarpani et al. 2022). The Renewable Energy Directive Recast (RED II) reveals a concentration of ECs in Austria, Germany, and Denmark, while the EU's Clean Energy Package (CEP) serves as a legislative framework addressing hurdles within the energy transition, akin to challenges faced by prosumers in Spain, Poland, and mirroring issues encountered in Colombia (European University Institute. 2020).

Given the absence of uniform standards across the EU, national strategies, and the establishment of "one-stop shops" (OSS) are imperative to support EC creation and development. These OSS address crucial aspects like team management, local intricacies, financial backing, and risk mitigation, underscoring the significance of expert guidance, community involvement, sustainable financing, and effective risk management for EC success (European University Institute. 2020; REScoop.eu 2022).

In Austria and Ireland, specific strategies encompass legal and infrastructural planning, operational governance, and strategic integration of energy communities with market and grid operators, alongside initiatives by the Cork City Council emphasizing service development and business planning for OSS efficacy. These instances underscore the tailored approaches within the EU to foster ECs, stressing the need for holistic strategies to navigate local challenges and capitalize on opportunities.

To bolster the growth of energy communities in Europe, research advocates for adopting well-defined business plans, promoting direct community participation, and ensuring inclusivity of minorities as foundational steps (Energieagentur Rheinland-Pfalz GmbH 2016; Hanke et Guyet 2023). Key components encompass developing business models, economic plans, legal frameworks, and establishing founding groups (dena 2022; Innova eG 2007; Gruber, Bachhiesl, et Wogrin 2021; European University Institute. 2020). InnovaEG (2007) delineates a structured approach through phases: orientation, planning, creation, and stabilization, aiming to mitigate risks and clarify member responsibilities. Supporting tools like intelligent measuring systems and distributed ledger technology are recommended for efficient management (dena 2022).

Furthermore, the role of third-party aggregators is underscored for managing energy flow and facilitating local energy trading (Energieagentur Rheinland-Pfalz GmbH 2016; dena 2022; Kyriakopoulos 2022; Gruber, Bachhiesl, et Wogrin 2021). Peer-to-peer (P2P) trading is advocated as a strategy for optimizing local energy consumption within communities, although microgrids, present in only 16% of reviewed literature, may not be indispensable (Gruber, Bachhiesl, et Wogrin 2021).

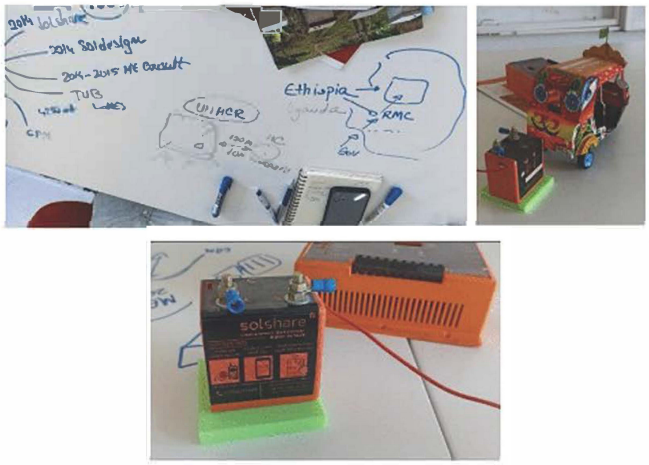
4. Results from interviews

Non-structured qualitative interviews were conducted with five institutions during the research: the Critical Infrastructure in Crisis - EADP, which held a workshop in which the goal of this research was carried out and some conclusions were extracted; Micro Energy System International - MEI; and the *Deutsche Energie-Agentur* - DENA. In addition, fieldwork in Lolland-Denmark was carried out, with visits to the Lolland Climate Center and *Ren Energi Lolland* -REEL.

4.1 Critical infrastructure in crisis (EADP)

The workshop on Critical Infrastructure in Crisis - EADP[9] concludes that complex challenges, including inadequate regulation, administrative limitations, and insufficient community participation, hinder addressing societal issues in energy communities. Competing needs and priority settings further complicate decision-making, leading to suboptimal outcomes. Moreover, limited access to supply chains and misinformation impedes resource delivery and accurate knowledge dissemination, affecting community cohesion. Paternalistic approaches exacerbate dependency and disempowerment, while Western-focused interventions may overlook Indigenous knowledge and cultural nuances. To address these challenges, a holistic and inclusive approach is necessary, integrating effective regulation, community engagement, and equitable resource access. Collaboration among stakeholders and culturally sensitive interventions can enhance community resilience and self-determination, fostering a sustainable societal landscape.

