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# Performance Evaluation and Economic Viability of Multi-step Basin Type Solar Still for the Hot Arid Climate of India

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**Abstract:** The multi-step basin-type metallic solar still was designed and developed at ICAR-CAZRI in Jodhpur, India. This unit features an absorber area of 1.5 $m^2$, with the capability to tilt according to seasonal variations. The previous iteration of this solar still utilized trays constructed from 24-gauge GI sheet, which led to issues such as algae growth and rust, ultimately compromising the unit's lifespan. In the current design, trays are fabricated from stainless steel to address these concerns. The water temperature in the trays reached approximately 65°C. The performance assessments of the device were conducted by measuring the daily production of distilled water, which ranged from 4.0 to 8.2 liters across different seasons in 2023. The average thermal efficiencies for water heating and distillation were recorded at 20.5% and 34.0%, respectively. Additionally, the economic feasibility and environmental sustainability of the multi-step basin solar still was evaluated. The economic evaluation of the unit demonstrated strong performance, with Internal Rates of Return (IRR) of 143% and 173% and correspondingly short payback periods of 0.80 and 0.65 years. These figures represent the scenarios without and with carbon credit monetization, respectively.These economic indicators demonstrate the system's viability. Furthermore, this device outperformed conventional reverse osmosis systems in terms of distillate quality. It also has the potential to reduce carbon emissions by approximately 35.1 tonnes over its 15-year lifespan. Consequently, this solar still is well-suited for desalinating saline water in rural arid regions, effectively addressing the need for potable water.

**Key words:** Multi-step basin-type solar still, Economic analysis, Carbon emission.

Water is essential to both maintaining life on Earth and conducting industrial operations. Depletion of the limited resources has been caused by the overuse of fresh water due to population growth and industrial expansion. The World Water Development Report was the first to bring this issue to the attention of the entire world (2003). Therefore, the globe is currently focused on applying different cleaning processes to reuse the available unclean water. However, the bulk of these cleaning methods rely heavily on non-renewable energy sources, which raises further environmental concerns. The world has begun employing renewable energy resources to clean water to solve this issue. In keeping with these developments, the United States has also set seventeen Sustainable Development Goals (SDGs) that describe targets to be achieved during the next fifteen years and represent the fundamental needs of states. The first seven objectives are especially important and need to be addressed right now. One of the main SDGs that the UN has defined is access to clean and drinkable water. In nations like India, where potable water is a major concern, this requirement is particularly urgent. The arid region of western Rajasthan, India, where access to clean water and electricity is limited and the communities in these areas frequently experience acute water scarcity, which can have negative health effects on both local wildlife and people. Solar energy is a renewable energy source that is abundant throughout the equator, inexpensive, and environmentally benign (Elsaid *et al.,* 2020). Traditionally, solar energy has been utilized for cooking, heating, cooling, and solar power generation (Poonia *et al.,* 2024a). Solar energy has recently been shown to be a useful energy source for the distillation process of cleansing brackish water. Using a device called a solar distillation unit or solar still, clean water is extracted from brackish water through the process of solar distillation (Kabir *et al.,* 2018). There are numerous types of solar stills, including pyramidal, hemispherical, stepped, and standard solar stills (CSS, SSS, etc.), but SSS (stepped solar still) is the most reliable.

India is fortunate to receive plenty of solar radiation. Nearly 300 clear sky days are recorded in the dry region of Rajasthan, India, where solar radiation is abundant. The region receives between 7600 and 8000 $MJm^{-2}$ of solar radiation annually, while semi-arid regions receive between 7200 and 7600 $MJm^{-2,}$ and hilly regions receive roughly 6000 $MJm^{-2}$ (Poonia *et al.,* 2024b). Consequently, with the plentiful availability of solar insolation in arid Rajasthan, India, solar distillation is a suitable alternative to traditional techniques in a hot, arid region of Rajasthan. To make it drinkable, the solar still's distillate output must be combined with the available saline water in the proper ratio. It is possible to turn raw water with 300 ppm TDS into up to 20 liters of drinkable water (150 ppm TDS) every day by constructing a solar still with a 10-liter capacity per day.

