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Scientific Correspondence

Economic Analysis of A Business Model of An Inclined Solar Dryer

A. K. Singh*, Surendra Poonia and Dilip Jain

ICAR-CAZRI, Jodhpur-342003, Rajasthan, India

***Corresponding Author**
akcazri@yahoo.co.in

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The development of any region depends on its energy consumption. Conventional sources of energy generally lead to the emission of greenhouse gases, which in turn pollute the environment. It is therefore the need of the day to resort to a green energy source, which will help mitigate the CO_2 emission and make the environment less polluted. Given this, an economic analysis of a business model for the fabrication of an inclined solar dryer was considered. It will not only fetch income but also generate employment and mitigate CO_2 emissions. Therefore, the economic evaluation of the business of fabricating solar dryers was carried out. The values of economic parameters were determined and found very encouraging. In addition, the value of the Break-even point was also determined which came to 37 units which is equal to 111 dryers. The economic parameters were determined for fabricating 300 solar dryers annually. The net average annual benefit accrued from this business fabricating 300 solar dryers annually is INR 2,17,672. The values of other economic attributes, such as pay-back period (PBP), internal rate of return (IRR), net present value (NPV), and benefit-cost ratio (BCR) were found to be 0.47 yr., 225%, INR 1334026, and 13.8, respectively. In addition, this business can play a vital role not only in income generation but also in generating employment for four persons.

INTRODUCTION

The consumption of conventional energy sources such as coal, diesel, and petrol is increasing very fast with the increase in population. The development of any region depends on its energy consumption. Conventional sources of energy generally lead to the emission of greenhouse gases, which in turn pollute the environment. It is therefore the need of the day to resort to a green energy source, which will help mitigate the CO_2 emission and make the environment less polluted. Given this, an economic analysis of a business model for the fabrication of an inclined solar dryer was considered. It will not only fetch income but also generate employment and mitigate CO_2 emissions. Keeping these points in view, we have to search for alternative sources of energy that are green clean, and inexhaustible. Only renewable sources of energy can ensure the sustainable development of society. Our country depends on agriculture to a great extent. The production of fruits and vegetables poses a lot of problems because of their perishable nature. During the season, there is a glut in the market and sometimes these need to be sold at throw-away prices. To overcome this problem they are required to be dried for later use during the off-season. Given this, a business model for fabricating an inclined solar dryer was considered and its economic evaluation needs to be carried out.

Drying fruits and vegetables is done in the open sun. This poses the problems like dust contamination, insect infestation, and spoilage due to rains as well as uneven drying (Poonia *et al.,* 2018). The environmental effects of fuel wood burning have been reported in several literatures (Elliott, 2004; Tingem and Rivington, 2009; Panwar *et al.,* 2011; Huttunen, 2009). The arid zone of the country receives 6.0 kWh m^{-2} day^{-1} mean annual daily solar radiation at Jodhpur (Pande *et al.*, 2009). To generate employment in India, the development of the solar dryer business can be very advantageous It will not only fetch income but also generate employment and mitigate CO_2 emission. Therefore, the economic evaluation of the business of fabricating solar dryer needs to be carried out. This dryer can supplement conventional energy sources for starting a new business, economic feasibility needs to be assessed in terms of break-even analysis and economic attributes. Banks provide loans only based on the economic attributes of the project. Therefore, an attempt has been made to determine the economic feasibility of the fabrication of solar dryers to guide new entrepreneurs in their endeavor to establish a new business.

MATERIALS AND METHODS

Design of solar dryer

An inclined solar dryer (Area 1.25 m^2) was designed and developed at ICAR-CAZRI, Jodhpur. Its orientation was south facing tilted at 26 degrees which is the latitude of Jodhpur. It helped receive maximum solar radiation. The dimension of the dryer are given in the following figures (Figure 1 and 2).

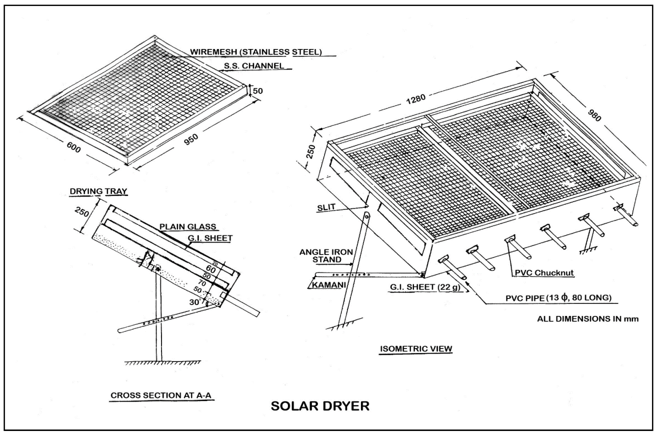

Figure 1. Schematic diagram of solar dryer

Figure 2. Solar dryer

Thermal efficiency of solar thermal devices

Efficiency of solar dryer (h)

