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Financial and Economic Analysis of a 1-Tonne Capacity Mobile Solar-Biomass Hybrid Dryer for Maize Drying

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Abstract: Drawbacks associated with natural convection solar dryers are encouraging the development of low-capacity hybrid drying systems which integrate renewable energy in their operation. However, information on the cost-effectiveness of such drying systems for decision-making by investors is lacking. This study seeks to assess the financial and economic feasibility of a solar-biomass hybrid dryer for maize drying. A cost-benefit analysis was done using net present value (NPV), benefit-cost ratio (BCR), and internal rate of return (IRR) as well as payback period to measure the financial viability of the dryer operation and the profitability of the investment. The results show that the total capital expenditure required to establish the drying system is $ 5,263 with a running cost of $ 1,166 per year. Using an economic utilisation period of 10 years, the investment in the dryer was determined to be viable with an NPV of $ 4,876 and an IRR of 38% at a capital cost of 24%. At a drying charge of $2.11/bag, the results show the initial capital invested can be recouped in a PBP of 2.7 years at a BCR of 1.48. These financial indicators suggest that investment in the dryer is profitable. Further analysis shows that, at a projected 30, 266.80 tonnes of maize produce per season by smallholder maize farmers in the study area, about 210 of the hybrid dryers are needed to provide drying services to the farmers. This translates into about 420 direct job opportunities created for the youth and the potential to prevent economic loss of maize grains equivalent to $ 5,684.2 per year due to post-harvest losses of maize in the study area. The adoption and scale-up of the dryer have implications in addressing maize post-harvest loss at the smallholder level and job creation for the youth in the country.

Keywords: Solar-biomass Hybrid Dryer, Post-harvest Loss Prevention, Cost-benefit Analysis, Job Creation

1. Introduction

Issues about high post-harvest losses and seasonality of food products have led to the development and introduction of improved and innovative ways to preserve food commodities [1, 2]. Several literature reviews have shown that drying of food products by the use of crop dryers is an effective and easy method that can be applied to many food crops to improve their shelf life and ensure availability during off-seasons. However, the process is a highly energy consumptive one that consumes a huge percentage of the total energy in the food industry. Energy sources such as fossil fuel and other electrical methods for drying are common but expensive [3]. The use of fossil fuel also poses a risk to the environment by the release of greenhouse gases

[4].

The traditional drying method which involves drying food products in the open sun is the most common in many parts of sub-Saharan Africa due to its low cost and operability. However, this method of drying is faced with some drawbacks that lead to severe qualitative and quantitative losses [5, 6]. To improve the drying process using sun energy, conventional solar dryers have been introduced as a better alternative option to the traditional open-sun method for drying crops by farmers [7, 8]. Solar dryers provide better efficiency in terms of moisture removal and quality of dried food grains compared to the traditional open-sun drying method. Solar dryers also provide farmers with an option on affordability and they are environmentally friendly compared to commercial drying systems powered by fossil fuels or

electricity [7, 9]. However, the commercialisation of conventional solar dryers has not been successful due to its high weather dependence. During periods of low incidence solar radiation, the performance of the system reduces leading to long drying periods [10]. According to Sekyere *et al.*, [11], commercialisation of solar dryers in Ghana has generally not been successful with limited or non-adoption of such systems by farmers.

To address this problem and encourage the scale-up of solar dryers in sub-Saharan Africa and other parts of the world, the provision of reliable and readily available energy is required [2]. Due to this, current research works focus on the development of hybrid drying systems that rely on solar energy and other renewable energy sources such as biomass [12-14]. However, to scale up for the adoption of hybrid drying systems, information on its financial and economic viability is necessary to provide confidence to investors and early adopters of new technologies. In this regard, the financial and economic viability of operating a locally manufactured 1-tonne capacity tractor-mounted solar biomass hybrid dryer (SBHD) has been investigated.

2. Materials and Methods

2.1. Description of the Dryer Unit and Study Area

The newly developed prototype unit, as shown in Figure 1, is a greenhouse-type solar dryer and consists of three major parts, namely; the drying chamber, solar PV system, and biomass furnace. The parts are all fabricated together as a single unit and can be hitched to a tractor and wheeled from one place to the other to provide drying services to the smallholder maize farmers in a local farming community. This is similar to the operational concept of the mobile mechanical thresher largely used by smallholder maize farmers for threshing/shelling their grains in Ghana and other parts of Sub-Sahara Africa. The design capacity of the dryer is approximately 1000 kg of maize per batch.

