Original Research Article

ECONOMIC EVALUATION OF PASSIVE SOLAR DISTILLATION SYSTEM

Abstract

A economic analysis of passive solar distillation unit is presented in the paper. Initial cost and maintenance costs, life of the system and estimates the cost of unit mass of distilled water were used to evaluate net present worth (NPW), benefit-cost ratio, payback period (PP) and internal rate of return (IRR) of solar distillation unit. Net Present Worth (NPW), Benefit-cost ratio, Payback Period (PP) and Internal Rate of Return (IRR) was calculated and found to be Rs. 26945.72, 1.5632, 1.538 year and 50 per cent respectively. This study found solar energy is one of the most attractive resources of energy to generate distilled water.

Key words: *Passive solar still, Economic Evaluation, Solar desalination, Distilled Water*

Introduction:

Safe drinking water is essential for a healthy existence, yet it is in short supply. Fresh water makes up only 3% of the total amount of water on the planet. Only about 1% of the pure water available is appropriate for human and animal consumption. The need for fresh water is rising as the world's population grows and lifestyles change. Water is essential for both agricultural and industrial purposes. As a result, desalination has become necessary to obtain fresh water from subsurface salty water reserves or the ocean.

Solar distillation is a low-carbon technique that is both easy and cost-effective. It can provide safe drinking water in modest quantities to households and other applications. Multiple solar distillation systems are necessary for large quantities. There are two types of solar distillation systems: passive and active.

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A cost estimate of a portable thermoelectric solar still was evaluated by Rahbar and Esfahani (2012). The initial expenditure was at 181$, the cost of distillate per litre was discovered to be 0.18 $/L/m^2. Velmurugan et al. (2009) conducted a cost-benefit study of a composite solar desalination system that included a wick-type solar still, a micro solar pond and a stepped solar still. The initial investment of composite system was Rs. 20,000 and daily distillate output was 6.12 litre. The cost of distilled water per litre was Rs. 0.3. Payback period was calculated to be 367 days. Omara et al. (2014) calculated the costs of a traditional still as well as a stepped solar still with interior and external reflectors. The total fixed cost of a traditional still was approximately 103 $. The cost of one litre distilled water was computed at $0.049. The unit was operational for 340 days a year with daily output of 2.5 l/day. On the other hand, total fixed cost of the upgraded still was around 160 $. The cost of one litre distilled water was computed at $0.031 while operating 340 days a year with a daily output of 6 l/day.

Rajasthan has abounded blessings of solar radiation. Solar energy can be used to produce distilled water for regular purposes. However, for a still to be made commercially viable there is a need to study economic aspects in addition to technical aspects. Due to lack of economical study available for southern part Rajasthan, this technology is not widely used. Therefore a need is existed to evaluate economics of solar distillation unit for southern part of Rajasthan. Hence economic analysis of passive solar distillation unit is presented in the paper.

Methodology and results Discussion

The cost of desalinating saline water with a passive solar still is primarily determined by the solar still's current capital cost (Cs), annual interest rate (i), expected useful life in years (n), future salvage value (S), average annual productivity in litres (yearly), and annual operation and maintenance cost (O&M). The cost of the land on which the solar still will be installed, the annual tax and insurance charge (if applicable), and the annual cost of saline water will all be ignored in this calculation. Regular cleaning of the glass cover, elimination of scaling due to salt deposition on the basin liner and side walls, and regular pouring of saline water to maintain the saline level are all included in the O&M.

The performance evaluation of a developed passive solar distillation unit was carried out in April 2021 at the Department of Renewable Energy Engineering, College of

Technology and Engineering, Udaipur. Specification of developed solar distillation system is mentioned in Table.1.

Table.1. Specification of developed solar distillation unit.

S.N.	Particular	Specification
1	Absorber area of the basin, m^2	1.00
2	Basin area, m^2	1.00
3	Area of the glass cover, m^2	1.16071
4	Insulation thickness, m	0.025
5	The angle of inclination of the glass	30°
6	Width of the basin, m	1
7	The thickness of glass cover, m	0.005
8	Dimensions of gunny bag, m	1.12 ×0.68
9	Total absorber area, m^2	1.32

The economics evaluation of solar system will be carried out in terms of net present worth, payback period, cost benefit ratio and internal rate of return.(Ranjan*et al.*, 2016)

Net present worth (NPW)

The net present worth can be computed by subtracting the total discounted present worth of the cost stream from that of the benefit stream. Net present worth of developed system was calculated from eq.1.

$$NPW = \sum_{t=1}^{n} \left(\cdot \frac{B_t - C_t}{(1+i)^t} \right) \text{..................... Eq.1.}$$

Where, C_t = Cost in each year, B_t = Benefit in each year, t = 1, 2, 3................n (years), i = Discount rate, %

Benefit cost ratio

It is a ratio obtained when the present worth of the benefit stream is divided by the present worth of the cost stream as expressed in eq.2.

$$\text{Benefit cost ratio} = \frac{\sum_{t=1}^{t=n} B_t}{\sum_{t=1}^{t=n} C_t} \text{..................... Eq.2.}$$

Internal rate of return (IRR)

Internal cash flow for measuring the worth of a project is to find a discount rate that makes net present worth to the incremental cash flow equal to zero

$$\sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} \text{.................... Eq.3.}$$

