CHAPTER –VII

ECONOMIC ANALYSIS OF SOLAR BIOMASS HYBRID DRYER

7.1 Introduction

In order to evaluate the cost and practicality of the solution, dryer must be studied to save energy. For the success and commercialization of any technology it is essential to know the technology developed is economically viable or not. Therefore an attempt has been made for estimation of economics of the developed solar biomass hybrid dryers. The capital cost, variable cost, fixed cost, total cost, revenue and benefits are considered for the analysis. Various economic indicators like net present worth, benefits cost ratio, payback and rate of return values are also used for the economic analysis.

Sujata Nayak et al.[122] conducted economic analysis of hybrid photovoltaic-thermal (PVT) integrated solar dryer. It was concluded that the total energy payback period for hybrid PVT solar dryer is 5.6 years, which is much less than the expected life of the dryer. Total benefits of dried cauliflower are calculated as Rs. 362 and benefits of dried product will be higher if large quantities of products are taken for drying.

Sengar et al. [123] carried out economic evaluation of greenhouse for cultivation of rose nursery. The total construction cost of 80 m^2 arch shape greenhouse was Rs.100000/-. Suitability of the economics of greenhouse, four economic indicators such as net present worth, internal rate of return, benefit cost ratio and payback period were calculated for rose nursery. Net present worth of investment made on greenhouse, the internal rate of return, the benefit cost ratio, when rose nursery grown inside the greenhouse were Rs.453221, 53%, 4.5 respectively.

Barnwal et al.[124] analyzed the cost of a hybrid photovoltaic greenhouse dryer. In this paper the hybrid PV/T integrated green house dryer has been used to dry grapes under forced mode of operation. The initial investment for Rs. 27,400 gives the lowest payback period of about 1.25 years and the cost of drying of the grapes is the lowest for initial investment of Rs.27,400 i.e. Rs.4.52 per kg as per the results of his work.

Sreekumar [125], evaluated a roof-integrated solar air heating system for drying food stuffs. Detailed technical analysis was done on the system by four methods namely annualized cost, present worth of annual savings, present worth of cumulative savings, and payback period. The cost of drying 1 kg mango worked out to be Rs. 11 which was roughly half of that of an electric dryer. The payback period worked out to 0.54 year, much less than the estimated life of the system (20 years).

Ahmed Fudholi et al.[126] analyzed a techno economic solar drying system for seaweed in Malaysia. The results of economic analysis indicates that the double pass solar collector is best suited for marketing marine products as its payback period is as low as 2.33 years.

Jekayinfa et al. [127] conducted a study for the estimation of energy consumption of eight unit operation of small scale cashew nut processing in India. In the study field, solar energy, electricity and fuel are the major source of energy consumed for cashew nut processing. Finally the total energy intensity in the cashew nut industry varied between 0.21 and 1.161 MJ/kg,electrical energy varied between 00052 and 0.029 MJ/kg, while thermal energy varied from 0.085 to 1.064 MJ/kg.

The economic analysis is very important for processing industries as well as the end users to find out the cost of drying. The study was conducted using the standard economic tool with the following objectives:

- To study the economic feasibility of solar, biomass and hybrid system for cashew drying.
- To estimate the energy cost associated with conventional small-scale cashew processing industries.
- To individually compare the economic feasibility of solar-biomass hybrid in terms of payback period, rate of return, discounted cash flow and B/C ratio.

