# Comparing the Economics of Energy and Environment for Active Single and Double Inclined Solar Distillers

Sushil Kumar, Mechanical Engineering Department, R. D. Engineering College, Ghaziabad, U.P, India 201206
Corresponding author- kumar.sushil@gmail.com

## Abstract

The compound illustrative concentrator (CPC) photovoltaic warm (PVT) connected to sun oriented photographs (N) of water gatherers called PVT-CPC Dynamic sun based filtration framework investigation is finished for a sun powered channel framework for a given molecule size under weather patterns of New Delhi. We look at framework efficiency, effectiveness, and life cycle cost analysis. With a yield on an annual basis, an energy restitution component, and an effectiveness of life cycle cost change examination of 5.0% and 12.63%, respectively, the warm model transformation productivity of life cycle (LCCE) is considered and a solo and double compound illustrative concentrator with photovoltaic framework for separating sun oriented distiller for the water profundity of 0.14 m. Not to mention, 22.21% exceeds the performance-slanted. The above examination closed, we can affirm that the twofold disposed are superior to the dynamic single PVT-CPC procedure for separating. The updated framework endures longer and can meet consumable water and DC power on radiant business days. For a long period of 50 years, with a loan fee of 5%, the water bowl region for a profundity of 0.14 m, the twofold disposed surpasses rural and efficiency, 16.09%, 21.48%, and 8.41%, individually.

**Keywords - energy payback time, energy payback factor, LCCE, yield, distiller**

## 1. Introduction

The solar distillation system in the remote area is the best choice to overcome the drinking water supply crisis economically, it does not create several adverse outcome on the surroundings, it is simple to keep up, with even for the period of the day, it provides D.C power supply, it is really simple and ease to design and manufacture. This is a role in the response circle that is differing from hydrological cycle or else, it is called a scanned view of hydrological cycle. This technology is provided water to a deserted area by clearing the brine; for the purpose, it can be still use as a solar device. Through a study of our literature, I have found that many researchers in solar distillation are researching active solar filtration system there. The above shortcomings can be overcome by solar distillation [1]. Various researchers reviewed numerous aspects such as energy matrices, design, and with or without smart materials. [2 – 9]. The traditional distiller represents simple design, performance. But the production of water was low later addition of elements heat gain can be improved. So, the new technology as nanotechnology in distillation can improve production of water [10]. In this work, the basefluid and nanoparticles optimized for without heat exchanger (basefluid/nanofluid) (system A), and (system B) with helically coiled heat exchanger (system B) the optimized parameters i.e. production of water, thermal energy, exergy, significantly improved with CuO. Moreover, based on energy and exergy CO2 mitigation annually found 14.95 tones and 3.17 tonnes correspondingly for the hybrid system (A); whereas, it was found to be 24.61 tones and 2.36 tonnes correspondingly for the hybrid system (B) using CuO nanofluid. Traditional solar distiller has been compared based on performance with (system C) and found better with these modifications. Later on, a using PVT-CPC double slope solar distiller optimized for enhanced matrices [11]. For FPC system the flow rate, depth of water, and number of collectors have been studied at 0.14 m. subsequently per annum. Obtained results were compared with previous researchers and found better with PVT-CPC based on water generation, and cost of distillate. The payback time of energy was lower based on exergy by 74.66% and 62.62%; factor of energy production is higher by 43.30% and 38.14%; higher LCCE by 48.57%, and cost of distillate output is lower by 35.37% and 4.88% for the proposed system with FPC rather than system with PVT and double slope still respectively. Also, this system has been analyzed further for the PVT-CPC solar distiller life cycle cost of it the thermal modeling has been developed [12]. Optimized flow rate achieved for PVT-CPC. The yearly production, EPF and conversion efficiency of life cycle have been found higher by 5%, 12.73%, and 22.22% correspondingly for double slope than single slope at 0.14 m depth of water. However the 5% rate of interest and EPT has been found to be lower by 10.09% and 17.98% respectively for double slope solar distiller. It is found that the double slope is better than single slope PVT-CPC on yearly basis less than 0.19m depth of water. This system met the water requirement and self sustainable. Further, an experiment has been done for the observation of the analysis of PVT-FPC active solar distiller performed [13] climate conditions have been collected of New Delhi. The results have been compared with experiment to theoretical the correlation varies 0.97 to 0.99. The determination of coefficient varies from 0.94 and 0.98. The annual water generation rate varies 120.29% and 883.55% evaluated of thermal energy, exergy. It has been seen that the electricity generation as well as water generation requirement achieved by system. Moreover, ETC is also one of the fairer element that lowers the heat loss corresponding to gain which utilize for fresh water production. Many a researchers have worked on identifying recital on evacuated tube collector orientation [14, 15]. Later, more modifications have been introduced by researchers for the performance of evacuated tube collectors [16, 17]. Investigated experimentally environeconomic and $CO_2$ emission with wick basin and found 4.99 kg/day yield, 17.65 tons $CO_2$ emission, and cost of production 1.74 R.S/kg at rate of interest 5% for life span of 20 years. [18]. Pyramid in triangular shape type solar distiller has been analyzed economically [19, 20]. Publicized economic analysis for miniature scale of desalination plant linked with the pool of garden [21]. Later on, environ-economic analysis parameter has been exposed for solar systems for reverse osmosis. The yield is produced by 4079 kg/year and 23.73 tons $CO_2$ mitigated in 20 years. The result was found as 25% improved extract output at 0.0343 $/l and prevents 15.6 tons of $CO_2$ emissions [22]. Further, this study was presented as a comparative learning for showing different aspects related to eco and economic parameters, etc., also shows maximum prevention of $CO_2$ emissions up to 41.6 tons [23].

The current work refers the analysis of energy matrices and environ-economic analysis of active solar still with N are equally integrated with the slightly sheltered PVT-CPC water collectors in which the basin type research works are carried out and compared to the value obtained, the system is establish in series; The exit from the second is associated with the third entry. Water receives in final collector in such a way. The collector is heated, and this water of the basin is circulated again in the system with the help of a DC pump motor, so this arrangement creates a loop connection between the solar through the insulated pipe, pumped Nth identical PVT-CPC water collector. There are two significant differences amid the previous researchers and proposed. The prime difference is that the beam intensity connected to the photovoltaic thermal compound parabolic concentrator's receiver surface with the help of a photovoltaic thermal -FPC. The water depth is second difference and proper marking and mass discharge of the flat plate. The calculations are made for different parameters: exergoeconomonic parameters, environeconomic parameters, energy matrix, productivity, and different capacities. But no such kind of literature is available in matrices analysis of N-PVT-CPC active for solo and dual inclined distiller.

## 2. System description

Solo inclined active solar still using CPC basin type as shown in Fig. 1 is analyzed. Table 1 shows the system specifications. Table 2 shows the mean velocity of each month in year. Partly covered PVT-CPC is 0.25 m × 1 m kept below the collector because the minimum temperature of water there is shallow (Chow et al. 2006). The collector is mounted in series that means second inlet is joint first the outlet, the 3rd inlet is connected to the 2nd outlet, and this arrangement continues until the plate. Our focus is on raising Basin's water temperature and the chain connection arrangement for it being the best; we can get more distilled by raising the temperature of the basin. This arrangement in which collectors are connected series and outlet of compound parabolic concentrator is connected to basin. Now we need some supply source to operate this system, for which a pump is applicable, which acts as medium to feed basin and collectors. Solar basin is connected to inlet of pump and the first

PVT-CPC water collector inlet to exit the pump, but the pump needs to be powered and powered by a DC motor. It is connected with help of pipes. In a box system made of aluminum to capture absorption, for heat reduction, the top box 0.1m thickness insulation is made of wool-insulation thickness 0.004 m parabolic-shaped CPC collector aluminum coating. There are basically two fields used in this system. The area of aperture and receiver is half of aperture area. With the help of a parabolic surface, the radiation beam is reflected towards the receiver surface. The collectors PVT-CPC with 30° inclined to horizontal to get maximum radiation. The pump is connected to motor which consumes power generated by PVT. The surrounding water PVT is get heat through the convection mode through the pipes connected. The 2 m × 1 m basin size is connected to a solo inclined active solar distiller is made of reinforced plastic and inclined at 15° the condensing cover, with the help of putty to close the upper system properly. To absorbed maximum heat the basin box wall is coated with black paint. The radiation energy is flows through reflection, absorption transmit with help of glass cover on top surface.