4.2 MicroEnergy International



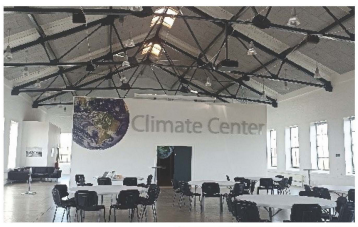
The interview[10] highlights the importance of understanding diverse community needs, especially among ethnic and vulnerable populations, in addressing energy infrastructure challenges effectively. It emphasizes the need for tailored interventions and incentivizing community ownership to ensure the longevity of energy projects. Formal registration and active participation in investment systems are crucial for economic empowerment and project sustainability. While private sector involvement can offer resources and expertise, it must align with community needs and project sustainability. Contextual relevance and cultural inclusion are essential for seamless integration of energy projects into communities. Regulatory sandboxes for testing innovative schemes require adaptive frameworks and voluntary participation. Overall, the interview stresses the importance of a holistic, community-centered approach that promotes self-sustainability and aligns with each community's specific needs, contributing to the discourse on resilient and inclusive energy communities.

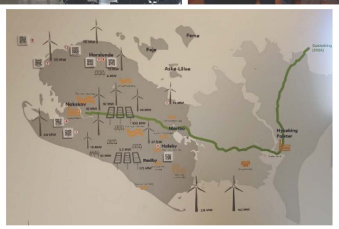
4.3 DENA

The interview[11] concludes by highlighting two crucial aspects of energy communities: energy digitalization and real-time market interaction, and the evolving

regulatory framework for peer-to-peer (P2P) models. It emphasizes the role of technology in optimizing energy distribution and fostering efficient market interactions. Robust regulatory frameworks are deemed necessary to support the growth of P2P energy models, balancing flexibility for community-driven initiatives with necessary oversight. The discussion emphasizes the interconnected nature of technological advancements and regulatory frameworks, stressing the need for collaboration between stakeholders, policymakers, and communities to ensure the evolution of energy communities towards a more resilient, inclusive, and sustainable energy future.

4.4 Lolland, Denmark: Lolland Climate Center, REEL





Fieldwork in Lolland[12] focused on sustainable cooperative approaches, including visits to the Lolland Climate Center and REEL, providing insights into innovative strategies for community development. A key observation was the challenge of educating adults, particularly men, leading to a strategic shift towards focusing on children as agents of change due to their effectiveness in disseminating sustainability messages at home. The imperative for change extends beyond energy generation to consumption reduction, with Lolland emphasizing the importance of educating the community about hourly consumption and energy prices. Co-ownership of systems, including energy communities and cooperatives, emerges as crucial for successful energy transitions, offering diverse solutions to evolving challenges. Transparent communication about the benefits of cooperative models is essential for their widespread adoption. Clear communication fosters community engagement and shared responsibility, accelerating the adoption of sustainable practices.

5. Implications for Colombia

5.1 Summary of relevant criteria

From the literature review and the conducted interviews, a number of relevant criteria than can be a sustainable variable for our targeted framework for energy communities in Colombia can be derived:

Table 1: Summary of criteria found.

Relevant criteria than can be a sustainable variable	Grouping under a collective term
Combat misinformation and strengthen social fabric Effective team management and advisory support are vital Understanding local complexities is crucial Risk management is essential, especially early on Educate communities about hourly consumption and energy prices Empower individuals to make informed energy choices	*Strong social fabric for a cooperative approach*
Trust and community cohesion promote renewable energy acceptance Promote community participation and ownership Encourage care for energy infrastructure Democratic governance empowers citizens against privatization Prioritize needs effectively amidst competition Tailor projects to diverse community needs Avoid paternalistic interventions and respect cultural differences Adapt projects to local contexts and include community culture Emphasize voluntary participation and avoid overburdening communities Long-term security ensures resilience	*Clear and defined motivation by the community*
Engage the private sector while aligning with community interests Self-sustained financial activity drives diversification Financial support must align with community values Policy support incentivizes community initiatives Focus on educating children as transformative agents Ensure transparent benefits for cooperative models Minimize reliance on subsidies for sustainability	*Community initiative, skills, and opportunities*
Establish self-sustainable mechanisms to reduce external financial dependence Improve access to the supply chain Third-party aggregators support various functions Peer-to-peer trading optimizes energy flow Microgrids enhance community functionality Supporting tools include intelligent systems and smart contracts	*Clear definition of a business plan*
Facilitate formal registration and investment participation Operational considerations follow a critical order Adaptive organizational structures are key Promote energy digitalization and real-time market interaction Recognize diversity in co-ownership structures Ensure adequate regulation and administrative capacities Explore regulatory sandboxes for testing schemes Develop regulatory frameworks for peer-to-peer energy models	*Formalization of the system*

Source: own elaboration.