The efficiency of solar energy in solar dryer has been worked out by using the following relation (Leon *et al.,* 2002; Poonia *et al.,* 2017, 2018):

$$\eta = \frac{ML}{A\int_0^{\theta} H_T\, d\theta} \quad \text{... (1)}$$

Where A = Absorber area (m^2); H_T = Solar radiation on horizontal plane (J m^{-2} hr^{-1}); L = Latent heat of vaporisation (J kg^{-1}); M = Mass of moisture evaporated from the product (kg); θ = Period of test (hr) and η = Efficiency of the solar dryer.

Economic analysis of solar dryer

For judging the economic viability of manufacturing solar dryer such as break-even point, net present value (NPV), payback period (PBP), benefit-cost ratio (BCR), annuity (A), and internal rate of return (IRR) were determined (Chandell *et al.,* 2017, Barnwal and Tiwari, 2008, Singh *et al.*, 2017, Poonia *et al.,* 2018 and Sodha *et al.*, 1991). Two types of cost i.e. fixed or ownership costs and variable or operating costs were determined for computing the Break-even point as given in Table 1.

Break-Even point (BEP)

The analysis of BEP was carried out to determine the minimum number of units for ensuring the profitability of the entrepreneur with a minimum scale of operation. Given as follows:

Fixed cost/yr. = BEP (x) X (Income/unit – Variable cost /unit)

$$BEP\ (x) = \frac{Fixed\ \cos t\,(Rs./\ yr))}{(Income\ from\ sale\ /\ units - Variable\ \ \cos t\ /\ unit} \quad \text{... (3)}$$

where, one unit is equal to three dryers

Economic attributes

The economic analysis of the fabrication of solar thermal devices was carried out and net present value (NPV), payback period (PBP), benefit-cost ratio (BCR), annuity (A), and internal rate of return (IRR) were taken into account for economic assessment considering the cost of material available at the manufacturing centre (Figure 3) and cost component as per Table 2, 3 and 4.

Net present value (NPV)

The net present value of solar devices was worked out using the following equation:

$$NPV = \frac{(E - M)}{a}\left[1 - \left(\frac{1}{1+a}\right)^n\right] - C \quad \text{... (4)}$$

- Initial cost (C) = INR 104000, a = 14% and n = 15 years

Table 1. Formulae and prevailing rates used to calculate fixed and variable cost

Type of cost	Component of cost	Formula	Remarks	Source
Fixed cost	Depreciation / yr.	$D = \frac{C - S}{L}$ D = INR 6250	C = Initial cost of solar devices = INR 1,04,000 Salvage value (S) = 10% of initial costLife of devices (L) = 15 years	Kepner *et al.,* 2005
	Interest on average Investment / yr.	$I = \left(\frac{C + S}{2}\right) \times \frac{i}{100}$ I = INR 8008	i = 14% per annum (Interest)	Kepner *et al.,* 2005
	Insurance & taxes	$I_n = \left(\frac{C \times in}{100}\right)$ I_n = INR 2080	in = 2% per annum	IS:9164-1979
	Housing/rent	Rent / INR	12 × 8000 = INR 96000	IS:9164-1979
	Fixed cost (FC) = D + I + In + Rent			
	Fixed cost (FC) = 6250 + 8008 + 2080 + 96000 = INR 112338			
Variable cost	Electricity	5 kWh/unit = 5 × 8 = INR 40/-	Unit (x) is number of units (solar dryer) fabricated per year	
	Repair and maintenance (R&M)	(R and M) = INR 60 per unit		Kumar *et al.,* 2013
	Materials	INR 21500/-		
	Operational and labour charges	25% of material cost = INR 5375/-		Kepner *et al.,* 2005
	• Variable cost (VC) = Electricity + R&M + Materials + Operational and labour charges/unit • Variable cost (VC) = 40 + 60 + 21500 + 5375 = INR 26975 • Income per unit sale = INR 30000			

Where, D = Depreciation, I = Interest on average investment, I_n = Insurance & taxes, RM= Repair and maintenance, P= Purchase price, S= Salvage value.

