Chapter 5

ECONOMIC ANALYSIS

5.1 Introduction

Economic analysis is also performed to check the feasibility of solar still. An economic aspect plays an essential role while developing any renewable energy-based product to extend its reach. It is found that the capital recovery factor is an essential factor for the interest rate and average period of operation of solar still. At the same time, the annual cost depends on AFC, AMC, and ASV. To determine whether modified solar stills are cost-effective or not economic analysis is done.

5.2 Cost analysis of modified solar still

The cost breakdown of the materials required to fabricate SSs is shown in Table 5.1. To assess cost-effectiveness and viability, the monetary cost and payback period are calculated for both traditional SSs and modified SSs (with QD-15g). According to the local climatic circumstances, both SS are expected to have a minimum of 10 years of lifespan and 300 working days per year. The selling prize of distilled water is assumed to be 5 INR to calculate the payback time.

Table 5. 1 Cost breakup for CSS and PSS coated with QD material and PCM

S. No.	Parts name	CSS		PSS		Total Cost (INR)
		Quantity	Cost	Quantity	Cost	
1.	Fiber reinforced plastic (FRP)	2 m^2	1500	1.5 m^2	1000	2500
2.	Glass Cover	1.1 m^2	1000	1.1 m^2	2000	3000
3.	Glass wool	7 cm thickness	500	7 cm thickness	500	1000
4.	Black dye	500 mL	200	500 mL	200	400
5.	Quantum dot	15 g	2000	15 g	2000	4000
6.	PCM	20 kg	5000	20 kg	5000	10000
6.	Iron stand and foundation	-	1500	-	1500	3000
7.	Aluminum sheet	-	1000	-	1000	2000
8.	Fabrication cost	-	1000	-	1500	2500
	Overall Cost		**13700**		**14700**	**28400**

5.2.1 Overall Cost

Overall cost includes the Fixed cost viz. component cost etc. and variable cost viz. labor cost etc. as mentioned in Table 5.1. Total project cost was 28400 INR.

Overall Cost for CSS without QD and PCM = 6600 INR

Overall Cost for CSS with QD and PCM = 13700 INR

Overall Cost for PSS with QD and PCM = 14700

5.2.2 Salvage Value

Salvage value is taken as the expected value of solar still after a working period or after a depreciation period. Since solar still does not have moving components so depreciation will be less; hence it can be considered as **10%** after 10 years of working life.

Salvage value for CSS without QD and PCM

$$= \frac{10}{100} \times 6600 = 660$$

Salvage value for CSS with QD and PCM

$$= \frac{10}{100} \times 13700 = 1370$$

Salvage value for PSS with QD and PCM

$$= \frac{10}{100} \times 14700 = 1470$$

5.2.3 Working Life

The working life of a solar still is dependent on its regular maintenance. Because basin water is salty, it accumulates white salt around the contact region and on the condenser surface. After taking all certain and uncertain conditions, the working period of solar is assumed to be 10 years. Since PCM, melting, and solidification are essential factors in determining the solar still working life.

5.2.4 Interest rate

The rate at which a bank or lander gives the principal amount to fabricate the solar still is taken as interest rate. Generally, private banks give loan at 6-16% for domestic purpose without subsidy. Although it's a solar powered system which completely renewable and zero climate impact hence can be borrowed at around 4% interest rate under government subsidy. In this economic analysis interest rate taken as **10%**.

5.2.5 Sinking fund factor

A factor used to calculate the future value of an asset based on present value when equal amount of cash flow occurs for **'n'** no. of years at **'i'** interest rate.

$$\text{SFF (i, n)} = \frac{i}{(i+1)^n - 1}$$

At i=10% and n= 10 years, **SFF = 0.062**

5.2.6 Annual Salvage Value

The actual value of an asset after every year of working degraded due to depreciation by the sinking fund factor that is known as salvage value. It is also called as scrap value or residue value. Every year due to depreciation actual value degraded automatically.

