The Energy Center, KNUST

RENEWABLE ENERGY FOR EFFICIENT FOOD PROCESSING TO IMPROVE RURAL LIVELIHOODS (RE4FOOD) PROJECT

REPORT ON THE TECHNO-ECONOMIC ANALYSIS OF THE DEVELOPED INNOVATIVE 5-TONNE CAPACITY SOLAR BIOMASS HYBRID DRYER (SBHD) AT EJURA SEKYEREDUMASI MUNICIPALITY OF ASHANTI REGION, GHANA

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INTRODUCTION

Among the various methods of drying available, traditional drying, which makes use of the solar radiation has commonly been accepted as the simplest and least expensive technique. The sun's energy is a resource that is underutilized in many areas. The traditional drying technique has a lot of disadvantages as it exposes the product to unpredictable weather, dust, rain, uncontrolled drying, potential damaging by Ultra Violet (UV) radiation, and infestation by insects (Madhlopa *et al*., 2002). Mechanical dryers provide the best alternative for drying agricultural produce. These dryers are efficient, convenient, and easy to operate (Rondiguez *et al*., 2004). However, the progressive price increases for fuel hinders the promotion and use of mechanical dryers as they result in high cost. The solar dryer serves as a blend of the mechanical and traditional drying methods. It is relatively cheap and simple compared to the mechanical dryers and encourages drying under more hygienic conditions compared to the traditional drying method. The solar-biomass dryer has been found to be the most effective in terms of the time it takes to dry the produce (Simate, 2001). This technology, therefore, presents a better option for drying of maize in rural areas. However, the technical and economic viability of such systems are not known. This section of the report, therefore, sought to undertake a technical and economic analysis of the solar biomass dryer and compare it with existing mechanical dryers in the study area. The specific objectives were to;

1. Determine the financial viability of the solar biomass dryer;
2. Determine the profitability of using the solar biomass drier from the perspective of farmers, maize aggregators and traders;
3. Identify employment potential of the solar biomass drier in the study area.

Methodology

Economic feasibility is determined by evaluating the financial net benefits of the production of a certain commodity or service. To calculate the profitability of a project, a cost-benefit analysis (CBA) is often used. CBA is a widely used financial and economic appraisal tool for projects. It is particularly useful when a choice has to be made out of several projects (selection), and when the project involves a stream of benefits and costs over time, covering more than one year (from several to dozens of years (usually 20 years is taken as a maximum) (ICRA, 2015). A cost-benefit analysis was used in this study to investigate the costs and returns for the hybrid solar system and mechanical dryers . The financial analysis and various calculations were estimated using models developed in Microsoft Excel V16.

Financial Return on Investment

The method used for the determination of the financial return was the Discounted Cash Flow (DCF) approach. DCF analysis is a technique for determining what a business is worth today in light of its cash yields in the future. Unlike other valuations, DCF relies on Free Cash Flows (FCF). To a larger extent, FCF is a reliable measure that eliminates the subjective accounting policies and window dressing involved in reported earnings hence the choice of DCF. The main purpose of the financial analysis was to use the projects cash flow forecasts to calculate suitable net return indicators. Special emphasis was put on two financial indicators:

Net Present Value (NPV)

This is the difference between the present value of cash inflows and the present value of cash outflows. NPV is used in capital budgeting to analyze the profitability of an investment or project. NPV compares the value of a dollar today to the value of that same dollar in the future, taking inflation and returns into account. The NPV of a project is the sum of the discounted net flows of a project. It is a very simple and precise performance indicator. A positive NPV, NPV>0, means that the project generates a net benefit, and is generally desirable. The NPV of a project must also be higher than the NPV of mutually exclusive project alternatives (Chowdhury and Kirkpatrick, 1994). The NPV was calculated using the equation 1,

$$NPV = \sum_{t=0}^{n} a_{tS_t} = \frac{S_0}{(1+i)^0} + \frac{S_1}{(1+i)^1} + \cdots + \frac{S_n}{(1+i)^n} \ldots\ldots\ldots equation\ (1)$$

Where:

$S_t = The\ balance\ of\ cashflow\ at\ time\ (t)$

$a_t = The\ financial\ discount\ factor$

$a_t = \frac{1}{(1+i)^t}\ \ldots\ldots equation\ (2)$: Where: t is the time between 0 and n (the time horizon) and i is the discount rate.

