Achieving Economic Viability of Solar Minigrids: Evidence from Productive Uses, Subsidies, and Tariff Optimization

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Abstract:
More than 730 million people worldwide lack access to electricity, preventing them from benefiting from basic services such as clean water supply, healthcare, refrigeration, and telecommunications. Solar minigrids represent a promising solution to address this issue, particularly in rural and remote areas. However, their economic viability remains a major concern.
This paper analyzes several deployment scenarios based on experimental data collected in Benin (West Africa) from 2023 to 2025. The impacts of capital subsidies, electricity tariffs, and the development of productive uses of electricity on the economic viability of solar minigrids are assessed. The analysis focuses on two villages of different sizes (approximately 3,000 and 15,000 inhabitants).
The results indicate that a payback period of less than five years can be achieved under conditions combining an optimized electricity tariff (around 0.35 €/kWh), appropriate minigrid sizing, and sufficient support to stimulate productive uses of electricity. These findings highlight the critical role of demand stimulation and tariff design in improving the financial sustainability of solar minigrids.

Keywords:
Solar minigrids, photovoltaic panel, economic assessment, productive uses of electricity, sensitivity analysis

1. Introduction

1.1. Context

Access to reliable electricity is a critical challenge in Sub-Saharan Africa. In rural and remote areas, centralized grid extension is often economically unfeasible. Solar minigrids, combining photovoltaic (PV) generation, battery storage, and diesel backup, offer a decentralized solution to provide electricity access for households and small businesses based on Productive Use of electricity (PUE). Yet, despite technical feasibility, many solar minigrid projects struggle to achieve economic viability, limiting scalability and impact.

1.2. State of the art

Existing studies converge on several key points regarding the economic viability of solar minigrids. [1] highlight the importance of scale effects: larger villages benefit from a more efficient allocation of fixed costs, which reduces the payback period. [2] confirm this finding and further demonstrate that village size and population density strongly influence profitability.
[3] emphasize the role of electricity tariffs: excessively high tariffs reduce user consumption and thus revenues, while too low tariffs fail to cover the initial CAPEX, prolonging the payback period. [4] show the significant effect of subsidies on CAPEX, which can substantially reduce payback

times and make otherwise unprofitable projects financially attractive. Finally, [5] demonstrate that the development of productive uses of electricity (PUE) is a key lever for optimal minigrid utilization and improved economic sustainability.
In summary, these studies highlight three main determinants of solar minigrid profitability: village size and density, tariff optimization, and support for productive electricity consumption. Our study complements these findings by proposing a parametric approach combining subsidies, tariffs, and PUE, and by integrating recent experimental data from Benin, which allows the identification of concrete conditions under which economic profitability can be achieved.

1.3 Aim of the paper

This study aims to assess the economic viability of solar minigrids using a simplified, generic model. Parametric analyses focus on:

- Capital subsidies
- Electricity tariffs
- Village size
- Productive use programs

The goal is to identify conditions under which solar minigrids can achieve financial sustainability.

2. Model and Assumptions

2.1. Hypotheses

- No decrease in component prices is assumed in the future.
- Full investment occurs in year zero, although a staged investment aligned with consumption growth would be more efficient.
- Electricity price elasticity is assumed to be 0.8.

2.2. Consumption Constraints

Consumption is limited by the maximum production capacity of the minigrid, following Benin data: 1,500 kWh per installed kW per year [6]. Diesel generators (gensets) are used at a maximum of 2% per year [1]. Interest rate is fixed at 10% per year [6]. Electricity tariff is 0.35 €/kWh. When tariffs exceed diesel costs, UPE consumption decreases by 12% per 0.03 €/kWh increment [6]. The project duration is 20 years (at least). It is assumed every customer or productive use is paying the same tariff.

Two villages are considered in order to study scale effect:

- SAM: small village, 120 connections (3000 inhabitants)
- DON: large village, 1,100 connections (15 000 inhabitants)

Costs and quantities come from 2023 to 2025 data in Benin [6] and are summarized in Table A1.

2.3. Consumption

The Total consumption is equal to the household's consumption (HH) plus productive uses consumption (PUE). The HH yearly consumption is equal to kWh per connection times fraction of connected customers (Table A1). PUE yearly consumption is evaluated as average PUE consumption (1.5 kWh/day) times number of PUE connections (Table A1). Payback period is evaluated according to (1)

$$Payback\ period = \frac{\sum_{i=1}^{time} (Revenues - costs - CAPEX)}{(1 + interest\ rate)^{time}} \quad (1)$$

3. Results

3.1 Tariff Influence

Figure 1 presents the tariff impact on payback time for SAM and DON (no subsidies). Also the impact of tariff on yearly consumption is depicted.