Annual Salvage value = Total cost ×SFF

Annual Salvage value for CSS without QD and PCM = 6600 × 0.062 = 409.2 INR

Annual Salvage value for CSS with QD and PCM= 13700 × 0.062=849.4 INR

Annual Salvage value for PSS with QD and PCM= 14700× 0.062=911.4 INR

5.2.7 Money Recovery Factor

Money or capital recovery factor give the idea to calculate the present value of an asset when a series of annual constant cash flow at **'i'** interest for **'n'** no. of years occurs.

$$\text{MRF (i, n)} = \frac{i(i+1)^n}{(i+1)^n - 1}$$

At i=10% and n=10 years, **MRF = 0.161**

5.2.8 Annual First cost

Annual first cost needs to calculate to estimate the annual cash flow to recovery the investment. It has to calculate to recover the investment after that profit is earned through the product.

Annual first cost = Total cost × MRF

Annual first cost for CSS without QD and PCM = 6600 × 0.161 = 1062.6 INR

Annual first cost for CSS with QD and PCM = 13700 × 0.161 = 2205.7 INR

Annual first cost for PSS with QD and PCM = 14700 × 0.161 = 2366.7 INR

5.2.9 Annual Maintenance cost

Annual maintenance incurred cost which is calculated by 10-20% of annual first cost. In this economic analysis 15% of annual first cost is taken as annual maintenance cost.

Annual maintenance cost for CSS without QD and PCM = 0.15 × 1062.6 = 159.39 INR

Annual maintenance cost for CSS with QD and PCM = 0.15 × 2205.7 = 330.85 INR

Annual maintenance cost for PSS with QD and PCM = 0.15 × 2366.7 = 355 INR

5.2.10 Annual total cost

Annual total cost consists annual first cost and annual maintenance cost subtracted by annual salvage value.

Annual total cost = AFC + AMC – ASV

Annual total cost for CSS without QD and PCM = 0.15 × 1062.6 = 812.79 INR

Annual total cost for CSS with QD and PCM = 0.15 × 2205.7 = 1687.15 INR

Annual total cost for PSS with QD and PCM = 0.15 × 2366.7 = 1810.3 INR

5.2.11 Average annual Production

Average annual production (AAP) from CSS without applying QD coating and PCM is taken as **300 liters** (at a rate of 1 l/day) while with QD and PCM it was **900 liters** (at a rate of 3 l/day) and PSS with QD and PCM is taken as **1105 liters** (at a rate of 3.68 l/day). Daily yield has been taken form experimental results. The working days in a year is taken 300 by considering rainy days and other unfavorable conditions.

5.2.12 Monetary cost

The monetary cost referred to the cost of one liter of distilled water which is calculated by the ratio of annual total cost to the average annual production.

$$\text{Monetary cost for CSS without QD and PCM} = \frac{ATC}{AAP} = 2.71$$

Monetary cost for CSS with QD and PCM = 1.9 INR/l

Monetary cost for PSS with QD and PCM = 1.6 INR/l

5.2.13 Annual equivalent energy

The annual equivalent energy refers to the annual energy saving using solar energy to produce distilled water. The latent heat value of water for condensation is 0.66kWh for 1 kg of water. The annual equivalent energy can be calculated as,

Annual equivalent energy (kWh) = Average annual production × Latent heat value

Annual equivalent energy for CSS without QD and PCM = 198 kWh

Annual equivalent energy for CSS with QD and PCM = 594 kWh

Annual equivalent energy for PSS with QD and PCM = 729.3 kWh

5.2.14 Overall annual gain

Annual gain is obtained when it will sell into the market. In market, 1 liter water bottle sold at minimum 15 INR. If distilled water sold at only 5 INR/l then overall annual gain can be calculated as,

Overall Annual gain = Average annual gain × Selling Prize (5 INR)

Overall Annual gain for CSS without QD and PCM = 1500 INR

Overall Annual gain for CSS with QD and PCM = 4500 INR

Overall Annual gain for PSS with QD and PCM = 5527 INR

5.2.15 Payback period

It is the length of time under which breakeven point is achieved. It means period of time under which invested money can be recovered after that profit will come. This period always intended to keep short. Payback period can be calculated as,

$$payback\ period = \frac{Total\ cost}{Overall\ annual\ gain - annual\ maintenance\ cost}$$

Payback period for CSS without QD and PCM = 4 years, 11 months

Payback period for CSS with QD and PCM = 3 years, 3 months

Payback period for PSS with QD and PCM = 2 years, 10 months.