Internal Rate of Return (IRR)

This is the discount rate in capital budgeting that makes the net present value of all cash flows from a particular project equal to zero. Generally speaking, the higher a project's internal rate of return, the more desirable it is to undertake the project. The decision rule for the IRR is that one accepts projects that have an IRR greater than the interest rate (Baum and Tolbert, 1985), in other words, if the discount rate equals or exceeds the opportunity cost of capital, it can be concluded that the projects is justified. The IRR was calculated using equation 3.

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

Where S_t is the balance of cash flow at time *t*

Financial Assumptions

1. Cash flows were discounted over a period of [1]15 and 20 years for the solar and mechanical drier respectively at a rate of 18% which is Ghana’s inflation rate as at 26th June, 2015 (GSS, 2015).
2. A rate of [2]5% of equipment and machinery cost was assumed as operation and maintenance cost in the financial analysis.

Technical Assumptions

[1] This is a typical life time for solar panels. It is also normally used to access the financial viability of projects.
[2] A rate of 3-5% is normally allowed from equipment and machinery cost for annual operation and maintenance.

Table 1 presents the technical parameters and assumptions considered for the financial analysis of the solar-biomass dryer.

Table 1 Technical parameters and assumptions considered for the financial analysis

Parameter	**Value**
Solar-biomass dryer	
Capacity of dryer (tonnes)	5
Number of batches per day	2
Number of hours required per batch of drying	8
Operational hours per year	2,688
Size of a bag of maize (kg)	130.00
Number of bags dried per day	77
Number of bags dried per week	462
Quantity of maize processed per year (tonnes)	1680
Number of bag of maize processed per year	12,923.08
Quantity of corn cobs required per hour (kg)	25.00
Quantity of corn cobs required per year (tonnes)	67.20
Average distance of farms to processing centre (km)	7.00
Cost of transportation of corn cobs per ton (USD)	11.43
Total amount of maize produced per year in the district (tonnes)	30,266.80
Number of driers required to process the total available maize	18
Quantity of corn cobs available in the district (tonnes)	7,566.70
Quantity of corn cobs required by the total number of driers (tonnes)	1,210.67
Direct employment generated by the total number of driers (persons)	72.06
Lifespan of drier (years)	15
Price charged per bag of maize (USD)	1.43
Mechanical dryer	
Capacity of dryer (tonnes)	11.7
Quantity of maize processed per year (bags)	4,000
Price charged per bag of maize (USD)	4.29

Estimation of the various cost components of the projects

a. Primary data (actual cost of construction of the solar drier and cost data provided by owners of mechanical driers) was used to estimate the various cost components (Investment, working capital and operation and maintenance cost).

Estimation of Investment cost

The investment cost considered in this study consisted of cost of land, machinery, civil works, and other expenses.

Estimation of operating and maintenance costs

The operating costs comprise all the data on the disbursements foreseen for the purchase of goods and services, which are not of an investment nature since they are consumed within each accounting period. The data was organized in a table that included:

1. The direct production costs (consumption of materials and services, personnel, maintenance, general production costs).
2. Administrative and general expenditures (salaries, transportation) .

Revenues expected from the various projects

The revenues expected will mainly come from monies realised from the provision of services (i.e. drying a bag of maize). The unit price and quantity produced were presented in the various models to determine annual total revenues generated from each projects.

Sensitivity analysis

Sensitivity analysis allows the determination of the 'critical' variables or parameters of the model. Such variables are those whose variations, positive or negative, have the greatest impact on a project's financial indices. The analysis was carried out by varying one element at a time and determining the effect of that change on NPV and, key parameters considered included:

1. Changes in the discount rate: discount rates from 0% to 30% were considered. One of the key variables that determine the NPV of the project is the discount rate. Depending on the decision to take one or other discount rate the project result may be bad, good, very good or excellent.
2. Based on the trend of drying charges using mechanical dryers in the target area, a 30% increase and decrease in the unit price for drying a bag of maize was used for the analysis.

Discussion of Results

Technical analysis of the solar biomass dryer

The solar biomass hybrid dryer (SBHD) is an integrated batch dryer system that utilizes both solar radiation and supplemental heat generated from a biomass furnace. The SBHD consists mainly of a solar tent that allows direct insolation for heat build-up and a biomass furnace for burning of biomass (maize stalk, husk and cob) to supplement the heat deficiency of the dryer during periods of low temperature. As shown schematically in Figure 1, the SBHD consists of the following major components: (1) a biomass furnace which burns biomass (rice husks, corn cobs, etc.) that is available in the farm; (2) an induced draft fan or blower which moves hot air from the furnace to the drying camber; (3) a solar PV system which provide the electrical energy for the blower, DC fans and bulbs (4) a drying chamber covered with transparent sheet known as Perspex. Grains to be dried are held on drying racks or shelves made of wire mesh spread across wooden beams. These racks are arranged in parallel rows with space between allowing easy access to the drying product.

