TECHNO-ECONOMIC ASSESSMENT OF FIVE MILLING MACHINES FOR PRODUCTIVE USES OF ELECTRICITY IN RURAL AREAS OF BENIN

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ABSTRACT

Maize is the most consumed product in Benin and particularly in rural areas, where economic development is hindered by the lack of access to electricity, insufficient training and support for economic actors. The Gini coefficient is 0.47 in 2020, with 50% of the population living on less than 2 USD per day. The development of economic activities in these areas is therefore crucial for the progress of the country. To address these challenges, this study focuses on the techno-economic analysis of an improved maize mill powered by photovoltaic solar energy, aimed at supporting economic activities. Five different mills, connected to photovoltaic solar micro-grids, are compared from both a technical and economic perspective: a fuel-powered mill, three electric mills, and an optimized electric mill with an innovative water injection system. This improvement aims to increase efficiency and reduce energy consumption required to process maize compared to conventional mills. The methodology includes modeling the mill, followed by validation through experimental field tests. The results highlight the economic and environmental benefits of the proposed solution for rural areas.

1 INTRODUCTION

Energy plays a crucial role in local economic development by meeting household needs and supporting productive uses. However, many developing countries, such as Benin, are characterized by a low electricity access rate, with a significant disparity that favors urban areas. In 2021, the electrification rate is 6.5% in rural areas of Benin compared to 59.2% in urban areas (OCIS-CCI Benin, 2023). This disparity is mainly due to the high investment required to connect rural areas to the national electricity grid and the low profitability that results from it.

In Benin, agriculture and agricultural processing hold a significant place in the economy (Domegni & Azouma, 2022; Miassi et al., 2024; our Badu-Apraku et al., 2017). The electrification of productive equipment, such as maize mills, which are the most prevalent, represents a major challenge for the country. Some studies have shown that there are, on average 9 cereal mills per 1,000 inhabitants, with a total cumulative consumption of approximately 400 kWh per month per 1,000 inhabitants (STG International & USTDA, 2021). These mills are primarily used for processing maize into flour. Maize is the main cereal, accounting for over 85% of human consumption in Benin (Tonato et al., 2025). A production of 2.1 million tons is recorded in 2023 (FAOSTAT, 2025).

In Sub-Saharan Africa, most of the estimated 500,000 to 750,000 maize mills, used to process 90 million tons of maize per year, run on diesel (Booth et al., 2018; CrossBoundary Group, 2024). Although functional, fuel-powered mills have major drawbacks, including high operating costs due to fuel price volatility, a significant carbon footprint, and high maintenance expenses. Given these challenges, the integration of solar PV mini-grids is emerging as a promising and sustainable alternative, promoting the use of electric mills, which are easier to operate and more reliable (Booth et al., 2018; Van Hove et al., 2022).

This study aims to compare different mills from both a technical and economic perspective, including an optimized mill featuring an innovative water injection system. Electrical mills are connected to photovoltaic solar micro-grids. To our knowledge, no similar studies have been conducted for fuel and electrical mills. The analysis focuses on several key indicators. The ultimate goal is to identify the most suitable solutions for rural areas in Benin, considering the economic constraints and the opportunities offered by solar electrification. The techno-economic assessment of maize mills relies on a comparison of the performance of electric and fuel-powered engines in terms of energy consumption, profitability and efficiency. Although this approach is not widely documented for agro-processing equipment, it has been extensively studied in other industrial and transportation sectors. For example, (Braun & Rid, 2017) conducted a comparative analysis of the energy consumption of an electric vehicle and an internal combustion vehicle, highlighting differences in efficiency and adaptability to operating conditions. This comparative methodology, although applied to a different field, justifies the examination of electric and fuel-powered mills from a similar perspective, considering the specific technical characteristics of each type of equipment.

2 METHODOLOGY

2.1 Technical performance testing

For each of the studied mills, milling was performed separately using samples of both dry and wet maize. Each maize sample had a mass of three kilograms, which corresponds to a ”sôgô” in the local language.

The number of passes required for milling varied depending on the type of maize processed and the characteristics of the mill. Generally, wet maize was ground in a single pass, whereas multiple passes were necessary for dry maize to achieve the desired product.

Five different maize mills were tested. It is important to note that the millstones used in each mill were new. The technical characteristics of these mills are presented in Table 1.The optimized mill is Mill 5. Table 2 presents the GPS coordinates of the localities visited during the tests.