Afshari (2024) found solar stills more efficient for the distillation of water due to their simplicity and higher thermal efficiency. El-Samadony and Kabeel (2014), show that the stepped solar still with glass cover cooling (film type) generated more distillate (55.55%) than a conventional solar still (CSS). They also recommended that the temperature of the film water be maintained at or below the ambient temperature in order to get better results. Kabeel *et al.* (2019) conducted a comparative study between a PV-active stepped solar still with a glass cover cooling arrangement and a simple conventional solar still and found that the yield of active SSS was 7.21 and 6.41 $Lm^{-2}$ in the summer and winter seasons, respectively, which were 62 and 83.1% greater than CSS. El-Samadony *et al.* (2015) reported that a stepped solar still, employed with internal and external reflectors, yielded 180% more distillate (7500 ml $m^{-2}$) than a conventional solar still. Singh *et al.* (2019) revealed that the average output of the vermiculite-cement-based building material desalination device was 8540 ml $d^{-1}$ in the summer and 7595 ml $d^{-1}$ in the winter. The vermiculite-cement-type solar desalination device's economic evaluation, the unit is very cost-effective due to its brief payback period (0.65 years) and high internal rate of return (151%). Poonia *et al.* (2022) reported that the PCM-based concentrated desalination unit produces an average monthly distillate of 4.51 L $month^{-1}$, while the distillate output without PCM is 3.84 L $month^{-1}$. The economic analysis of the unit is extremely cost-effective due to its high internal rate of return (IRR) of 87.2% and short payback period of 1.40 years. Davra *et al.* (2024) found that during the sunshine hours of 8:00 A.M. to 5:00 P.M., the double-basin stepped solar still (DBSSSS) and vertical wick solar still could produce a maximum of 5.29 kg $m^{-2}$ and 1.29 kg $m^{-2}$ of drinkable water, respectively. The performance was shown to be significantly better than that of a wick-assisted solar still. The thermal efficiency of the double-basin stepped distiller is 22% greater than that of the wick-aided still. Prakash and Kumar (2025) developed a modified concatenated stepped

