BARRIERS TO THE IMPLEMENTATION OF DISTRIBUTED PHOTOVOLTAIC GENERATION IN THE NORTHEAST OF ARGENTINA.

Luis H. Vera[1,2], Lorena Ledesma[1], Claudia Pilar[1], Manuel Cáceres[2], Andrés Firman[2] and Alexis Gonzales Mayans[2]

[1] Facultad de Ingeniería - Universidad Nacional del Nordeste, Resistencia (Argentina)

[2] Grupo en Energías Renovables (GER) - Universidad Nacional del Nordeste, Resistencia (Argentina)

Abstract

This paper explores why distributed generation from photovoltaic systems has not evolved significantly in Argentina, particularly in the northeastern region, despite its high solar potential, reduced costs, and available technological advances. Through interviews and surveys of residential users, public officials, and installers, this paper analyzes 70 houses in a neighborhood in the city of Resistencia in the Chaco province to determine the level of knowledge, perceptions, and causes that explain the low adoption of these technologies. The study reveals the complex interaction of social, cultural, economic, technical, and energy factors hindering the development of distributed generation. The study identifies weak articulation between institutional and private actors and a widespread perception that energy is the State's exclusive responsibility. Thus, the barriers to the development of distributed generation in northeastern Argentina have not changed since the Distributed Generation Law was enacted.

Keywords: Distributed Generation, Photovoltaic Energy, Sustainable Development.

1. Introduction

The transition to clean and renewable energy sources is a strategic priority at the global level. In this context, on-grid photovoltaic systems have become increasingly important in Latin America. This growth is driven by three main factors: sustained increases in electricity prices, reduced costs of photovoltaic technology, and public policies that promote self-consumption. This type of solution, known as distributed generation (DG), enables users to produce their own electricity, reduce their dependence on the grid, and promote a cleaner, more decentralized energy matrix.

However, since 2006, the Argentine government has prioritized the development of centralized renewable energy generation, especially through programs such as RenovAr and the MATER market (Barrera, Sabbatella and Serrani, 2022), which benefit large generators. These policies have focused on public tenders and long-term contracts, ignoring distributed generation, which has experienced slow development with little financial support.

In countries with high energy demand, such as Brazil, Mexico, and Argentina, the adoption of photovoltaic solar energy has progressed at different levels. Brazil and Mexico have positioned themselves with significant shares of distributed generation (DG) in their total photovoltaic (PV) installed capacity, 66% and 35%, respectively (CONUEE, 2025; ABSOLAR, 2025). According to the latest available data, Argentina accounts for just 3.4% of installed photovoltaic capacity in the form of distributed generation, amounting to 0.066 GW out of a total of 1.95 GW (CAMMESA, 2025). This difference exists despite the existence of a specific regulatory framework since December 2017: Law 27.424 on the Regime for the Promotion of Distributed Renewable Energy Generation Integrated to the Public Electricity Grid.

Silveira et al (2024) have carried out a comparative analysis of photovoltaic (PV) energy policies in Spain, Germany, and Brazil from 2000 to 2022. It aims to identify the factors influencing PV deployment and

10.18086/swc.2025.08.04 Available at http://proceedings.ises.org

efficiency to derive policy recommendations for enhancing solar capacity. The analysis reveals starkly contrasting outcomes driven by policy stability. Germany's success is attributed to its consistent and predictable Feed-in Tariff (FIT) policy, which featured gradual, pre-announced reductions. This stability fostered market confidence, leading to sustained growth and making Germany a global leader in PV adoption. In contrast, Spain experienced a dramatic boom-and-bust cycle due to abrupt and retroactive policy changes, which shattered investor confidence and caused a collapse of its domestic PV industry.

Brazil represents a more recent, successful case. Despite a late start, it achieved exponential growth in installed capacity by implementing a net-metering system (Normative Resolution 482/2012) and later establishing a robust legal framework (Law 14.300/2022). A critical element of this success was the initial adoption of a pure net metering scheme, where the energy injected into the grid is valued at the same retail price as the energy consumed. This mechanism creates a simple and financially attractive credit for the prosumer, significantly improving the return on investment and stimulating market adoption. A key to Brazil's success has been incorporating the principle of legal certainty, offering long transition periods for existing consumers to avoid the market shocks seen in Spain. Brazil has emerged as a case study for successfully integrating distributed generation, specifically photovoltaics, into national social policy. The Brazilian governmental program "Minha Casa, Minha Vida" (MCMV) played an important role in achieving this goal (Dantas et al., 2022).