Table 1: Technical characteristics of the tested mills

No.	Characteristics	Mill 1	Mill 2	Mill 3	Mill 4	Mill 5
1	Locality	Gbowele	Gbowele	Samionta	Samionta	Hêvié
2	Type	Millstone	Millstone	Millstone	Millstone	Millstone
3	Fuel/Electric motor	Electric	Electric	Fuel (Diesel)	Electric	Electric
4	Mechanical output power [kW]	7.5	7.5	18.6	7.5	8.9
5	Rated Rotational Speed [rpm]	1440	1400	2200	1440	-
6	Number of Phases	3	3	-	3	3
7	Voltage [V]	380 / 660	380	-	380	380
8	Current [A]	15.4 / 8.9	15.2	-	15.4	-
9	Investment cost [USD]	1,409.12	995.02	1,657.54	1,321.89	912.78
10	Age [month]	< 1	4	14	< 1	60
11	Supplier	Songhaï Center	Local manufacturer	Local manufacturer	Inclusive Grids SA	Local manufacturer

Table 2: GPS coordinates of the visited localities

No.	Locality	Latitude (°)	Longitude (°)
1	Gbowele	7.626767	2.202472
2	Samionta	7.096650	2.245532
3	Hêvié	6.440988	2.247894

The figures 1 and 2 illustrate the aforementioned mills.

(a) (b)

(c) (d)

Figure 1: (a) Mill 1, (b) Mill 2, (c) Mill 3, (d) Mill 4

Figure 2: Mill 5

Figure 2 illustrates the optimized mill with its main components identified as follows:

- **A**: water reservoir;
- **B**: piping system;
- **C**: water injection point into the mill;
- **D**: mill outlet after optimization;
- **E**: mill outlet before optimization.

In order to optimize the conventional mill for wet maize milling, several modifications have been made. These adjustments mainly include:

- a water injection system, consisting of a reservoir and piping. This system allows water to be injected into the maize at the entrance of the millstone during milling.
- a device for regulating the flow of maize entering the millstone, ensuring a controlled feed to improve milling efficiency.
- a secondary outlet, located just below the millstone, facilitating the discharge of wet flour to the outside and thus optimizing the milling process.

The modifications aim to improve the system's efficiency by integrating a water injection system and optimizing the mill outlet. The injection system is primarily used for the milling of wet maize.
During the tests, the following data were collected:

- the quantity of maize grains to be milled;
- the quantity of flour obtained after milling;
- the energy consumption;
- the durations (duration per pass and total duration for all passes).

These measured data allowed us to evaluate the performance parameters presented in the underlying sections.

2.1.1 Calculation of milling efficiency and the throughput capacity

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The milling efficiency and the throughput capacity were determined using equations (1) and (2) (Anh et al., 2021; Olajide et al., 2016; Verasol, 2023).

$$\eta_m = \left(\frac{M_{\text{flour}}}{M_{\text{grains}}}\right) \times 100 \tag{1}$$

with η_m: milling efficiency [%], M_{flour}: mass of flour obtained [kg], M_{grains}: mass of the grains used [kg]

A stopwatch was used to record the milling time necessary to process 3 kg of maize grains. This measurement was essential in assessing machine productivity, which is expressed in kilograms per hour.

$$TC = \left(\frac{M_{\text{flour}}}{t}\right) \tag{2}$$

with TC: throughput capacity [kg/h], t: milling time [h]

2.1.2 Calculation of specific energy consumption

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Specific energy consumption is the energy cost to mill one kilogram of maize grains into the flour. The specific energy consumption [kWh / kg] was determined using the equation (3) (Ali et al., 2025; Anh et al., 2021) :

$$Specific\ energy\ consumption\ [kWh/kg] = \frac{Energy\ consumption\ [kWh]}{M_{\text{flour}}\ [kg]} \tag{3}$$

For the assessment of electricity consumption in electric mills, electric meters were utilized. In the case of the fuel-powered mill, the quantities of fuel consumed were recorded, and the energy consumption was evaluated using the following equation (4):

$$Energy\ consumption\ = V_{fuel} \times LHV_{fuel} \tag{4}$$

with V_{fuel}: volume of diesel consumed [L], LHV_{fuel}: lower heating value of diesel [kWh / L] considered equal to 10 kWh/L (Muselli et al., 1999; Notton et al., 1998).

2.1.3 Uncertainty analysis

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The Table 3 presents the uncertainty values related to the various measurements performed.

