Economics of Solar Drying

Deepali Atheaya

Abstract Solar drying is an ancient and inexpensive technique used for the preservation of agricultural item. Solar drying involves the removal of moisture content from crop. It is very important that the solar crop drying system should be cost-effective. Different methods of solar drying have been developed like open sun drying and greenhouse solar drying. The recent development in this area is greenhouse photovoltaic thermal mixed-mode drying in which electricity is also produced while crop drying is done. This system is quite useful for people living in remote areas. The solar drying of commercial industrial crops such as cotton, jute, sugarcane, tobacco, and ground nut has been popular and feasible. There is a need to invent cheaper solar drying methods to meet the demands of farmers of developing countries.

Keywords Cash flow • Uniform annual cost • Payback period • Net present value

1 Introduction

The controlled drying of crops is essential to ensure good quality of crops. It is evident that the cost of solar drying system should be studied to evaluate its performance and feasibility. The analysis of solar drying systems has been done on the basis of prime factors given as:

- Money spend in fabrication of solar dryer system
- Annual maintenance amount for the above system
- Life cost of solar drying system
- Salvage value of system

The economic evaluation of solar energy dryer is one of the key means which decides the overall performance of the system. The economic analysis of various solar drying systems can be done by unacost method, sinking fund factor method,

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and cash flow diagrams, by calculating payback period. For the economic analysis of unconventional energy resources, the CO_2 credit earned by utilizing unconventional energy resources must be evaluated. Also the effect of embodied energy of renewable energy system on environment should be studied.

Bala et al. (2003) studied pineapple drying by means of solar tunnel dryer. The quality of dried pineapple was found to be best. Janjai and Tung (2005) have designed solar dryers which use air collectors placed at the rooftop. The invested rate of return and payback time period were found to be 70.3% and 3.9 years. A hybrid photovoltaic thermal greenhouse dryer has been designed and fabricated by Barnwal and Tiwari (2008). A novel mixed-mode solar greenhouse dryer to dry red pepper and grapes was proposed by Elkhadraoui et al. (2015). The economic analysis indicated payback time period as 1.6 years when the life of the system was 20 years. Kurt et al. (2015) investigated the economic performance of solar sludge drying by employing greenhouse solar dryer system. It was reported that though the capital cost of greenhouse solar dryer was more than conventional thermal dryer, but due to less energy requirements, it proved to be cost-effective. Nabnean et al. (2016) presented a novel design to dry osmotically dehydrated cherry tomatoes. The payback time of the dryer was 1.37 years. Dejchanchaiwong et al. (2016) studied mixed-mode and indirect solar drying. It was observed that the performance of mixed-mode solar dryer was excellent as compared to other methods. Recently, Misha et al. (2016) investigated the performance of solar dryer used to shrink the moisture content of crushed oil palm leaves.

The economic study of solar drying system is essential for the performance estimation. It also helps in the system optimization to benefit the user. The overall cost analysis has been done by critical understanding of system with the help of cash flow diagrams and payback diagrams. Sangamithra et al. (2014) have developed a polyhouse dryer and found it to be cost-effective. It was noted that the heat transfer coefficients between the greenhouse and open conditions were in the range 0.26–0.34 W/m^2 K. Recently Tiwari and Tiwari (2016) fabricated a PVT mixed-mode dryer. It was observed that the above system provided better product quality as compared to the conventional solar drying system.

2 Evaluation of Solar Drying Cost

If the initial present cost to fabricate solar crop system or any other system at zero time ($n = 0$) at an interest rate “i” per year is “A,” the cash flow illustration is given in Fig. 1.

After year 1 the future value will be as follows:

$$F_1 = A + i \times A \tag{1}$$

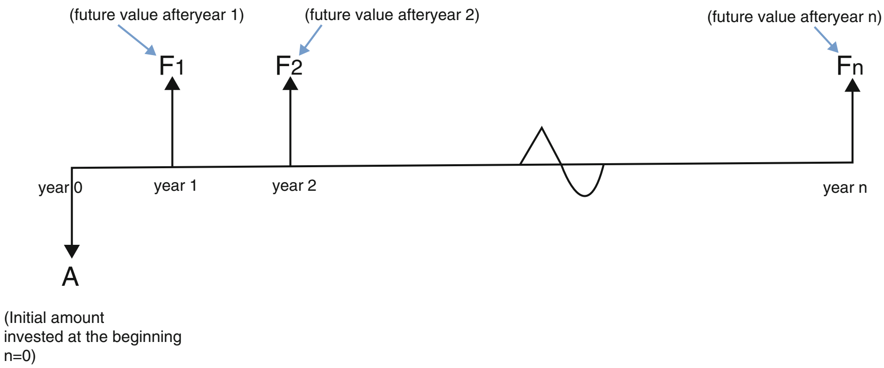

Fig. 1 Cash flow illustration for the evaluation of solar drying system cost

$$= A \times (1 + i) \tag{2}$$

Again after 2 years the new future value (F_2) will be given as:

