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FROM SELF-GENERATION TO PHOTOVOLTAIC PROSUMPTION IN SENEGAL REGULATORY DEVELOPMENTS EXPORT POTENTIAL INDICATORS AND A NATIONAL ASSESSMENT FRAMEWORK

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ABSTRACT

In Senegal, photovoltaic self-generation takes the form of both autonomous installations and systems operated in parallel with the public grid. Recent regulatory reforms have introduced conditional rights to sell surplus electricity, thereby institutionalizing the possibility of PV prosumption. This article analyzes that shift by juxtaposing an exploratory 2015 survey of 50 self-generators with the evolving legal framework comprising the 2021 Electricity Code, Decree No. 2023-286, and its 2025 amendment. Among surveyed households, 97% had adopted solar technologies and 67.7% coupled them with grid supply; no household held an export contract. In the business segment, 88.8% of installations were operational, yet no surplus-sale agreements with Senelec were identified. At the national level, official statistics refer to a broader constituency: the 2025 Energy Information System report attributes 17.05% of recorded 2024 electricity production to self-generators and 4.18% of national output to decentralized solar, although neither statistic isolates grid-connected PV prosumption. The paper formalizes the notions of self-consumption, self-sufficiency, export ratio, and surplus value, and advances a protocol for nationwide monitoring. A simulation based on synthetic load and generation profiles shows that these indicators must be interpreted jointly. Increasing PV output relative to demand raises self-sufficiency while simultaneously directing a larger fraction of generation to the grid. Consequently, sizing choices are contingent on the temporal structure of consumption, the local network's export hosting capacity, and the feasibility of demand shifting and energy storage.

KEYWORDS: Self-generation; prosumption; photovoltaic; self-consumption; surplus electricity; grid connection; exports; storage; Senegal.

Nomenclature and abbreviations

Abbreviations and units

Abbreviation or unit	Definition
LV / MV	Low voltage / medium voltage
CERER	Centre d'Études et de Recherches sur les Énergies Renouvelables (Renewable Energy Studies and Research Centre)
COPERES	Conseil Patronal des Énergies Renouvelables du Sénégal (Senegal Renewable Energy Employers' Council)
ER	Export ratio
FCFA	CFA franc (West African currency)
KPI	Key performance indicator
PCC	Point of common coupling
PV	Photovoltaic

SCR	Self-consumption ratio
SIE	Système d'Information Énergétique (Energy Information System)
SOC	State of charge of the battery
Abbreviation or unit	Definition
SSR	Self-sufficiency ratio
THD	Total harmonic distortion
kW / MW	Kilowatt / megawatt, units of power
kWp / MWp	Kilowatt-peak / megawatt-peak, units of rated PV capacity
kWh / MWh / GWh	Kilowatt-hour / megawatt-hour / gigawatt-hour, units of energy

Symbols and indicators

Symbol	Definition	Unit
ΔT	Period over which the energy balance is established	h or day
E_PV	PV energy generated over the period	kWh
E_load	Energy consumed by loads over the period	kWh
E_PV→load	PV energy supplied directly to loads	kWh
E_PV→bat	PV energy allocated to battery charging	kWh
E_bat→load	Energy discharged by the battery to loads	kWh
E_import	Energy imported from the grid	kWh
E_export	Energy exported to the grid	kWh
E_curtail	PV energy curtailed or unused	kWh
E_PV,self	PV-origin energy consumed on site, directly or after storage; attribution adjusted for losses	kWh
r = E_PV/E_load	Ratio of PV generation to consumption	dimensionless
SCR	E_PV,self/E_PV: share of PV generation consumed on site	fraction or %
SSR	E_PV,self/E_load: share of consumption supplied by PV	fraction or %
ER	E_export/E_PV: share of PV generation exported	fraction or %
E_export,t	Energy exported during interval t	kWh
T_buy,t	Surplus purchase tariff applicable during interval t	FCFA/kWh
V_surplus	Gross surplus-sale revenue over the period	FCFA
Vmin / Vmax	Minimum / maximum voltage at the coupling point	V
t / Σ_t	Interval index / sum over intervals in the period	—

All energy metrics are computed over an identical temporal window and expressed in consistent units. SCR, SSR, and ER are pure numbers; they may be multiplied by 100 only when presented as percentages. In the absence of storage, EPV, self is identical to EPV→load. When storage is present, only the share of PV-derived energy that is actually discharged to the loads, net of storage losses, is counted. SOC may be reported either as a fraction or as a percentage. The tariff T_buy, t refers to the price signal at time t and must not be conflated with the sampling interval ΔT.