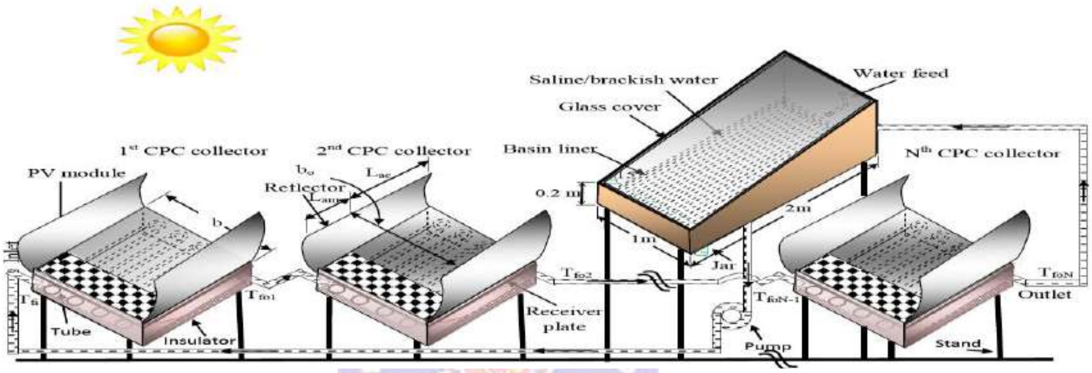


**Fig. 1 Solo inclined PVT-CPC active solar filtration system**

A certain percentage after absorbing of solar energy in water, the rest is transmitted and reflected in to basin liner, the temperature of basin liner rises. However, the thermal energy carried away by water and temperature rises. The risen water temperature is amid glass and water surface. The evaporated water on the glass cover (shelter) condenses through film-type condensation. The frozen water on the inside portion of glass is stored in jar with the help of a pipe attached. The wall is on the down side the opening is provided from the basin with the help of pipes and water through this collected to Jar. To receive maximum solar radiation box is faced in south direction.

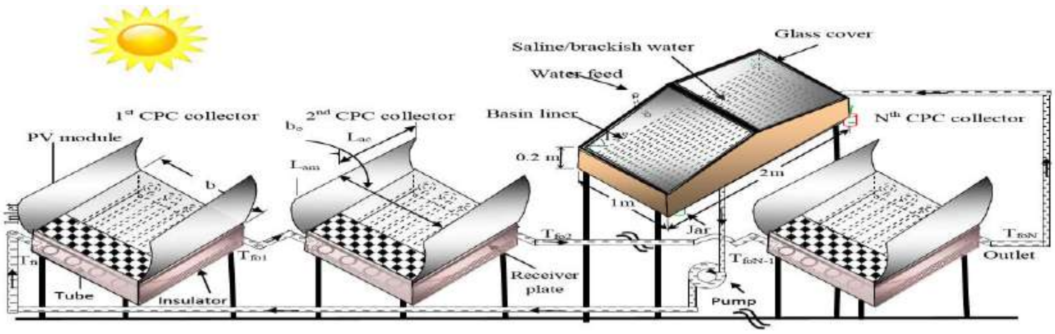


**Fig. 2 Dual inclined PVT-CPC active solar filtration system**

**Table 1 technical details of solo and dual inclined photovoltaic active solar distiller**

| Solo inclined active solar still | | Dual inclined active solar still | |
|---|---|---|---|
| **Component** | **Specification** | **Component** | **Specification** |
| Length | 2.0 m | Length | 2.0 m |
| Width | 1.0 m | Width | 1.0 m |
| Inclination of glass cover | 15° | Inclination of glass cover | 15° |
| Altitude of smaller side | 0.2 m | Altitude of smaller side | 0.2 m |
| Material of body | GRP | Material of body | GRP |

| | | | |
|---|---|---|---|
| Material of stand | GI | Material of stand | GI |
| Material of cover | Glass | Material of cover | Glass |
| Direction | South | Direction | East to west |
| **Photovoltaic thermal compound parabolic concentrator collector** | | | |
| **Item** | **Specification** | **Item** | **Specification** |
| Collector and active | Tube in plate type, N | Area of the aperture | 2 $m^2$ |
| Solar water collector receiver area | 1.0 m * 1.0 m | Area of module aperture | 0.5 m * 2.0 m |
| Thickness of collector plate | 0.002m | Area of receiver aperture | 0.75 m * 2.0 m |
| Cu tube thickness | 0.00056 m | Area of module receiver | 0.25 m *1.0 m |
| Copper tubes length | 1.0 m | Receiver | 0.75 m * 1.0 m |
| $K_i$ ($Wm^{-1}K^{-1}$) | 0.166 | $F^{/}$ | 0.968 |
| FF | 0.8 | ρ | 0.84 |
| CPC inclination with horizontal | 30° | $\alpha c$ | 0.9 |
| CPC toughen glass thickness | 0.004 m | βC | 0.89 |
| Under glass the collector effective area | 0.75 $m^2$ | $\alpha p$ | 0.8 |
| Insulation | 0.1 m | $\tau g$ | 0.95 |
| Diameter of pipe | 0.0125 m | Under PV module collector effective area | |
| Motor rating of DC | 12 v, 24 w | 0.25 $m^2$ | |



In Fig. 2 the diagram of dual inclined solar distiller, the direction of unit basin is east-west facing, and the specifications are shown in Table 1. For solo and dual inclined, PVT-CPC active solar distiller has same working principle as solo inclined.

Table 2 for active solar distiller average wind velocity of each month year for PVT-CPC

| **Month** | Jan | Feb | March | April | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Velocity (m/s)** | 2.77 | 3.13 | 3.46 | 3.87 | 4.02 | 4.11 | 3.39 | 2.91 | 2.85 | 2.16 | 1.83 | 2.4 |

## 3. Mathematical formulations

The balancing equations are shown for all types of heat transfer from the system and write equilibrium equation. Now we have to write the energy balance equation when determining the parameter, but solving this equation will lead to some complex situations, so we have to do some makeup to overcome this situation, but the error is estimated that this option is a single and double-tilt PVT-CPC Active Solar Filtration This is done when writing the energy balance equation for the system. The various components are as follows.

i. You are ignoring the ohmic losses of solar cells. The connecting wire is usually copper or aluminum, and inter connect has a meager electrical resistance, which is on the order of 10-8 or m and the resulting damage.

ii. Which is less than losses of other systems; due to the loss of heat transfer, it is mattered to that extent the overall performance.
iii. The efficiency of solar cell can be reduced due to solar heat calculated, glass cover. The heat loss caused by it is much less than other heat losses by the system, therefore it is minimal.
iv. The steady state never will prove to be same vapor leakage, and that this will create a complex situation for the energy equilibrium equation.
v. It can be said the level of variation in water is minimal and can be neglected.
vi. Configuration no layer meaning is no solar stratification still occur in sink waters. The damage caused by stratification is minimal and neglected.
vii. Film type abstraction involves glass. But even then some water droplets form on the inner surface and it is neglected.

**3.1 obtainable energy gains from partly covered N-PVT-CPC collectors linked in series**

The expression for partly covered N-PVT-CPC is given by Tripathi et al. (2016)

$\dot{Q}_{uN} = (1- K_p^N)/(1-K_p)\,(A\,FR\,(\alpha\tau))1Ib(t) + (1- K_p^N)/(1-K_p)(\,A\,FRUL\,1(\,Twi - Ta\,)$ (1)

The exhaust temperature of the N$^{th}$ photovoltaic thermal compound parabolic concentrator collector ($T_{woN}$) is given by

$T_{woN} = (AF_R(\alpha\tau))_1/\dot{m}_{fi}C_{fi}*(1-K_p^N)/(1-K_p)*I_b(t) + (AF_RU_L)_1/\dot{m}_{fi}C_{fi}*(1- K_p^N)/(1-K_p)*T_a + K_p^N * T_{fi}$ (2)

anywhere, Twi = Tw, and Two = TwoN Nth is outlet temperature of the solar photovoltaic thermal compound parabolic concentrator water collector, which is given in the basin.