$$\begin{aligned} F_2 &= F_1 + F_1 \times i \\ &= F_1 \times (1 + i) \qquad (3) \\ &= A \times (1 + i)(1 + i) \end{aligned}$$

$$= A \times (1 + i)^2 \tag{4}$$

After a period of 3 years the future value will be as follows:

$$F_3 = A \times (1 + i)^3 \tag{5}$$

Following the above pattern, the future value after n years will be as follows:

$$F_\mathrm{n} = A \times (1 + i)^n \tag{6}$$

To make a general equation $F_n = F$, the expression for the determination of future value at the end of n years is given as:

$$F = A \times (1 + i)^n \tag{7}$$

Now for the case when ($F > A$; I > 0) by means of compound interest principle, Eq. (7) can be written as:

$$F = A \times F_\mathrm{CI} \tag{8}$$

where F_CI {compound interest factor} = $(1 + i)^n$.

Therefore, it can be inferred that future value is the product of present cost and compound interest factor.

Q. 1 Calculate the rate of return of an open solar dryer of cost USD 600 compounded to USD 820 over a 6-year period.

Solution Cost of solar dryer A = \$ 600

n = 6 years

Future value = F_6 = F = \$ 820

i = ?

820 = 600 1 + i

By solving the above equation, the rate of interest $i = 5.23\%$.

Now, let us consider the situation when 1 year has been divided into "q" equal intervals.

Therefore, new period will be equal to product of period and q equal intervals:

$$N = n \times q$$
$$i^{‘} = i/q$$

Therefore, another expression for the future value will be:

$$F = A \times (1 + i/q)^{nq} \tag{9}$$

The above expression can be rewritten as:

$$F = [A \times (1 + i/q)^{q}]^{n} \tag{10}$$

The above expression (1+ $i/q)^q$ can be further expressed as:

$$(1 + i/q)^{q} = 1 + \text{effective rate of return} \tag{11}$$

For case (a) when $q = 1$,

$$\text{Effective rate of return} = (1 + i/1)^{1} - 1 = i \tag{12}$$

For case (b) when $q > 1$,

$$\text{Effective rate of return is greater than } ‘i’ \tag{13}$$

2.1 Simple Interest

Simple interest is calculated by multiplying the principal amount by the interest rate and the number of years in a loan:

$$\text{Future value } F = A \times (1 + n \times i) \quad (14)$$

Q. 2. Calculate the time taken for money to be tripled if compounded every year at 15% per year?

Solution The money tripled in "n" number of years or $F = 3A$.

From Eq. (7)

$$F = A \times (1 + i)^n$$
$$3A = A \times (1 + i)^n$$

The solution of above equation gives number of years as 7.95 years ~ 8 years.

Q. 3. Evaluate the effective rate of return for (i) 20% interest and $q = 2$ and (ii) 25% interest and $q = 4$.

Solution From Eq. (8) we know Effective rate of return = $(1+ i/q)^q - 1$

(i) $i = 20\%, q = 2$

$$\text{Effective rate of return} \quad (1 + 0.20/2)^2 - 1$$
$$= 0.29$$

(ii) $i = 25\%, q = 4$

$$\text{Effective rate of return} \quad (1 + 0.25/4)^2 - 1$$
$$= 0.125$$

Q.4. Mr. Smith took a loan of USD 20,000 from a bank. He returns USD 25000 at the end of the year. Calculate the rate of interest paid by Mr. Smith.

Solution From the Eq. (11)

$$F = A \times (1 + n \times i)$$
$$n = 12/12 = 1$$
$$\$25000 = \$20000(1 + 1 \times i)$$

Solving the above equation gives the value of interest rate as 0.2%.

Q. 5. Mr. Daniel borrowed USD 18,000 from bank at 15% for duration of 5 years and 6 months. Determine the money paid by him considering the compound interest.

Solution By following Eq. 11

$$\begin{aligned} F &= A \times (1 + n \times i) \\ &= 18000[1 + (6/12) \times (0.1)] \\ &= 18000 \left[1 + 1.075\right. \\ &= \$19350 \end{aligned}$$

Now by using Eq. (7)

$$\begin{aligned} F &= A \times (1+i)^n \\ &= 19350(1+0.15)^6 \\ &= \$44757 \end{aligned}$$

Q. 6 Mr. Niel takes a loan of USD 2500 to buy a greenhouse solar dryer, and he returns USD 3000 after 6 months. Evaluate the rate of interest paid by him.

Solution By following Eq. 11

$$\begin{aligned} F &= A \times (1 + n \times i) \\ 3000 &= 2500[1 + (6/12) \times i] \\ i &= 0.40 \\ i &= 40\% \end{aligned}$$

Q. 6a In the 5-year development plan of a state, it was decided to implement solar drying technologies to 30 million farmers. Calculate the required growth rate to achieve the potential of better solar drying technologies in the state in the next 5 years when the technology is distributed to 10 million.