1. INTRODUCTION

For residential and commercial users, adopting PV fundamentally reshapes electricity sourcing and use. Daytime generation can directly satisfy concurrent demand, and some end-uses can be rescheduled toward hours of higher solar output. Adding a battery further broadens these options by shifting energy across time. Monetizing residual surpluses requires an adequate grid interconnection together with appropriate metering and contractual arrangements. Consequently, system sizing decisions are intertwined with equipment performance and with the network's export hosting capacity.[12,15,18,20,27]

The exploratory survey conducted in 2015 provides an early snapshot of such practices in Senegal. The households and firms sampled already operated on-site generation, yet none held surplus-sale agreements with the utility. Since then, the legal framework has evolved, and national statistics now register a non-negligible contribution from self-generation and decentralized solar. Interpreting this transition demands careful attention to the scope of official statistics, as well as empirical measurements of exchanges with the grid.[5,6]

1.1. Research question and contributions

This work examines how Senegal can foster PV prosumption that can be consistently measured and evaluated at the distribution-network scale. It distinguishes the technical capacity to generate from realized output and from the portion contractually exported. Its primary contributions are:

- A critical reanalysis of the 2015 survey that separates sample-specific findings from national indicators;
- An examination of the Electricity Code and the regulatory framework governing self-generation;
- The formulation of harmonized energy indicators applicable to households, enterprises, and aggregated portfolios;
- An initial simulation exploring the trade-off among

self-consumption, self-sufficiency, and exports;
- A proposal for a national architecture to collect data, qualify installations, and monitor prosumption.

2. Data and methods

2.1. Documentary sources

The study synthesizes evidence from the 2015 exploratory survey, the 2021 Electricity Code, and implementing regulations for self-generation. SIE 2025 provides national statistics, including data for 2024. Country energy-transition strategies and residential solar program documents supply the deployment context, while international literature informs assessments of sizing, storage, and distributed generation.[1,6,8,28]

2.2. Interpretation of the evidence

Each source illuminates a distinct level of analysis. The 2015 survey characterizes installations within its sample, whereas SIE compiles national aggregates. Newly executed simulations investigate how energy indicators behave under synthetic demand and generation profiles. These results serve as methodological demonstrations and should not be interpreted as estimates of the current Senegalese PV fleet.[5,6]

3. Empirical basis from the exploratory 2015 survey

Indicator	Reported result	Interpretation
Sample size	50 self-generators	Exploratory survey
Households	64% of the sample	Largest segment
Household solar use	97%	Predominant technology in the sample
Household hybrid grid/PV operation	67.7%	Frequent complementarity with Senelec
Household export contracts	0%	None in the 2015 sample
Average household PV capacity	≈ 2.027 kWp	Observed order of magnitude
At least annual household maintenance	83%	Reported practice
Household 24-hour availability	74.2%	Reported availability
Operational business systems	88.8%	Reported availability
Businesses > 1 kW	72%	Variation in system sizes
Business sale contracts	0%	No contracts recorded

Across the sample, households indicated a mean willingness-to-pay of FCFA 87.37 per kWh for purchased electricity. This value derives from a 2015 stated-preference elicitation and should not be construed as a regulated tariff or as an appraisal of current surplus value. The report additionally documents a pilot export metering arrangement at CERER implemented for research and training purposes.[5]