In stark contrast to Brazil's integrated model, Argentina's journey with solar DG has been characterized by policy volatility and a lack of sustained, nationwide integration. Crucially, Argentina's regulatory framework (Law 27.424) adopted a net billing model from the outset. Under this scheme, the energy injected into the grid is valued at a much lower wholesale market price, while the energy consumed is purchased at the full retail rate, which includes distribution, taxes, and subsidies (Figure 1). This significant price differential drastically reduces the economic value of the energy surplus for the prosumer, extending the payback period and diminishing the financial appeal of the investment. This billing structure has been identified as one of the fundamental elements that limited the take-off of distributed generation in the country. A 2021 analysis of the Argentine DG market highlighted the challenges, noting that "the absence of stable economic rules and accessible credit lines has severely limited the diffusion of distributed photovoltaic generation, confining it largely to a high-income niche market" (Bermúdez and Cánova, 2021). The policy has been isolated from other national social and housing strategies, preventing the kind of synergistic effect seen in Brazil.

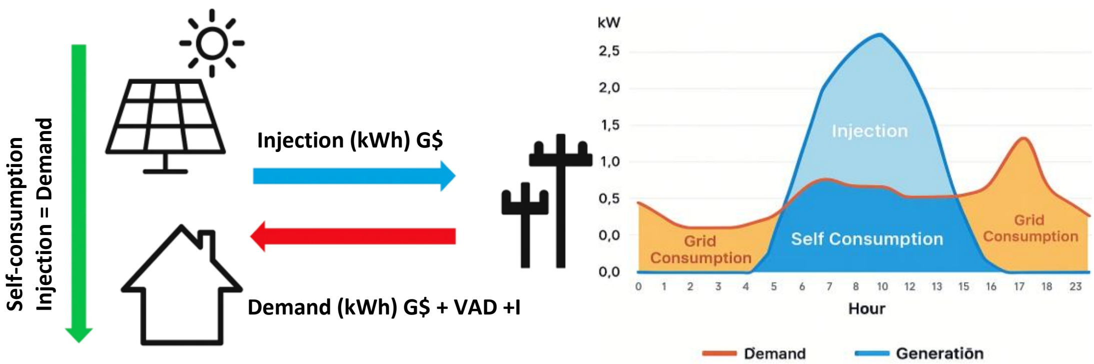

Figure 1: Net billing scheme, the economic value of the injected energy is lower than that of the energy purchased from the electricity distributor because it does not take into account the distribution value (VAD) and taxes (I).

In light of this situation, the present study aims to evaluate the reasons for the low level of adoption of distributed generation in Resistencia city, through fieldwork in the selected neighborhood (MUPUNNE). The objective is to survey the perceptions, barriers and motivations from the point of view of four key actors: residential and commercial users, installers of the sector, political referents and authorities, and academics linked to the energy area.

2. Methodology

This research employed a mixed-method approach, combining quantitative technical simulation with qualitative socio-institutional analysis to evaluate the feasibility of implementing photovoltaic (PV) systems in a social housing context.

2.1. Case Study Selection and Description

The study was conducted in the MUPUNNE neighborhood in Resistencia, Chaco, Argentina (lat.: 27.46056W long.: 58.98389S). This neighborhood was selected as a representative case of government housing programs with high potential for PV implementation.

The neighborhood was constructed in 1998 and occupies an area of approximately one hectare, distributed in two blocks containing a total of 70 duplex-style social housing units, each with a surface area of 82 m². A purposive sampling method was used to survey the 70 resident families, a technique appropriate for making valid inferences about the specific population under study.

Figure 2(a) provides an aerial view of Resistencia, highlighting the area occupied by the analyzed neighborhood. Figure 1(b) is a zoomed-in aerial view of the homes analyzed in this study. Note that the neighborhood is 45° off true north, which explains why the main roofs of the houses face northeast, northwest, southeast, and southwest.

a) **b)**

Figure 2: a) aerial view of Resistencia city, detailing the area occupied by the neighborhood under analysis. Figure 1 b) aerial view of a zoom-in on the homes that were analyzed in this study.