7.2 Materials and methods

7.2.1 Theoretical Approach of profitability methods

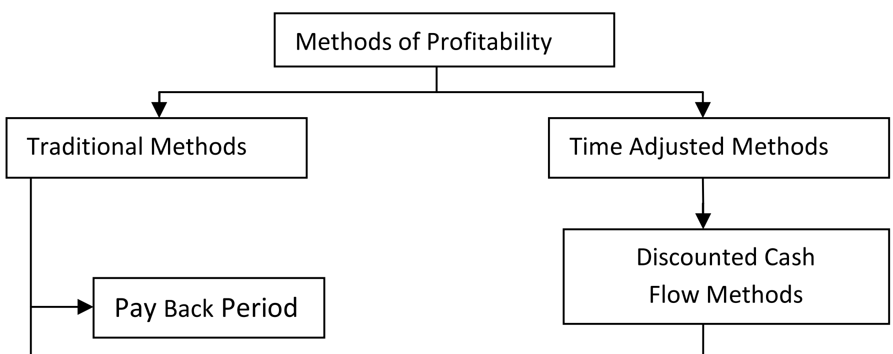


Fig. 7.1. Classification of profitability methods

7.2.2 Simple Pay Back Period

The simple payback period is calculated by dividing the initial investment by the annual cash-flows. The formula is

$$Payback\ Period = \frac{Initial\ investment}{Anual\ cash\ Benifit}$$

The payback method measures the time period between investment and its recovery. The returns are therefore referred to as cash benefits of revenues in excess of expenditure.

7.2.3 Accounting Method of Rate of Return

According to this method, the profitability of investment proposal is measured on the basis of accounting information derived from the financial statement. It is therefore, also known as the Accounting Rate of return Method (ARR).The accounting rate of return (ARR) is calculated by dividing the average income after taxes by the average investment or average book value after depreciation.

$$Average\ Rate\ of\ Return = \frac{Average\ Net\ Income\ after\ Taxes}{Average\ Investment\ over\ the\ life\ of\ the\ project}$$

Discounted cash Flow Method

The discounted cash flow technique (DCF) recognizes the changing value of money and it takes into account the fact that the same amount of money received today is more valuable than the one received after a year and so on. For investment projects stretching over several years, one should take into account the cash-flows expected from the project over future year and discounted them back to the present in order to determine the 'Net Present Worth of the investment. The expression used for discounted cash flow is as follows.

$$F = P\left(\frac{(1+i)}{100}\right)^n \tag{7.1}$$

7.2.4 Net Present Value

This method under discounted cash flow attempts to compare the present value of the future benefits with the present value of the investment. An important advantage of this method is that it allows comparison of the projects having different service lives, even if the life span of the project differs. The formula for finding out the total present value of all cash inflows generating out of an investment may be stated as follows.

$$NPV = \sum_{t=1}^{n} \frac{Rt + S}{(1+i)^t} \tag{7.2}$$

7.2.5 Revenue - dominated cash flow diagram.

Generalized revenue - dominated cash flow diagram to demonstrate the present worth method of comparison is presented in Fig 7.2.

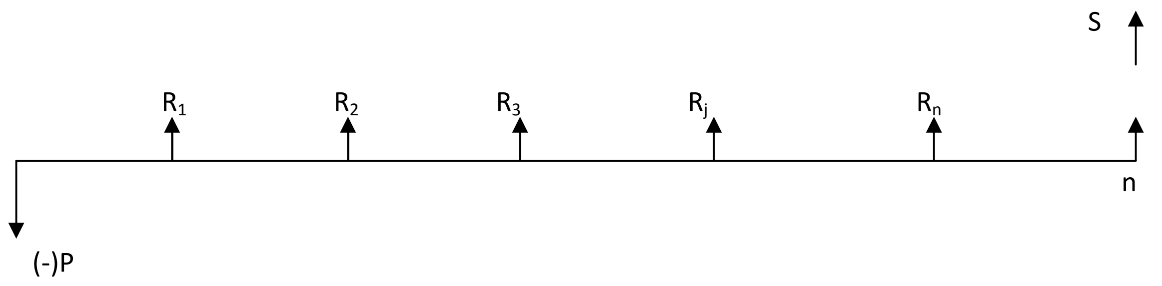


Fig. 7.2 Revenue - Dominated Cash Flow Diagram

Fig 7.2 represents an initial investment and R_j the net revenue at the end of j^{th} year. The interest rate is i, compounded annually. 'S' is the average value at the end of the n^{th} year.