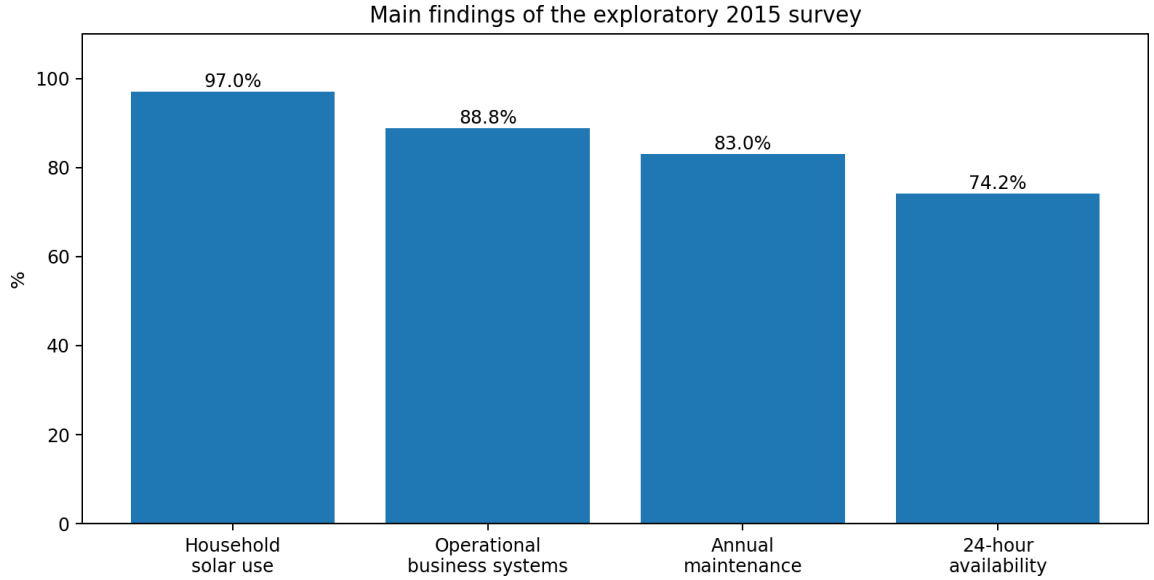

Figure 1: Main findings of the exploratory 2015 survey. Source: author's elaboration from the 2015 survey report.[5]

4. Recent energy context and changes in scale

According to SIE 2025, self-generation accounted for 17.05% of documented electricity output in 2024. This segment comprises private enterprises that satisfy their own demand with on-site solar plants, thermal facilities, or other generators, and in some cases sell surplus electricity to Senelec. The contribution of decentralized solar to national generation rose from 3.06% in 2022 to 4.18% in 2024. In 2024, installed off-grid PV capacity reached 288.66 MW, yielding 366.65 GWh. While these results quantify the role of decentralized production, they do not disaggregate the portion attributable to grid-connected PV prosumers.[6]

National indicator	Value	Year	Relevance to prosumption
Self-generators' share of total generation	17.05%	2024	Significant contribution from self-generation
Decentralized solarin national generation	4.18%	2024	Measurable distributed PV contribution
Decentralized solar	3.06%	2022	Historical comparison
Installed off-grid PV	288.66 MW	2024	Large fleet; does not represent grid exports
Off-grid PV generation	366.65 GWh	2024	Documented decentralized generation
Grid-connected solar	267.01 MW	2024	General solar context
System peak	1,159 MW	2024	Reference for system scale