Solution We know from Eq. 7 $F = A \times (1 + i)^n$

$$F = 30 \text{ million},\ A = 10 \text{ million}, n = 5 \text{ years}$$

Taking log on both sides and solving further

$$\text{Log}\ (30/10) = 5 \log\ (1 + i)$$

Solving the above equation, we get $i = 9.9\%$.

2.2 Present Value Calculation of System

From Eq. (7) the future value can be calculated as:

$$F = A \times (1+i)^n$$

The above equation can be rewritten as:

$$A = F \times (1+i)^{-n} \tag{15}$$

The present value can be calculated by multiplying the future value and the present value term

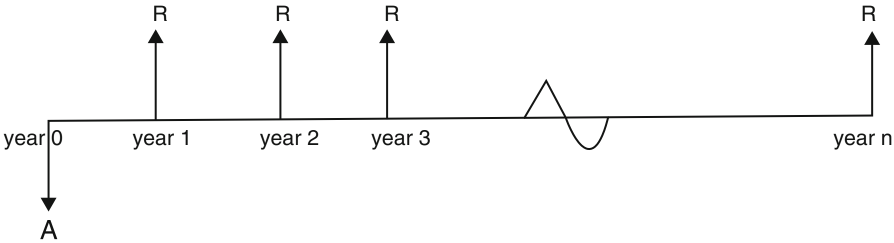

Fig. 2 Drawing showing unacost for n years

$$f_{PV} = (1 + i)^{-n} \tag{16}$$

From Eq. (8) we know that $F_{CI} = (1 + i)^n$

$$F_{CI} \times F_{PV} = 1u$$

2.3 Uniform Annual Cost (Unacost Method)

The comparison of various systems can be done by annualized uniform method. The term "una" means "uniform annual." Therefore, unacost implies uniform annualized cost. Figure 2 shows the unacost (R) for each year for "n" number of years.

In the above diagram, unacost is denoted as "R." Initially the present value "A" at $n = 0$. From Eq. (15) the present value A is given as:

$$A = R \times [(1 + i)^{-n}]$$

$$A = A = R\left[\frac{1}{1+i} + \frac{1}{(1+i)^2} + \frac{1}{(1+i)^3} + \cdots + \frac{1}{(1+i)^n}\right] \tag{17}$$

Present worth factor $= \dfrac{1}{(1+i)^n}$

$$A = R\sum_{1}^{n} \frac{1}{(1+i)^n} \tag{18}$$

Equation (18) can be solved further as:

$$A = R\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \tag{19}$$

Present value = Unacost × Unacost Present value factor

$$F_{RA,i,n} = \text{Unacost present value factor} \tag{19a}$$

From Eq. (19) the unacost can be calculated as:

$$R = A\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] \tag{20}$$

If the energy saving cost in a year is “R” and the carbon credit earned by utilizing the non-conventional energy resources is C_c, the money earned by utilizing renewable energy technology is as follows:

$$\text{Money earned} = [R + C_c] \times \left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \tag{21}$$

Q.7a By using a hybrid water heater, a farmer saves USD 5000 per year of fuels. Calculate the present worth of fuel which is saved by the farmer in 4th, 8th, and 12th year. Take $i = 10\%$.

Solution (i) When $n = 4$ years

$$\begin{aligned} \text{Present value factor} &= \frac{1}{(1+i)^n} = \frac{1}{(1+0.1)^4} = 0.6830 \\ \text{Present value} &= 5000 \times 0.6830 \\ &= \$\ 3415 \end{aligned}$$

(ii) When $n = 8$ years

$$\begin{aligned} \text{Present value factor} &= \frac{1}{(1+i)^n} = \frac{1}{(1+0.1)^8} = 0.466 \\ \text{Present value} &= 5000 \times 0.466 \\ &= \$\ 2332.52 \end{aligned}$$

(iii) When $n = 12$ years

$$\begin{aligned} \text{Present value factor} &= \frac{1}{(1+i)^n} = \frac{1}{(1+0.1)^{12}} = 0.3186 \\ \text{Present value} &= 5000 \times 0.3186 \\ &= \$\ 1593.15 \end{aligned}$$