To find the present worth of the above cash flow diagram for a given interest rate, the formula is

$$PW(i) = -P + R_1 [1/(1+i)^1] + R_2 [1/(1+i)^2] + \ldots\ldots$$

$$R_j [1/(1+i)^j] + R_n [1/(1+i)^n] + S [1/(1+i)^n] \qquad (7.3)$$

In this formula, the expenditure is assigned a negative sign and revenues are assigned a positive sign.

If some more alternatives are there to be compared with this alternative, then the corresponding present worth amounts are to be computed and compared. Finally, the alternative with the maximum present worth amount should be selected as the best alternative.

7.2.7 Benefit/Cost ratio analysis.

Cost-benefit analysis is a systematic process for calculating and comparing benefits and costs of a project. It has two purposes:

1. To determine if it is a sound investment/decision (justification/feasibility).
2. To provide a basis for comparing projects. It involves comparing the total expected cost of each option against the total expected benefits, to see whether the benefits outweigh the costs, and by how much.

7.2.8 Life cycle cost analysis

Life Cycle Cost analysis is the systematic, analytical process of evaluating alternative courses of action early on in a project, with the objective of choosing the best alternative to employ scarce resources.

Annualized uniform cost, unacost (R) is defined as the product of the net present value of the system and capital recovery factor (CRF)

Annual Cash Flow (CF) = Savings from RE based dryer or cost of electricity in conventional dryer.

Annualized Uniform cost/ Unacost(R) = P_{NPV} x CRF

$$R = \frac{P_{NPV} * i(1+i)^n}{(1+i)^n - 1} \quad (7.4)$$

$$\text{Annualized salvage value } R' = \frac{S}{(1+i)^n - 1} \quad (7.5)$$

$$\text{Annualized cost of dried cashew kernel} = R - R'$$

$$\text{Cost of Drying Cg} = (\text{R/dried product per year}) \quad (7.6)$$

$$\text{Total Benefits B} = \text{CF} - (R - R') \quad (7.7)$$

7.2.6 Assumptions

The following assumptions were made to assess the economic feasibility of solar biomass hybrid dryer for cashew drying.

1. The useful life of the solar dryer, biomass dryer and hybrid dryer are taken as 20, 10 and 15 years respectively.
2. Dryer processing capacity is 40 kg/batch/day.
3. The discount rate is 8 percent.
4. The dryer can be operated 200 days in a year.
5. The annual maintenance cost of the solar dryer, biomass dryer and Hybrid solar dryer are taken as 1%, 2 % and 3% respectively.

   The economic indicators like payback period, cost-benefit and life cycle cost were used to perform the economic analysis of solar biomass hybrid dryer.

7.3 Results and Discussion

7.3.1 Cost analysis of cashew kernel drying by conventional system (Steam drying)

Table 7.1. Energy cost of conventional drying

S.No	Factor	Existing conventional system
1	Dryer capacity (kg)	180kg
2	Energy / batch (MJ)	575.64 MJ
3	Energy/day/batch (kwh)	159.9 KWh
4	Energy per kg (kwh/kg)	0.888 KWh
5	Energy consumption for 40kg	35.52 KWh
6	Annual Total Energy consumption	7104 KWh
7	Annual Energy Cost (Rs) @ Rs5.6 per unit	Rs 39787
8	Specific cost (Rs/kg)	Rs 4.97 /kg

The total energy consumption and energy cost associated with drying of 40 kg of cashew kernel can be observed in Table. 7.1. The energy consumption was 7104 kWh and the specific cost of drying per kg of cashew kernel is around Rs 5/kg. The energy required to achieve the moisture reduction from 10 % - 5 % can be achieved using renewable energy based drying systems. The total amount of electrical energy used in the conventional dryer can be reduced substantially by adapting renewable energy based dryer.