Summary of economic analysis of conventional solar still and prismatic solar still is tabulated in Table 5.2.

Table 5. 2 Summary of economic analysis of CSS and PSS

S. No.	Parameters	Formula	CSS	CSS with PCM and QD (15g)	PSS with PCM and QD (15g)
1.	**Overall cost (TC), INR.**	-	6600	13700	14700
2.	**Salvage value (SV), INR.**	10% of TC	660	1370	1470
3.	**Working life (n)**	-	10 years	10 years	10 years
4.	**Interest rate (i)**	-	10%	10%	10%
5.	**Sinking Fund factor (SFF)**	$\frac{i}{(1+i)^n - 1}$	0.062	0.062	0.032
6.	**Annual Salvage value (ASV), INR.**	TC × SFF	409.2	849.4	911.4
7.	**Money Recovery factor (MRF), INR.**	$\frac{i\,(1+i)^n}{(1+i)^n - 1}$	0.161	0.161	0.161

8.	**Annual First Cost (AFC), INR.**	TC × MRF	1062.6	2205.7	2366.7
9.	**Annual Maintenance Cost (AMC), INR.**	15% of AFC	159.39	330.85	355
10.	**Annual total cost (ATC), INR.**	AFC+AMC-ASV	812.79	1687.15	1810.3
11.	**Average Annual production (AAP), l.**	Avg. daily yield ×300	300 l	900	1105
12.	**Monetary Cost, INR/l**	$\frac{ATC}{AAP}$	**2.71**	**1.9**	**1.6**
13.	**Annual Equivalent Energy (AEE), kWh**	AAP × LHV (0.66 kWh/kg)	198	594	729.3
14.	**Energy cost, INR/kWh**	$\frac{ATC}{AEE}$	**4.10**	**2.84**	**2.48**
15.	**Overall annual gain (OAG), INR**	Avg. daily yield×300×5	1500	4500	5527
16.	**Payback period, yr.**	$\frac{TC}{OAG - AMC}$	**4 yrs. 11 m.**	**3 yrs. 3 m.**	**2 yrs. 10 m.**

5.3 Cost analysis with QD

Similarly, conventional solar stills with and without black phosphorus quantum dot were analyzed where economic analysis suggest that SS with QD has less payback period and cost per liter for distilled water production as compared to SS without QD. However initial cost was high with QD solar still. Summary of cost analysis of quantum dot coated SS is tabulated in Table 5.3.

Table 5. 3 Summary of economic analysis of QD coated SS

S. No.	Parameter	Formula	SS (0g QD)	SS (15g QD)
1.	**Total cost (TC), INR**	-	6600	8600
2.	**Salvage value (SV), INR**	10% of TC	660	860
3.	**Working life (n)**	-	15 years	15 years
4.	**Interest rate (i)**	-	10%	10%
5.	**Sinking Fund factor (SFF)**	$\frac{i}{(1+i)^n - 1}$	0.032	0.032
6.	**Annual Salvage value (ASV), INR**	TC × SFF	207.9	270.9
7.	**Capital Recovery factor (CRF), INR**	$\frac{i\,(1+i)^n}{(1+i)^n - 1}$	0.131	0.131
8.	**Annual First Cost (AFC), INR**	TC × CRF	864.6	1126.6
9.	**Annual Maintenance Cost (AMC), INR**	15% of AFC	129.7	169
10.	**Annual total cost (ATC), INR**	AFC+AMC-ASV	786.4	1024.7

11.	**Average Annual yield, (AAY) INR**	Avg. daily yield ×300	300 l	900 l
12.	**Monetary Cost of distilled water, INR/l**	$\frac{ATC}{AAY}$	**2.62**	**1.14**
13.	**Annual Equivalent Energy (AEE), kWh**	AAY × LHV (0.66 kWh/kg)	198	594
14.	**Energy cost of distilled water, INR/kWh**	$\frac{ATC}{AEE}$	**3.97**	**1.72**
15.	**Total annual earning (TAE), INR**	Avg. daily yield×300×5	1500	4500
16.	**Payback period, Years**	$\frac{TC}{TAE - AMC}$	**4 yrs. 9 m**	**1 yrs. 11 m**