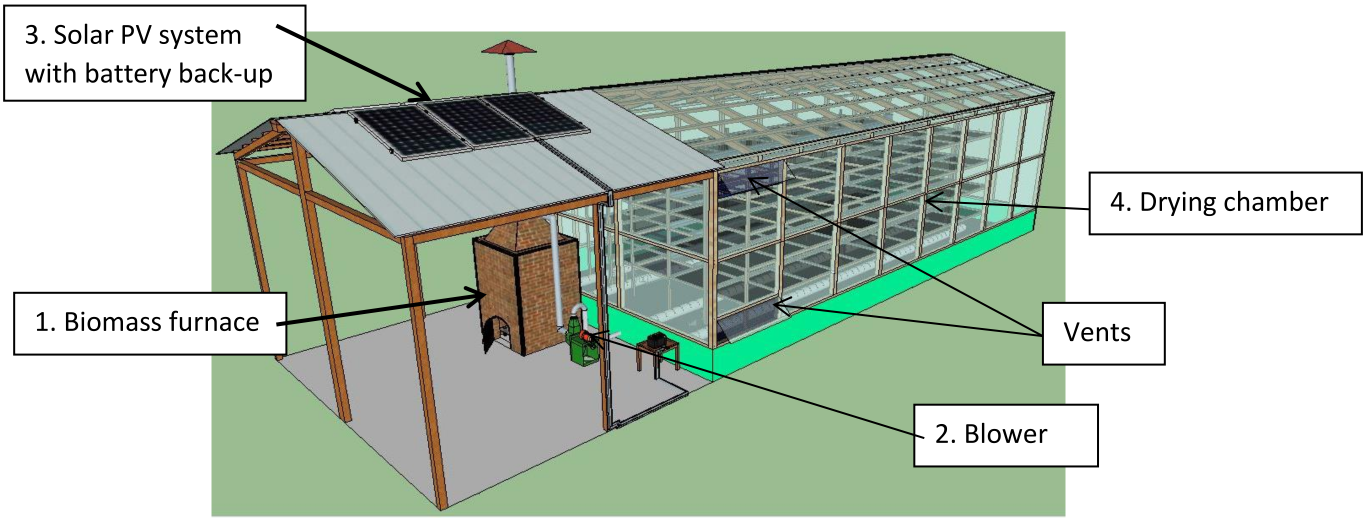

Figure 1: Schematic view of the integrated solar biomass hybrid dryer

With a dryer capacity of 5 tonnes, and an assumption that there will be two batches for drying within a day, maximum drying period of 8 hours was required to dry each batch, and this resulted in annual operational hours of 2,688. Based on these parameters, 77 bags of maize are expected to be dried each day. Annually, 1,680 tonnes of maize, which translates into 12,923.08 bags, is expected to be processed. Averagely 30,266.80 tonnes of maize is produced in the study area. Based on the capacity and number of bags of maize expected to be processed by the solar drier, 18 of such driers will be required to process the total quantity of maize generated in the district. This therefore translates into direct employment for 72 persons expected to operate these dryers in the district. As indicated earlier, corn cobs are utilized for heat generation when there is not enough solar radiation. The system requires 25 kg of corn cobs per hour and 67.20 tonnes annually. Using Residue to Product Ratio (RPR) of 0.25, 7,566.70 tonnes of corn cobs were estimated to be produced annually in the study area. This indicates that even if all the 18 proposed driers are in operation there will be enough corn cobs (1,210.67 tonnes).