From Figure 1, larger villages benefit from scale effects, with payback time reduced by ~22% in this example. Also, high tariffs (>0.35 €/kWh) reduce revenue due to price elasticity; low tariffs (<0.35 €/kWh) reduce income for the same CAPEX. With optimal tariffication, the payback time can be reduced to 5 years without subsidies.

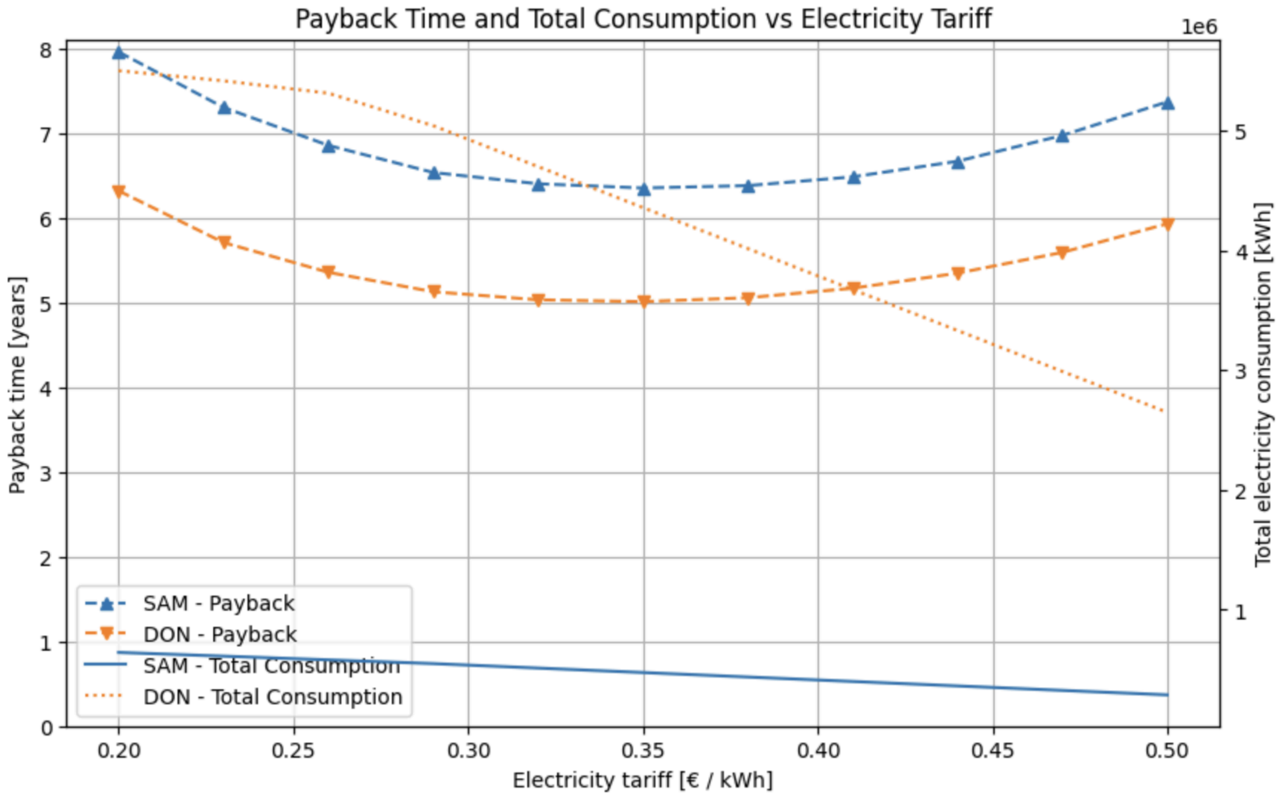

Figure. 1. *Tariff impact on payback time for SAM and DON (no subsidies).*

3.2 Influence of Subsidies

Figure 2 depicts the payback time versus the fraction of subsidies compared to CAPEX. The payback time decreases proportionally to the fraction of subsidies.