(iv) When $n = 16$ years

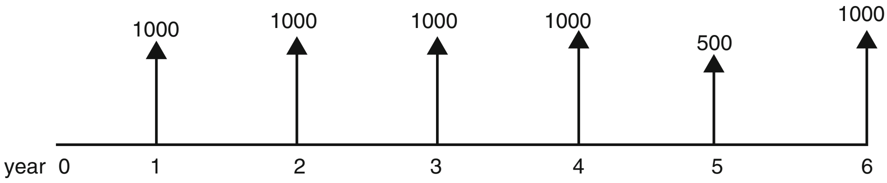

Fig. 3 Cash flow diagram in USD

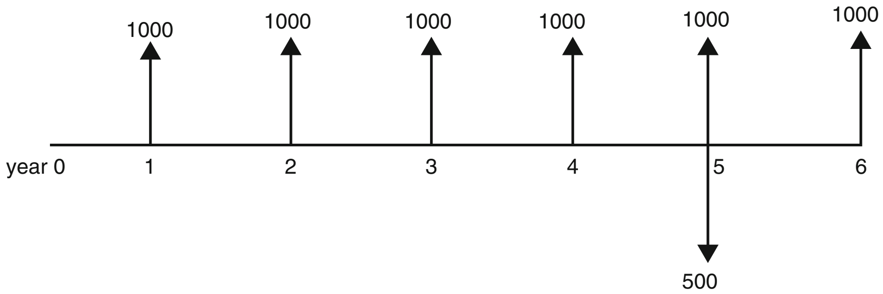

Fig. 4 Cash flow diagram in USD

$$\text{Present value factor} = \frac{1}{(1+i)^n} = \frac{1}{(1+0.1)^{16}} = 0.2176$$
$$\text{Present value} = 5000 \times 0.2176$$
$$= \$\ 1088.14$$

Q.7b Figure 3 shows the cash flow diagram (USD)S for 6 years. Determine the equivalent present value (Fig. 4).

Solution The above cash flow diagram can be redrawn as follows:

$$A = R\left[\frac{(1+i)^n - 1}{\mathrm{i}(1+i)^n}\right] + F \times (1+i)^{-n}$$

$$= 1000\left[\frac{(1+0.20)^6 - 1}{i(1+0.20)^6}\right] + 500 \times (1+0.20)^{-5}$$

$$= \$\ 3114.5$$

2.4 Sinking Fund Factor

It is a method for depreciating an asset in records and making money to buy a replacement for the asset when it reaches the end of its useful term.

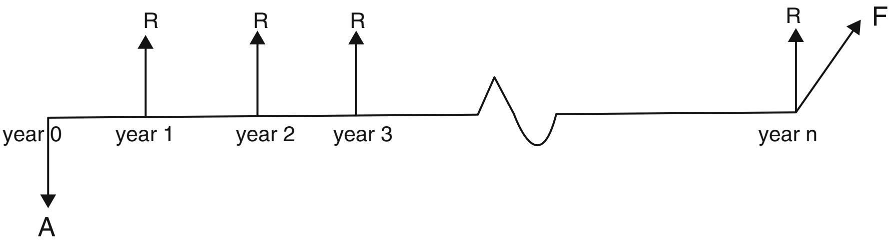

Fig. 5 Diagram showing unacost for "n" number of years

Figure 5 shows unacost (R) for each year for n number of years. From Eq. (20) the unacost is given as:

$$R = A\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right]$$

From Eq. (7)

$F = A \times (1 + i)^n$

The above equation can be rewritten further as:

$$A = F \times (1+i)^{-n} \tag{22}$$

So, the unacost is as follows:

$$R = F(1+i)^{-n}\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] \tag{23}$$

$$R = F\left[\frac{i}{(1+i)^n - 1}\right] \tag{24}$$

Unacost = Future value × Sinking fund factor (SFF)

$$\text{where SFF} = \left[\frac{i}{(1+i)^n - 1}\right]$$

The future value can be rewritten from Eq. (23) as:

$$F = R\left[\frac{i}{(1+i)^n - 1}\right]^{-1}$$

$$F = R\left[\frac{(1+i)^n - 1}{i}\right] \tag{25}$$

Future value = Unacost × Equal payment series future value factor

3 Expression for a Uniform Beginning of the Year Annual Amount R_B

A uniform beginning of year annual amount R_B, $\underline{R}$ cash flow diagram are given below (Figs. 6 and 7).

By following Eq. $A = F \times (1 + i)^{-n}$, the R and R_B relationship is as follows:

$$R_B = \frac{R}{(1+i)} \quad (26)$$
$$R = R_B \times (1+i)$$

Q. 8 Obtain an expression of RB in terms of A and F.

Solution By following Eq. 20

$$R = A\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right]$$

or,

$$R_B = \frac{A}{(1+i)} \times \left[\frac{i(1+i)^n}{(1+i)^n - 1}\right]$$
$$R_B = A \times \left[\frac{i(1+i)^{n-1}}{(1+i)^n - 1}\right] \quad (27)$$