2.2. Simulation

The technical phase of the study was designed to quantitatively assess the solar energy potential of the MUPUNNE neighborhood's social housing units. The primary objectives were to evaluate the available roof area, determine the degree of achievable solar coverage based on actual consumption patterns, and model the performance of standardized photovoltaic systems under local conditions.

To establish a reliable baseline, a typical residential load profile was developed using historical electricity billing data provided by the provincial energy utility (SECHEEP). This data revealed an average monthly consumption of 573 kWh per residence. A detailed three-dimensional model of the characteristic duplex housing units was subsequently generated (Figure 3) to serve as the digital foundation for energy simulation using PV*SOL® Premium software, a specialized tool for planning and analyzing photovoltaic systems.

The simulation focused on a standard 2.04 kWp grid-connected photovoltaic system (GCPS) for a prototypical residence. A comprehensive performance analysis was conducted, calculating key indicators including total energy yield, the plant performance ratio (PR) as a measure of efficiency, energy losses due to inter-building shading, and the potential for CO_2 emissions avoidance. To account for the varied urban layout, this analysis was rigorously performed for the four principal roof orientations (Northeast, Northwest, Southeast, and Southwest), ensuring the resulting planning proposal was robust and reflective of the neighborhood's real-world constraints.

Beyond its core technical function, the simulation served a critical communicative role. The photorealistic renders and performance data it produced were instrumental in bridging the gap between abstract concepts and tangible outcomes during stakeholder engagement. This visual tool was essential for explaining not only the economic and technical benefits but also for addressing potential concerns regarding the aesthetic integration of PV panels into the existing architecture, thereby fostering informed participant feedback and social acceptance.

a) **b)**

Figure 3: a) Front picture of the neighborhood houses being studied, b) Top view of the 3D design created in PVSol and used to simulate the neighborhood's energy performance.

2.3. Socio-Institutional Analysis

This phase gathered qualitative and quantitative data from key stakeholders to understand the social and institutional landscape.

Residential Users (MUPUNNE): A structured survey was administered to all 70 households via digital and printed forms. The survey collected data on residents' general opinion of renewables, willingness to install PV, knowledge of Distributed Generation Law 27.424, and perceived barriers to adoption.

Semi-structured interviews were conducted with: Qualified PV Installers registered in Chaco, to understand market and bureaucratic obstacles. Public Officials from the Chaco Provincial Housing Institute (IPDUV) and the Sub-secretariat of Energy, to gauge institutional knowledge and policy alignment. An Existing GCPS User from a different neighborhood to document real-world experience with the technology and the utility provider.

2.4. Data Analysis

Survey data were processed using descriptive statistics, particularly frequency distributions, to characterize the socioeconomic profile of respondents and their level of knowledge regarding distributed photovoltaic generation.

In line with a methodological approach, structured and semi-structured interviews were carried out with key actors, including residents, certified installers, and representatives from the provincial housing institute and energy authorities.

Prior to each interview, participants were informed about the purpose, format, and ethical considerations of the study. They were explicitly told that the objective was to gather their perceptions based on personal experience or technical knowledge of photovoltaic systems and distributed generation.

For certain responses, particularly those related to perceptions, feasibility, and acceptance of distributed photovoltaic systems, participants were asked to rate their views using a numerical scale from 0 to 10. This system allowed the quantification of qualitative judgments, enhancing comparability across subjects. Each participant assigned a score according to their individual assessment, based on their knowledge, experience, or observed outcomes.

In the case of installers, data collection combined Google Forms questionnaires and a semi-directed interview format, which enabled the exploration of technical experiences, perceived economic barriers, installation frequency, customer motivations, and system profitability.

Responses were then grouped by thematic affinity, such as economic feasibility, regulatory knowledge, user awareness, and perceived growth of distributed generation, to identify dominant perceptions, challenges, and recurring barriers (Ledesma, 2024).

Additionally, interviews with end-users (prosumers) provided insights into real-life system operation, motivations for adoption (e.g., continuity of supply during blackouts rather than financial return), delays in administrative procedures, and interactions with the distribution company (SECHEEP).