5.2 Design of the Sustainable Organizational Model

Based on Figure 1 and the mapping of the central elements of the research framework (Beckers, Gizzi, et Jäkel 2012, 3), an organizational model emerges that considers the five key sustainable variables at several points and clearly shows where interfaces and critical coordination issues arise (cf. Figure 2).

5.3 Discussion

Applying the Organizational Model framework to the results of our literature review and interviews reveals five key variables crucial for sustainability in energy communities: a strong social fabric, clear community motivation, community initiative and skills, a defined business model, and system formalization.

5.3.1 Strong social fabric for a cooperative approach

A robust social fabric is essential for fostering unity and shared purpose within a community. Active citizen participation, property involvement, voluntary yet reliable engagement, reconfiguration of social practices, and effective coordination between formal institutions and informal networks are key elements. Citizen participation reflects commitment and strengthens collective resolve, while property involvement signifies shared ownership and responsibility for communal resources. Voluntary but reliable participation builds trust, and reconfiguring social practices aligns norms with cooperative principles. Effective coordination ensures a synergistic balance between structure and grassroots connectivity, sustaining mutual trust, shared responsibility, and adaptive resilience.

5.3.2 Clear and defined motivation by the community

Community motivation stems from understanding its needs, wishes, and priorities, forming a shared vision. Examining tangible and intangible needs establishes a roadmap for action, ensuring efforts address pressing issues. Understanding community wishes inspires purpose, driving collaboration towards shared goals, whether it's infrastructure improvement or cultural preservation. Prioritization allocates resources efficiently, focusing on initiatives with the greatest impact. Clear motivation, derived from needs, wishes, and priorities, guides purposeful community initiatives, fostering growth and development.

5.3.3 Community initiative, skills, and opportunities

Communities must appropriate external support for projects, crucial for their success and related to securing financing. Community initiative, skills, and opportunities form a dynamic framework empowering local initiatives. Technical appropriation, understanding and applying relevant technologies, enhances self-sufficiency and resource utilization. Access to financing mechanisms, including grants and loans, is essential