Table 3: Uncertainty values of measurements made using different instruments in the study

S. No	Parameter	Instrument	Test location	Uncertainty
1	Energy consumption (kWh)	Electric meter	Gbowele, Samionta	±1% of the reading value (kWh)
2			Hêvié	±10% of the reading value (kWh)
3	Maize quantity (kg)	Analog scale	Gbowele, Samionta	±0.07 kg
4		Digital scale	Hêvié	±0.001 kg

2.2 Economic criterion

The following investment appraisal criteria were applied in this study : the Net Present Value (NPV), the Internal Rate of Return (IRR), the Payback Period (PP). (Dai et al., 2022; Ferrari et al., 2019; Herlianto et al., 2023; Marpaung et al., 2024).

2.2.1 Net Present Value (NPV)

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The Net Present Value (NPV) is a financial metric used to assess the profitability of an investment. It is the difference between the present value of future net cash flows and the initial investment. The NPV is calculated using equation (5).

$$NPV = \sum \frac{CF_t}{(1+k)^t} - I_0 \tag{5}$$

With :

- CF_t: the net cash flow at time t, representing the cash inflows minus cash outflows generated by the investment during period t.
- k: the discount rate [%]
- t: the number of periods [typically in years]
- I_0: the initial investment

The assessment criteria for Net Present Value (NPV) are as follows: if the NPV is greater than zero, the project proposal is accepted, indicating that the projected earnings exceed the initial investment. Conversely, if the NPV is less than zero, the project proposal is rejected, suggesting that the investment would result in a loss. Additionally, if the NPV equals zero, it implies that the company's value remains unchanged, regardless of whether the project proposal is accepted or rejected.

2.2.2 Internal Rate of Return (IRR)

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The Internal Rate of Return (IRR) is defined as the discount rate k at which the Net Present Value (NPV) of an investment equals zero. The calculation of the IRR is typically expressed in Equation (6), which involves solving for k such that:

$$\sum \frac{CF_t}{(1+IRR)^t} - I_0 = 0 \tag{6}$$

This equation allows investors to determine the rate of return at which the investment breaks even.

2.2.3 Payback Period (PP)

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The payback period is an indicator that represents the number of years required to fully recover the initial investment. It can be calculated using equation (7).

$$\text{Payback Period (PBP)} = \frac{\text{Investment Value}}{\text{Net Cash Inflows}} \tag{7}$$

Net cash inflows refer to the total amount of cash generated by an investment after accounting for all expenses, taxes, and operational costs. It is calculated by subtracting the total outflows (such as operating costs, taxes, and other expenses) from the gross cash inflows (revenues or income generated by the investment) during a specific period.

If the payback period is less than the maximum allowable payback period, the investment proposal is considered acceptable.

For the profitability studies, the PERESCUP software developed by Takaz-Engineering (https://www.takaz-eng.com/) was used. It is a tool for estimating the technical and financial added value of solar or cooking equipment for productive use.

3 RESULTS

3.1 Tests data

Table 4 and 5 present a summary of the data collected in the field. These are the average values.

Table 4: Average values of collected data from the tested mills with dry maize

No	Collected Data	Mill 1	Mill 2	Mill 3	Mill 4	Mill 5
1	Number of tests conducted on site	2	2	2	3	4
2	Milling time (min)	14.13	9.15	6.56	6.38	6.68
3	Initial mass of corn grains (kg)	3	3	3	3	3
4	Mass of flour obtained (kg)	2.8	3	2.5	2.7	2.7
5	Energy consumption (kWh)	0.47	0.66	1	0.50	0.58
6	Number of passes for milling	6	10	11	5	5
7	Fuel consumption (L)	-	-	0.1	-	-

Table 5: Average values of collected data from the tested mills with wet maize

No	Collected Data	Mill 1	Mill 3	Mill 4	Mill 5
1	Number of tests conducted on site	2	2	3	5
2	Milling time per pass (min)	2.06	2.12	1.74	1.66
3	Initial mass of maize grains (kg)	3	3	3	3
4	Mass of flour obtained (kg)	2.6	3.0	2.9	2.9
5	Energy consumption (kWh)	0.15	0.50	0.19	0.10
6	Number of passes for milling	1	1	1	1
7	Fuel consumption (L)	-	0.05	-	-
8	Water injected (L)	-	-	-	1.01

For Mill 3, the milling process showed an average diesel consumption of 0.1 liter for dry maize and 0.05 liter for wet maize. In the optimized Mill 5, the average water injection per milling process reached 1.01 liter.

Data for Mill 2 could not be collected for wet maize milling tests. There was no wet maize available for milling during the period of tests.