Cost benefit analysis of the solar and mechanical dryer

Based on the technical parameters and assumptions presented in Table 1, the investment cost of the solar dryer at 5-tonne capacity was estimated to be $17, 106.76, obviously lower compared to the 11-tonne capacity mechanical dryer which is the only available dryer in the target area with capacity closer to the solar dryer (see Figure 2). It is important to note that, mechanical dryers are economically viable to operate at higher capacities due to economy of scale. The lower investment cost of the SBHD presents a very good alternative for farmer groups, NGO's, government and other private investors to invest in this technology. Annual operating cost of $7,550.4 is expected, which is lower than that of the mechanical dryer (see Figure 2). Annual revenues expected to be generated by the solar-biomass and mechanical dryer were $18,461.54 and $17,142.86 respectively. At a discount rate of 18%, NPV and IRR values of $38,447.46 and 63.74% respectively. This indicates that the solar drier is financially viable since it has a positive NPV (Chowdhury and Kirkpatrick, 1994) and IRR greater than interest rate of 25% in Ghana (BoG, 2015; Baum and Tolbert, 1985). The mechanical dryer is likewise financially viable since it has positive NPV and IRR greater than the interest rate (see Table 2). However, from financial perspective, the solar dryer is selected over the mechanical dryer since it has higher NPV and IRR values.

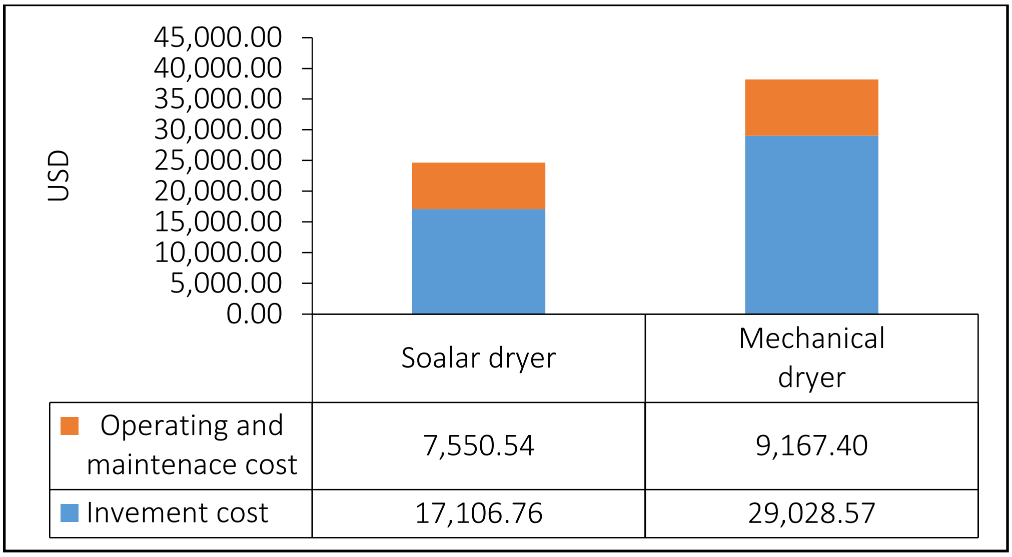

Figure 2: Investment and production cost for solar and mechanical dryer

Table 2: NPV and IRR for the solar and mechanical dryers

Parameter	**Solar dryer**	**Mechanical dryer**
IRR- 5 years	57.12%	11.61%
IRR- 15 years	63.74%	26.68%
IRR 20 years	-	27.25%
NPV	38,447.46	13,662.02

Figure 3 indicates the variation of NPV over the life of the two projects. It suggests that, the solar biomass dryer attains positive NPV between the first and second year and that of the mechanical dryer in the sixth year. This reinforces the point that, the solar dryer is more finically profitable than the mechanical dryer.

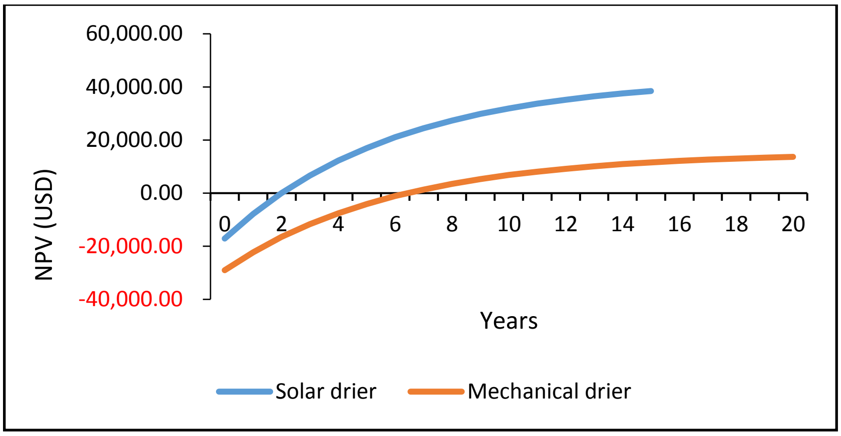

Figure 3: Variation of NPV over the lifetime of the two projects

Sensitivity analysis

Critical parameters identified in the CBA analysis were discount rate and prices charged for drying of maize using the solar dryer. Figure 4 shows variation of NPV as discount rate varies from 0-30%. From the Figure 4,it can be seen that, the solar biomass dryer project is financial viable for the range of discount rates considered, however, the solar dryer is not financial viable at discount rates greater than 28%.