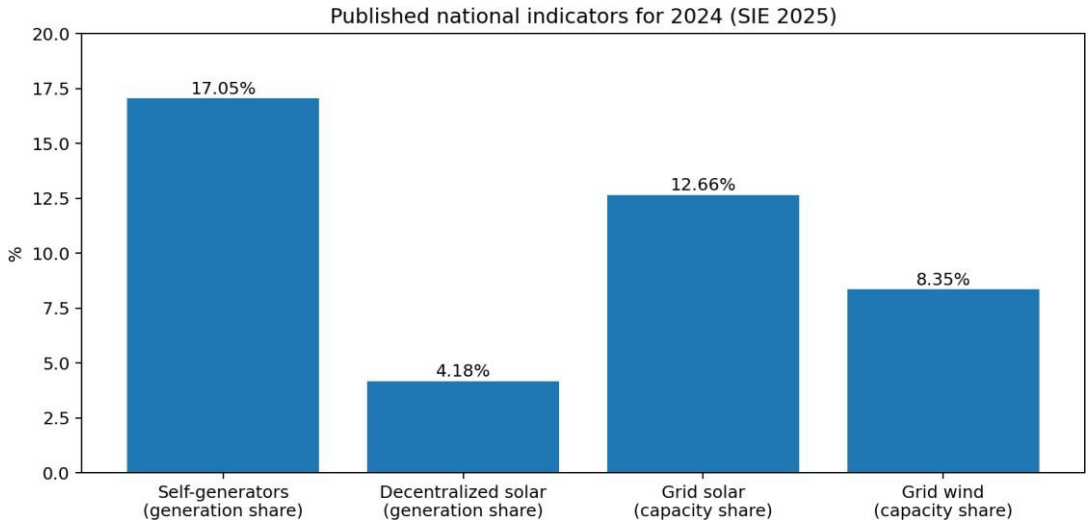

Figure 2: Published national indicators for 2024.

5. Evolution of the regulatory framework for prosumption

The 2021 Electricity Code authorizes, within the concessionaire's service territory and subject to the relevant rules, the sale of renewable energy surpluses arising from self-consumption or self-generation. Decree No. 2023-286 details the applicable declaratory or licensing regimes, the modalities for sale and export, the obligation to install dedicated meters for surplus measurement, and the technical conditions for connection. It also introduces ceilings on system sizing and on the quantities eligible for surplus transactions. Since Decree No. 2025-1757 has amended the 2023 text, operational implementation must be aligned with the consolidated version currently in force.[1,4]

Relative to the 2015 baseline, the salient change concerns the contractual governance of surplus electricity. Although hybrid configurations were already identified in the survey, there were no instruments providing for the sale of excess output. Recent regulations now supply a legal basis for the counterparty relationship with the concessionaire. To translate this framework into practice, the parties must quantify the surplus, verify its exportability, and agree on remuneration and settlement arrangements.[1,5]

6. Prosumer energy balance

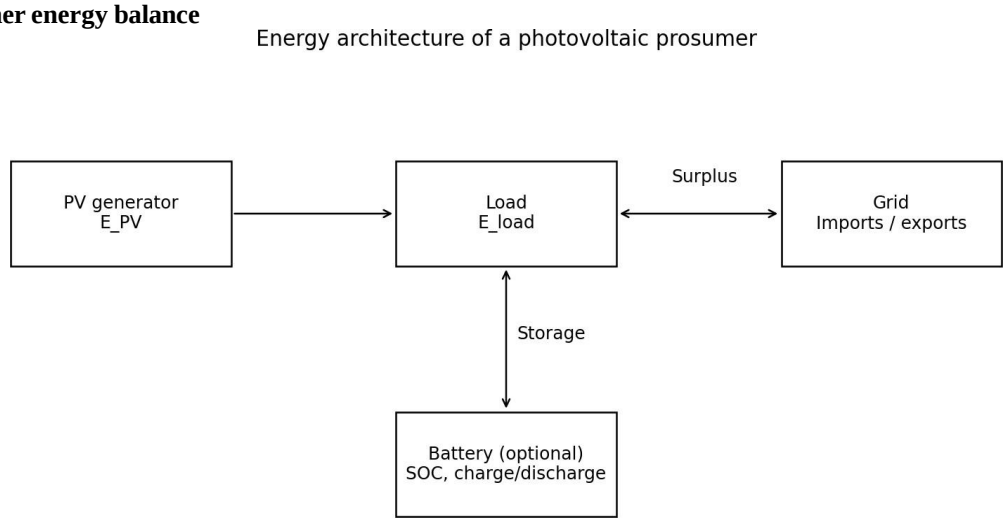

Figure 3: Simplified energy architecture of a photovoltaic prosumer. Source: author's elaboration.