3.2 Technical comparison

3.2.1 Technical comparison in the case of dry maize

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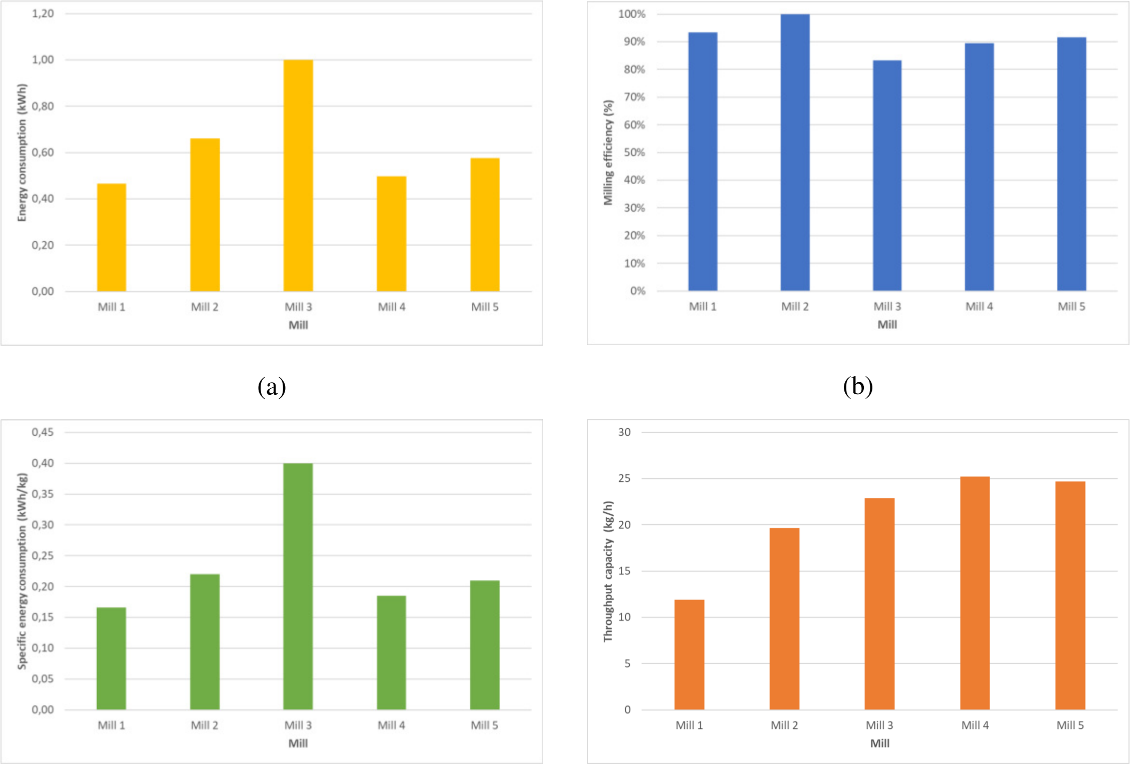
The results show a significant variation in the performance of the tested mills. Mill 2 stands out with optimal milling efficiency (100%), while Mill 3 which runs on gasoline, has the lowest efficiency (83%), indicating higher losses. In terms of throughput capacity, Mills 4 and 5 are the most efficient (25.22 kg/h and 24.69 kg/h), whereas Mill 1 has the lowest productivity (11.89 kg/h).

Regarding energy consumption, Mill 3, being gasoline-powered, is the most energy-intensive (1 kWh) and has the highest specific energy consumption (0.4 kWh/kg), which is likely due to its less efficient fuel source compared to electric mills. In contrast, Mill 1 is the most economical (0.17 kWh/kg), but its low capacity limits its suitability for large-scale production. Overall, Mills 4 and 5 offer the best balance between high capacity, efficiency, and moderate energy consumption, making them the most suitable for optimized use.



(a) (b)

(c) (d)

Figure 3: (a) Energy consumption, (b) Milling efficiency, (c) Specific consumption, (d) Throughput capacity