The drying chamber has an overall dimension of 3 m x 1.8 m x 1.9 m and is designed as a greenhouse tent dryer with the roof and sides of the drying chamber covered with a 0.03 m thick UV-protected transparent Acrylic sheet. The drying chamber is divided into seven levels (L1, L2, L3…., L7). Each level accommodates six (6) movable drying trays, each with a dimension of 0.9 m x 0.8 m x 0.05 m. The trays are made from wood with the base of the trays fixed with perforated plastic mesh to hold the drying grain. The movable trays slide on a mild steel angle line frame and are spaced to allow for smooth flow of drying air on top and beneath the product preventing the need to stir during drying.

To ensures a continuous drying process in the dryer during periods of no sunshine or cloudy weather, a biomass furnace (0.95 m x 0.95 m x 1 m) with an in-built cross-flow heat exchanger is connected to the drying chamber to provide supplementary heat. Agro-residues such as maize cobs, dried coconut husk, rice husk, palm nut shells, etc. are the main feedstock burnt in the furnace to generate the required heat for

drying grains in the dryer. In communities with no electricity access, the installed PV system with backup batteries provides electricity to supports the dryer operation.

Figure 1. *Developed mobile solar biomass hybrid dryer with Solar PV system. A – Solar PV unit; B – Furnace with enclosed heat exchanger and chimney; C -Drying chamber with drying racks.*

The study area was Ejura, the district capital of Ejura-Sekyedumase Municipal area, in the Ashanti Region of Ghana. The district is located about 100 km north of Kumasi, the Ashanti Regional capital and lies between Longitudes 1°5''W and 1°39'' W and Latitudes 7°9'' N and 7°36''N in the transitional zone of Ghana. The district experiences a mean monthly temperature of between 21°C to 30°C, relative humidity between 90% to 55% and, a bi-modal rainfall pattern with an average rainfall of 1,200 mm – 1,500 mm yearly. The district is among the leading maize-producing districts in the Ashanti Region that contributes about 60% of maize produced in Ghana. However, maize post-harvest loss in the district is estimated to be about 15 to 20% [15].

2.2. Method of Data Collection

Primary and secondary data were used for the study. Secondary information was accessed from various sources, including journals, articles, Ghana Statistical Services, and the Ministry of Food and Agriculture, the Bank of Ghana, and other online sources. The secondary data provided information about production and post-harvest loss data on maize for the study area, the average on-farm maize yield for the area, relevant financial indicators like interest rate, exchange rate as well as the minimum daily wage for unskilled labour in Ghana. Primary data was obtained mainly from personal interviews with dryer operators, smallholder farmers, and Agric Officers in communities in the study area. All technical details related to the study were from the 1-tonne capacity hybrid dryer. Some important information captured for the financial analysis includes capital expenditure for the installation of the dryer, the annual operating costs and revenue from the dryer operation, and the cost of a bag (100 kg) of dried maize. Other data collected include dryer performance data (drying rate, drying capacity), farm size of smallholder farmers in the district, membership of Farmer Based Organisations or Enterprise (FBO/FBE) in the study area, the daily wage paid for labour hands in the area. The data

collected was limited to the 2019 production and marketing season. The main component that provides electrical power to the dryer is the solar PV system. It is often estimated to have a lifespan of 10 to 15 years. For this study, the cost and returns associated with the dryer operation were projected over 10 years lifespan.

The major capital costs captured in the financial analysis include the cost of the dryer, Solar PV system, biomass furnace, and blower with a motor. Labour and maintenance costs were captured under operating costs. Data on revenue was limited only to payment accrued from the dryer for drying maize in the study area. The cost and returns on the dryer operation are therefore limited only to maize drying.