Payback period

The payback period is the length of time from the beginning of the project until the net value of the incremental production stream reaches the total amount of the capital investment.

$$\text{Payback Period} = \frac{Total\ investment}{Total\ profit} \text{.................... Eq.4.}$$

Researchers are working in various types of solar still and have identified several technically viable stills. The economic analysis was carried out based on the following assumptions:

- The life of the passive solar distillation unit is 10 years.
- The discount rate is assumed to be 10 per cent.
- The annual repair and maintenance cost is 5 per cent of the total capital cost.
- Cost of salty water is 1 Rs/l.
- Cost of distilled water is 12 Rs/l.
- Daily production of distilled water is 4.5 liters
- Labor cost: one person can be involved to distilled water, so the labor charge of one labor is 40 Rs/hr and it is assumed that the labor works for half hour per day.
- The passive solar distillation unit can be operated 300 days in a year.
- The cost of the system is Rs 9000.

Cash flow analysis, net present worth, benefit cost ratio, internal rate of return and the payback period of passive solar still was calculated and described in Table.2. From the economic analysis of passive solar still, the parameters such as Net Present Worth (NPW), Benefit-cost ratio, Payback Period (PP) and Internal Rate of Return (IRR) was calculated and found to be Rs. 26945.72, 1.5632, 1.538 year and 50 per cent respectively.

Conclusion:

From the economic analysis of passive solar still, the parameters such as Net Present Worth (NPW), Benefit-cost ratio, Payback Period (PP) and Internal Rate of Return (IRR) was calculated and found to be Rs. 26945.72, 1.5632, 1.538 year and 50% respectively. For the state of Rajasthan where solar energy is available for more than 300 days a year, this technology is viable to use for regular use. It is suggested that combining a concentrated solar collector and an electric heater may improve the performance of a solar still desalination system.

Reference:

- Bait, O. (2019). Exergy, environ–economic and economic analyses of a tubular solar water heater assisted solar still. *Journal of cleaner production*, **212**, 630-646.
- Dhivagar, R., Mohanraj, M., Hidouri, K., & Belyayev, Y. (2020). Energy, exergy, economic and enviro-economic (4E) analysis of gravel coarse aggregate sensible heat storage-assisted single-slope solar still. *Journal of Thermal Analysis and Calorimetry*, **25:** 1-20.
- Fang, S., Mu, L., & Tu, W. (2021). Application design and assessment of a novel small-decentralized solar distillation device based on energy, exergy, exergoeconomic, and enviroeconomic parameters. *Renewable Energy*, ***164*****:** 1350-1363.
- Kianifar, A., Heris, S. Z., &Mahian, O. (2012). Exergy and economic analysis of a pyramid-shaped solar water purification system: active and passive cases. *Energy*, ***38*****:** 31-36.
- Rahbar, N., Gharaiian, A., & Rashidi, S. (2017). Exergy and economic analysis for a double slope solar still equipped by thermoelectric heating modules-an experimental investigation. *Desalination*, ***420*****:** 106-113.
- Rahbar, N. and Esfahani, J.A. (2012) 'Experimental study of a novel portable solar still by utilizing the heat pipe and thermoelectric module', Desalination, Vol. 284, pp.55–61.
- Ranjan, K. R., and Kaushik, S. C. (2013). Energy, exergy and thermo-economic analysis of solar distillation systems: A review. *Renewable and Sustainable Energy Reviews*, ***27*****:** 709-723.
- Rumayor, M., Dominguez-Ramos, A., Perez, P., &Irabien, A. (2019). A techno-economic evaluation approach to the electrochemical reduction of CO2 for formic acid manufacture. *Journal of CO_2 Utilization*, ***34*****:** 490-499.
- Singh, G., Kumar, S., & Tiwari, G. N. (2011). Design, fabrication and performance evaluation of a hybrid photovoltaic thermal (PVT) double slope active solar still. *Desalination*, ***277*****:** 399-406.
- Tiwari, G. N., and Tiwari, A. K. (2008). *Solar distillation practice for water desalination systems*. Anshan Pub.

- Tiwari, A. K., &Somwanshi, A. (2018). Techno-economic analysis of mini solar distillation plants integrated with reservoir of garden fountain for hot and dry climate of Jodhpur (India). *Solar Energy*, ***160*****:** 216-224.
- Tiwari, A. K., &Somwanshi, A. (2018). Techno-economic analysis of mini solar distillation plants integrated with reservoir of garden fountain for hot and dry climate of Jodhpur (India). *Solar Energy*, ***160*****:** 216-224.
- Ullah, I., & Rasul, M. G. (2019). Recent developments in solar thermal desalination technologies: a review. *Energies*, ***12*****:** 119.
- Velmurugan, V., Pandiarajan, S., Guruparan, P., Harihara Subramanian, L., David Prabaharan, C. and Srithar, K. (2009) 'Integrated performance of stepped and single basin solar stills with mini solar pond', Desalination, Vol. 249, pp.902–909.
- Yousef, M. S., and Hassan, H. (2019). Energetic and exergetic performance assessment of the inclusion of phase change materials (PCM) in a solar distillation system. *Energy Conversion and Management*, ***179*****:** 349-361.