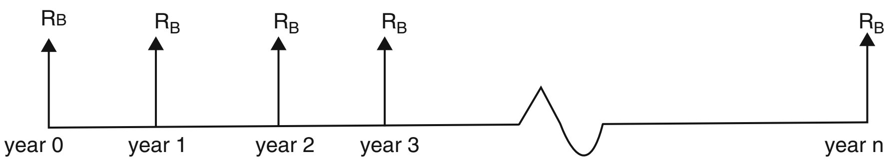

Fig. 6 Cash flow diagram showing R_B

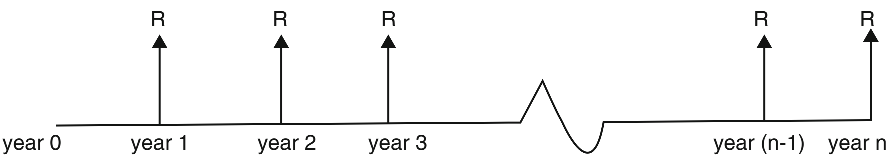

Fig. 7 Cash flow diagram showing R

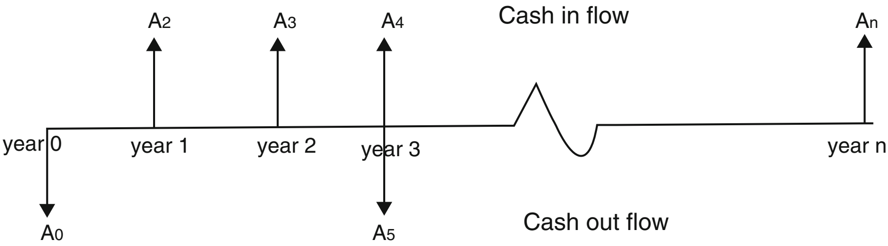

Fig. 8 Diagram depicting cash inflows and outflows

4 Diagram for Cash Flow

A cash flow diagram depicts the cash flows and outflows over a period of time. It is used to evaluate the system cost:

In Fig. 8 the upward arrows indicate the cash flows for, e.g., credit money into account, and downward arrow signifies cash outflow, e.g., withdrawing money.

Q. 6 Mr. Schmid deposits every year USD 2000 as a fourborne annuity for 10 years. He wishes to take money from bank after 16 years. Calculate the money value after 16 years. (Assume $i = 0.10$.)

Solution By following Eq. (19)

$$A = R\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right]$$

$$A = 1000\left[\frac{(1+0.20)^{10} - 1}{0.20(1+0.20)^{10}}\right]$$

$$= \$4191$$

USD 4191 is deposited every year for 10 years. So, the future value at the end of 10 years will be

$$\begin{aligned} F &= A \times (1+i)^n \\ &= 4191.06(1+0.20)^{10} \\ &= \$\ 25950 \end{aligned}$$

Q.7 A farmer sells a solar drying system for USD 2000 after using it for 15 years. Calculate its present value when the rate of interest is 20%.

Table 1 Cost comparison details of cabinet dryer and greenhouse dryer respectively

System	Capital cost	Maintenance cost per year	Salvage cost	Life of system	Profit as a uniform end of amount per year
Cabinet dryer	$ 2500	$ 200	$ 475	8	$ 50
Greenhouse dryer	$ 3000	$ 200	$ 325	10	$100

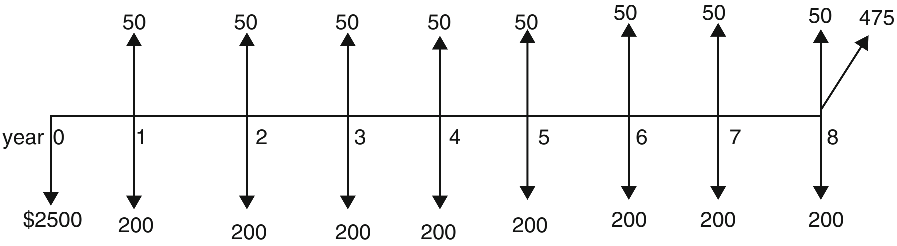

Fig. 9 Cash flow diagram of a cabinet dryer

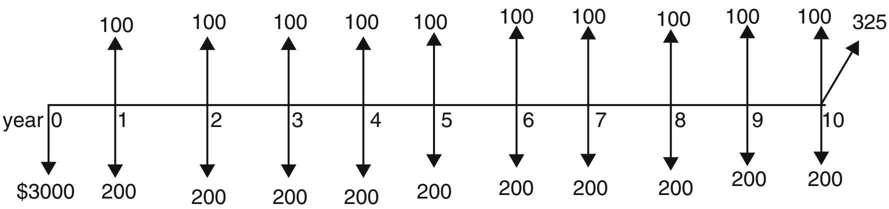

Fig. 10 Cash flow diagram of a greenhouse dryer

Solution

$$\begin{aligned} A &= F \times (1+i)^{-n} \\ &= 2000 \times (1+0.20)^{-15} \\ &= \$\ 129.81 \end{aligned}$$

Q.8 Table 1 shows the uniform cost of a cabinet dryer and a greenhouse dryer. Evaluate the economic performance of system considering the rate of interest as 20%.