Anywhere, the typical capacity of the test conditions the mean high temperature of the N$^{th}$ PVT-CPC collectors is $T_{woN}$, an expression is given to calculate the value of Tripathi et al. (2016).

**3.2 balancing equations for solo inclined solar still**

The balancing equations for solo inclined distiller is given ref. Singh et al. (2015)

3.2.1 glass cover inside surface

$\acute{\alpha}_{gi} I_s t A_{gi} + h1_1(T_w - T_{gi})*A_b = K_g/L_g*(T_{gi}-T_{go})*A_{gi}$
(4)

3.2.2 Outer surface of glass cover

$K_g/L_g\,(T_{gi} - T_{go})*A_{gi} = h1_{1g}\,(T_{go} - T_a)*A_{gi}$
(5)

Anywhere, $h1_{1g} = h1_{r,g} + h_{c,g}$ or $h1_{1g} = 5.7 + 3.8*V$

3.2.3 Mass of basin water

$\dot{Q}_{uN} + \acute{\alpha}_{wi} I_s(t) A_b + h1_{bw}(T_b - T_w)*A_b = h1_{1w}(t_w - t_{gi})*A_b + Mw*Cw(dt_w/dt)$ (6)

Anywhere, $\dot{Q}_{uN}$ represents thermal energy overall outcome and

3.2.4 Basin liner

$\acute{\alpha}(t)*A_b = h1_{bw}\,(T_b - T_w)*A_b + h1_{ba}\,(T_b - T_a)*A_b$
(7)

By solving the above equations, the equations for basin water temperature can be obtained.

$dT_w/dt + \alpha_1 T_w = f_1(t)$ (8)

The following assumptions are taken to obtain the inexact explanation of above equations

(i) Time hiatus (Δt) that is $(0 < t < \Delta t)$.
(ii) $\alpha_1$ constant for time interval time Δt.
(iii) At mean amount of $T_a$, $I_b$ (t) and $I_c$ (t) amid '0','t', and can represent as $\bar{T}_a$, $\bar{I}_b$ (t) and $\bar{I}_s$(t). Therefore, $f_1$(t) give a steady rate and its mean amount representation as $\bar{f}_1$(t).

Preliminary conditions are as $T1_w = T_{w0}$ at t = 0, in the Eqs. 4.7 We obtained the result as

$T_w = (\bar{f}_1(t))/\alpha_1)*(1 - e^{-\alpha 1t}) + T_{w0}*e^{-\alpha 1t}$ (9)

We can determine glass temperature by using $T_w$,

$T_{gi} = (\acute{\alpha}_g*Ic\,(t)*A_g + h_{1w}T_w*A_b + U_{c,}ga*Ta*Ag)/(U_{c,ga}*A_g + h_{1w}*A_b)$ (10)

$T_{go} = (K_g/L_g)T_{gi} + h_{1g}T_a/(K_g/L_g) + h_{1g}$ (11)

Per hour yield can be expressed as $m_{ew}$

$m_{ew} = (h_{ewg} * A_b(T_w - T_{gi})/L) * 3600$ (12)

The following equation represents yield in single slope solar still.

**3.3 balancing equations of dual inclined solar still**

Dwivedi and Tiwari gives the balancing equations.

3.3.1 East side

3.3.1.1 For inside condensing cover

$\acute{\alpha}_{gi} I_{SE} * A_{gE} + h_{2wE}(T_w - T_{giE1})*(A_b/2) - h_{EW}(T_{giE1} - T_{giW})*A_{gE} = (K_g/L_g)(T_{giE1} - T_{goE1})*A_{gE}$ (13)

Representation of overall heat transfer coefficients $h_{1wE} = h_{rwgE} + h_{cwgE} + h_{ewgE}$.

3.3.1.2 For outside condensing cover

$(K_g/L_g)(T_{giE1} - T_{goE1})*A_{gE} = h_{1gE}(T_{goE1} - T_a)*A_{gE}$ (14)

Where, $h_{1gE} = h_{rgE} + h_{cgE}$ or $h_{1gE} = 5.7 + 3.8V$

3.3.2 West side

3.3.2.1 For inside glass cover

$\acute{\alpha}_{gi} I_{SW}(t)*A_{gW} + h_{1wW}*(T_w - T_{giW1})*(A_b/2) + h_{EW}*(T_{giE1} - T_{giW1})*A_{gE} = (K_g/L_g)*(T_{giW1} - T_{goW1})*(A_{gW})$ (15)

3.3.2.2 For outside glass area

$(K_g/L_g)*(T_{giW1} - T_{goW1})*A_{gw} = h_{1gW}*(T_{goW1} - T_a)*A_{gW}$ (16)

3.3.2.3 for liner of basin

$\acute{\alpha}_{bi}\{I_{SE}(t) + I_{SW}(t)\}*(A_b/2) = h_{bw}*(T_b - T_w)*A_b + h_{ba*}(T_b - T_a)*A_b$ (17)

3.3.2.4 Mass of water in basin

$(M_w * C_w)*(dT_w/dt) = (I_{SE}(t) + I_{SW}(t))\ \acute{\alpha}_{wi}\ (A_b/2) + h_{bw}*(T_b - T_w)*A_b - h_{1w}*(T_w - T_{giE1})*(A_b/2) - h_{1w}*(T_w - T_{giE1})*(A_b/2) + \dot{Q}_{uN}$

(18) the expression get for $(T_w)$ solving the equations (1), (12) to (18) and by initial input $T_w = T_{w0}$ at $t = 0$

$T_w = (\bar{f}_2(t)/\ \alpha_2)*(1 - e^{-\alpha 2t}) + T_{w0}e^{-\alpha 2t}$ (19)

comparative study shows in single and dual inclined solar still water temperature is same, but constants of equation (19) is of dual inclined photovoltaic thermal compound parabolic concentrator active solar distiller unit is different from the solo inclined distiller system and they are given in appendix.

By solving $T_w$ from equation (19) we can calculate the glass temperature as follows

$T_{giE1} = (A_{11} + A_{12}T_w)/p$ (20)

$T_{giw1} = (B_{11} + B_{12}T_w)/p$ (21)

$T_{goE1} = \{(K_g/L_g)*(T_{giE1}) + h1_{1gE} * T_a\}/\{(K_g/L_g) + h1_{1gE}\}$ (22)

$T_{goW1} = \{(K_g/L_g)*(T_{giw}) + h_{1gw}T_a\}/\{(K_g/L_g) + h_{1gw}\}$ (23)

By using the following equations we can get the water temperature for dual inclined solar still.

East and West side yield can be obtained as follows.

$\dot{m}_{ew,E} = [h_{ewE}*(A_b/2)*(T_w - T_{giE1})]/L * 3600$ (24)

$\dot{m}_{ew,W} = [h_{ewW}*(A_b/2)*(T_w - T_{giW1})]/L * 3600$ (25)

equations represents hourly yield in east and west side.

## 4. Analysis

The second laws of thermodynamics satisfy the thermal equations by balancing of exergy equations i.e. first and second both laws are related to entropy.

$E_{Xout1} = A_b * h_{ewg}\ [(T_w - T_{gi}) - (T_a + 273) \times \ln\{(T_w + 273)*(T_{gi} + 273)^{-1}\}]$ (26)

The annual overall thermal energy kWh, overall thermal exergy kWh, annual yield in kg can be calculated using monthly energy, exergy and yield.