3.2.2 Technical comparison in the case of wet maize

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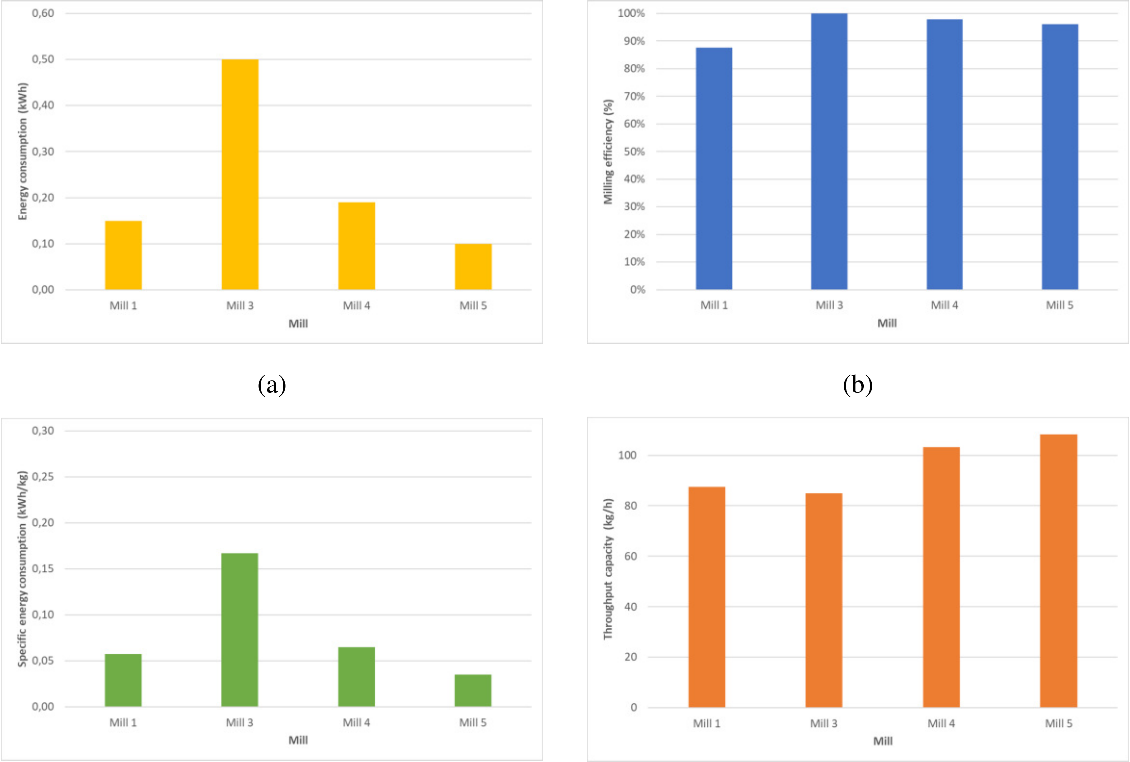
The performance analysis shows that Mill 5 stands out with a throughput capacity of 108.22 kg/h. It also has the lowest energy consumption of 0.10 kWh and a specific energy consumption of 0.03 kWh/kg. In contrast, Mill 3 operates on diesel and achieves a milling efficiency of 100%. However, its energy consumption is high at 0.5 kWh, with a specific energy consumption of 0.17 kWh/kg. This makes it less competitive.

These results indicate that, compared to the other tested mills, the optimized Mill 5 is the best choice for efficient production and reduced energy costs in wet maize milling.



(a) (b)

(c) (d)

Figure 4: (a) Energy consumption, (b) Milling efficiency, (c) Specific consumption, (d) Throughput capacity

3.3 Economic comparison

The economic evaluation of the tested mills is based on the assumptions presented in Table 6. These assumptions are derived from the collected data.

Table 6: Economic assumptions for the tested mills

Designation	Value (USD)	Unit
Number of working days per week	6	Days/week
Number of working weeks per year	52	Weeks/year
Number of working months per year	12	Months/year
Milling price for dry maize	0.249	USD/kg
Milling price for wet maize	0.166	USD/kg
Annual sales growth	0	%
Project analysis duration	10	Years
Discount rate	10	%
Electricity cost per kWh	0.275 and 0.372	USD/kWh
Lifespan	10	Years
Annual maintenance cost	139.11	USD
Monthly labor cost	66.34	USD/month
Monthly rental cost (store)	4.97	USD/month
Diesel price per liter	1.19	USD/liter
Oil change cost for fuel-powered mill	2.16	USD/month
Ratio (wet maize quantity per day / total milled maize per day)	20	%

The profitability conditions are given by the following system of equations:

- $NPV > 0$;
- $IRR > 10\%$;

- $PBP < 10$ years.