Solution The cash flow diagrams of a cabinet dryer and a greenhouse dryer are as follows (Figs. 9 and 10):

For cabinet dryer

$$\text{The present value} = 2500 + (200 - 50)\left[\frac{(1+0.20)^8 - 1}{0.20(1+0.20)^8}\right]$$
$$= \$\ 3073.86$$

The greenhouse dryer is more economic.

5 Payback Period of Solar Dryer System

Payback period is the time required to recover the money invested in fabrication of solar dryer system. A system with small payback period is considered to be more economical.

Q. 9 A manufacturing firm spends USD 500000 in establishing the manufacturing plant. The firm receives USD 100000 as profit every year. Calculate the payback period.

Solution The payback period will be:

$$= \$500000/\$100000$$
$$= 5 \text{ years}$$

The payback time is 5 years.

5.1 Payback Period Calculation

The payback period is calculated by adding the annual cash flow values:

Sum of annual cash flows – money invested in business = 0.

Case (a) When annual savings are equal

$$Payback\ \ period = \frac{Initial\,\mathrm{Pr}esent\,\mathrm{Cos}t}{Annual\,cash\,flow} \tag{28}$$

Case (b) When annual savings are unequal

$$0 = -A + \sum_{T=1}^{n} CF\left(f_{\mathrm{PV,i\%,T}}\right) \tag{29}$$

Here CF_{T} is cash flow at the end of the year T. If cash flow is the same every year, $\boldsymbol{F_{RA,i,n}}$ factor may be used in the relation:

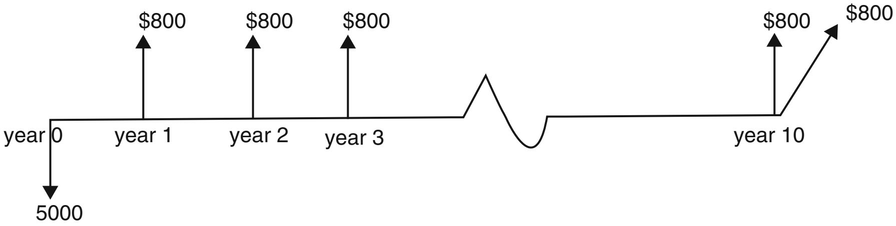

Fig. 11 Cash flow diagram of a greenhouse dryer

$$0 = -A + CF_{\mathrm{T}}(F_{RA,i,n,}) \tag{29a}$$

After n years, the cash flow will be recovered from the money spent.

If $i = 0$ then above equation becomes:

$$0 = -A\sum_{T=1}^{n} CF_T \tag{29b}$$

And if cash flow is equal at the end of year T are equal, then:

$$\mathrm{n} = \mathrm{A/CF} \tag{29c}$$

Q.9 The cost of mixed-mode solar greenhouse dryer is \$ 5000. It gives profits of \$800 annually. The salvage value of dryer is \$800 at any time till 10 years. Calculate the payback time period (take $i = 15\%$) (Fig. 11).

Solution From Eq. 29a

$$0 = -A + CF_{\mathrm{T}}\left(F_{RA,15\%,n}\right) + \text{Salvage value}\left(f_{\mathrm{PV},15\%,n}\right)$$
$$0 = -5000 + 800\,\frac{(1+0.15)^n - 1}{0.15 \times (1+0.15)^n} + 800 \times \frac{1}{(1+0.15)^n}$$

Solving the above equation, we get $n = 18.06$ years.

Therefore, it can be observed that $n = 18.06$ years is not cost-effective with high interest rate.

For $i = 0$,

$$0 = -5000 + 800\,n + 800$$

Or $n = 5.25$ years.

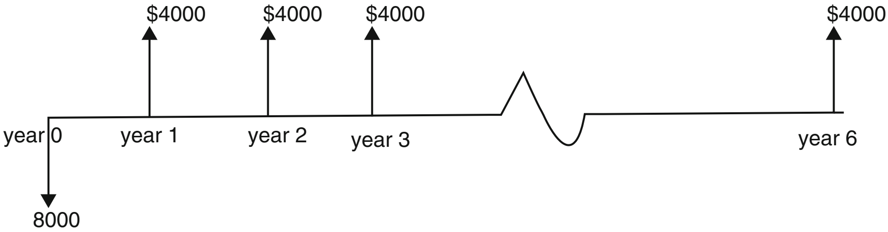

Fig. 12 Cash flow diagram of solar dryer

The payback period time is 5.25 years which turns out to be a cost-effective option.

Q.10 The table gives the information about indirect solar dryer system and hybrid solar dryer system. Calculate the payback period of the systems.

	Indirect solar dryer system	Hybrid solar dryer
Capital cost	\$ 8000	\$12,000
returns per year	\$4000	5000
Maximum life	6 years	7 years
Rate of interest	15%	15%

Solution For Indirect solar dryer system (Fig. 12).