Using equation (26), to find solar energy in pairs, the term energy gain can be given as

hourly exergy gain = $h_{ewgE} * (A_b/2) * [(T_w - T_{giE1}) - (T_a + 273) * \ln\{(T_w + 273)*(T_{giE1} + 273)^{-1}\}] + h_{ewgW} * (A_b/2) * [(T_w - T_{giw1}) - (T_a + 273) * \ln\{(T_w + 273)*(T_{giw1} + 273)^{-1}\}]$ (27)

**Table 3 Solo inclined PVT-CPC for daily screening daily, monthly and annual yield**

| Month | weather | | | weather | | | weather | | | weather | | | Yield monthly |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ya | a | ma | Yb | b | mb | Yc | c | mc | Yd | d | md | |
| Jan | 24.49 | 3 | 73.47 | 22.79 | 8 | 182.32 | 6.26 | 11 | 68.82 | 1.46 | 9 | 13.10 | 337.71 |
| Feb | 24.29 | 3 | 72.87 | 23.53 | 4 | 94.12 | 6.70 | 12 | 80.37 | 1.40 | 9 | 12.64 | 260.00 |
| Mar | 26.46 | 5 | 132.3 | 27.39 | 6 | 164.34 | 11.38 | 12 | 136.61 | 5.41 | 8 | 43.30 | 476.55 |
| Apr | 28.1 | 4 | 112.4 | 27.91 | 7 | 195.37 | 12.18 | 14 | 170.52 | 9.25 | 5 | 46.23 | 524.51 |
| May | 28.73 | 4 | 114.92 | 22.54 | 9 | 202.86 | 15.85 | 12 | 190.15 | 7.88 | 6 | 47.29 | 555.22 |
| Jun | 27.03 | 3 | 81.09 | 22.72 | 4 | 90.88 | 12.07 | 14 | 169.01 | 5.08 | 9 | 45.76 | 386.74 |
| Jul | 24.09 | 2 | 48.18 | 19.28 | 3 | 57.84 | 12.58 | 10 | 125.78 | 3.15 | 17 | 53.49 | 285.29 |
| Aug | 23.47 | 2 | 46.94 | 20.92 | 3 | 62.76 | 9.79 | 7 | 68.55 | 3.93 | 19 | 74.59 | 252.84 |
| Sep | 27.98 | 7 | 195.86 | 25.58 | 3 | 76.74 | 15.96 | 10 | 159.64 | 5.49 | 10 | 54.94 | 487.18 |
| Oct | 25.12 | 5 | 125.6 | 18.72 | 10 | 187.2 | 12.45 | 13 | 161.83 | 3.43 | 3 | 10.30 | 484.93 |
| Nov | 23.93 | 6 | 143.58 | 15.19 | 10 | 151.9 | 5.28 | 12 | 63.34 | 3.87 | 2 | 7.75 | 366.57 |
| Dec | 24.48 | 3 | 73.44 | 18.71 | 7 | 130.97 | 8.62 | 13 | 112.08 | 1.66 | 8 | 13.28 | 329.77 |
| Annual Yield(Kg) | | | | | | 4747.307 | | | | | | | |

**Table 4 Dual inclined PVT-CPC effective daily filtering system, monthly and annual yield**

| Month | weather | | | weather | | | weather | | | weather | | | Yield monthly |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ya | a | ma | yb | b | mb | yc | c | mc | yd | d | md | |
| Jan | 26.56 | 3 | 79.67 | 22.91 | 8 | 183.27 | 7.93 | 11 | 87.20 | 1.68 | 9 | 15.12 | 365.26 |
| Feb | 25.43 | 3 | 76.29 | 23.69 | 4 | 94.76 | 7.64 | 12 | 91.72 | 1.65 | 9 | 14.85 | 277.61 |
| Mar | 26.79 | 5 | 133.97 | 27.47 | 6 | 164.80 | 11.36 | 12 | 136.29 | 6.04 | 8 | 48.33 | 483.39 |
| Apr | 29.46 | 4 | 117.83 | 28.65 | 7 | 200.57 | 12.33 | 14 | 172.65 | 9.97 | 5 | 49.84 | 540.90 |
| May | 27.77 | 4 | 111.07 | 21.36 | 9 | 192.20 | 14.91 | 12 | 178.92 | 8.92 | 6 | 53.49 | 535.69 |
| Jun | 26.94 | 3 | 80.81 | 21.83 | 4 | 87.33 | 13.14 | 14 | 184.02 | 3.89 | 9 | 34.97 | 387.14 |
| Jul | 24.52 | 2 | 49.04 | 18.54 | 3 | 55.63 | 12.64 | 10 | 126.37 | 3.5 | 17 | 59.53 | 290.56 |
| Aug | 22.62 | 2 | 45.24 | 19.56 | 3 | 58.68 | 10.13 | 7 | 70.91 | 3.83 | 19 | 72.68 | 247.51 |
| Sep | 31.42 | 7 | 219.91 | 26.51 | 3 | 79.54 | 15.13 | 10 | 151.34 | 5.68 | 10 | 56.77 | 507.56 |
| Oct | 26.95 | 5 | 134.74 | 18.57 | 10 | 185.75 | 12.98 | 13 | 168.76 | 3.86 | 3 | 11.57 | 500.81 |
| Nov | 25.43 | 6 | 152.58 | 15.24 | 10 | 152.35 | 5.40 | 12 | 64.80 | 4.19 | 2 | 8.38 | 378.11 |
| Dec | 24.07 | 3 | 72.20 | 18.80 | 7 | 131.58 | 9.46 | 13 | 122.98 | 1.75 | 8 | 14.01 | 340.77 |
| Annual Yield(kg) | | | | | | | | | | 4855.31 | | | |

Using equation $h_{ewgE}$ and $h_{ewgW}$ can be calculated the value of solo and dual inclined N-PVT-CPC distiller units for profit calculated using sums (27) and (28). Solo and Dual inclined N-PVT-CPC solar distiller equipment that operates maximum power per year ($G_{ex1,annual}$) is determined by

$G_{ex1,\, annual} = E_{xout1} + (P_m - P_u)$ (28)

Where, $E_{xout1}$ represents the solar emissions that are still active every year, Pm represents the electrical power available from water collectors which is connected in series and pump is represented by Pu.

### 4.1 Energy matrices

The duration of energy recovery, efficiency of the life cycle cost conversion can be determined by using energy matrices. for which the above parameters are considered according to [Tiwari and Mishra (2012)].

**Table 5 for single slope active PVT-CPC solar distiller Daily, Monthly, and annually yield**

| Month | weather | | | weather | | | weather | | | weather | | | Yield monthly |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exa | a | Exma | Exb | b | Exmb | Exc | c | Exmc | Exd | d | Exmd | |
| Jan | 2.4868 | 3 | 7.5 | 2.2635 | 8 | 18.108 | 0.5 | 11 | 5.806 | 0.041 | 9 | 0.3654 | 31.7391 |
| Feb | 2.3548 | 3 | 7.1 | 2.0605 | 4 | 8.2418 | 0.3 | 12 | 3.045 | 0.01 | 9 | 0.0914 | 18.4426 |
| Mar | 2.4462 | 5 | 12 | 0.6395 | 6 | 3.8367 | 0.4 | 12 | 4.263 | 0.213 | 8 | 1.7052 | 22.0357 |
| Apr | 2.3041 | 4 | 9.2 | 2.2635 | 7 | 15.844 | 0.6 | 14 | 8.242 | 0.396 | 5 | 1.9793 | 35.2814 |
| May | 2.1823 | 4 | 8.7 | 1.3094 | 9 | 11.784 | 0.7 | 12 | 8.404 | 0.426 | 6 | 2.5578 | 31.4752 |
| Jun | 2.2432 | 3 | 6.7 | 1.7357 | 4 | 6.9426 | 0.5 | 14 | 6.537 | 0.183 | 9 | 1.6443 | 21.853 |
| Jul | 1.8981 | 2 | 3.8 | 1.3601 | 3 | 4.0803 | 0.5 | 10 | 4.568 | 0.091 | 17 | 1.553 | 13.9969 |
| Aug | 1.8067 | 2 | 3.6 | 1.4718 | 3 | 4.4153 | 0.5 | 7 | 3.41 | 0.081 | 19 | 1.5428 | 12.9819 |
| Sep | 2.5172 | 7 | 18 | 2.2635 | 3 | 6.7904 | 0.7 | 10 | 7.41 | 0.122 | 10 | 1.218 | 33.0383 |
| Oct | 2.6695 | 5 | 13 | 0.8729 | 10 | 8.729 | 0.9 | 13 | 11.35 | 0.102 | 3 | 0.3045 | 33.7285 |
| Nov | 2.3751 | 6 | 14 | 0.9034 | 10 | 9.0335 | 0.2 | 12 | 2.801 | 0.213 | 2 | 0.4263 | 26.5118 |
| Dec | 2.2939 | 3 | 6.9 | 1.7458 | 7 | 12.221 | 0.3 | 13 | 4.486 | 0.071 | 8 | 0.5684 | 24.157 |
| Annual Exergy (kwh) | | | | | | | | | | | | | 305.241 |