7.3.2 Analysis of initial cost of Renewable energy based dryer

The economic feasibility of the hybrid dryer for drying of cashew was calculated by considering the initial investment of the dryer, repair and maintenance cost, cost of raw material. The cost calculations of different raw materials used for fabrication of the system are summarized in Table 7.2.

Table 7.2. Initial cost of components of Renewable energy based dryer

Item	Specification	Quantity	Rate(Rs)	Total(Rs)
Solar Air collector				
Glazing	4mm thick(21.12 ft^2)	2 glass	90/sq. feet	3802.00
Aluminum L-Angle	¾ x ¾ inch x 2mm	5 length	270/length	1350.00
GI Sheet	8’ x 4’ x 1.6mm	3 sheet	2550/	7650.00
Aluminum absorber plate	8’ x 4’ x 2mm	1 sheet	5880	5880.00
Step Angle	1/2 “	5 length	250/length	1250.00
Rivet	1“	200	1/unit	200.00
Glass Wool Insulation	-	10 Kg	40/ Kg	400.00

Labour cost				3500.00
	Total			24032.00
Drying Chamber				
GI Sheet	8' x 4' x 1.6mm	4 sheet	2550/	10200.00
Aluminum L-Angle	¾ x ¾ inch x 2mm	5 length	270/	1350.00
Perforated aluminum	8' x 4' x 1.5mm	2 sheet	3350/	6700.00
Square Pipe	¼' x ¼' x 1.6mm	5 length	500/	2500.00
Glass Wool Insulation	-	10 Kg	40/ Kg	400.00
Rivet	1"	200	1/unit	200.00
Labour cost				3000.00
	Total			24350.00
Blower				
Blower	0.37 KW, 0-2800 rpm,	1	10000	10000.00
Connecting Pipe	3" MS pipe	1 length	2500/	2500.00
Connecting Pipe	1.5" MS Pipe	1 length	850/	850.00
	Total			13350.00
Biomass heater				
GI Sheet	8' x 4' x 1.6mm	1 sheet	2550/	2550.00
MS Sheet	6mm (1.25m x 2.5m)	1 sheet	4100/	4100.00
Glass Wool Insulation	-	8 Kg	40/ Kg	320.00
Chimney Pipe	6" x 1m	1m	1320/ m	1320.00
Stand	20"dia x 10mm	1 piece	300	300.00
Stand Pipe	1½ " x 1"	3 pipe	200/pipe	600.00
Rivet	1"	50	1/unit	50.00
Labour cost				2000.00
	Total			11240.00

Table 7.3. Initial Cost of Renewable Energy based dryers

S.No	Component details	Solar dryer	Biomass dryer	Hybrid dryer
1	Solar air collector	+	-	+
2	Drying chamber	+	+	+
3	Blower	+	+	+
4	Biomass Heater	-	+	+
	Total cost	Rs.61, 732	Rs.48, 940	Rs.72, 972

+ Applicable

-Not Applicable

The initial investment for the three cases of dryer viz solar, biomass and hybrid dryer are Rs.61,732, Rs.48,940 and Rs.72,972 respectively. It is arrived by adding the materials cost of the components of the dryer (Table 7.3).

7.3.3 Economic analysis of solar biomass hybrid (Renewable Energy based dryer for Cashew processing)

Table 7.4. Initial investment and annual cash flow data

S.No.	Factor	Solar dryer	Biomass dryer	Hybrid dryer
1	Initial Investment (P) in Rupees	61732	48940	72972
2	Salvage Value (S) (@10% of P) in Rupees	6173	4894	7297
3	Annual Savings (Conventional Energy Cost) in Rupees	39787	39787	39787
4	Annual Operating Cost (Annual Fuel Consumption and Cost) in Rupees	0	For 8 hours operation: 4 kg/Batch/day Cost = 4*200*Rs.2 = Rs.1600	For 8 hours operation: 2.5 kg/Batch/day Cost = 2.5*200*Rs.2 = Rs.1000
5	Annual Cash Flow (3) – (4)	39787	38187	38787
6	Maintenance Cost	@1% of P = 617	@2% of P = 980	@3% of P = 2190
7	Total Cost (4) + (6)	617	2580	3190
8	Expected Economic Life	20 years	10 years	15 years
9	Time value of money (Annual Interest Rate in %)	8%	8%	8%