Over a period ΔT, the energy balance can be written as follows:

$E_{PV} = E_{PV \to load} + E_{PV \to bat} + E_{export} + E_{curtail}$ (1)

$E_{load} = E_{PV \to load} + E_{bat \to load} + E_{import}$ (2)

For systems with a battery, the measurements must identify where the charging energy came from and account for conversion losses. Otherwise, electricity imported from the grid could be counted as PV generation, or the same solar energy could be recorded twice.[12,13,19]

6.1. Harmonized indicators

$SCR = E_{PV,self} / E_{PV}$ (3)

$SSR = E_{PV,self} / E_{load}$ (4)

$ER = E_{export} / E_{PV}$ (5)

$V_{surplus} = \Sigma_t E_{export,t} \times T_{buy,t}$ (6)

Indicator	Meaning	A high value indicates	Interpretation limit
SCR	Self-consumption ratio	High local use of PV	Can be high with very small PV
SSR	Self-sufficiency ratio	Low energy dependence on the grid	Does not measure peak power
ER	Export ratio	Large relative surplus	Depends on sizing and load
V_surplus	Surplus value	Gross export revenue	Depends on tariff and contract rules

7. Sizing and grid connection constraints

Using annual energy yield as the sole criterion for photovoltaic sizing is inadequate. When on-site demand during daylight hours is limited, additional PV capacity chiefly increases surplus generation. If exports are capped, this excess is curtailed; if exports are permitted, higher reverse power flows can exacerbate voltage management issues and make returns more sensitive to the purchase tariff for exported energy. A rigorous sizing analysis should therefore integrate time-resolved consumption profiles, export constraints, and the technical and operational potential for demand shifting or energy storage.[12,17,20,23,26]

Dimension	Minimum measurement	Risk addressed	Associated decision
Energy	PV, load, imports, exports	Inconsistent balance	Sizing / settlement
Power	Import and export peaks	Local overload	Export limit
Voltage	Vmin/Vmax at PCC	Overvoltage / undervoltage	Connection
Quality	THD, events, flicker	Quality deterioration	Inverter qualification
Protection	Anti-islanding / disconnection	Grid safety	Operating authorization
Battery	SOC, energy, cycles	Double counting / ageing	Control strategy

8. Illustrative simulation of the PV-to-load ratio

For illustration, we analyze synthetic PV and load time series at 15-minute resolution without a battery. The daily energy requirement is fixed at 20 kWh, with a dominant evening peak. PV output is modeled using a normalized diurnal profile. By varying r = EPV/Eload between 0.25 and 1.50, we examine how plant scale influences the selected indicators. These profiles are strictly methodological constructs and do not reflect measured consumption or generation in Senegal.

r = E_PV/E_load	PV (kWh/day)	Self-consumed (kWh/day)	Export (kWh/day)	Import (kWh/day)	SCR	SSR	ER
0.25	5.0	5.0	0.0	15.0	100.0%	25.0%	0.0%
0.50	10.0	6.7	3.3	13.3	67.2%	33.6%	32.8%
0.75	15.0	7.2	7.8	12.8	48.3%	36.2%	51.7%
1.00	20.0	7.5	12.5	12.5	37.7%	37.7%	62.3%
1.25	25.0	7.7	17.3	12.3	30.9%	38.7%	69.1%
1.50	30.0	7.9	22.1	12.1	26.3%	39.4%	73.7%

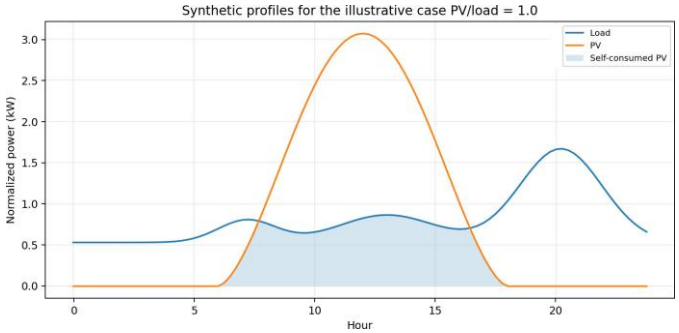

Figure 4: Synthetic load and PV generation profiles for r = 1.0. These profiles are used solely to illustrate the method.