**Table 6 Daily, monthly and annual thermal exergy for dual slope PVT-CPC active solar still**

| Month | weather | | | weather | | | weather | | | weather | | | Yield monthly |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Exa | a | Exma | Exb | b | Exmb | Exc | c | Exmc | Exd | d | Exmd | |
| Jan | 2.8249 | 3 | 8.5 | 2.4098 | 8 | 19.278 | 0.3 | 11 | 3.453 | 0.051 | 9 | 0.4556 | 31.6609 |
| Feb | 2.5515 | 3 | 7.7 | 2.3693 | 4 | 9.477 | 0.3 | 12 | 3.281 | 0.03 | 9 | 0.2734 | 20.6854 |
| Mar | 2.7439 | 5 | 14 | 3.2501 | 6 | 19.501 | 0.6 | 12 | 7.533 | 0.142 | 8 | 1.134 | 41.8871 |
| Apr | 2.8148 | 4 | 11 | 2.8553 | 7 | 19.987 | 0.5 | 14 | 6.379 | 0.334 | 5 | 1.6706 | 39.2951 |
| May | 2.4908 | 4 | 10 | 1.7415 | 9 | 15.674 | 0.7 | 12 | 8.141 | 0.425 | 6 | 2.5515 | 36.3285 |
| Jun | 2.8755 | 3 | 8.6 | 1.9845 | 4 | 7.938 | 0.5 | 14 | 7.229 | 0.071 | 9 | 0.6379 | 24.4316 |
| Jul | 2.2073 | 2 | 4.4 | 1.4074 | 3 | 4.2221 | 0.9 | 10 | 8.606 | 0.091 | 17 | 1.5491 | 18.792 |
| Aug | 2.1364 | 2 | 4.3 | 1.4884 | 3 | 4.4651 | 0.5 | 7 | 3.331 | 0.081 | 19 | 1.539 | 13.608 |
| Sep | 3.1894 | 7 | 22 | 2.8958 | 3 | 8.6873 | 0.8 | 10 | 7.898 | 0.122 | 10 | 1.215 | 40.1254 |
| Oct | 3.321 | 5 | 17 | 1.4681 | 10 | 14.681 | 0.8 | 13 | 10.4 | 0.081 | 3 | 0.243 | 41.9276 |
| Nov | 2.8958 | 6 | 17 | 1.2859 | 10 | 12.859 | 0.2 | 12 | 2.916 | 0.192 | 2 | 0.3848 | 33.534 |
| Dec | 2.4806 | 3 | 7.4 | 1.8833 | 7 | 13.183 | 0.6 | 13 | 8.424 | 0.051 | 8 | 0.405 | 29.4536 |
| Exergy annually (Kwh) | | | | | | | | | | | | | 371.729 |

### 4.2 Energy payback time (EPT)

The enhancement in energy using material to combined energy and the recovering time the total energy lost in the photovoltaic thermal compound parabolic concentrator organization.

Energy payback time (EPT) = (Energy in ($E_{in1}$)/Energy out annually ($E_{out}$)) (29)

Exergy payback time (EPT) = (Energy ($E_{in1}$)/exergy out annually ($G_{ex1,\ annual}$) (30)

It also gives the impression that down to the use of EPT the best and most efficient resources. Using equation (29) and (30) EPT can be easily calculated for solo and dual inclined PVT-CPC distiller system is valid and this number is presented in the Table (6)

### 4.3 Factor of energy payback

The factor of energy payback (EPF) is inversed of time of energy payback (EPT). Corresponding to Tiwari and Mishra (2012), determining the number of EPFs yearly on the basis of photovoltaic thermal compound parabolic concentrator (PVT-CPC) effective solar distiller tools is provided as follows,

EPF on energy basis = $E_{out1}/E_{in1}$ (31)

EPF on exergy basis = $G_{ex1,\ annual}/E_{in1}$ (32)

Anywhere, $G_{ex1}$, per annum, $E_{in1}$, $E_{out1}$ is used in PVT-CPC active solar filtering tools that represent the total gains per year, the power incorporated into the content used and the power that comes out yearly represent. With the help of equation (31) and equation (32) we can find the total annual amount of the total energy output and the total annual profit on the test. Similarly with the help of equation (31) and equation (32) PVT-CPC alone and EPF performance is taken out and its amount is presented in Table (6).

### 4.4 Efficiency of life cycle cost conversion (LCCE)

For photovoltaic thermal compound parabolic concentrator (PVT-CPC) solar distiller unit the operation of the LCCE is obtained using Tiwari and Mishra (2012) provided as

Based on energy LCCE = $\{(E_{out1} * n - E_{in1}\}*(E_{sol1} * n)^{-1}$ (33)

Based on exergy LCCE= $\{(G_{ex1,annual} *n) - E_{in1}\}*\{(\text{annual solar exergy}) * n\}^{-1}$ (34)

By using equation (34) in the active PVT-CPC and two active filters, can be determined based on LCCE and expressed in Table (7), using equation (33 & 34) the LCCE can be calculated for PVT-CPC active and dual inclined presented in Table (8).

Table 7 embodied energy $E_{in}$, for solo inclined and dual inclined N-PVT-CPC active solar still.

| Components name | Solo inclined N-PVT-CPC active solar still | Dual inclined N-PVT-CPC active solar still |
|---|---|---|
| | Embodied energy (kwh) | Embodied energy (kwh) |
| Solo inclined distiller | 1747.95 | 1491.66 |
| compound parabolic concentrator collector (N = 7) | 5741.90 | 5741.90 |
| Glass to glass PV (N = 7) | 1719.37 | 1719.37 |
| Others | 25 | 25 |

**Table 8 energy payback time (EPT), time of energy payback (EPT), embodied energy $E_{in}$, and life cycle cost conversion efficiency for solo inclined and dual inclined N-PVT-CPC active solar still.**

| Solo inclined N-PVT-CPC active solar still | |
|---|---|
| Embodied energy | 9234.13 kWh |
| Yield per annum | 4747.3 kg |
| annual energy available | 3389.0 kWh |
| Annual exergy | 305 kWh |
| (EPT)e | 2.72473591 |
| (EPT)ex | 30.27583607 |
| (EPF)e | 0.367008045 |
| (EPF)ex | 0.033029641 |
| (LCCE)e | 0.126542591 |
| (LCCE)ex | 0.000115172 |
| **Dual inclined N-PVT-CPC active solar still** | |
| Embodied energy | 8977.81 kWh |
| Yield per annum | 4855.31 kg |
| annual energy available | 3537.67 kWh |
| Annual exergy | 371.72 kWh |

| | |
|---|---|
| (EPT)e | 2.537774863 |
| (EPT)ex | 24.15272659 |
| (EPF)e | 0.394045987 |
| (EPF)ex | 0.041403193 |
| (LCCE)e | 0.132999262 |
| (LCCE)ex | 0.002975458 |

## 5. Methodology

In N-PVT-CPC alone and prone to using a solar filter system the calculation is done using a number of method measures.