Using Eq. 29a

$$0 = -8000 + 4000 \times F_{RA,15\%,n}$$
$$0 = -8000 + 4000 \times \frac{(1+0.15)^n - 1}{0.15 \times (1+0.15)^n}$$

Solving the above equation, $n = 2.5$ years (Fig. 13).

5.1.1 For Hybrid Solar Dryer

Following Eq. 29a

$$0 = -12000 + 5000 \times F_{RA,15\%,n}$$
$$0 = -12000 + 5000 \times \frac{(1+0.15)^n - 1}{0.15 \times (1+0.15)^n}$$

Solving the above equation, $n = 3.17$ years which is less than the maximum life.

Depreciation It can be defined as the decrease in the value of a product with respect to time. It may give rise to profit when there is tax advantage because of depreciation (Fig. 14).

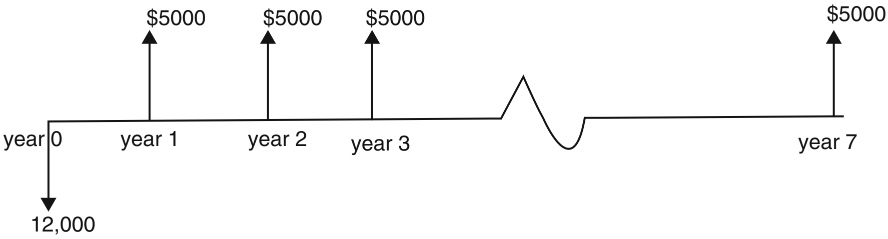

Fig. 13 Cash flow diagram of hybrid solar dryer

Fig. 14 Graph showing the cumulative cash with respect to years

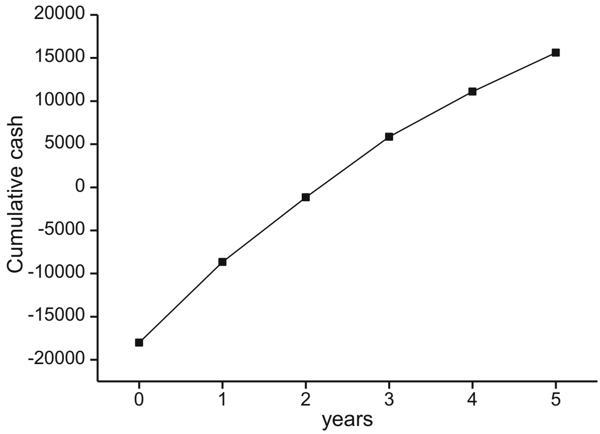

Table 2 Record showing profit and cash flow in USD

Time (year)	Profit after tax USD (I)	Tax benefit because of depreciation USD (II)	Cash flow (I + II)
0	−18,000	0	−18,000
1	4850	4500	9350
2	3000	4500	7500
3	2500	4500	7000
4	750	4500	5250
5	0	4500	4500

$$\text{Taxes} = (\text{Income} - \text{deduction})\text{tax rate}$$

Q. 11 Determine the payback time for the following record as shown in Tables 2 and 3.

From the above records, it can be seen that the payback time is between 2 and 3 years.

Table 3 Record showing cumulative cash flow

Time (years)	Cumulative cash flow
0	−18,000
1	−8650
2	−1150
3	5850
4	11,100
5	15,600

6 Various Terms Used for Economic Analysis

6.1 *Initial Cost (c_i)*

It is defined as the total cost involved in the installation of system. It comprises of the actual cost, delivery cost, installation charges, and service charges spent for the working of the system.

6.2 *Salvage Cost (c_{sa})*

It is basically the cost of an asset at the end of valuable life of the asset.

6.3 *Depreciation (c_d)*

It is the reduction in value of a system with time. The decrease in the worth of a system is termed as depreciation:

$$c_{\mathrm{d}} = c_{\mathrm{i}} - c_{\mathrm{sa}}$$

6.4 *Book Value (B_V)*

It is defined as the asset value mentioned in the firm's book. It is evaluated by subtracting asset value from the accumulated depreciation. It is calculated at the end of every year.

6.5 *Depreciation Rate*

It is ratio of depreciation cost of the asset to the number of years:

$$\text{Depreciation rate} = c_d = (c_i - c_{sa})/(N)$$

6.6 Recovery Period (Expected Life, N)

It is defined as the number of years the value of an asset can be recovered.

6.7 Market Value

It is the price of a commodity after selling it in open market. The market price of a house will increase with time. Its book value will decrease if depreciation charges are considered. A mobile phone will have less market value than book value because of technology change.

Q. 12 Evaluate the rate of depreciation and book value of a commodity having first cost of USD 30,000 and salvage value of USD 5000 after 4 years.