- Gross benefits from sale of one hundred units (E) = 30000 × 100 = 30,00000
- Cost of hundred units (M) = Electricity cost + Repair and maintenance + Materials cost + Operational and labour charges + Annual rent

  = (40+60+5375+21500) X 100+96000
  = INR 2793500/-

Where, C is the initial cost, a is the rate of interest, n is the number of years

The benefit-cost ratio (BCR)

The benefit-cost ratio was computed using the following formula

$$BCR = \frac{C + NPV}{C}$$

$$BCR = 1 + \frac{NPV}{C} \quad \text{... (5)}$$

Annuity (A)

The annuity (A) of the project indicates the average net annual returns. This term can be given as,

$$\text{A (Annuity)} = \frac{NPV}{\sum_{t=1 \text{ to } n} \left(\frac{1}{1+a}\right)^n} \quad \text{... (6)}$$

Pay back period (PBP)

The payback period was worked out using the following equation;

$$PBP = \frac{\log\frac{(E-M)}{a} - \left(\log\frac{(E-M)}{a} - C\right)}{\log(1+a)} \quad \text{... (7)}$$

Internal rate of return (IRR)

IRR can be determined using the following relationship and taking a low discount rate of 200% and a higher discount rate of 250%.

$$\text{IRR} = \text{lower discount rate} + \frac{\text{Difference of discount rate x NPV at lower discount rate}}{\text{(NPV at lower discount rate - NPV at higher discount rate)}} \quad \dots (8)$$

Energy saving

Annual energy saving from the use of these solar units was computed by using the following formula (Panwar *et al.,* 2013).

$$\text{Useful energy gained} = \frac{\text{A x efficiency x average daily insolation x 3600 x days of use}}{1000} \quad \dots (9)$$

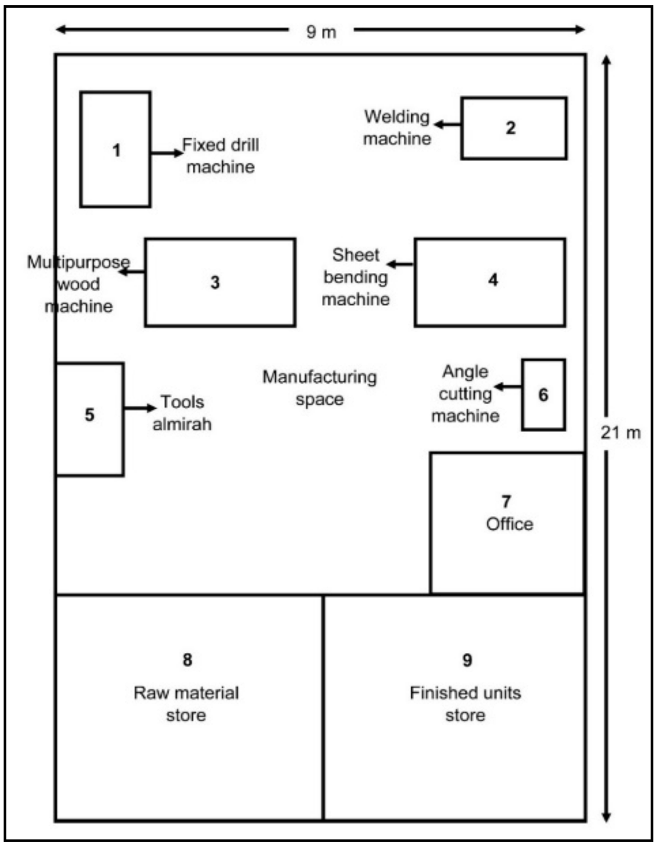

Figure 3. Layout of Solar devices manufacturing centre
1. Fixed Drill Machine; **2.** Welding Machine; **3.** Multipurpose wood machine; **4.** Sheet bending machine; **5.** Tools almirah; **6.** Angle cutting machine; **7.** Office; **8.** Raw material store; **9.** Finished units store

RESULTS AND DISCUSSION

In this business model, the land and building area for this solar devices manufacturing centre is 441m^2 and 81m^2 of the building (Figure 3). The number of working days in a year is 300 days and the production capacity is 100 units/year, which is 300 dryers/year. In this analysis, total fixed costs and variable costs were calculated. The purchase price of fabrication machinery and tools of animal feed and non-tracking solar cooker and solar dryer is INR 104000 and an appropriate discount rate of 14% was selected to reflect the time value of money. The break-even point was determined as the level of operation where total income from the sale of the units is equal to total expenses (both fixed cost and variable cost) musing equation 3.