2.3. Analytical Approach

Discounting methods for investment analysis, including net present value (NPV), internal rate of return (IRR), and benefit-cost ratio (BCR) were used to analyse the financial viability of the solar-biomass hybrid dryer. However, the undiscounted method (payback period) was used to determine how quickly the installed dryer generates enough funds to cover initial capital investments. Sensitivity analysis was carried out to establish changes in the viability measures due to variations in some key variables such as discount rate and drying charge during the dryer operation. Economic analysis was also performed to additionally highlight the potential for job creation for the youth in the study area from the scale-up of the hybrid dryer. The number of smallholder farmer-beneficiaries and potential economic loss of maize due to post-harvest loss prevented by using the dryer as against the traditional open-sun method was also estimated. The economic output indicators were determined with an analytical tool developed with the built-in-commands in Microsoft Excel.

2.3.1. Net Present Value (NPV)

NPV is a discounting method for evaluating the economic viability of investments and it simply refers to the present worth of the net cash flow of a firm. According to Adams *et al.*, [16], NPV is the difference between the present value of an investment cash inflows (benefits) and the present value of the investment cash outflows (costs) at a given discount rate. A positive NPV indicates an economically feasible investment or project while a negative value shows that it is not economically feasible to carry out such an investment or project [17]. Mathematically, NPV is expressed as indicated in Equation 1.

$$NPV = \sum_{t=0}^{N} a_t S_t \qquad (1)$$

Where:
S_t is the net cash flow at a specific time (t)
N is the number of years (10 years)
a_t is the financial discount factor calculated using Equation 2

$$a_t = \frac{1}{(1+i)^t} \qquad (2)$$

Where:

t is the time between 0 and N
i is the discount rate

2.3.2. Internal Rate of Return (IRR)

IRR is a measure of investment worth at which the discount rate which applies to an investment's cash flow produces a zero NPV. Generally, the higher the IRR the more desirable it is to undertake the project [18]. Mathematically, the IRR was calculated using Equation 3:

$$NPV = \sum \frac{S_t}{(1+IRR)^t} = 0 \qquad (3)$$

2.3.3. Payback Period (PBP)

The payback period estimates the number of years it takes to recover an investment's initial capital. It provides a simple way to assess the economic merit of investments. Cash inflows for the PBP are undiscounted hence do not consider the time value of money. The payback period was mathematically expressed using Equation 4.

$$PBP = \frac{C_i}{S} \qquad (4)$$

Where;
C_i is the initial investment cost
S is the net cash flow

2.3.4. Benefit-cost ratio (BCR)

This is the ratio of total discounted benefit to the total discounted cost of the investment cash flows. It measures the relative profitability of investment, unlike the NPV which accounts for total net benefits. According to Gittinger (1984) cited in Adams *et al.*, [16], BCR becomes more relevant over the NPV when investors are interested in knowing the generated profitability from the amount invested in a business. Projects with a benefit-cost ratio greater than 1 have greater benefits than costs hence they have positive net benefits. The higher the ratio, the greater the benefits relative to the costs. Mathematically, the BCR was estimated using Equation 5.

$$BCR = \sum \left(\frac{B_i}{(1+d)^i} \right) \div \sum \left(\frac{C_i}{(1+d)^i} \right) \qquad (5)$$

Where
B_i represents the benefit of the project in year i, $i = 0$ to n
C_i represents the cost of the project in year i
d represents the discount rate

2.3.5. Sensitivity Analysis

According to Saltelli *et al.*, [19], sensitivity analysis is needed to assess the impact of changes in key variables of investment on NPV, IRR, BCR, and payback period. Adams *et al.*, [16], also reported that sensitivity analysis helps to measure the effect of achieving investment objectives when the assumptions behind cash flows vary wholly or partially. In this study, a sensitivity analysis was performed to assess the impact of changes in the discount rate and drying charge on the key economic indicators. The discount rate is a key parameter that affects the NPV of a project. The drying charge

is also considered a key variable for investment decisions in dryer installation for commercial operation as it relates directly to cash inflows. The sensitivity analysis was performed by varying the discount rate based on the policy rate trend of the last two decades of the Ghanaian economy. According to Bank of Ghana, [20], the policy rate has fluctuated from a minimum of 12.5% to a maximum of 27.5% since the last two decades.

2.4. Methods of Data Analysis

Descriptive analytical tools such as frequency tables and graphs were used to characterise the cost and returns from the use of the hybrid dryer for drying maize in the study area. The discounted methods of investment appraisal were also used to analyse the data.