Solution Depreciation rate = $c_d = (c_i - c_{sa})/(N)$

$$= \frac{30000 - 5000}{4} = \$\ 6250 \text{ for 4 years}$$

(i) The book value at the first year end = B_{V1} = 30,000–1 × 5000 = $ 25,000
(ii) The book value at the second year end = B_{V2} = 30,000–2 × 5000 = $ 20,000
(iii) The book value at the third year end = B_{V3} = 30,000–3 × 5000 = $ 15,000
(iv) The book value at the fourth year end = B_{V4} = 30,000–4 × 5000 = $ 15,000.

7 Analytical Expression for Book Value

Let first cost of an asset be "c_i."

Also salvage value after N years = "c_{sa}."

$$\text{Therefore, depreciation,} \quad c_d = c_i - c_{sa} \tag{30}$$

Let F_{d1}, F_{d2}, F_{d3}, and F_{d4} be the fractional depreciation for each year.

So, depreciation for xth year will be as follows:

$$F_x = F_{dx} \times c_d \tag{31}$$

Book value = First cost × accumulated cost

$$\begin{aligned} B_V &= c_i - c_d \Sigma F_{di} \\ &= c_i - c_d + c_d + c_d \Sigma F_{di} \\ &= c_{sa} + c_d [1 - c_d \Sigma F_{di}] \end{aligned} \tag{32}$$

7.1 Straight Line Depreciation

If fractional depreciation is same for all years,

$$\begin{aligned} &\text{Let } F_{d1} = F_{d2} = F_{d3} = F_{d4} = \cdots = F_{dn-1} = F_{dn}, \text{or Let } F_d = 1/N \\ &\text{Depreciation for x}^{\text{th}}\text{year} = c_d/N \end{aligned} \tag{33}$$

Accumulated depreciation up to *x*th year:

$$\begin{aligned} B_{VX} &= c_i - c_d \Sigma F_{di} \\ &= c_i - c_d (X/N) - c_d + c_d \\ &= c_{sa} + c_d [1 - (X/N)] \end{aligned} \tag{34}$$

Book value = Salvage value × Future depreciation.

8 Net Present Value (NPV)

The purpose of calculating net present value is to determine whether the project will turn out to be profitable or not. If NPV is positive, the investor will gain profits after taking the project. If NPV is negative, the investor will lose money by taking the project:

$$\text{NPV} = \sum_{k=0}^{n} \frac{(B_k - C_k)}{(1+i)^k} \tag{35}$$

where B_k is profit gained after time period “k”.

C_k is cost after time period “k”.

N is life of project and “i” is the interest rate.

Case(i) when $k = 0$, (Bk - Ck) is constant:

$$\mathrm{NPV} = (B_0 - C_0) + \sum_{k=0}^{n} \frac{(B_k - C_k)}{(1+i)^k} \tag{36}$$

B_0 is the profit in the "0" year, $B_0 = 0$, $C_0 =$ initial money invested in the project, and $(B_k - C_k)=$ constant $(B - C)$for $k = 1$ to n:

$$\begin{aligned} \mathrm{NPV} &= (-C_0) + (B - C) \sum_{k=0}^{n} \frac{1}{(1+i)^n} \\ \mathrm{NPV} &= (-C_0) + (B - C)\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \end{aligned} \tag{37}$$

Q.13 A hybrid PVT solar water heater system cost price is USD 12000. The usage of this system leads to savings of USD 2000. The maintenance cost every year is USD 200. Evaluate the net present value of the money invested in system. Consider useful life of the system as 20 years and interest rate as 20 years:

Solution

$$\begin{aligned} \mathrm{NPV} &= (-C_0) + (B - C)\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \\ \mathrm{NPV} &= (-1000) + (2000 - 200)\left[\frac{(1+0.1)^{20} - 1}{0.20 \times (1+0.20)^{20}}\right] \\ &= \$\ 5304.34 \end{aligned}$$

As NPV is positive, the hybrid PVT solar water heater is profitable.

The calculation of NPV is a decisive factor of taking an assignment and is as follows:

(a) If NPV is **positive**, then take the assignment.
(b) NPV is **negative** then decline the assignment.

When the interest rate "I" varies with time:

$$\begin{aligned} \mathrm{NPV} = (B_0 - C_0) + \frac{(B_1 - C_1)}{(1+i_1)} + \frac{(B_2 - C_2)}{(1+i_1)(1+i_2)} + \cdots \\ + \frac{(B_n - C_n)}{(1+i_1)(1+i_2)\cdots(1+i_n).} \end{aligned}$$

where i_1, i_2, $i_{3\ldots}$and$_{\ldots,}$ i_n are the interest rate for 1st year, 2nd year, 3rd year and nth year.

9 Conclusions

Developments of solar drying system technologies are economically feasible way to tackle problems of food spoilage in developing countries. It is considered as the cheapest way to reduce the moisture contents of dried products. Also, it drastically reduces environmental pollution problems and gives rise to huge energy savings in terms of cost. In this chapter various methods such as annual cost methods, sinking fund method, cash flow diagrams, payback periods, and net present value have been discussed.

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