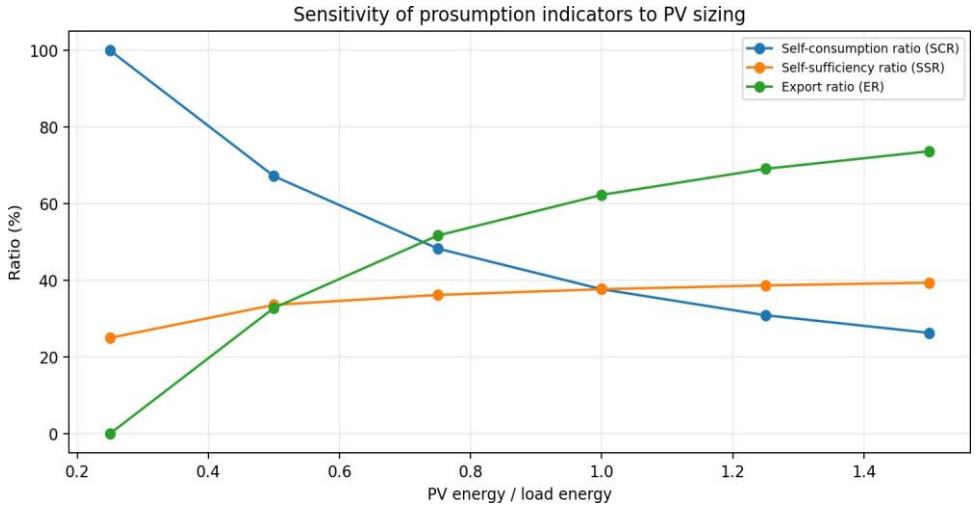

Figure 5: Illustrative sensitivity of self-consumption, self-sufficiency and export ratios to PV sizing. Source: author's calculations using synthetic profiles.

8.1. Interpretation of the results

For r = 0.25, the system generates 5 kWh, all of which is consumed on site. SCR is therefore 100%, even though PV meets only 25% of the daily energy requirement. At r = 1.00, total daily production equals total daily consumption in magnitude while remaining temporally misaligned; SCR and SSR are each 37.7%, and 62.3% of PV output is exported. Increasing r to 1.50 raises self-sufficiency to 39.4% and the export share to 73.7%. Given an evening-peaking demand profile, most of the added PV capacity produces surplus rather than displacing imports. Whether such capacity is economically justified depends on installation costs, purchase and retail tariffs, export constraints, and the cost of a battery.[12,17,27]

Incorporating storage can shift part of the midday output into the evening, thereby increasing both self-consumption and self-sufficiency. These gains come with conversion losses, investment costs and battery ageing. PV and storage capacities should therefore be evaluated jointly, since an improved energy ratio does not necessarily yield a superior financial outcome.[12,14,19]

9. Assessment scenarios for Senegal

Scenario	Configuration	Main question	Outputs to measure
P0	Without PV	Reference	Load, peak, bill
P1	PV without exports	Self-consumption only	SCR, curtailment, import peak
P2	PV with exports	Simple prosumption	SCR, SSR, ER, export peak
P3	PV + battery without exports	Local flexibility	SOC, cycles, peak reduction
P4	PV + battery with exports	Joint optimization	SCR, SSR, ER, net value
P5	Aggregated portfolio	Grid effect	Diversity, aggregate peak, voltage

Testing these cases requires measured profiles at hourly or subhourly resolution. The analysis can then vary PV capacity, purchase and retail tariffs, storage costs and export limits. A site-specific appraisal of feeder hosting capacity is also essential, because an identical installation may interact differently with different distribution networks.[12,17,19,20]

10. Market potential and interpretation safeguards

The Crédit Énergie project documentation anticipates equipping approximately 285,000 households in urban and peri-urban areas by 2030. The indicative aggregate capacity is around 570 MWp, corresponding to an estimated market size of FCFA 712 billion when valued at FCFA 2.5 million per system. These values are prospective and reflect a plausible deployment scenario rather than installations already delivered. If implementation proceeds at this scale, distribution system planning will need to incorporate provisions for metering, equipment quality assurance, and suitable financing structures.[9]

A nameplate capacity of 570 MWp does not translate into 570 MW of coincident exports. The power actually observed by the grid will depend on module tilt and azimuth, the diurnal generation profile relative to demand, on-site consumption, inverter limits and potential clipping, as well as the configuration and dispatch of storage. Counting systems and summing rated capacity is therefore necessary but insufficient; the power and energy exchanged with the network must also be measured and evaluated.[20,23,26]