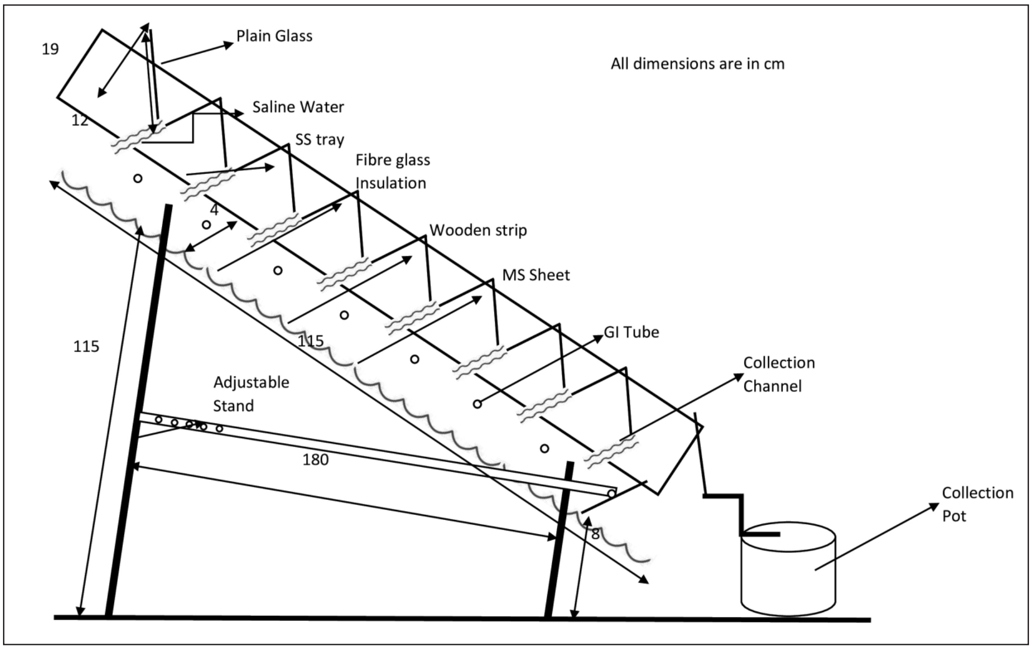


*Fig. 1. Schematic diagram of multi step basin type solar still.*

solar still (MCSSS) unit that generated 3.43 L of distillate day$^{-1}$, which was 18.72% more than that of a basic concatenated stepped solar still (SCSSS) unit. In comparison to the SCSSS unit, the MCSSS unit earned more carbon credits and had a shorter energy payback period. It was determined that the MCSSS unit's economic payback period was 1.297 months less than that of the SCSSS unit. Prakash *et al.* (2025), a redesigned flat plate collector system combined with a stepped solar still filled with beeswax and distributed with nanoparticles increased the energy, exergy, and productivity efficiencies by 8.79%, 12.42%, and 17.58%, respectively. Compared to the beeswax-loaded system, this system's yearly energy output, $CO_2$ mitigation, and carbon credit obtained were 8.79%, 9.17%, and 9.18% greater, respectively. The nano-dispersed system has an annual productive cost of $183.0 and a payback period of 513.67 days.

The objective of this work is to overcome the problem of corrosion of GI-made metallic still and improve the production of distilled water by designing trays made of stainless steel sheets of multi-step basin solar still. Economic analyses and carbon emission of solar still have also been carried out to study the real-time possibilities for its use in desalination process.

## Materials and methods

### *Experimental setup and observations*

The multi-step basin type solar still has been designed and developed (Fig. 1). This solar still features a box constructed from 24-gauge galvanized iron (GI) sheets, measuring (180 × 115 × 19 cm) and a glass sheet (3 mm thicken). Eight trays having a basin area of 180 × 19 m, made of SS sheet (24 gauge) fixed inside the box. Previous designs utilized GI sheets for the trays, which suffered from issues such as algae growth and rust, leading to deterioration. To address these challenges, stainless steel was selected as a replacement for the GI sheets. Sufficient fiberglass insulation has been installed beneath the trays to minimize heat loss from the bottom. Additionally, an adjustable angle bar stand has been constructed to allow for tilt adjustments based on latitude and seasonal changes. The still has been designed to be leak-proof, and a GI tube has been incorporated for filling the trays with water. The distilled output from the solar still is collected in a distillate channel located at the lower section and is then directed through a pipe into a collection cylinder.

### *Experimental arrangement and procedure*

A field experiment was conducted at the ICAR-Central Arid Zone Research Institute in Jodhpur, India (26°18′N and 73°04′E) to assess the performance of a multi-step basin type solar still during the winter, summer, and monsoon months of 2023. The solar still experiment commenced at 10:00 AM and continued for a duration of 24 hours. During the experiment, the solar radiation intensity ($I_b$) on a horizontal surface was recorded using a thermopile pyranometer. The internal water temperatures were measured with a DTM-100 thermometer equipped with point contact thermocouples, which have an accuracy of 0.1°C. Ambient air temperature was recorded using a mercury thermometer (also with an accuracy of 0.1°C) situated in an ambient chamber, while the distillate output was measured using a measuring cylinder with a least count of 10 ml. The performance of the solar still was evaluated by calculating the amount of distilled water produced daily, measured with a measuring jar.

*Efficiency of step basin solar still (η)*

The thermal efficiency of water heating was assessed by recording the temperatures of the tap water and the tray, while the efficiency of the distillate was evaluated by gathering the distillate in the collection pot and measuring its volume in liters per day (l/day). The subsequent formulas were employed to calculate both water heating and distillate efficiency.

$$\eta_{distillation}(\%) = \frac{\sum_{i=1}^{i=8} m\,(T_2 - T)C_p}{A\int_0^{\theta} H d\theta} \quad \ldots 1$$

$$\eta_{system}(\%) = \frac{m_d L}{A\int_0^{\theta} H d\theta} \quad \ldots 2$$

where m = Quantity of distillate, (l/d); $T_2$ = Final temperature of water in trays (°C); T= Initial temperature of water in trays (°C); m = Mass of water in each tray (lit.); $C_p$ = specific heat of water (4184 J/kg/°C); H = Solar radiation on glass sheet (kWh/m$^2$/d); θ = Period of the test; A = aperature area (m$^2$); $m_d$ = mass of distillate water obtained (lit.); L = latent heat of distiller water (J/kg); $\eta_{distillation}$ = distillation efficiency (%); $\eta_{system}$ = system efficiency (%).