**Step I**

Using Liu and Jordon formula with MATLAB 2016a and providing input details for calculation according by IMD, Pune, India for type (a), type (b), type (c) and type (d) days.

**Step II**

For the inclined distiller PVT-CPC, $T_{woN}$, $\eta_{cN}$, $T_w$, $T_{gi}$, $T_{go}$, and $h_{ewg}$ is listed, and the yield is checked. Correspondingly the active system with dual value of $T_{goE1}$, $T_{giW1}$, $T_{goW1}$, $T_{giE1}$, $T_w$ and calculate coefficient of heat transfer. After that, with photovoltaic thermal compound parabolic concentrator (PVT-CPC) effective solar filtering tools the advantages o $\dot{m}_{ew,E}$ and $\dot{m}_{ew,W}$ are calculated.

**Step III**

Eqs. (1) and Eqs. (2), the photovoltaic thermal compound parabolic concentrator (PVT-CPC) solar filtering devices the maximum thermal energy and emissions are to be calculated.

Step IV

With the help of equation (29) to (34) energy payback time (EPT), energy payback factor (EPF), and life cycle cost conversion efficiency (LCCE) can be calculated.

## 6. Results and discussion

At MATLAB2016a we can provide all statistics related to weather data especially general

velocity, solar radiation and ambient temperature and emissions that can be found in MATLAB