These qualitative testimonies were subjected to thematic analysis to complement the statistical interpretation of survey results and to triangulate findings from multiple stakeholder perspectives.

3. Results

The research findings are presented across three key dimensions: technical feasibility, social acceptance, and stakeholder perspectives, revealing both the potential and the primary barriers to PV implementation in social housing.

3.1. Technical Feasibility: High Generation Potential with Orientation Dependence

The energy simulation conducted for a standard 2.04 kWp photovoltaic system unequivocally confirms the high technical potential for solar generation within the MUPUNNE social housing neighborhood. This potential is fundamentally underpinned by the local climate; the analysis utilized meteorological data for Resistencia (2001-2020) from Meteonorm 8.2, which reports a high annual solar irradiance of 1884.2 kWh/m². This abundant solar resource provides an excellent foundation for photovoltaic energy production.

The simulation results, detailed in Table 1, reveal a clear performance gradient directly correlated with roof orientation, a consequence of inter-building shading that varies throughout the day.

Tab. 1: Table with simulation results of a 2.04 kWp array for each orientation.

Simulation parameters	units	(SE)	(SW)	(NE)	(NW)
Annual yield	kWh/kWp	1.194,21	1.264,56	1.369,71	1.428,96
Plant performance ratio (PR)	%	71,4	74,1	77,1	78,4
Yield reduction due to shading	%/year	9,6	6,1	2,3	0,6
Avoided CO_2 emissions	kg/year	1.490	1.578	1.709	1.783
Solar coverage/consumption	%	36,5	38,6	41,8	43,7

As shown, the northwest (NW) and northeast (NE) orientations delivered the best performance, with annual yields of 1,428.96 and 1,369.71 kWh/kWp, respectively, and solar coverage of consumption reaching up to 43.7%. The 2.04 kWp system size comprising four Trina Solar Vertex TSM-510-DE18M.08(II) modules, mounted parallel to the roof at an 11° inclination This system is managed by a single Huawei SUN2000-2KTL-1 three-phase inverter, with a conservative DC-to-AC dimensioning ratio of 102%was. This system was identified as a technically and economically efficient solution for this grid-connected urban context. In other words, considering the neighborhood's average energy consumption, using four 510 Wp solar panels and a 2.04 kW inverter can meet over 35% of a home's energy demand regardless of its orientation. This requires a total roof coverage area of 9,6 m² and occupies 50% of the usable roof area.

An aspect of the technical design involves the integration with the existing low-voltage grid. Each dwelling is equipped with a single-phase inverter, connected to the distribution network in a carefully planned manner. The objective of this configuration is to distribute the energy consumed and injected by the set of photovoltaic systems evenly across the three phases of the grid. This strategic connection is essential to maintain the equilibrium of the electrical system, preventing voltage imbalances and power quality issues that could arise from a concentrated and uncoordinated injection of energy on a single phase.

Therefore, solar power generation systems with conservative technical and dimensional values adequately respond to this study's proposal. These results conclusively demonstrate that solar energy itself is not an obstacle to implementation

3.2. Social Acceptance: A Receptive Public Hampered by an Information Gap

The survey data from the 70 households reveals a marked dichotomy between high social acceptance and a critical deficit in specific knowledge. While an overwhelming majority of residents (91.4%) expressed a

"Favorable" or "Very Favorable" opinion of renewable energy, and 80% indicated a willingness to structurally modify their homes to accommodate a photovoltaic (PV) system, this positive disposition is juxtaposed with a profound lack of awareness regarding the enabling regulatory framework. Specifically, 91.4% of respondents were unaware of the existence of National Distributed Generation Law 27.424, the key legislation that facilitates the integration of decentralized generation into the grid. When probed on the primary factors for implementation, residents identified financial and informational hurdles as the most significant barriers, with the high cost of equipment (51.4%) and a lack of information or training (34.3%) being the predominant concerns, as detailed in Table 2. This combination of high willingness, low awareness, and perceived financial-informational barriers highlights a crucial non-technical challenge for the widespread adoption of PV systems in this context.