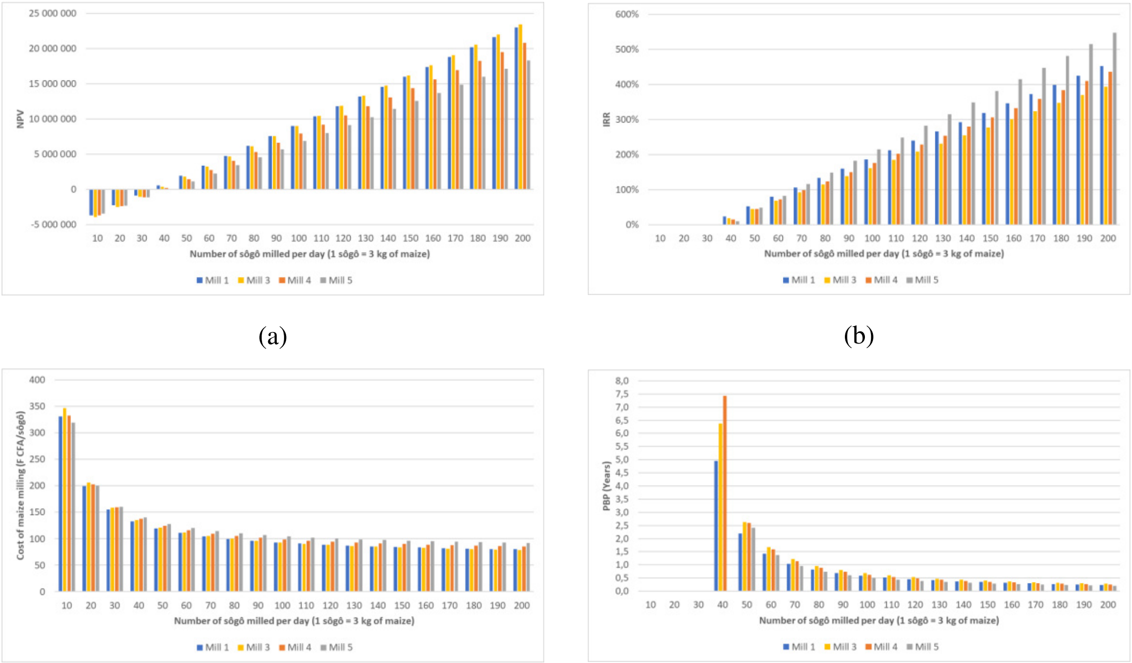
Considering the current cost per kWh (0.275 USD) for mini-grids supplying localities, the analysis of milling costs highlights a difference between electric mills (Mill 1, Mill 4, and Mill 5) and the fuel-powered mill (Mill 3) as illustrated on Figure 5. At a typical rate of 10 to 50 sôgô/day, observed in the rural areas visited, the milling cost of the fuel-powered mill remains higher than that of electric Mill 1, making the latter more economical to use.

The Internal Rate of Return (IRR) confirms this economic advantage: electric mills show higher profitability, with Mill 5 and Mill 1 performing the best. In contrast, the fuel-powered mill has a lower IRR, indicating a weaker return on investment. Regarding the Payback Period (PBP), electric Mill 1 is amortized in less than 5 years, compared to approximately 7 years for the fuel-powered mill. Finally, the analysis of the Net Present Value (NPV) shows that electric Mill 1 offers a significant financial advantage for a production rate of 50 to 90 sôgô/day.

Furthermore, it is observed that:

- A PBP of two years is reached with a daily production of 50 sôgô for Mills 1 and 5, and 60 sôgô for Mills 4 and 3.
- A PBP of six months is reached with a daily production of 110 sôgô for Mills 1 and 4, 100 sôgô for Mill 5, and 120 sôgô for the fuel-powered mill (Mill 3).

These results demonstrate that electric mills, particularly Mill 1, are more economically advantageous for the studied localities. These findings confirm that electric mills, especially Mill 1, represent a more economically viable solution for the studied regions.



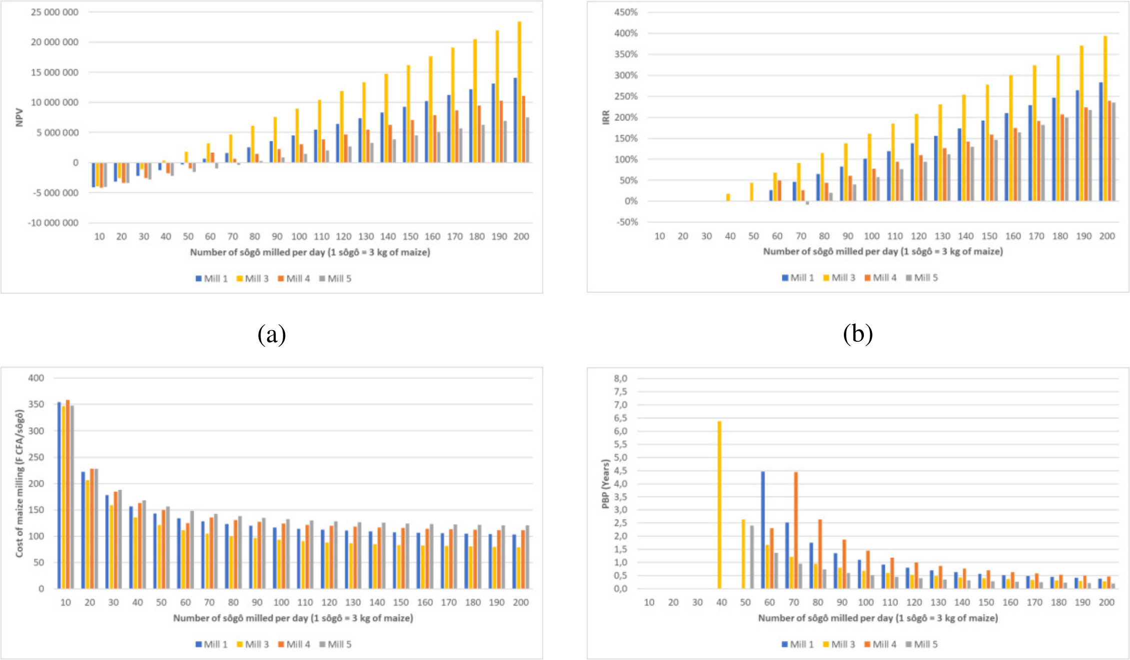
(a) (b)