**shown in Fig. 3 to 6.3.**

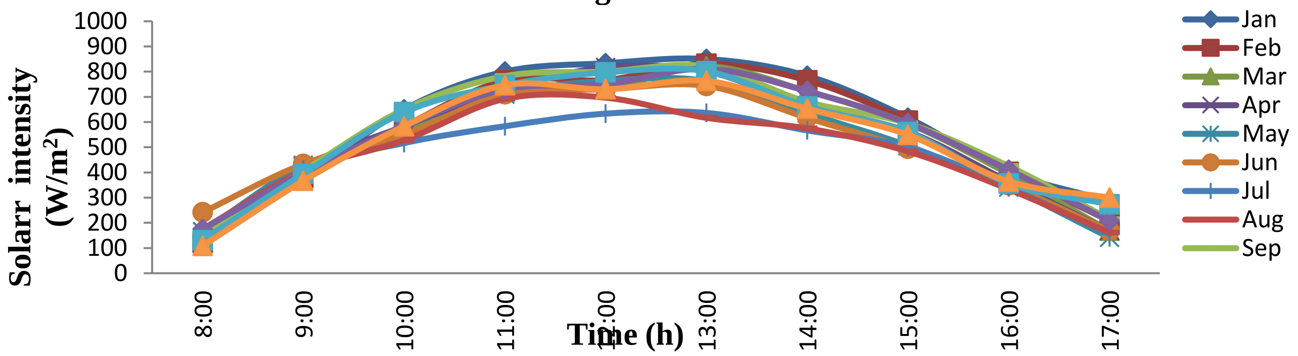


**Fig 3 per hour variation of the beam radiation ($I_b$) month-wise**

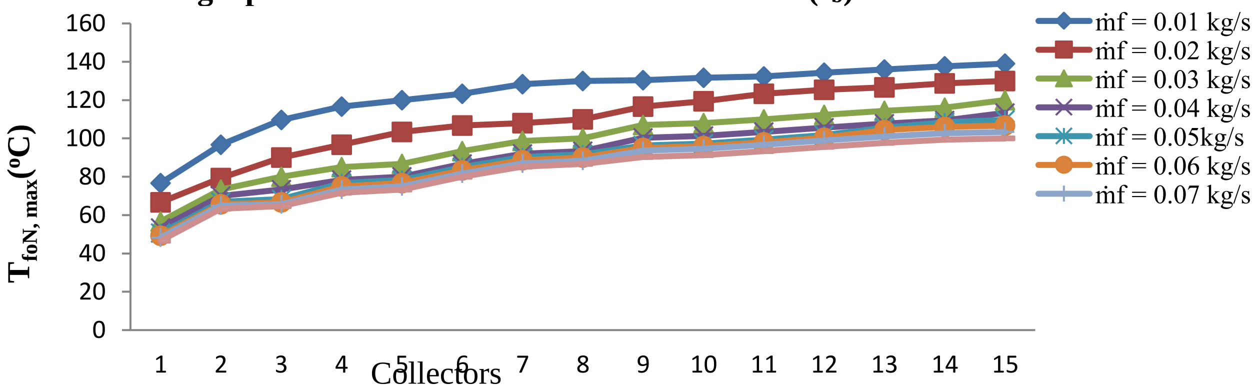

**Fig. 4 For solo inclined water temperature collector ($T_{woN,max}$) in the month of June**

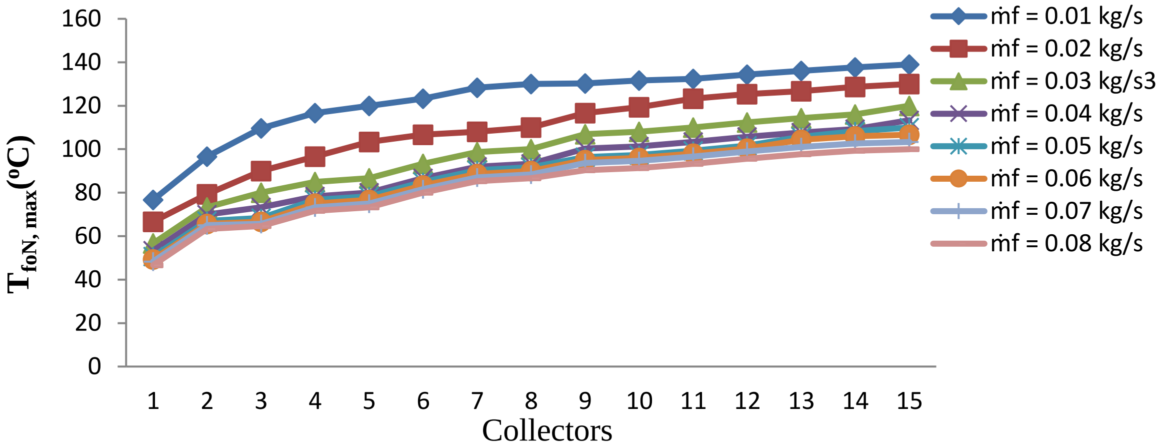


**Fig. 5 for Dual inclined water temperature collector ($T_{woN,max}$) in the month of** June

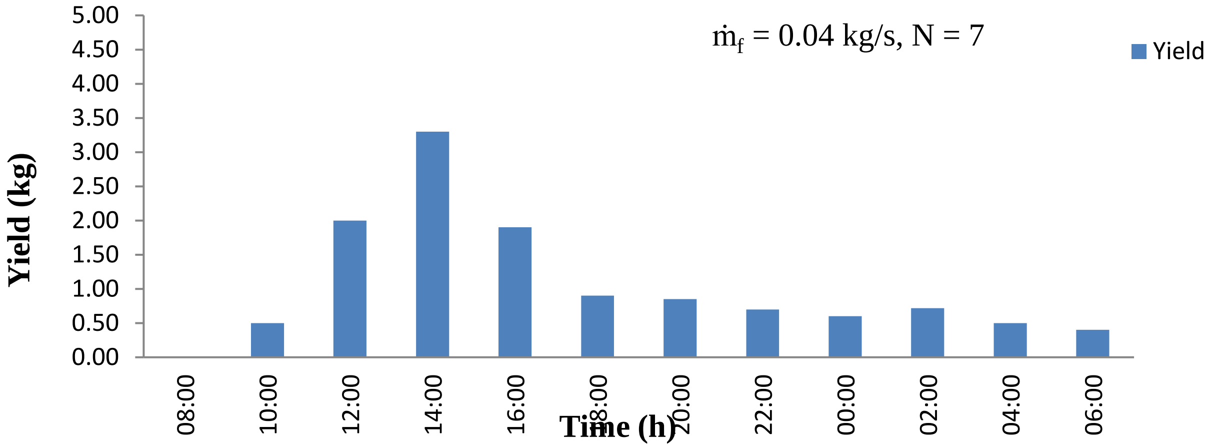


**Fig. 6 for solo inclined hourly yield disparity for June**

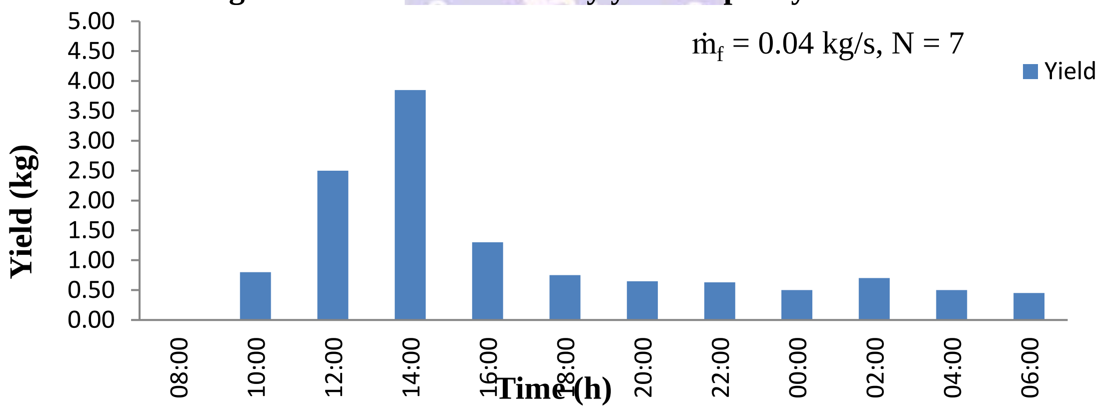


**Fig. 7 For dual inclined hourly yield disparity for June**

The correct value of the collector N = 7 in this case is the flow of the equity yield of the single and double the trend of PVT-CPC effective solar filters the difference in the production day of the day represented in June and January in Fig. 5.14, and 5.16 as expected, water generation rate is deduced as the flow rate increases. This is because water tubes get less time to absorb heat at which the water absorbs heat transfer increases and the temperature of the Nth collection store becomes lower as flow rate increases. Since the output of the Nth collector is connected to the solar distiller and the temperature of the Nth collection is relatively low which is why it contributes to the small temperature increase of the water container. So that the temperature of the water tank rises slightly, the temperature difference is made between the glass settlement and the lower water, as a result of which the yield is lower because evaporation occurs lower.

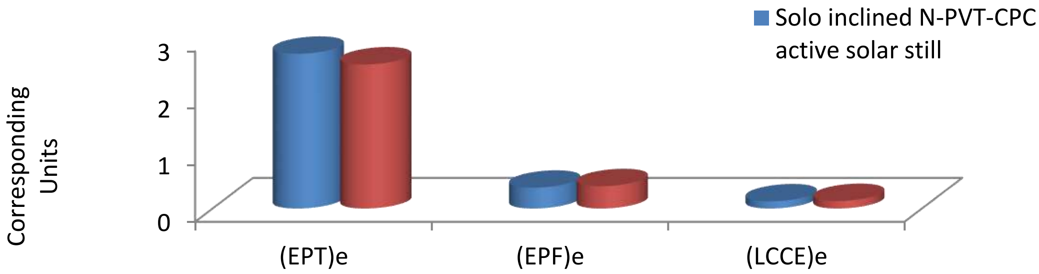


**Fig. 8 energy matrices analysis of the solo and dual inclined distillation system**

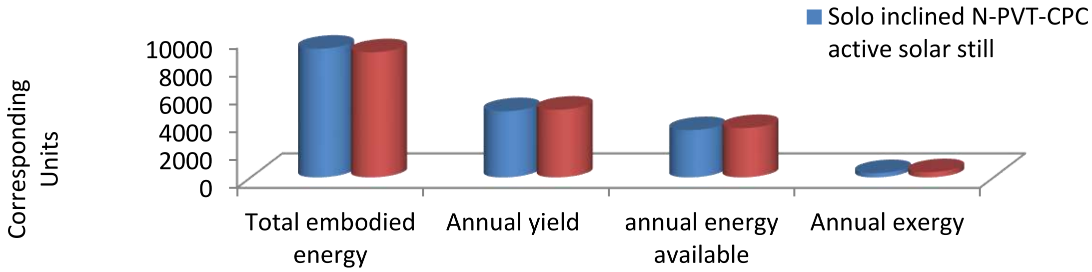


**Fig. 9 economic analysis of the solo and dual inclined distillation system**

## 7. Conclusions

In the analysis of single and dual inclined solar filter systems, we can find that the change in the analysis of the cost of a life cycle in energy matrices and their effect on the recovery time by energy. Finally, the measurement of practical PVT-CPC tools for solar thermal differs from the depth of the gorge water is analyzed and included with their effect on performance and efficiency on an hourly basis.

Sole and dual inclined PVT-CPC active distiller apparatus basin type for daily product items of 0.04 kg / s, 0.7, and 0.74 are ideal for weight loss, a large number of collectors, and great depth of systems, correspondingly. However, since the lake's water depth is 0.74 m, the system will be extensive, and as a result, we have re-evaluated the durability of the system, efficiency, and strength. Considering that there are four types of climates type-a, type-b, type-c, and type-d and in this case, a depth of 0.14 m water channel to test the strength and output power and complete the total output volume of the collectors. In these analysis it is found that at a water depth of less than 0.19 m, the two slopes provide much better performance than the active PVT-CPC filters operating at a given range of weight loss and plate number and vice versa at a depth of less than 0.19 m. At a depth of 0.14 m of brook water, a double-sided solar filtering system is better than the single inclination operating system because the amount of energy, energy, and energy metrics are better than the given number of collector plate and weight flow rate. In the EPBT components, the loss or reduction in the amount of power and energy of two trends than the end of the active PVT-CPC system filtering the sun by 17.98% and 7.5%, respectively. According to the EPF, the operating capacity and power received a higher value of two trends than a single filtering device of 12.72% and 5.12%. Similarly, according to LCCE, the maximum output power is 22.223% and 5.557%, respectively, of the two trends than the reduction of PVT-CPC only solar energy efficiency. We calculate the production price of water in ₹ / kg and the cost of electricity in ₹ / kwh.

The total volume output and the collection plate number of 0.14 m, the maximum energy, and thermal energy each year are determined because both slopes have a higher value than the only active PVT-CPC 12.79% 4.2% correspondingly. In the same way, at 0.14 m basin water deepness 50-year life cycle and interest rate is 5%.

Considering the typical daily production, high operating capacity, daily mean heat capacity, and overall heat efficiency, the absolute value of gorge sole water depth and dual incline PVT-CPC practical solar filtering tools available at 0.7 m. with a water depth of less than 0.31 m in terms of daily energy consumption, daily production and heat efficiency both tend to have the best performance of PVT-CPC solar filtering equipment. When the basin depth is higher than 0.31 m, then dua inclined performance is much better than the dual inclined PVT-

CPC active solar filtration system. The above analysis shows that the overall energy, total thermal energy, productivity, and thermal efficiency in both active and two fewer solar filters will decrease as the water depth increases. At sunrise, the various components are produced hourly, thermal energy, exergy, complete exergy, and thermal efficiency of both trends are better than when PVT-CPC only works with solar immersion apparatus at all basin depths.

## References

[1] M. Faegh, M. B. Shafii, Experimental investigation of a solar still equipped with an external heat storage system using phase change materials and heat pipes, Desalination, 409 (2017) 128–135.

[2] A. K. Singh, D. B. Singh, A. Mallick, N. Kumar, Energy matrices and efficiency analyses of solar distiller units: A review, Solar Energy, 173 (2018) 53 – 75.