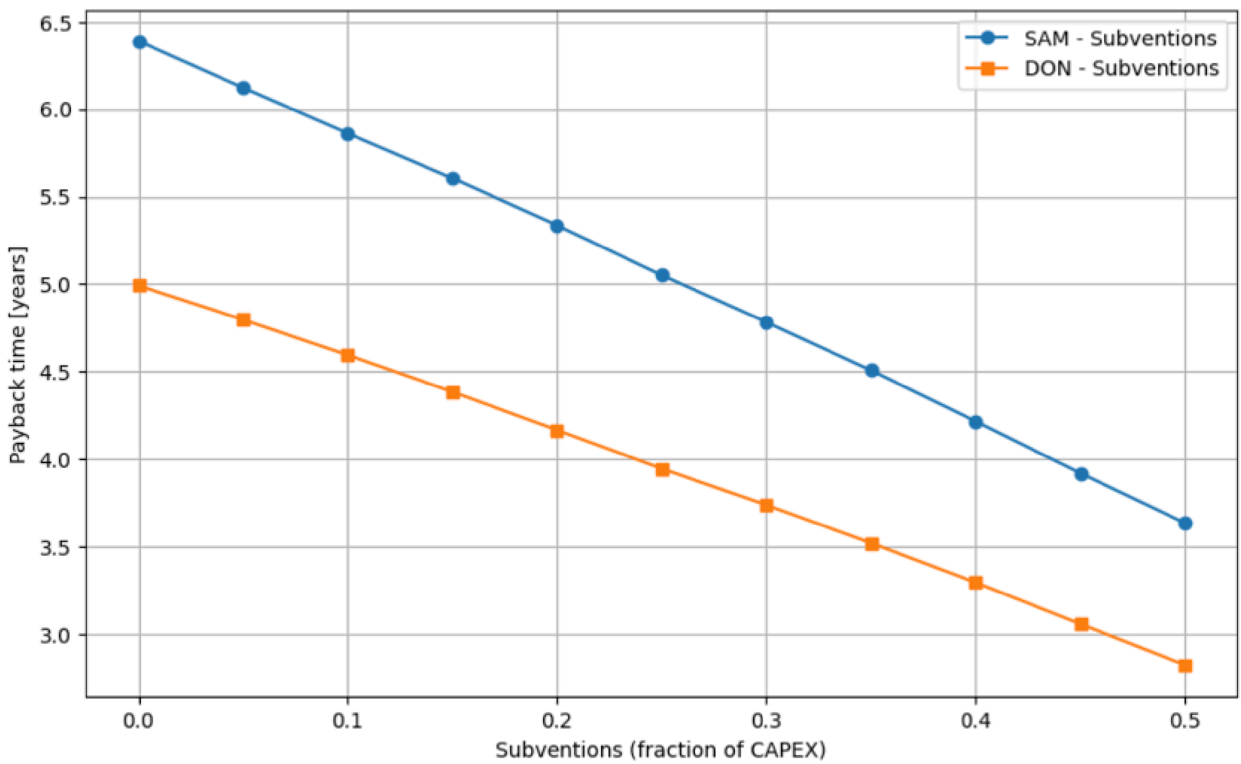

Figure. 2. *Subvention impact on payback time for SAM and DON.*

3.3 Productive Use Influence

The payback time is presented in function of the fraction of PUE (e.g. 1 corresponds to values from Table A2, 0.5 corresponds to half of PUE consumption). Increasing PUE consumption directly improves CAPEX utilization. Minigrids without PUE programs are generally not economically viable in a short period of time.