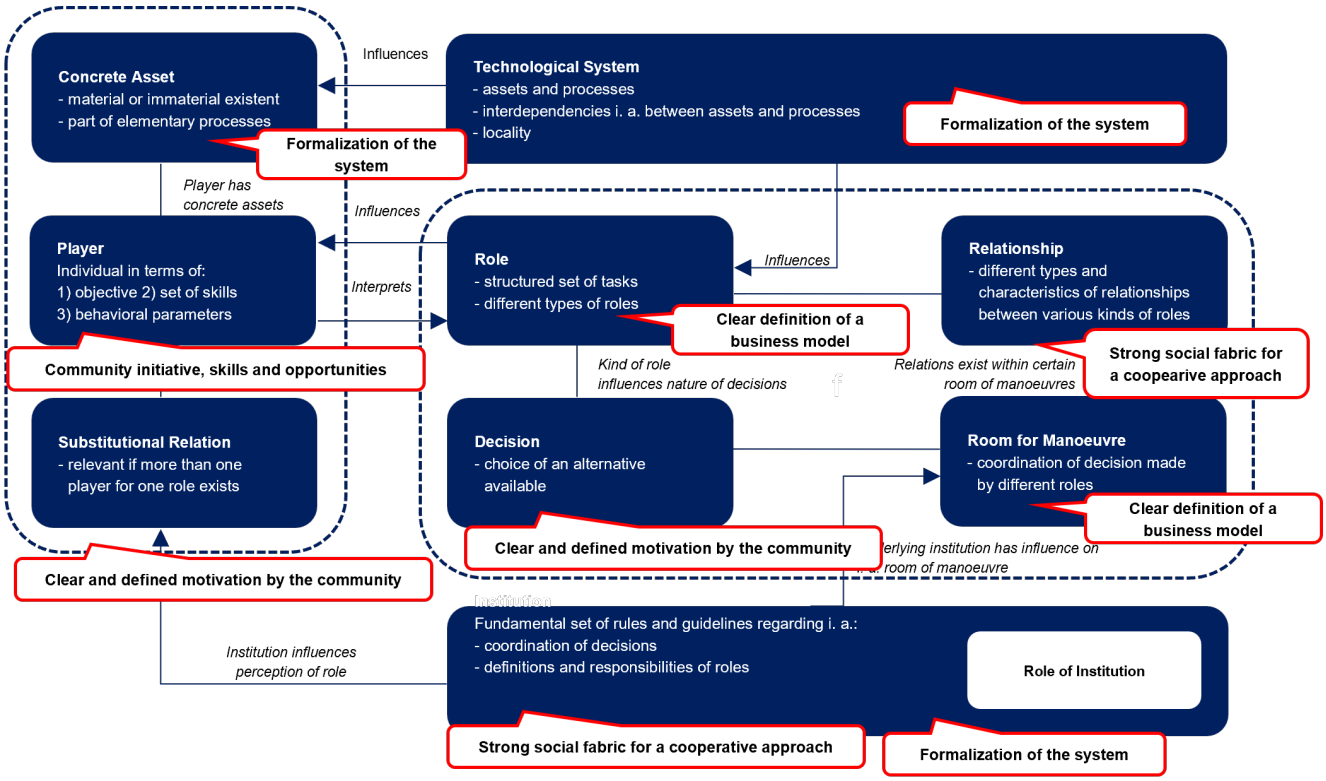


Figure 2: Organizational Model with five sustainable variables for energy communities in Colombia.
Source: own elaboration, based on Beckers et al. (2012, 3).

for funding and sustaining projects, fostering economic independence. Community knowledge is pivotal, enabling informed decisions and effective project implementation. Overall, community initiative, skills, and opportunities converge to drive positive change, economic growth, and member well-being.

5.3.4 Clear definition of a business model

Consolidating a business model and income will be important in understanding how the systems will be funded. It is vital in this model to avoid earnings for external dependency as constant subsidies, which indicate the non-finance closure of the electrical system. Involving the private sector will also be required for a successful business plan.

5.3.5 Formalization of the system

The formalization of the energy system is crucial for efficiency, accountability, and adaptability. Defined roles establish clear responsibilities, streamlining decision-making and promoting transparency. Citizen participation should mirror their responsibilities, enhancing engagement and fostering ownership. Resilience is essential to accommodate new technologies and changing conditions, ensuring the system can adapt and integrate innovations effectively. Ultimately, formalization aligns roles, responsibilities, and citizen participation, fostering resilience and serving as a foundation for sustainable energy practices.

5.3.6 Sustainable analysis of the variables

Sustainability, as defined by Ramírez-Tovar (2021), is a dynamic process balancing human well-being, social justice, and biosphere respect. This study evaluates sustainability in five components: environmental (ENV), social (SCL), financing (FNG), and technical (TEC). Each variable is scored 0-3 in each component (cf. Figure 3). The result emphasizes social and financing aspects as most crucial, prioritizing community engagement and ownership over financing. Environmental and technical aspects, while important, are secondary due to renewable energy's mature technology.

6. Conclusions

In conclusion, establishing a sustainable paradigm in Colombian energy communities requires a strong social component, with community participation, behavioral change, and social cohesiveness laying the groundwork for long-term success. Financing serves as an enabler for social efforts, contributing to overall resilience and success. The study provides insights from a literature review and interviews, capturing the diverse landscape of energy communities and highlighting key components for success. Challenges include regulatory dependencies and financial hurdles, but collaborative efforts can overcome these obstacles. Colombia can learn valuable lessons from Europe's experience, particularly in community engagement and regulatory frameworks, fostering energy cooperative growth. Prioritizing regulatory clarity and community engagement can create an enabling environment for sustainable energy practices.