[3] G. N. Tiwari , L. Sahota, Review on the energy and economic efficiencies of passive and active solar distillation systems, Desalination, 2016, in press.

[4] A. K. Singh, S. Chattopadhayaya, D. B. Singh, N. Kumar, Performance study for active solar stills based on energy metrics: a short review, JoRACHV, 4(3) (2017) 21–26.

[5] D. B. Singh, A. K. Singh, N. Kumar, V. K. Dwivedi, J. K. Yadav, G. Singh, Performance Analysis of Special Design Single Basin Passive Solar Distillation Systems: A Comprehensive Review, Advances in Engineering Design. Lecture Notes in Mechanical Engineering, Springer (2019) 301 – 310.

[6] A. K. Singh, D. B. Singh, V. K. Dwivedi, N. Kumar, J. K. Yadav, A Review of Performance Enhancement in Solar Desalination Systems with the Application of Nanofluids, ICACCCN (2019) 814 – 819.

[7] Dharamveer, Samsher, D. B. Singh, A. K. Singh, N. Kumar, Solar Distiller Unit Loaded with Nanofluid—A Short Review, Advances in Interdisciplinary Engineering. Lecture Notes in Mechanical Engineering, Springer, (2019) 241 – 247.

[8] A. K. Singh, D. B. Singh, A. Mallick, Harender, S. K. Sharma, N. Kumar, V.K. Dwivedi, Performance analysis of specially designed single basin passive solar distillers incorporated with novel solar desalting stills: A review, Solar Energy,185 (2019) 146–164.

[9] A. K. Singh, D. B. Singh, N. Kumar, V. K. Dwivedi, G. Singh, R. Kumar, Basin-Type Solar Distiller Associated with PVT Collectors—A Comprehensive Review, Advances in Energy and Built Environment. Lecture Notes in Civil Engineering, Springer, 36 (2019) 253 – 260.

[10] Lovedeep sahota, G.N. Tiwari, Exergoeconomic and enviroeconomic analyses of hybrid double slope, Energy Conversion and Management, 148 (2017) 413-430.

[11] D.B Singh, G.N. Tiwari, Enhancement in energy metrics of double slope solar still, Solar Energy, 143 (2017) 141-161.

[12] D. B singh and G.N. Tiwari, Effect of energy matrices on life cycle cost analysis of partially covered photovoltaic compound parabolic concentrator collector active solardistillation system, Desalination, 397 (2016) 75-91.

[13] D. B Singh, Experimental studies of active solar still integrated with two hybrid PVT collectors, Solar Energy, 130 (2016) 207-223.

[14] Runsheng Tang, Yuqin Yang, Wenfeng Gao, Comparative studies on thermal performance of water-in-glass evacuated tube solar water heaters with different collector tilt-angles Solar Ene.rgy 85 (2011) 1381–1389.

[15] A.E. Kabeel, A. Khalil, S.S. Elsayed, A.M. Alatyar, Modified mathematical model for evaluating the performance of water-in-glass evacuated tube solar collector considering tube shading effect, Energy 89 (2015) 24-34.

[16] M.B. Shafii, S. Jahangiri Mamouri, M.M. Lotfi, H. Jafari Mosleh, A modified solar desalination system using evacuated tube collector, Desalination 396 (2016) 30–38.

[17] H. Jafari Mosleh, S. Jahangiri Mamouri , M.B. Shafii, A. Hakim Sima, A new desalination system using a combination of heat pipe, evacuated tube and parabolic through collector, Energy Conversion and Management 99 (2015) 141–150.

[18] H. Sharon, K.S. Reddy, D. Krithika , L. Philip, Experimental performance investigation of tilted solar still with basin and wick for distillate quality and enviro-economic aspects, Desalination, 410 (2017) 30–54.

[19] H. Panchal, Y. Taamneh, R. Sathyamurthy, A.E. Kabeel, S.A. El-Agouz, P. Naveen Kumar, A. Muthu Manokar, T. Arunkumar, D. Mageshbabu, R. Bharathwaaj, Economic and Exergy investigation of triangular pyramid solar still integrated to inclined solar still with baffles, International Journal of Ambient Energy, 2017, DOI: 10.1080/01430750.2017.1422143

[20] A.K. Kaushal, M.K. Mittal, D. Gangacharyulu, Productivity correlation and economic analysis of floating wick basin type vertical multiple effect diffusion solar still with waste heat recovery, Desalination, 423 (2017) 95–103.

[21] A. K. Tiwari, A. Somwanshi, 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 (2018) 216–224.

[22] Md. S. Yousef, H. Hassan, H. Sekiguchi, Energy, exergy, economic and enviroeconomic (4E) analyses of solar distillation system using different absorbing materials, Applied Thermal Engineering, 150 (2019) 30–41.

[23] Md. S. Yousef, H. Hassan, Assessment of different passive solar stills via exergoeconomic, exergoenvironmental, and exergoenviroeconomic approaches: A comparative study, Solar Energy, 182 (2019) 316–331.

[24] R. V. Singh, S. K., M.M. Hasan, M. E. Khan, G.N. Tiwari, Performance of a solar still integrated with evacuated tube collector in natural mode, Desalination 318 (2013) 25–33.

[25] K.S. Reddy, H. Sharon, D. Krithika, L. Philip, Performance, water quality and enviro-economic investigations on solar distillation treatment of reverse osmosis reject and sewage water, Solar Energy, 173 (2018) 160–172.

[26] G.N. Tiwari, R.K. Mishra, Advanced Renewable Energy Sources, *RSC Publishing Cambridge*, UK, 2012.

[27] A.K. Singh, D.B. Singh, V.K. Dwivedi, G.N. Tiwari, A. Gupta, Water purification using solar still with/without nano-fluid: A review, Materials Today: Proceedings 21 (2020) 1700–1706.

[28] A.K. Singh, Samsher, Material conscious energy matrix and enviro-economic analysis of passive ETC solar still, Materials Today: Proceedings (2020). https://doi.org/10.1016/j.matpr.2020.05.117

**[30] Dharamveer, Samsher.** Comparative analyses energy matrices and enviro-economics for active and passive solar still. materialstoday:proceedings. 2020.https://doi.org/10.1016/j.matpr.2020.10.001.

**[31] Dharamveer, SamsherKumar A.** Analytical study of $N^{th}$ identical photovoltaic thermal (PVT) compound parabolic concentrator (CPC) active double slope solar distiller with helical coiled heat exchanger using CuO Nanoparticles. Desalination and water treatment.2021;233:30-51.https://doi.org/10.5004/dwt.2021.27526

**[32] Dharamveer,Samsher, Kumar A.** Performance analysis of N-identical PVT-CPC collectors an active single slope solar distiller with a helically coiled heat exchanger using CuO nanoparticles. Water supply. 2021.https://doi.org/10.2166/ws.2021.348

**[33] Dharamveer Singh**, Ashok Kumar Yadav, Anil Kumar, Samsher, "Energy matrices and life cycle conversion analysis of N-identical hybrid double slope solar distiller unit using $Al_2O_3$ nanoparticle". *Journal of Water and Environmental Nanotechnology*, http://doi:10.22090/jwent.2022.03.006

**[34]Dharamveer Singh**, Satyaveer Singh, Ashok Kumar Yadav, Osama Khan, Ashish Dewangan, Saiful Islam, Meshel Q. Alkahtani, Saiful Islam "From Theory to Practice: A Sustainable Solution to Water Scarcity by Using Hybrid Solar Distiller with Heat Exchanger and Aluminum Oxide Nanoparticles" Journal ACS Omega, https://doi.org/10.1021/acsomega.3c03283

**[35]Dharamveer Singh**, Satyaveer Singh, Aakersh Chauhan, Anil Kumar "Enviroeconomic analysis of hybrid active solar desalination system using nanoparticles" Journal of Environmerntal engineering and Science, Vol. 18 (3) 1-10, July 2022, **ESCI Index,** Emerald Publishing Ltd. https://doi.org/10.1680/jenes.23.00045