*Economic assement of multi-step basin type solar still*: An economic assessment of the multi-step basin solar still was conducted by evaluating five financial metrics: net present value (NPV), pay-back period (PBP), benefit-cost ratio (BCR), annuity (A), and internal rate of return (IRR). These metrics were utilized to assess the economic feasibility of the solar still.

*Net Present Value (NPV):* The purpose of calculating the net present value (NPV) is to assess the relationship between the future benefits and the initial investment costs, while also considering the appropriate interest rate. The net present value for solar still was determined using the equation below (Poonia *et al.,* 2024a):

$$NPV = \frac{(E-M)}{a}\left[1-\left(\frac{1}{1+a}\right)^n\right] - C \quad \ldots 3$$

- Initial cost (C) = Rs 16000 /-, a = (0.12) and n = 15 years
- Gross annual benefit (E) = Rs 23090/-
- Maintenance cost 5% of initial cost C (M) = Rs 800/-

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

*Benefit-Cost Ratio (BCR):* The benefit-cost ratio of a solar still is expressed as the ratio of initial cost and current price to initial cost as follows:

$$BCR = \frac{E\ \sum_{n=1}^{15}\frac{1}{(1+a)^n}}{C + M\ \sum_{n=1}^{15}\frac{1}{(1+a)^n}} \quad \ldots 4$$

*Annuity (A):* The annuity (A) associated with the project reflects the average net annual returns. This term can be given as (Poonia *et al.,* 2018, 2020, 2022 and 2024a and Singh *et al.*, 2020),

$$A = \frac{NPV}{\sum_{t=1ton}\left(\frac{1}{1+a}\right)^n} \quad \ldots 5$$

*Pay Back Period (PBP):* The payback period was determined as the duration needed to recoup the initial investment through the net average annual cash inflows produced by the investment. The PBP was computed using the following equation (Poonia *et al.,* 2024a)**:**

$$PBP = \frac{log\frac{(E-M)}{a} - \left(log\frac{(E-M)}{a} - \ log\ \left[\left(\frac{E-M}{a}\right) - C\right]\right)}{log\ \ (1+a)} \quad \ldots 6$$

*Internal rate of return (IRR):* The internal rate of return (IRR) represents the ratio of the initial investment to the future income generated by that investment. Generally, a higher IRR is considered more favorable (Poonia *et al.,* 2018, 2020, and 2022; Singh *et al.,* 2020). At an interest rate of 12%, the net present value (NPV) amounts to Rs 169,359.10; at 50%, the

NPV is Rs 38,338; and at 100%, it is Rs 11,230.90. Conversely, at an interest rate of 180%, the NPV turns negative, resulting in Rs -871. The IRR can be calculated using the relationship that equates NPV to zero, employing a lower discount rate of 100% and a higher discount rate of 180%.

Solving an equation for a, which is the IRR

$$NPV = (E\text{-}M) \sum_{t=1 to n} \left(\frac{1}{1+a}\right)^t = C$$

or $$\frac{x(1-x^n)}{(i-x)} = \frac{C}{(E-M)}$$

where $x = \frac{1}{(1-a)}$ as $x^{15}$ tends to be zero,

$$\frac{x}{(1-x)} = \frac{C}{(E-M)}$$

or = $$\frac{\frac{1}{(1+a)}}{1-\left(\frac{1}{1+a}\right)} = \frac{C}{(E-M)}$$

or a (IRR) = $$\frac{(E-M)}{C} \quad ...7$$

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

Carbon credit: The yearly energy savings using a multi-step basin solar still for Jodhpur (India) conditions were calculated (Singh *et al.*, 2020). Furthermore, the potential reduction in CO2 emissions associated with this energy production was calculated according to Poonia *et al.*, (2024b). If the electricity were to be produced from coal-fired power plants, the average $CO_2$ equivalent would be approximately 0.98 kg of $CO_2$ per kWh. The useful energy output, measured in kWh, was calculated using the following formula,

$$\text{Useful energy gained} = \frac{A \times \text{efficiency} \times \text{average daily insolation} \times 3600 \times \text{days of use}}{1000} \quad ...9$$

$$\text{Quantity of carbon mitigation (kg)} = 0.98 \times \text{Energy gain (kWh)} \quad ...10$$

A carbon credit is given in terms of tonnes of carbon, Therefore,

$$\text{Carbon credit} = \frac{\text{Carbon mitigation (kg)}}{1000} \quad ...11$$

Net $CO_2$ reduction was monitored under the Kyoto Protocol with an emission credit of 21 € (euro) (where 1 € = INR 92.7) per t $CO_2$ e (European Climate Exchange, 2008). Therefore, carbon credit can be monetized.