2.5. Assumptions

To assess the viability of investment in the dryer business set-up using financial indicators such as NPV, BCR, IRR, and PBP, the following assumptions were made in the financial and economic analysis. Grounds for the assumption were based on data from the performance of the dryer, prices obtained from the study area, and data from government and private agencies such as the Ghana Statistical Service and the Bank of Ghana. Maize is harvested in two seasons in a year in the study area; the major harvest season in which over 60% of maize produced by smallholder farmers in the area is harvested spans over a period of 3 months (June/July to August/September). This is the same period when the area experiences intermittent rainfall making it difficult for farmers to properly dry their harvested grains. The minor harvest season is limited to 2 months (November/ December to January/February) and it falls within the harmattan period so most farmers resort to drying their grains in the field or open space. As a result, the financial and economic analysis of the dryer business was based on the major harvest season at an operational period of 3 months in a year. Other major relative assumptions used in the financial and economic analysis include:

1) A dollar (USD) to Cedi (GH₵) exchange rate of 5.7 was used for the analysis based on official foreign exchange rates in Ghana for January 2019.
2) The dryer is expected to operate at a full capacity of 1000 kg.
3) Cash flows were discounted over 10 years based on the expected useable lifespan of the dryer.
4) A 10% annual increase in revenue was considered in the financial analysis based on the trend of increment in drying fees charged by commercial drying facilities set up in the study area.
5) The cost of capital used for the analysis is 24%. This is based on the average lending rate offered by commercial banks in Ghana at the time of the study [20]. It is assumed an investor will borrow capital to set up the dryer business.
6) A rate of 2% of the investment cost is considered as

maintenance cost in the financial analysis.
7) Two labour hands are considered adequate to operate the dryer at a wage of GHS 12.0 (US$ 2.11) /labour. This was the daily minimum wage as of January 2020 in Ghana [21].
8) Labour cost is projected to increase by 10% each year based on the minimum wage trend in Ghana.
9) Electricity and fuel (biomass) costs are not considered in the operational cost analysis since maize cobs and husk is available and free in the study area. It is considered the main fuel that produces the heat required for the drying process. Electricity to run the blower is expected to be provided by the solar PV system.

3. Results and Discussion

3.1. Economic and Financial Analysis of Hybrid Dryer Operation

Economic and financial analysis are important means to assess the viability of any long-term project. Such analyses provide an opportunity to determine the benefits of such projects to investors and users. In this study, the economic and financial analysis of the 1-tonne capacity mobile solar-biomass hybrid dryer was investigated. Table 1 presents the financial and technical parameters used in the economic analysis of the dryer. Performance study of the dryer shows that a farmer can dry his maize grains from an initial moisture content of 22% (wb) to a safe moisture content of 13% (wb) in 7 h at an average drying rate of 1.3%/h. This translates to 1,008 h during the operational period of three months from June/July to August/September. This is the harvest period for the major production season of maize along the transition zone of Ghana where the study was conducted. The harvest time usually coincides with the onset of the peak rainfall season when smallholder farmers in particular, critically require drying services to dry their crops. Maize farmers in Ghana are typically smallholders and cultivate on an average farmland size of 2 ha or less with an average production output of 1.8 t/ha of maize per cropping season. This corresponds to 3.6 tonnes (3600 kg / 36 bags) of maize produced by a farmer in the study area in a cropping season. This quantity of maize is projected to be dried within two operation days at an expected dryer operation of 2 batches in a day. This means the dryer would be available to other smallholder maize farmers who use the unreliable open-sun method for drying their maize particularly during the time open-air drying becomes challenging. Based on the specified capacity and the drying time of the dryer, it is estimated that 144 tonnes of maize (1,440 bags) are expected to be processed within the operational period of three months in a year. This translates into about 40 smallholder maize farmers (144 tonnes of maize ÷ (2ha/smallholderfarmer×1.8 tonnes of maize/ha)) who could benefit directly from the dryer to dry their crops. This represents less than 1% of the total estimated production output of 30, 266.80 tonnes of maize produced by the smallholder farmers in the district. To support the other

smallholder maize farmers in the area to meet their drying needs, it is projected that about 210 dryers of similar capacity are needed. This has the potential to create about 420 direct job opportunities for the youth in the area to provide drying services within the 3-month operational period.