Sustainability in energy communities is a multifaceted process, balancing human well-being, social justice, and environmental limits, with social issues emerging as most critical. Prioritizing community participation and engagement, supported by adequate

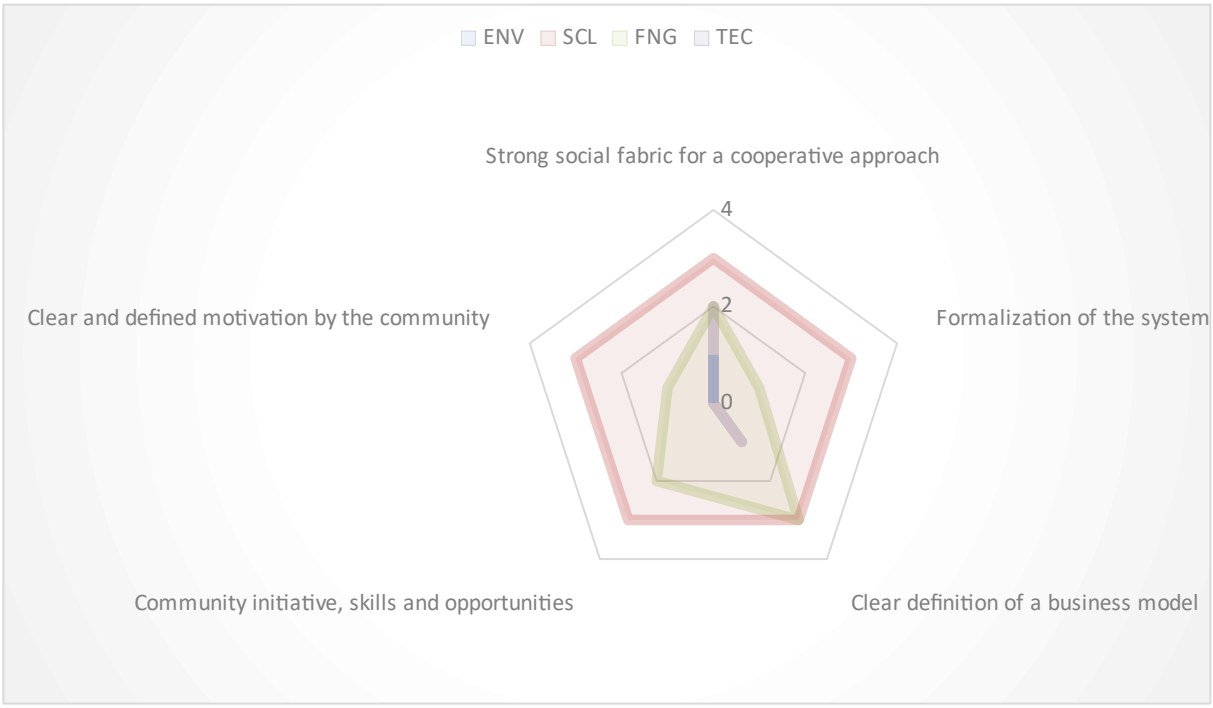


Figure 3: Rating sustainability of the five variables selected for a sustainable energy community model.
Source: own elaboration.

financing, lays the foundation for successful models, enabling long-term sustainability.

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Footnotes

[1] El Departamento Administrativo de la Función Pública de Colombia. 2023. "Ley 2294 de 2023." Accessed February 28, 2024.

[2] El Departamento Administrativo de la Función Pública de Colombia. 2023. „Decreto 2236 de 2023." Accessed February 28, 2024.

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[6] El Departamento Administrativo de la Función Pública de Colombia. 2023. "Ley 2294 de 2023." Accessed February 28, 2024.

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[8] El Departamento Administrativo de la Función Pública de Colombia. 2023. „Decreto 2236 de 2023." Accessed February 28, 2024.

[9] This synthesis is a result from the 06/2023-09/2023 Berlin workshop series „Critical Infrastructure in Crises: Local Perspectives on the Role of Energy in (Violent) Conflict" organized by the Energy Access and Development Program (EADP). We thank the organizers for discussion and suggestions; the usual disclaimer applies.

[10] This snapshot is a result from an interview with MicroEnergy International carried out on September 24, 2023, in Berlin, Germany. We thank Diego Garcia and Dr. Raluca Dumitrescu for their time, discussion, and suggestions; the usual disclaimer applies.

[11] This summary presents the results of an interview conducted with DENA on October 24, 2023, in Berlin, Germany. We would like to express our gratitude to Robert Westermann, Claire Gauthier, and Tim Sternkopf from DENA for their time, insightful discussion, and valuable suggestions. Please note that the usual disclaimer applies.

[12] These findings were derived from a field trip to Lolland, Denmark, conducted from October 16 to October 17, 2023. We extend our appreciation to Leo Christensen of Lolland Climate Center/REEL and Henry Hecker from RLI for sharing their time and insights. The standard disclaimer is applicable.