## Results and Discussion

Table 1 presents the hourly experimental data on average air temperature, water temperature, and solar intensity for a typical day in May, August, and December 2023, covering 11 hours from 8:00 AM to 6:00 PM in the multi-step basin-type solar still. The average maximum water temperature for brackish water recorded in May, August, and December was 51.9°C, 45.0°C, and 35.6°C, respectively, while the corresponding ambient temperatures are 39.5°C, 30.9°C, and 31.5°C (as detailed in Table 1). Additionally, the average solar insolation ranged from 430 $Wm^{-2}$ to 890 W $m^{-2}$ in May, 105 $Wm^{-2}$ to 626 $Wm^{-2}$ in August, and 250 $Wm^{-2}$ to 670 $Wm^{-2}$ in December, as indicated in Table 1.

*Table 1. Performance of multi-step basin-type solar still in summer, monsoon and winter months*

| Time (Hrs) | Insolation ($Wm^{-2}$) | | | Maximum water temperature (°C) | | | Ambient temperature (°C) | | |
|---|---|---|---|---|---|---|---|---|---|
| | May | Aug | Dec | May | Aug | Dec | May | Aug | Dec |
| 8:00 A.M. | 430 | 105 | 250 | 35.8 | 30.4 | 25.2 | 27.1 | 24.0 | 22.8 |
| 9:00 A.M. | 630 | 204 | 420 | 40.4 | 35.6 | 32.8 | 30.2 | 26.2 | 24.0 |
| 10:00 A.M. | 770 | 258 | 560 | 45.6 | 41.5 | 36.9 | 33.4 | 28.4 | 25.8 |
| 11:00 A.M. | 860 | 244 | 640 | 51.4 | 45.2 | 41.0 | 36.0 | 31.0 | 29.8 |
| 12:00 A.M. | 940 | 626 | 710 | 56.2 | 50.1 | 45.1 | 38.1 | 33.3 | 31.5 |
| 1:00 P.M. | 890 | 588 | 650 | 61.1 | 52.3 | 43.8 | 39.5 | 34.1 | 32.0 |
| 2:00 P.M. | 790 | 332 | 570 | 64.5 | 54.4 | 42.1 | 41.2 | 35.4 | 31.5 |
| 3:00 P.M. | 650 | 473 | 450 | 61.2 | 51.6 | 40.4 | 40.8 | 34.1 | 29.4 |
| 4:00 P.M. | 540 | 353 | 350 | 56.4 | 47.4 | 40.0 | 40.1 | 33.1 | 28.5 |
| 5:00 P.M. | 460 | 255 | 260 | 51.2 | 45.4 | 39.1 | 38.1 | 31.3 | 27.0 |
| 6:00 P.M. | 340 | 151 | 190 | 47.4 | 41.5 | 38.0 | 36.0 | 29.4 | 25.1 |

*Table 2. Average distillate output (Lday-1) from multi-step basin-type solar still*

| Month/Season | Optimum tilt angle (degree) | No. of days of data collection | Average distillate output (L $day^{-1}$) | Average solar radiation on horizontal plane (Wh $m^{-2}$ $day^{-1}$) |
|---|---|---|---|---|
| Winter | | | | |
| December 2022 | 48.15 | 20 | 4.52 | 433 |
| January 2023 | 48.45 | 17 | 5.20 | 461 |
| February 2023 | 39.80 | 16 | 6.41 | 544 |
| March 2023 | 28.60 | 22 | 6.85 | 639 |
| Summer | | | | |
| April 2023 | 16.77 | 20 | 7.01 | 708 |
| May 2023 | 7.39 | 23 | 8.40 | 739 |
| June 2023 | 2.87 | 16 | 7.60 | 692 |
| Monsoon | | | | |
| July 2023 | 4.66 | 12 | 6.05 | 586 |
| August 2023 | 10.85 | 15 | 5.80 | 542 |
| September 2023 | 21.96 | 18 | 6.45 | 597 |
| October 2023 | 33.90 | 20 | 6.60 | 569 |
| November 2023 | 44.09 | 21 | 5.56 | 481 |