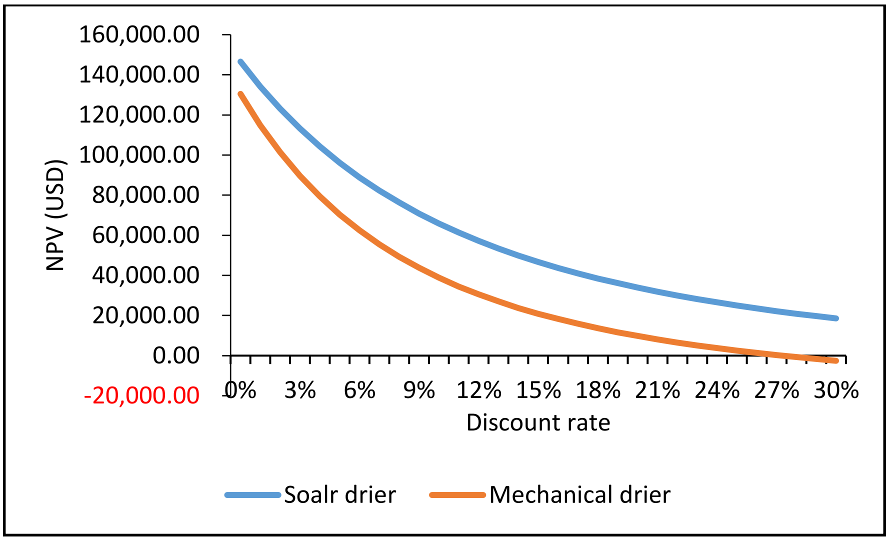

Figure 4: NPV curves for the two projects

Sensitivity analysis was also conducted on the solar dryer projects by varying the prices charged for drying a bag of maize (see Figure 5). A positive NPV was obtained when the price charged per bag of maize was decreased to $0.9/bag, at a discount rate of 18%. A higher financial return (NPV) was obtained when the price was increase to $2/bag. This indicates that, the dryer can be financially viable if the price charged per bag of maize fluctuates.

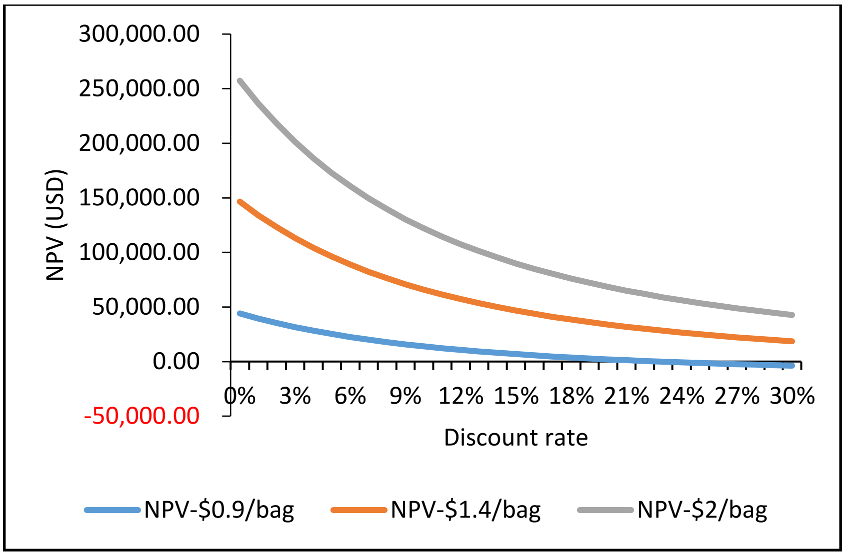

Figure 5: Effect of price variations NPV

Comparison on profitability of different drying methods to improved case (IC) scenario

This section of the study assesses the profitability of three drying methods including the case scenario (solar dryer) from the perspective of farmers. A case study of a farmer harvesting 10 bags of maize was used. From Table 2, it can be seen that, different profitability is achieved based on the drying method a farmer choses. The solar dryer had the highest net cash flow of $409.43. From the analysis it can be seen that a farmer that chooses to use the solar dryer over sun drying methods seeks to gain $120 more (see table 2).