Table 2. Main Barriers and Motivations Identified by Residents (N=70)

Factor Category	Specific Factor	Resident Priority
Primary Barrier	High Cost of Equipment	51.4%
Primary Barrier	Lack of Information / Training	34.3%
High-Value Solution	Access to Financing	High
Low-Value Factor	Knowledge of DG Law	Low

3.3. Stakeholder Perspectives: Alignment on Barriers, Institutional Resistance

Interviews with key actors revealed a consensus on challenges, with the most profound barrier emerging at the institutional level.

The perceptions of the principal stakeholders regarding distributed photovoltaic (PV) generation, captured through structured surveys, are visualized in the radial diagrams of Figure 4. These diagrams provide a comparative analysis of the critical factors influencing adoption, from public awareness to institutional readiness.

Figure 4 a) illustrates the knowledge and understanding of distributed photovoltaic generation systems among MUPUNNE neighborhood residents. Figure 4b illustrates the perspective of an existing user who has installed a photovoltaic system. This user has experience with a hybrid photovoltaic system, which was chosen due to the low quality of the power supply and frequent power outages. A system with battery storage was the most suitable solution for this issue.

A comparative analysis of these two figures reveals a critical divergence in perception. The residents of the studied neighborhood demonstrate greater awareness of perceived economic barriers, such as high investment costs, long payback periods, and the absence of effective incentive policies. In contrast, the existing prosumer's perspective is rooted in the tangible operational benefits of energy self-sufficiency and resilience. This contrast highlights a fundamental gap between potential adopters' abstract understanding of economic constraints and those who have already overcome them through practical, value-driven justifications.

Figures 4 c) and d) reveal the perspectives of the other critical stakeholders: the installation companies and government entities responsible for promotion, regulation, and policy implementation.

Figure 4c), representing installation companies, highlights a sector constrained by a stagnant market. While installers exhibit high confidence in their technical capabilities, their outlook is dampened by a perception of weak public demand and insufficient governmental planning and incentives. Their primary identified barriers include a lack of effective financing mechanisms for end-users and a resulting uncertainty about the future growth prospects of distributed generation (DG).

Figure 4d), illustrating the viewpoint of government entities, uncovers a significant institutional barrier. While these bodies demonstrate adequate theoretical knowledge of the technology, this does not translate into actionable policies or a proactive promotion strategy for residential DG. The most critical challenges identified from this perspective are a lack of specific training programs, limited technical knowledge applied to practical policy design, and an overarching institutional inertia that fails to create a supportive ecosystem.

Together, these figures offer an integrated perspective on the systemic friction hindering DG expansion. They reveal a disconnect between a technically ready private sector and a passive public sector, creating a policy vacuum. This institutional shortfall, in turn, fails to address the financial and informational barriers faced by citizens, ultimately stifling the social acceptance and economic viability required for widespread adoption. The future expansion of distributed photovoltaic generation is thus shaped not by a single failure, but by this misalignment between social willingness, market readiness, and institutional vision.

In brief, qualified Installers identified public "ignorance" as a major obstacle, confirming the survey findings, the prosumer provided real-world validation and reported significant difficulties with the utility energy company (SECHEEP), including prolonged delays in obtaining a bidirectional meter and correct billing, the public officials revealed limited technical knowledge of PV systems within housing and energy agencies. A statement from a Sub-secretariat of Energy official crystallized the core institutional resistance: “in the case in which all users could generate their own energy, the distributors and cooperatives would not be able to collect.” This perspective frames

These figures reveal a fragmented and high-friction environment for distributed PV growth. A willing but uninformed public (as shown in the previous MUPUNNE survey) encounters a supply chain of installers frustrated by market conditions, while the existing user base validates the technology's benefits but faces bureaucratic inertia. The most profound challenge is institutional: a paradigm that views distributed generation as a fiscal threat or a niche interest, rather than an integral component of energy and housing policy. This misalignment between social willingness, market readiness, and institutional vision constitutes the primary impediment to adoption.