11. Proposed national monitoring protocol

National KPI	Unit	Frequency	Purpose
Declared/licensed PV capacity	MWp	Quarterly/annual	Planning
Installations by class	Number	Quarterly	Fleet segmentation
PV energy generated	GWh/year	Monthly	Energy balance
Self-consumed energy	GWh/year	Monthly	Net demand
Exported energy	GWh/year	Monthly	Grid flows / settlement
Aggregate export peak	MW	15 min or less	Hosting capacity
National KPI	**Unit**	**Frequency**	**Purpose**
Share with storage	% / MW / MWh	Annual	Flexibility
Connection compliance	%	Annual	Safety / quality
Voltage / quality incidents	Number	Monthly	Grid impact

The proposed database would assign a pseudonymous identifier to each installation and capture its capacity class, voltage level, inverter technology, and connection status. It would also note the presence of any battery, store the commissioning date, and archive import and export time series. Publishing only aggregated outputs would inform planning while protecting individual users' privacy.[22,26,28]

12. DISCUSSION

The main divergence between the 2015 survey and the current framework is institutional. Participants in 2015 were already generating electricity, often alongside Senelec supply, but lacked contracts to sell surpluses. The new regulations now define mechanisms for metering and contracting those exports. Reliable exchanges will depend on certified equipment, appropriate protection schemes, and records that enable both parties' obligations to be verified.[1,5,27]

The statistics remain coarse. The 17.05% share attributed to self-generators blends multiple technologies and business models; it is not a proxy for residential PV or for grid exports. Likewise, the reported 288.66 MW of off-grid PV does not indicate exportable capacity. Planning would be strengthened by distinct records for thermal self-generation, off-grid PV, grid-tied PV without export, and PV with export, with storage explicitly identified where relevant.[6]

The simulation highlights why temporal patterns of demand are pivotal. For evening-peaking loads, additional PV primarily increases daytime surpluses. Load shifting, storage, and calibrated export limits can alleviate the mismatch. Aggregation can also be effective where adequate measurement and control are in place. The synthetic case cannot quantify their contribution to Senegal's power system; each option must be assessed against measured profiles.[12,15,19,20]

12.1. Operational recommendations

- Create a unified national registry of self-generators and prosumers that interoperates with concessionaire and regulator datasets;
- In official statistics, separate installed capacity, gross generation, on-site consumption, exports, and curtailed energy;
- Harmonize requirements for bidirectional metering and minimum inverter performance[23,25,26];
- Publish clear connection rules, anti-islanding provisions, and export limits by capacity class[23,25];
- Run a monitoring pilot on several distribution feeders with contrasting load profiles;
- Integrate storage into the measurement protocol by recording state of charge, charged and discharged energy, and cycle counts[13,19];
- Periodically revise limits and operating parameters using measured network data rather than fixed assumptions.

12.2. Limitations

The 2015 survey covered only 50 self-generators and cannot represent national conditions in 2026. SIE categories do not map cleanly onto grid-connected PV prosumption. This work also lacks a consolidated public national database of authorized installations, bidirectional metering time series, or LV/MV feeder voltage profiles. The simulations are therefore illustrative. Validation requires measurements of consumption, generation, voltage, and exports from operating systems.[5,6]

13. CONCLUSION

Senegal's recent regulations establish a basis for interconnecting self-generators and contracting surplus sales. National statistics indicate that self-generation and decentralized solar already contribute to electricity supply, yet PV prosumption is not isolated. The next assessment should identify the relevant installations and quantify what they generate, consume on site, and exchange with the grid. Voltage records and peak-power measurements would then show how those exchanges interact with local distribution constraints.[1,6]

SCR, SSR, ER, and surplus value provide a common indicator set for that task, complementing measurements of power, voltage, power quality, and storage. The synthetic example makes one point clear: aligning annual or daily energy totals does not ensure autonomy when temporal profiles are mismatched. Imports and surplus exports can coexist. Instrumented pilots on several distribution feeders would allow these effects to be tested

empirically. Together with harmonized interconnection procedures and a national observatory, they would supply the evidence base for subsequent deployment decisions.[12,15,19,20,23,27]

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