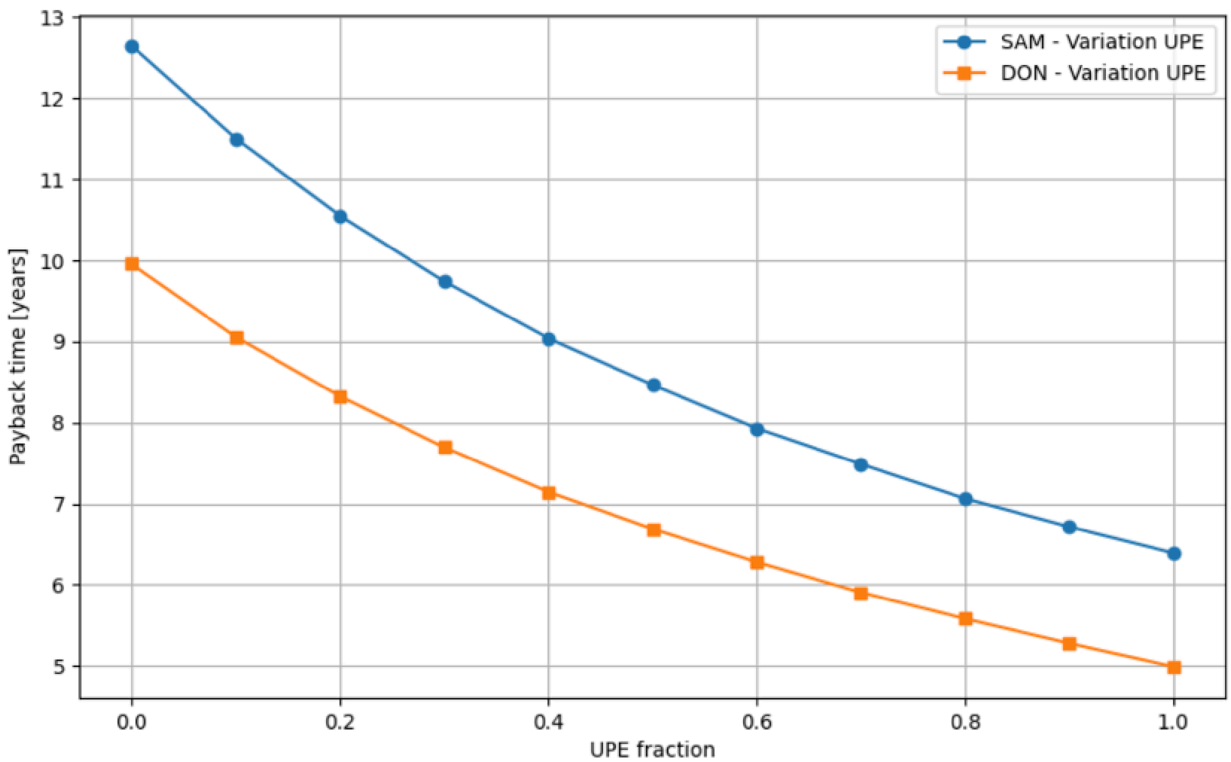

Figure. 3. *UPE impact on payback time for SAM and DON.*

4. Discussion

Important note: This model is using real data from Benin [6] and investment costs from 2025 and therefore some conclusions might not be relevant in other cases. However, this work is based on a pessimistic hypothesis and should therefore guarantee better economic viability practically.

Economic viability is highly sensitive to tariffs, subsidies, and productive use programs.

Small or remote villages are less profitable, highlighting the importance of portfolio approaches for developers. The study confirms that careful minigrid sizing, tariff design, and demand stimulation are critical for achieving payback periods below five years.

5. Conclusion

Minigrids can be economically viable under optimal conditions:

- Optimal tariff (~0.35 €/kWh) in this specific case
- Effective PUE programs to ensure sufficient electric consumption
- Optimal sizing (accurate prediction of future consumption)
- Smaller villages remain less profitable, underscoring the importance of aggregated investment strategies.

5.1 Perspectives

- Consider other indicators besides payback time (e.g., NPV, IRR, social return).
- Introduce staggered investments to follow demand growth, optimizing CAPEX allocation.
- Consider more case studies
- Include different tariffs for different types of consumers

Appendix A

Table 1.

Component	Value	Unit	Qty SAM	Qty DON
PV Modules	125	€/kW DC	30	240
Inverters	190	€/kW AC	33	264
Racking (tracker)	153	€/kW DC	30	240
Balance of System	140	€/kW DC	30	240
Smart Meters / Monitoring	30	€/unit	120	1100
Batteries	180	€/kWh	50	620
Backup Generators	120	€/kW AC	15	120
Installation Labour	50	€/kW DC	30	120
Poles, wiring & accessories	450	€/pole	72	310

Table 2.

Years	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	20
% Connexions HH	0.25	0.41	0.5	0.6	0.7	0.8	0.9	1	1	1	1	1	1	1	1	1	1
% connexions UPE	0.08	0.20	0.25	0.29	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
conso HH [kWh/con/day]	0.2	0.3	0.35	0.4	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45

Nomenclature

References

[1] Barnes, D. F., Khandker, S. R., & Samad, H. A. (2018). Rural Electrification and Development: Lessons from South Asia.

[2] Kumar, A., et al. (2020). Economics of Off-Grid Solar Minigrids in Sub-Saharan Africa. Renewable Energy, 150, 1234–1245.

[3] Mondal, M. A. H., et al. (2017). Pricing Strategies for Rural Electrification. Energy Policy, 101, 123–133.

[4] Zomer, T., et al. (2019). The Role of Subsidies in Off-Grid Electrification. Energy for Sustainable Development, 50, 75–86.

[5] Karekezi, S., & Kithyoma, W. (2003). Productive Uses of Energy for Rural Development. Energy Policy, 31(14), 1273–1288.

[6] OnePower Benin. Available at: https://onepowerbenin.com/en/home/