10	Annual Cash Benefit (3) – (7)	39170	37207	36597

The above Table 7.4 comprises the data about the factors like the initial investment, salvage value, annual savings, conventional energy cost, operating and maintenance cost, expected economic life of asset, time value of money and annual cash benefit for all the three types of renewable energy based dryers.

7.3.4 Economic analysis using simple payback period method:

Table 7.5. Simple payback period

S.No	Factor	Solar	Biomass	Hybrid
1	Initial Investment (P)	61732	48940	72972
2	Annual Cash Benefit	39170	37207	36597
3	Pay-Back Period in Years	1.58	1.32	1.99

Simple Pay Back Period = Initial Investment / Annual Cash Benefit

Based on the estimated Initial and annual operating costs of the drying system for drying of cashew kernel (Table 7.5), the payback period of the solar ,biomass and hybrid drying system for this product is estimated and found to vary between 1.3 to 2 years. The payback period of the biomass dryer is 1.34 years less than solar and hybrid dryers, which indicates that within this short period, the investment can be recovered (Table 7.6). The amount invested in hybrid dryer can be recovered within 2 years .Both of these systems solar and biomass dryer have almost the same payback period, but considerable increase in initial cost and number of components make hybrid system payback period higher than other two systems.

7.3.5 Economic analysis using accounting rate of return method:

Accounting rate of return

= Average Net Income / Investment over the life of the Project

From the Table 7.6, it can be inferred that out of these three renewable energy based dryers biomass dryer gives the highest rate of return (75%) when compared to other two dryers. Hybrid dryer gives the lowest return, nearly 50% whereas solar dryer gives 65% rate of return.

Table 7.6. Accounting rate of return

S.No	Factor	Solar	Biomass	Hybrid
1	Annual Cash Benefit	39170	37207	36597
2	Initial Investment (P)	61732	48940	72972
3	Salvage Value (S)	6173	4894	7297
4	Net Investment (2) – (3)	55559	44046	65675
5	Expected Life of the Project	20 years	10 years	15 years
6	Average Net Investment (4) /	2778	4410	4378
7	Average Net Income (1) – (6)	36392	32797	32219
8	Accounting Rate of Return	65.5%	74.5%	49.1%

7.3.6 Economic analysis using discounted cash flow method (Net Present Value):

Present Worth Factor (P/F) calculations – Formula: $1/(1+i)^n$ where i = 8%

Table 7.7. Net Present Value (NPV)

N	P/F	N	P/F	N	P/F	N	P/F
1	0.9259	6	0.6289	11	0.4292	16	0.2915
2	0.8573	7	0.5834	12	0.3698	17	0.2703
3	0.7937	8	0.5405	13	0.3676	18	0.2500
4	0.7353	9	0.5000	14	0.3491	19	0.2315
5	0.6897	10	0.4630	15	0.3155	20	0.2146

From the above Table 7.7 , $\sum (1 / 1.08^{20}) = 9.8068$ (for 20 years)

$\sum (1 / 1.08^{10}) = 6.7177$ (for 10 years)

$\sum (1 / 1.08^{15}) = 8.5489$ (for 15 years)