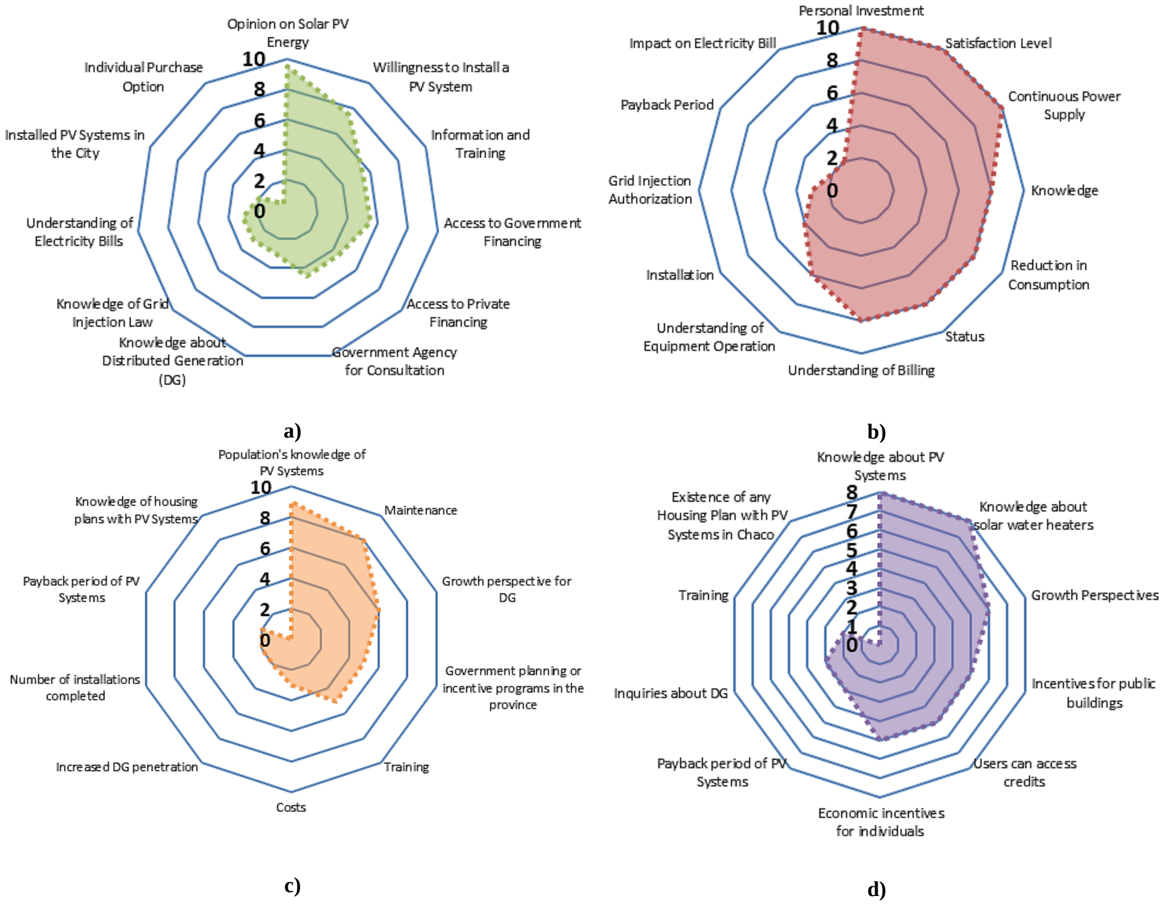

Figure 4: Perceptions of the principal stakeholders regarding distributed photovoltaic (PV) generation a) neighborhood residents, b) prosumer, d) installation companies and d) government.

4. Discussion

This study confirms the central hypothesis that the primary barriers to distributed generation (DG) adoption in Northeast Argentina are indeed financial. However, the findings significantly expand this understanding, revealing a tripartite impediment structure where financial constraints are compounded and reinforced by deeply entrenched institutional and socio-cultural barriers.

The results decisively demonstrate that the core problem is not technical feasibility. As detailed in Section 3.1, energy simulations confirm that high solar coverage (reaching up to 43.7% of household consumption) is technically achievable with modest 2.04 kWp systems, even considering suboptimal roof orientations and inter-building shading. The true obstacle lies in a "complex interaction of social, cultural, economic, technical, and energy factors" that stifles market development.

A critical disconnect was identified at the social level: while resident willingness to adopt is remarkably high (80% expressed readiness to modify their homes), this potential is blocked by a profound information vacuum (91.4% unaware of Law 27.424) and the prohibitive upfront cost of equipment. This gap between intent and action underscores a failure of public information and energy literacy campaigns, which are essential for transforming willingness into viable projects.