At a likely post-harvest loss of 15 to 20% for grains dried in the open at market places or on the shoulder of roads in the area, the study postulates that a farmer loses about $ 3.95 per bag of maize dried (minimum estimated quantity of grain lost (15%) per bag (100 kg) × price per bag of maize dried ($26.32) ÷ 100) in the open particularly in the major harvest season when the drying of grains often coincides with intermittent rains resulting in mould infestation and other contaminations from pest and the droppings of scavenging animals. This study, therefore, postulates that if the projected 1440 bags of maize is dried using the dryer for the 3-month operational period, an estimated savings of $5,688 (estimated quantity of maize dried per year by a dryer (1440 bags) × monetary value lost per a bag of dried maize due to post-harvest loss ($ 3.95)) will be made per year due to post-harvest loss of maize prevented.

Table 1. *Technical and financial parameters associated with the dryer operation.*

Parameter	Value
Capacity of dryer (kg)*	1000
Number of batches per day	2
Number of hours required per batch of drying	7
Number of operational days per week	6
Number of operational hours per week	84
Number of operational months per year	3
Operational hours per year	1008
Quantity of maize per bag (kg)	100
Average on-farm maize yield per hectare	1.8
Average size of farmland (ha) for a typical smallholder maize farmer	2
Average membership of a farmer-based organisation (FBO) in the study area	50
Number of bags of maize dried per day	20
Number of bags of maize dried per week	120
Quantity of maize dried per year (t)	144
Number of bags of maize processed per year	1,440
Estimated production average of maize for the area (t)	30,266
Number of dryers required to process the total available maize	210
Number of direct employments generated (persons)	420
Lifespan of the dryer (yr.)	10
Drying charged per bag of maize ($)	2.11
Number of hectares of maize dried per year	80
Number of smallholder farmer-beneficiaries	40
Number of FBO beneficiaries	~1
Cost of purchasing a bag of dried maize ($) in a local market in the study area	26.32
Estimated post-harvest loss in maize for the study area (%)	15~20
Economic loss per bag of dried maize due to post-harvest loss ($)	3.95-5.26
Monetary value of post-harvest loss prevented ($)	5,688
Exchange Rate (1$ to GHS)	5.70

3.2. Cost Analysis of Dryer Operation

The initial capital expenditure used to establish the dryer is estimated as GhȻ 30,000 (US$ 5,263.16). The main cost component is the material cost for the construction of the drying chamber and biomass furnace, estimated to be 70% of the total investment cost. The other initial capital expenditure is the solar PV system estimated to be 20% of the investment cost. Labour and overhead charges were about 10% of the total expenditure. According to Adams *et al*., [16], the overall capital demand to set up the dryer operation is consistent with the figure (less than US$100, 000) reported by the World Bank for the classification of small-scale enterprises in Africa.

The cost associated with the operation and maintenance of the dryer is presented in Table 2. It represents the cost incurred after the capital expenditure period from year one to the tenth (10th) year of the dryer operation. An amount of GhȻ 6,648 (US$1,166.32) is estimated as the total operating cost. This involves an amount of GhȻ 600 (US$105.26) representing 2% of the total investment cost which is allocated for maintenance and overhead expenses. At a labour charge of GH Ȼ12 (US$2.11) per person for 4 hours of work per day, an amount of GhȻ 6,048 (US$1,061.05) is estimated for salaries if two people are hired to operate the dryer for 14 hours per day during the 3-month operation cycle.

Table 2. *Annual operating cost.*

Item	Cost value (USD)/operation cycle
Maintenance and overhead expenses (2% of investment cost)	105.26
Salary of two operators	1,061.05
Total running cost	1,166.32

Official exchange: USD1 = GhȻ5.7 as of January 1, 2020

For the sustainable operation of the dryer during the ten-year lifespan, the total operating cost is projected to increase annually at 10% due to price inflation in Ghana. Historically, prices of goods and services in Ghana have always experienced a slight variation due to inflation with an annual average of 10% [16]. The annual operating cost is therefore projected to increase from GhȻ 6,648.02 (US$1,166.32) to GhȻ 15,675.63 (US$2,750.11) at the end of the 10th year of operation.