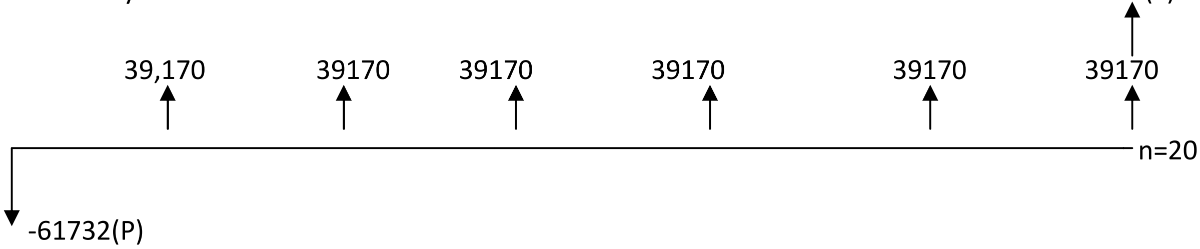
For Salvage value: $(1 / 1.08^{20}) = 0.2146$ (for 20 years)

$(1 / 1.08^{10}) = 0.4632$ (for 10 years)

$(1 / 1.08^{15}) = 0.3152$ (for 15 years)

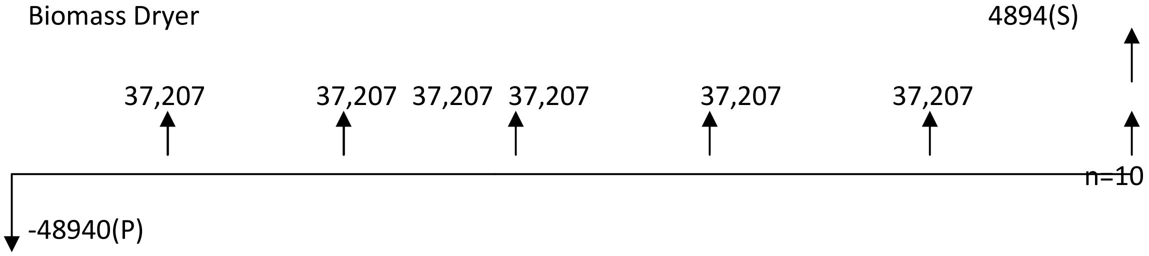
Present value of the future benefits

Solar Dryer

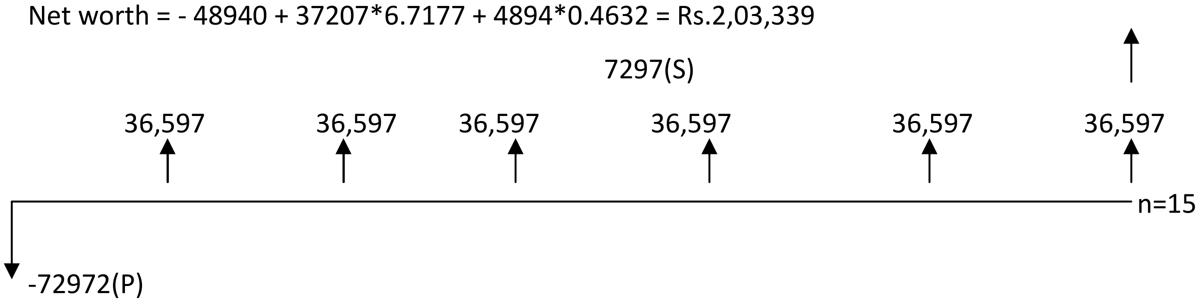


Net worth = - 61732 + 39170*9.8068 + 6173*0.2146 = Rs.3,23,725

Biomass Dryer



Net worth = - 48940 + 37207*6.7177 + 4894*0.4632 = Rs.2,03,339



Net worth = - 72972 + 36597*8.5489 + 7297*0.3152 = Rs.2,42,192

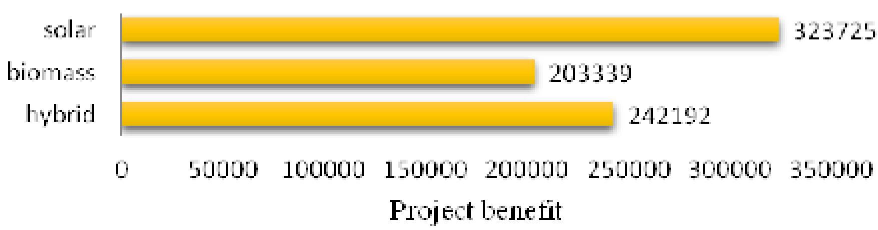


Fig. 7.3. Project benefit using net present value

From the above Fig 7.3 it can be inferred that solar dryer can be considered as the best choice on the basis of highest future worth (Rs. 323725) followed by hybrid dryer (Rs. 242192) and biomass dryer (Rs. 203339).

7.3.7 Economic analysis using Benefit-Cost ratio (Life Cycle Analysis)

Table 7.8. Benefit-Cost ratio (Life-Cycle Analysis)

S.No.	Factor	Solar Dryer	Biomass Dryer	Hybrid Dryer
1	Initial Investment (P)	61732	48940	72972
2	Salvage Value (S)	6173	4894	7297
3	Annual Savings	39787	39787	39787
4	Annual Operating	0	1600	1000
5	Annual Cash Flow (3)	39787	38187	38787
6	Maintenance Cost	@1% of P = 617	@2% of P = 980	@3% of P = 2190
7	Total Cost (4) + (6)	617	2580	3190
8	Expected Economic	20 years	10 years	15 years
9	Time value of money	8%	8%	8%
10	Annual Cash Benefit	39170	37207	36597
11	Capital Recovery	0.102	0.149	0.117
12	Annualized Uniform	(Rs.61732*0.102)	(Rs.48940*0.149)	(Rs.72972*0.117)
13	$R' = \frac{S}{(1+i)^n - 1}$	Rs.134.86	Rs.338	Rs.269
14	Annualized Cost of	Rs.6154	Rs.6955	Rs.8257
15	Cost of Drying	(6289/8000)	(7293/8000)	(8526/8000)
16	Total Benefits	(Rs.39170-6154)	(Rs.37207-6955)	(Rs.36597-8257)
17	Benefit-Cost Ratio	5.23	4.15	3.32