Table 2 presents the optimal angle for each month, the duration of experimental data collection, the average distillate yield, and the average solar radiation on the horizontal plane for the multi-step basin-type solar still during the summer, monsoon, and winter seasons of 2023. Distillate yield was recorded using a measuring jar at hourly intervals from 8:00 AM to 6:00 PM, capturing both daytime and nighttime condensation. It was noted that the internal temperature rose as a consequence of increased solar intensity, resulting in a higher rate of heat utilization for water heating at noon, resulting in higher evaporation rates post-noon. Additionally, the condensation rate peaked around noon as solar intensity waned. The highest distillation rate, reaching 260 ml, was recorded between 4:00 PM and 5:00 PM in the multi-step basin-type solar still.

During the winter months (December, 2022 to March 2023), the optimal average tilt angle was recorded at 45.5°C, resulting in a total average daily productivity of 5.745 L $day^{-1}$ from the multi-step basin-type solar still, which included both day and night condensation. In contrast, the summer months (April to June 2023) saw a decrease in the optimal tilt angle to 16.0°C, leading to an increase in average distillate productivity to 7.670 L $day^{-1}$ from the same solar still. Furthermore, in the monsoon and post-monsoon periods (July to November 2023), the average optimal tilt angle was 19.6°C, and the average distillate productivity exceeded that of the winter season, reaching 6.092 L $day^{-1}$. Table 2 illustrates the variation in average total distillate output per day across different seasons for the multi-step basin-type solar still. The performance analysis of the still throughout various months and seasons indicated that the average distillate yield ranged from 4.520 to 6.850 L $day^{-1}$ during the winter months, from 7.010 to 8.400 L $day^{-1}$ during the summer season, and from 5.560 to 6.600 L $day^{-1}$ during the monsoon and post-monsoon seasons. The total average annual distillate yield was calculated to be 2310 L $day^{-1}$.

The efficiencies of the developed system were evaluated separately for its applications in water heating and distillation. The average efficiency for distillate production was approximately 25%, while the efficiency for water heating reached up to 35%. Overall, the combined efficiency was 65%, indicating its effectiveness for both water heating and distillate collection. A comparison was made between the performance of the multi-step basin-type solar still and conventional reverse osmosis (RO) plants in terms of salinity (EC) reduction. The electrical conductivity (EC) of raw saline water, with salt concentrations ranging from 15.0 $dSm^{-1}$ to 18.30 $dSm^{-1}$, was decreased to between 1.75 $dSm^{-1}$ and 5.06 $dSm^{-1}$ in commercial RO plants. In contrast,

*Table 3. Comparison of desalination unit with conventional RO*

| Electrical conductivity (EC) of raw water ($dSm^{-1}$) | Electrical conductivity (EC) after desalination ($dSm^{-1}$) | |
|---|---|---|
| | Conventional RO | Solar still |
| 15.01 | 1.75 | 0.17 |
| 17.90 | 3.40 | 0.54 |
| 18.30 | 5.06 | 0.84 |

the multi-step basin solar still achieved an EC reduction ranging from 0.17 $dSm^{-1}$ to 0.84 $dSm^{-1}$ (Table 3). Furthermore, the multi-step basin solar still was tested with highly saline water, demonstrating superior performance compared to conventional RO plants.

*Economic analysis of multi step basin type solar still* : An economic assessment of the multi-step basin-type solar still was conducted under two scenarios: one without the monetization of carbon credits and the other with monetization of carbon credit. This analysis involved calculating the life cycle cost (LCC) and life cycle benefit (LCB) of the system. Furthermore, five economic indicators were evaluated to assess the technology's economic feasibility, including the Benefit-Cost Ratio (BCR), Net Present Worth (NPW), Annuity (A), Internal Rate of Return (IRR), and Payback Period (PBP).

The initial investment (C) for the solar still unit amounts to INR 16,000. The annual operational and maintenance costs (O&M), which include labor, are estimated at 5% of the initial investment, totaling INR 800 per year. The benefit (E) derived from the still's output, calculated at a rate of 7.7 liters per day over 300 days annually and priced at INR 10 per liter, amounts to INR 23,090. The discount rate (a) is set at 12% of the initial investment, and the lifespan of the solar still unit is projected to be 15 years. Equation (3) has been utilized to calculate the net present value (NPV) of the solar still device, indicating an NPV of INR 151,732 without accounting for carbon credit monetization and INR 169,359 when carbon credits are included. The benefit-cost ratio is determined by dividing the present value of benefits by the present value of costs, as per Equation (4), resulting in a ratio of 7.33 for the fabrication of the step basin solar still device without carbon credit monetization and 8.78 with it.