3.2.1. Revenue Analysis

The design capacity of the hybrid dryer is 1000 kg per batch and is anticipated to operate at two batches per day. Given that the dryer will operate six (6) days per week for the 3-month operational period, it is expected that the dryer will be used to dry 144 tonnes (1440 bags) of maize per year. At a drying fee of GHȻ 12 (US$ 2.11) per bag (100 kg) of maize dried, the total revenue of GhȻ17,280 (US$3,031.58) is expected in the first operational year of the dryer. To match the rise in the operating and maintenance cost due to inflation, the drying fee is projected to also increase at 10% annually thereby resulting in an increase in revenue to GHȻ 25,451.24 (US$ 4,465.13) at the end of the 10th year of operation of the dryer.

3.2.2. Financial Viability Analysis

According to Abbood *et al*., [17], a business is financially viable if the NPV is positive and the IRR is greater than the commercial discount rate of loans offered to investors. For this

study, a discount rate of 24% was adopted as the opportunity cost of capital. This was the average interest rate charged on loans by commercial banks in Ghana at the time of the study [20]. The result of the financial analysis based on the discounted and undiscounted cash inflows and outflows of the dryer investment is presented in Table 3. It revealed that over a projected 10-year lifespan of the drying system, an NPV of GhȻ 27,793.43 (US$ 4,876.04) and IRR of 38% can be achieved at a payback period of 2 years and 7 months after operations begin. The BCR (1.48) reported for this study is greater than one which implies that for every dollar invested in the dryer there will be a return of US$ 1.48. The values of the financial viability indicators for this study demonstrate the feasibility of a business opportunity for an investor or a farmer to invest in owning and running the hybrid dryer as a business in the study area. In a similar study on profitability analysis of mango chips processing and cashew plantations in Ghana respectively, a similar trend in NPV and IRR values was the basis for a conclusion that small-scale mango chips processing business and cashew project is profitable and viable to invest in Ghana [16, 22]. Furthermore, Asante and Kuwornu [23], reported that investment in pineapple juice processing in Ghana is profitable and viable when their reported IRR (23%) was greater than the discount rate which was 21%.

***Table 3.** Projected operating cost for entire dryer investment.*

Item/Year	0	1	2	3	4	5	6	7	8	9	10	Total
Total revenue	0	3031.58	3334.74	3668.21	3851.62	4044.20	4125.09	4207.59	4291.74	4377.57	4465.13	39,397.46
Total cost incurred	5263.16	1166.32	1282.95	1411.24	1552.37	1707.60	1878.36	2066.20	2272.82	2500.10	2750.11	3,851.23
Net cash flow	-5263.16	1865.26	2051.79	2256.97	2299.25	2336.60	2246.72	2141.39	2018.92	1877.47	1715.01	5,546.24
Discounted factor	1.00	0.86	0.74	0.64	0.55	0.48	0.41	0.35	0.31	0.26	0.23	
Discounted Revenue	0	2613.43	2478.25	2350.07	2127.22	1925.5	1693.11	1488.77	1309.09	1151.1	1012.17	8,148.70
Discounted cost	5263.16	1005.44	953.44	904.12	857.36	813.01	770.96	731.08	693.27	657.41	623.41	13,272.66
Discounted Net cash flow	-5263.16	1607.99	1524.81	1445.94	1269.86	1112.49	922.15	757.69	615.82	493.69	388.77	4,876.04
Net Present value	4,876.04											
Internal Rate of Returns	38%											
Benefit-cost ratio	1.48											
Payback period	2.67											

3.2.3. Sensitivity Analysis

The potential for other farmers to invest in other similar small capacity drying systems in the area could pose a threat to the investment in the hybrid dryer business and affect revenue flow. One strategy to remain competitive is through a reduction in the drying fee charged ($/bag of maize) dried by the dryer. Additionally, an increase in operating cost and a potential rise in the discount rate or opportunity cost, a common trend in Ghana could also affect investment in the dryer business. The effect of decreased revenue due to reduced drying fees at 10% and 20%, and a 10% increase in the operating cost on the financial indicators (NPV, IRR, PBP, and BCR) is presented in Table 4. The analysis of the results shows that the NPV, IRR, and BCR values decreased considerably when the drying fee charged per bag of maize dried was reduced by 10% ($2.11 to $1.89). The NPV decreased by 37% (from $ 4,876.04 to $ 3,061.17), IRR from 38% to 31%, and BCR from 1.48 to 1.33. The payback period however increased from 2.7 years to 3.2 years 2. A similar trend is observed at a further reduction in the drying fee by 20% with the NPV drastically reducing to $ 1,246.30 and the payback period going beyond 4 years. Though under both scenarios of revenue reduction the investment in the dryer is still viable and profitable, it however signifies that a reduction in the drying fee is sensitive to an investment in the dryer business. Similar results have been reported by Abbood *et al*., [17], who performed a financial analysis of a 1MW PV plant and observed that variations in the selling price of electricity considerably affected the NPV and IRR.