(c) (d)

Figure 5: (a) Net Present Value (NPV), (b) Internal Rate of Return (IRR), (c) Cost of Milling, (d) Payback Period (PBP) for an electricity cost of 0.275 USD/kWh

The increase in the cost of electricity from 0.275 USD to 0.372 USD leads to a rise in the milling cost of electric mills, reducing their advantage over the fuel-powered mill (Mill 3). At a production level of 10 sôgô/day, the milling cost for Mill 1 increases from approximately 0.55 USD/sôgô to 0.59 USD/sôgô, representing a 7.25% rise, while that of Mill 5 rises from 0.53 USD/sôgô to 0.58 USD/sôgô, an 8.75% increase. The cost difference with Mill 3, which previously ranged from 0.027 to 0.045 USD/sôgô in favor of electric mills, narrows to 0.0017-0.033 USD/sôgô, making them less competitive.

These results highlight the sensitivity of the economic model of electric mills to electricity prices, reducing their competitiveness and profitability at different production levels. It is illustrated by Figure 6.



(a)

(b)

(c)

(d)

Figure 6: (a) NPV, (b) IRR, (c) Cost of milling, (d) PBP for an electricity cost of 0.371 USD/kWh

4 CONCLUSION

A technical and economic comparison was conducted among five corn mills located in Gbowele, Samionta, and Hêvié. Among these mills, four are electric, and one operates on fuel. Data were collected on-site during the regular operating periods of the millers.

The data collected enabled the evaluation of milling efficiency, throughput capacity, and specific energy consumption for technical criteria, as well as Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PBP) for economic criteria.

The results indicate that the optimized Mill 5 and Mill 4 offer the best balance between high capacity, efficiency, and moderate energy consumption, making them the most suitable for optimized use. The optimized Mill 5, with its innovative water injection system, significantly reduces energy consumption, particularly for wet corn milling, compared to conventional mills. It exhibits the lowest energy consumption at 0.10 kWh and a specific energy consumption of 0.03 kWh/kg.

Furthermore, the economic comparison shows that electric mills, particularly Mill 1, exhibit the best financial performance. Considering an electricity cost of 0.275 USD per kWh, the PBP for these mills ranges from 2 to 6 years for a daily production of 40 to 60 sôgôs (120 kg to 180 kg) per day.

The study also highlights the significant impact of mini-grid electricity pricing on the profitability of electric mills. Simulations indicate that an increase in electricity prices necessitates a higher daily production to maintain mill profitability. This underscores the need for studies to establish pricing that promotes the adoption of electric mills in rural areas. Indeed, high electricity costs can hinder the competitiveness of electric mills compared to fuel-operated mills.

The tests were conducted on-site during normal mill operations, without disrupting the entrepreneurs' income-generating activities. More in-depth laboratory tests are necessary to confirm and refine the obtained results.