Costs of processing of cashew kernel in the different renewable energy based dryers are shown in Table 7.8. It was found that cost of drying is as low as Rs 1 /kg in all the three systems. The cost-benefit ratio was also high which shows the potential of using solar dryers in place of conventional dryers. The B/C ratio of solar dryer was highest among all the dryers because of less operating cost and nil fuel cost. The next system worth considering is biomass dryer with B/C ratio 4.15 followed by Hybrid dryer. The slight reduction in B/C ratio is due to higher initial cost, fuel cost and operating cost of biomass and hybrid dryers. Solar, biomass and hybrid are economically viable than conventional drying system in terms of environmental benefits associated with adoption of this technology.

7.6 Conclusion

Renewable energy-based drying systems with loading capacity of 40/kg were proposed for application in small scale cashew nut processing industries. A techno economic analysis of drying cashew kernel in solar, biomass dryers and hybrid dryers was carried out. The following conclusions could be drawn from the study

- The cost of drying of cashew kernel is lowest (Rs 0.8/kg) for solar dryer with initial investment of Rs 61732.
- The estimated payback period of the hybrid dryer is about 1.99 years. The initial investment of biomass dryer (Rs 48,940) gives the lowest payback period of about 1.32 years.
- Biomass dryer gives the highest rate of return (75%) whereas the hybrid dryer gives the lowest rate of return nearly 50%.
- Solar dryer is the best option based on the cash discounted future worth and Benefit cost ratio
- The developed system was found be economically suitable for processing of 40 kg/batch of cashew kernel.
- The economic effectiveness of hybrid dryer can play a vital role in bringing sustainable energy to small scale cashew farmers in the rural communities of India.