Table 2: Profitability from the perspective of farmers among the various drying method

Parameter	**Solar dryer**	**Mechanical dryer**	**Sun drying**
Number of bags for base scenario	10	10	10
Quantity of maize left after moisture loss (20% to 12%) (bags)	9.2	9.2	9.20
Percentage losses during drying	-	-	12%
Quantity of maize left after drying losses (bags)	9.2	9.2	8.10
Unit cost for drying a bag of maize(USD)	1.43	4.29	1.14
Total Cost of drying the maize (USD)	14.3	42.9	11.43
Price of a bag of maize (USD)	46	46	37.14
Net cash flow(USD)	409.43	380.83	289.28

Employment and Income Generation Opportunities

Smallholder farmers throughout rural Ghana usually have low incomes. This prevents them from purchasing appropriate drying technology that assures extended storage life and food security for their crops. Therefore, paying low drying fees for the use of a SBHD available through nucleus farmers and FBE's gives smallholder farmers a better economical option to reduce their typical 30% post-harvest loss in maize. That way they also do not incur the expenses that come with equipment ownership such as maintenance and operating costs.

In Ghana, with 90% of farm holdings less than 2 ha in size (Chamberlin, 2007), farmers generally lack access to credit needed to invest in equipment and technologies for producing and preserving grains, oilseeds and pulses. The developed 5-tonne capacity solar biomass hybrid dryer (SBHD) is not aimed to be owned and operated by individual smallholder farmers. With the existing practice in Ghana where smallholder farmers are used to hiring and paying for labour and services such as ploughing and seeding their fields, and weeding, harvesting and threshing their crops, the availability of SBHDs provides them access to paying for affordable drying services within reasonable travel distances to their fields, household and trading outlets.

The developed SHBD has the potential to employ directly 4 persons in the management and operation of the dryer at the location where it is constructed. With an estimated number of 18 of such dryers to handle the average production rate of maize within the study area, there will be direct job opportunity for 72 persons. There are currently 65 farmer based organisation or enterprises (FBO/FBEs) who operate within the radius of the location where the SBHD is situated. Each organisation has membership between 25 and 35 people who are mainly farmers, aggregators, traders, local food vendors or processors. These members have direct access to the dryer and may potentially use the SBHD for drying maize particularly during the major season when the harvest period coincides with the rainfall season. Per the profitability analysis in Table 2, and assuming half of the members of the FBOs within the locality use the dryer, there will be about 1,105 people who may indirectly benefit from the dryer in terms of realising quality dried maize, and the additional income generated through the sale of the premium quality maize. Members that choose to use the solar dryer over sun/open air drying and mechanical drying method will gain $120 and $28 more for every 10 bags of maize dried using such systems respectively. Translated to the whole Municipality where 18 of the SBHD is required, indirect job and income opportunities will be available to about 19,890 people. The replication of the innovative system in other parts of the country can contribute in addressing the challenges of unemployment situation in the country.

Conclusions

This study sought to undertake a technical and economic analysis for solar biomass dryer, and compare it with an existing mechanical dryer in the study area. From the study it was concluded that:

1. Reduction in production values of maize in major season can be addressed if an affordable innovative drying system is introduced.

2. 12,923 bags of maize can be processed annually using the developed solar biomass hybrid dryer. This represents 5.56% of total maize produced in the Municipality.

3. 18 of the solar dryers will be required to process the total quantity of maize estimated annually (30,266.80 tonnes). With 4 workers required to manage and operate the dryer, direct employment for 72 persons can be generated within the study area. The existence of 65 FBOs with membership of 25 and 35 people may directly use the SHBD. Assuming half of such members' use the SHBD, indirect job and income opportunities can therefore be created for 780 to 1,105 people who operate as farmers, aggregators, traders, food vendors or processors living within the locality where the SBHD is situated.

4. At NPV of $38,447.63 and IRR of 63.74% estimated for the SBHD, an economic utilisation period of 15 years, with a payback period of approximately 2 years, this project demonstrated the viability of using the SBHD on a commercial scale for higher economic returns for investors and rural maize farmers.

5. From the financial and economic perspective, the solar biomass hybrid dryer is selected over of other drying methods in the locality such as open air/sun drying and mechanical drying methods. It is more profitable for farmers to use the solar biomass hybrid dryer compared to these other drying methods in the study area.

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