The most formidable barrier, however, is institutional. The perspective from public officials reveals a fundamental conflict of interest and a paradigm misaligned with national policy. While Law 27.424 promotes a decentralized energy model, the provincial energy utility and its regulators perceive DG as a direct threat to their traditional revenue stream, based on volumetric energy sales. This institutional resistance materializes as practical obstacles for early adopters, exemplified by the protracted delays in installing bidirectional meters and resolving billing issues, as reported by the existing user. This "weak articulation between institutional and private actors" creates a high-friction, high-uncertainty environment that actively discourages installers from scaling their operations and deters potential prosumers.

Furthermore, this institutional inertia perpetuates a significant cultural barrier: the "widespread perception that energy is the State's exclusive responsibility". This paternalistic mindset is subtly reinforced by the very institutions that, as the interviews show, remain unconvinced of the strategic advantages of a distributed energy model. Consequently, the enactment of Law 27.424 has proven insufficient to dismantle the foundational barriers that existed prior to its implementation. The law provided a regulatory framework but failed to catalyze the necessary institutional and cultural shift, resulting in a policy-practice gap that continues to hinder Argentina's DG potential.

5. Conclusion

This study investigated the factors limiting the expansion of residential grid-connected photovoltaic systems in Resistencia, Argentina. The analysis confirms that despite a favorable national legal framework and excellent solar resources, implementation is scarce.

The main conclusion is that the barriers are not technical, but are a combination of financial, social, and, most critically, institutional factors. The hypothesis that implementation is hindered by financial factors has been verified.

The primary barriers identified are:

1. Institutional Resistance: A prevailing view within public energy bodies that DG is a financial threat to the utility's collection model.

2. Weak Articulation: A lack of coordination between public actors (government, utility) and private actors (installers, users), leading to bureaucratic delays and a lack of clear procedures.

3. Social Knowledge Gap: A profound lack of public information and awareness of the technology and its legal framework, which coexists with a high positive perception of renewables.

4. Financial Unviability: High upfront equipment costs, coupled with subsidized electricity tariffs, result in excessively long payback periods, deterring residential investment.

Overcoming these barriers requires more than a legal framework. It demands integrated energy planning that prioritizes distributed development, proactive public information campaigns, the creation of accessible financing lines, and, most importantly, a cultural and political shift within provincial institutions to align their objectives with the goals of distributed generation.

6. Acknowledgments

We would like to thank the Faculty of Engineering and the Secretary of Science and Technology at the National University of the Northeast for their support.

7. References

ABSOLAR -Associação Brasileira de Energia Solar Fotovoltaica (2025). Dados e números do setor fotovoltaico. https://www.absolar.org.br/

Barrera, M. A., Sabbatella, I., & Serrani, E. (2022). Macroeconomic barriers to energy transition in peripheral countries: The case of Argentina. Energy Policy, 168, 113117.

Bermúdez, J. M., and Cánova, L. P. (2021). Barriers to the development of distributed generation in Argentina: A regulatory and economic analysis. Energy Policy, 159, 112602.

CAMMESA- Compañía Administradora del Mercado Mayorista Eléctrico Sociedad Anónima (2025). Informe mensual de operaciones del MEM - Marzo 2025. https://portalweb.cammesa.com

CONUEE-Comisión Nacional para el Uso Eficiente de la Energía (2025). Energía solar en México. Gobierno de México. https://www.gob.mx/conuee

Dantas, G. M., Jannuzzi, G. de M., and Tolmasquim, M. T. (2022). Photovoltaic systems for multi-unit buildings: Agents' rationales for supporting distributed generation diffusion in Brazil. Energy Policy, 160, 112681.

Ledesma, L. T. (2024). Gestión para Implementar en Viviendas Energía Renovable integrada a la Red Eléctrica en la ciudad de Resistencia Chaco. Tesis de Maestria. Universidad Nacional del Nordeste. Chaco, Argentina.

Silveira, B., dos Santos, M. E. M., Ferreira, F. J., Basso, A. P., Singh, J. N., & de Medeiros Costa, H. K. (2024). Incentives for photovoltaic energy generation: A comparative analysis of policies in Spain, Germany, and Brazil. Energy Strategy Reviews, 54, 101415.