NOMENCLATURE

Abbreviations

OCIS	Observatory of Trade, Industry, and Services
CCI Benin	Chamber of Commerce and Industry of Benin
STG	Solar Turbine Group International
USTDA	United States Trade and Development Agency
TC	Throughput capacity
NPV	Net Present Value
IRR	Internal Rate of Return
PBP	Payback Period

Latin Symbols

η_m	Milling efficiency, %
M_{flour}	Mass of flour obtained, kg
M_{grains}	Mass of the grains used, kg
t	Milling time, h
V_{fuel}	Volume of diesel consumed, L
LHV_{fuel}	Lower heating value of diesel, kWh/L
CF_t	Net cash flow at time t, F CFA
k	Discount rate, %
I_0	Initial investment, F CFA

Superscripts and Subscripts

t	Time period
m	Milling
0	Initial value

REFERENCES

1-Article from a periodical:

Ali, K. A. M., Li, C., Han, W., Issa, S., Eid, M. H., Mahmoud, S. F., & Mohammed, M. A.-E. (2025). Performance evaluation and prediction of optimal operational conditions for a compact date seeds milling unit using feedforward neural networks. *Scientific Reports*, *15*(1), 4764.

Anh, D. L., Van, K. P., Van, R. T., Dinh, K. T., & Trung, T. B. (2021). Study on performance evaluation and optimization of brewers grains hammer mill. *AIP Conference Proceedings*, *2406*(1).

Braun, A., & Rid, W. (2017). Energy consumption of an electric and an internal combustion passenger car. a comparative case study from real world data on the erfurt circuit in germany. *Transportation Research Procedia*, *27*, 468–475.

Dai, H., Li, N., Wang, Y., & Zhao, X. (2022). The analysis of three main investment criteria: Npv irr and payback period. *2022 7th International Conference on Financial Innovation and Economic Development (ICFIED 2022)*, 185–189.

Domegni, K., & Azouma, Y. (2022). Productive uses of energy: A solution for promoting energy justice in rural areas in west africa. *Renewable and Sustainable Energy Reviews*, *160*, 112298.

Ferrari, C., Bottasso, A., Conti, M., & Tei, A. (2019). Investment appraisal. *Economic Role of Transport Infrastructure: Theory and Models*, 85–114.

Herlianto, D., Tahalea, S., Wibowo, A., & Rahatmawati, I. (2023). Economic feasibility of modified cassava flour milling in gunungkidul region, indonesia: A value-added agribusiness venture. *IOP Conference Series: Earth and Environmental Science*, *1242*(1), 012027.

Marpaung, N., Manurung, R., & Eriza, F. (2024). Analysis of business feasibility on rice milling business in porsea district of toba samosir regency. *IOP Conference Series: Earth and Environmental Science*, *1302*(1), 012145.

Miassi, Y. E., Akdemir, Ş., Şengül, H., Akçaöz, H., & Dossa, K. F. (2024). Exploring the nexus of climate change, energy use, and maize production in benin: In-depth analysis of the adequacy and effectiveness of adaptation. *Climate Smart Agriculture*, *1*(1), 100006.

Muselli, M., Notton, G., & Louche, A. (1999). Design of hybrid-photovoltaic power generator, with optimization of energy management. *Solar energy*, *65*(3), 143–157.

Notton, G., Muselli, M., & Poggi, P. (1998). Costing of a stand-alone photovoltaic system. *Energy*, *23*(4), 289–308.

Olajide, O., Ale, M., & Abisuwa, T. (2016). Performance evaluation of a burr mill for processing of maize grits. *International Journal of Engineering Sciences and Research Technology*, *5*(4), 65–70.

our Badu-Apraku, B., Fakorede, M., & Cham, S. (2017). Advances in genetic enhancement of early and extra-early maize for sub-saharan africa.

Tonato, O., Dannon, E. A., Hounsou, S., Chougourou, D. C., & Tamò, M. (2025). Assessing insecticide residues in stored maize in southern and central benin. *Journal of Stored Products Research*, *111*, 102529.

Van Hove, E., Johnson, N. G., & Blechinger, P. (2022). Evaluating the impact of productive uses of electricity on mini-grid bankability. *Energy for Sustainable Development*, *71*, 238–250.

2-Report:

Booth, S., Li, X., Baring-Gould, I., Kollanyi, D., Bharadwaj, A., & Weston, P. (2018). *Productive use of energy in african micro-grids: Technical and business considerations* (tech. rep.). National Renewable Energy Lab.(NREL), Golden, CO (United States).

CrossBoundary Group. (2024). *Mini grid innovation insight: Electric grain milling* (tech. rep.).

OCIS-CCI Benin. (2023). *Chiffres clés sur le secteur de l'énergie du bénin*. Observatory of Trade, Industry, Services & Chamber of Commerce, and Industry of Benin. Bénin.

STG International & USTDA. (2021). *Task 6.1 endogenous analysis of productive uses* (tech. rep.).

Verasol. (2023). *Rapid product assessment solar milling test method* (tech. rep.).

3-Database Online:

FAOSTAT. (2025). *Data on production of primary crops*. http://faostat.fao.org

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