Using equation (5) to determine the annuity/annual revenue of the still device, it shows that the average annual return of the device is INR 22254 without monetization of carbon credit and 24840 with monetization of carbon credit. The payback period is eight months without monetization of carbon credit and 6.5 months with monetization of carbon credit, which is less than the expected life of the unit, which is approximately 15 years. Since investments with longer payback periods are considered risky and unreliable, and therefore the return on investment is faster, investors may prefer systems with shorter payback periods (Poonia *et al.,*2023 and 2024; Singh *et al.*, 2020; Poonia *et al.* (2024a) estimated the business model of construction-type solar thermal desalination device and the economic attributes, such as payback period (PBP), rate of return (IRR), cost-present value (NPV) and cost-benefit ratio was 1 month, 1350%, INR 4916083 and 1.15, respectively. The techno-economic feasibility of solar-based desalination with reverse osmosis in Pakistan found the payback period for a solar desalination reverse osmosis system was 1.83 years (Ghafoor *et al.,* 2020). Izquierdo and Blanchard (2020) developed a solar desalination system for irrigation/potable water and electricity generation in desert or arid regions. The study shows that the simple payback period (SPB) for the first year of use is 11.8 years without inflation. The payback period is 10.1 years after accounting for inflation and taking into account the total annual income. Equ (8) has been used to determine the internal rate of return (IRR) of the solar still device and it reveals that the internal rate of return (IRR) comes to 143% in the case of without monetization of carbon credit and 174% in case of with monetization of carbon credit, which is very high for a project to be economically viable. The internal rate of return (IRR) is 0.1041 (10.41%), which means that the project is still profitable with a discount rate of up to 10% (Izquierdo and Blanchard 2020). Sherrick *et al.* (2000) showed that the most commonly used financial method for decision-making by large companies is IRR (88% of companies) and NPV method (63% of companies). Therefore,

*Table 4. Values of economic attributes*

| Attributes economics | Without monetization of carbon credit | With monetization of carbon credit |
|---|---|---|
| BCR | 7.33 | 8.78 |
| NPV (Rs.) | 1,51,732 | 1,69,359 |
| A (Rs.) | 22,254 | 24,840 |
| IRR (%) | 143 | 174 |
| PBP (years) | 0.80 | 0.65 |

the decision tool used here is the true IRR, which is found to be the highest (174%). All else being equal, with IRR as the deciding factor, the one with the highest IRR will be considered the better option. One reason for this decision is that a higher IRR indicates a lower risk (Poonia *et al.,* 2024a).

The values of economic parameters viz., BCR, NPV, A, IRR, and PBP were computed as 7.33, INR 151732, INR 22254, 143%, and 0.80 years. The technology is economically feasible as IRR is considerably high and PBP is abysmally low. These values get better when carbon credit is monetized with BCR, NPV, A, IRR, and PBP computed as 8.78, INR 169359, INR 24840, 174%, and 0.65 years. The values of five economic attributes, namely, benefit-cost ratio (BCR), net present worth (NPW), annuity (A), internal rate of return (IRR), and payback period (PBP) were presented without monetization of carbon credit and with monetization of carbon credit, in Table 4.

## Conclusion

The multi-step basin-type solar still (1.5 m$^2$) offers a practical solution for potable water scarce ares, producing 6-8 liters of distilled water daily. Its tilting mechanism maximizes solar radiation capture, while 26-gauge stainless steel trays prevent algae growth and corrosion. This green energy technology significantly reduces carbon emissions, potentially mitigating approximately 35 tonnes over its lifetime, contributing to a greener environment.The unit is highly cost-efficient with a considerably high IRR (174%) and abysmally low PBP (0.65 years) when carbon credit monetization is taken into consideration. In addition, it can also provide hot water as and when required. It has multiple applications, such as mixing distilled water with saline water to make it drinkable, in dispensaries, laboratories, batteries, etc. The solar still unit will overcome the problem of corrosion associated with metallic solar still.

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