The effect of an increase in the operating costs by 10% showed a marginal variation in the financial indicators. As shown in Table 4, the NPV reduced marginally to $ 4,147.14 while IRR reduced from 38% to 35% and BCR reduced to 1.39 from 1.48.

***Table 4.** Effect of reduction in revenue and an increase in operating cost on NPV, IRR, PBP, and BCR.*

Stimulus	NPV (USD)	IRR (%)	BCR	PBP
10% decrease in revenue	3,061.17	31	1.33	3.24
20% decrease in revenue	1,246.30	22	1.18	4.12
10% increase in operating costs	4,147.14	35	1.39	2.87

The final sensitivity analysis was done to investigate the effect of variation in the discount rate on the financial indicators at a constant drying price of $2.11 per bag of maize and the result is shown in Figure 2. The analysis shows that when the discount rate increases, the NPV decreases. This is an indication that business start-ups are affected negatively in an environment where the opportunity cost is too high. This does not provide confidence to investors who may have to take loans to invest in the dryer business. In all the scenario analyses, profitability measures for the investment in the dryer business were generally stable and profitable.
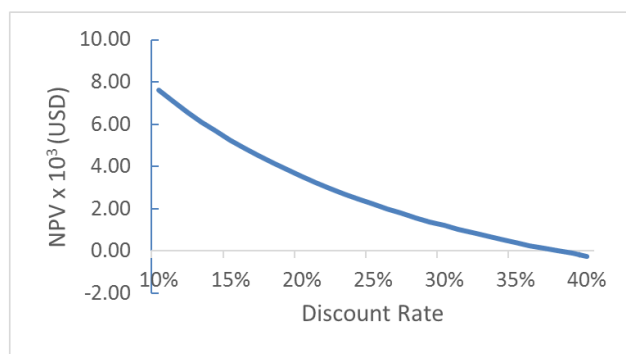
Figure 2. Effect of variations in the discount rate on the NPV.

4. Conclusions

The economic and financial viability of a 1-tonne capacity hybrid dryer for drying maize was successfully analysed using discounted and undiscounted investment appraisals methods such as NPV, IRR, BCR, and PBP.

The financial indicators of a case study show it is profitable and viable for an investment by a smallholder maize farmer or an investor to operate a dryer to provide drying services to maize farmers. The economic analysis over a 10-year lifespan operation of the dryer resulted in an NPV of Gh₵ 27,793.43 (US$ 4,876.04), and an IRR of 38%. Further analysis shows that at a drying charge of $2.11/bag, the initial investment in the dryer can be recovered within a PBP of 2 years and 7 months with a BCR of 1.48. The sensitivity analysis on the dryer operation revealed that variations in revenue, operating costs, and the discount rate showed a slight vulnerability of the financial indicators. At an assumed 10% decrease in revenue and 10% increase in operation costs, the NPV reduced to $ 3,061.17 and $ 4,147.14 respectively. However, under both scenarios, the IRR was higher than the discount rate and the BCR greater than one. This is an indication of a positive outlook for investment in the dryer and it provides confidence for scale-up and adoption by smallholder maize farmers in Ghana.

Finally, the study postulates that to mitigate a probable 15% post-harvest loss of maize grain in the study area, about 210 of the hybrid dryers are required to meet the drying needs of the smallholder maize farmers who produce on average about 30, 266.80 tonnes of maize per production season. This translates into about 420 direct job opportunities for the youth to operate these dryers and provide real-time drying services and prevent the economic loss of grains equivalent to $1,195,507 lost annually due to post-harvest loss of maize in the study area.

Acknowledgements

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