Table 2. Details of investment costs

S. No.	Machines/tools	Quantity	Total cost (INR)
1.	Sheet-bending machine	01 no.	20000.00
2.	Wood planner-cum cutter with gauge	01 no.	40000.00
3.	Portable welding machine	01 no.	10000.00
4.	Hand drill with stand	01 no.	5000.00
5.	Cut off machine for angle cutting	01 no.	7000.00
6.	Hand cut-off machine	01 no.	2000.00
7.	Scissor	02 nos.	20000.00
8.	Small size hammer	02 nos.	
9.	Medium size hammer	02 nos.	
10.	Screw driver	01 set	
11.	Centre punch	01 nos.	
12.	wooden chisel	01 nos.	
13.	Tri-square	02 nos.	
14.	L-square	02 nos.	
15.	Wooden hammer	02 nos.	
16.	Measuring tape	02 nos.	
17.	Silicon machine	01 nos.	
18.	Spanner set	01 nos.	
19.	Drill bit set	01 nos.	
20.	Manual wooden planer	01 nos.	
21.	Glass cutter	01 nos.	
	Total	INR 104000	

The overall efficiency of the solar dryer depends on drying time, climatic conditions (insolation and temperature), the drying characteristics of the dried materials, and the structure of the drying devices etc. The average efficiency of utilization of solar energy in the solar dryer was calculated by equ (2) and it was found that about 17.57% of solar energy was utilized in this solar dryer. Sherrick *et al.* (2002) observed that the capital budgeting practices employed by large firms to make decisions were mainly IRR (88% firms) and NPV methods (63% firms). One reason for this conclusion is that a higher IRR indicates less risk (Chandel *et al.,* 2017).

Table 3. Details of operational cost

S.No.	Cost	(Volume/month)	Total cost (INR)
1.	Rent of land and building/month	One	INR 8000
2.	Carpenter/month	One	INR 18000
3.	Sheet metal cutter-cum-welder/month	One	INR 18000
4.	Store keeper cum sales executive/month	One	INR 18000
5.	Unskilled labour/month	One	INR 9000
	Total	INR 70000	

Table 4. Raw material for solar dryer

S.No.	Material	Quantity	Approx. price (INR)
1.	G.I. Sheet (24 gauge) 2.20 x 1.500	3.30 sqm	2500.00
2.	Plain glass (1.28 x 0.980 m)	1.25 sqm	700.00
3.	M.S. angle (37 x 37 x 6 mm)	4.65 sqm	1200.00
4.	Kamani (25 mm wide x 3 mm thick)	1.12 m	175.00
5.	PVC chuck nut	6 Nos.	75.00
6.	PVC pipe (13 mm f) 6 x 0.800	4.8 m	300.00
7.	Aluminium angle (25 mm x 25 mm)	4.52 m	350.00
8.	Wooden batten (0.025 x 0.025 x 0.980 x 2)	0.00122 cum	-
9.	Drying tray		
	(i) S.S. channel (50 mm x 50 mm) – 3.1 x 2	6.2 m	1166
	(ii) Wire mesh (stainless steel) (1.10 x 0.60) x 2	1.32 sqm	
	(iii) Hinges (100 mm long)	10 Nos.	
10.	Nut bolts/screws	250 g	100.00
11.	Fevicol	250 g	100.00
12.	Black board paint	1.5 lit.	100.00
13.	Zinc Chromate Primer	1.0 lit.	150.00
14.	Synthetic Enamel paint	1.0 lit.	175.00
15.	Rubber gasket (25 mm x 3 mm)	4.52 m	75.00
	Total (INR)	7166	

The values of five economic attributes, namely, benefit-cost ratio (BCR), net present value (NPV), annuity (A), internal rate of return (IRR) and pay back period (PBP) are presented in Table 5. The capital budgeting method based on NPV, IRR, Payback Period, and BCR can be used by entrepreneurs to derive a confident decision on investment (Baker, 2000). These values of economic parameters as given in table 6 show that there is no risk in starting the business.

Table 5. Economic attributes of solar thermal technologies

S.No.	Attributes economics	Values
1	BCR	13.8
2	NPV	INR 1334026
	A	INR 217622
4	IRR (per cent)	225
5	PBP (years)	0.47 years

CONCLUSION

Based on the values of BEP and other economic parameters such as BCR, NPW, IRR, A, and PBP the business of fabricating 300 solar dryers annually was found to have great potential. The dryer can mitigate about 850 kg CO_2 annually. It will not only save conventional energy but also make the environment clean. It can pave the way for switching to a green source of energy from a conventional one in addition to proving employment to four persons.

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