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Research Article

Economic, Enviroeconomic Analysis Of Active Solar Still Using Al_2O_3 Nanoparticles

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Abstract

The water scarcity is primary need of analysis. The current study analyses the Economic and Enviro-economic of an N-identical (N-PVTCPC) collector double slope solar desalination units (DS-DU) with a heat exchanger (HE) using water based Al_2O_3 nanoparticles. An analytical program fed into MATLAB, and the analysis was monitored on an annual basis New Delhi, India. The Indian Metrological Department in Pune, India provided the input data necessary for the mathematical procedure. Considering the energy production of the winter and summer, the average yearly energy production will be calculated. The system performance has been analyzed based on Economic and Enviro-economic. In an economic analysis was performed for 15 years has found for cost of water 1.25, 1.51, and 1.79₹/kg respectively, Enviro-economic analysis for life span of 15, 20, and 30 years have found CO_2 mitigation/ton 40.85, 57.46, and 90.67 kg/ton respectively and carbon credit earned 204.26, 287.30, and 453.36 ($) respectively. The proposed system has foundenergy, yield, and productivity 7.31%, 8.5%, and 5.17% greater respectively. Therefore overall the proposed system found better to previous system.

Keywords: *Economic; CO_2 mitigation; carbon credit earned; environ-economic; nanoparticles.*

1. Aim and Scope

For various applications, such as heat exchangers, photovoltaic systems integrated into buildings, greenhouse dryers, space heaters, solar air collectors, solar water collectors, etc., renewable energy or photovoltaic thermal energy systems are a viable choice. A basic requirement for maintaining life on earth, along with access to clean food and air, is the availability of drinkable water. Lawrence and Tiwari [1] discussed the theoretical evaluation of a mathematical use it to analyze the influence of various parameters on the system's performance, such as the solar radiation, the cover plate's transmissivity, and the ambient temperature. Tiwari [2] provided a summary in the field of solar energythat was a useful for students and professionals in the subject overall, "Solar Energy: Fundamentals, Design, Modeling and Applications". Tiwari and Tiwari [3] provided a comprehensive understanding of the principles, design, and applications of solar distillation systems for water desalination. The book covers economics of solar stills and their applications in rural and remote areas, where access to potable water is limited. Otanicar and Golden [4] conducted a comparison of traditional solar hot water technology with nanofluid in terms of the environment and the economy. They discovered that although the inclusion of nanoparticles in the nanofluid technology results in improved thermal efficiency and heat transfer rates, it also necessitates a higher initial system cost and may have potential adverse environmental effects. Khullar and Tyagi [5] evaluated for several types of nanofluids, the potential environmental impact was assessed in terms of greenhouse gas emissions and energy consumption, and it was compared to the traditional water-based system. Faizel et al. [6] conducted an analysis. It is discovered that CuO nanofluid's performance is best explained by its for different thermo-physical properties. Liu et al. [7] studied and found, using ETCs can greatly increase the solar desalination system's thermal performance, resulting in higher levels of freshwater output and reduced specific energy consumption. Sharon and Reddy [8] estimated environmental cost at $6.29 per year. A saline water-filled active solar distiller's annual economic performance was examined. Dhivagar et al. [9] developed a mathematical model of the system and validate it using experimental data. The 4E analysis reveals that the system has a high exergy efficiency and low environmental impact, and its cost-effectiveness can be improved through optimization of the design parameters. Dharamveer and Samsher [10] compared the Energy matrices Enviroeconomic for active and passive solar desalination system. Performance of different solar still configurations have been discussed by the authors based on a variety of factors, including productivity ratio, thermal efficiency, exergy efficiency, and enviro-economic analysis. Shahsavaret al. [11] comparison made between the efficiency of hybrid, earth-air heat exchanger, and integrated photovoltaic/thermal systems utilized in buildings in terms of energy, the environment, economy, and finances. The analysis of energy matrices and the life cycle cost effectiveness of employing nanofluids for single and double slope flat plate collectors with a heat exchanger using water loaded nanofluids have only been briefly studied. Shatar et al. [12] based on the examination of a solar still employing a partly coated condensing cover with thermoelectric cover cooling in terms of energy, efficiency, economics, and the environment. The system's productivity ratio, energy efficiency, energy destruction, leveled cost of water, and CO_2 emissions were all examined by the researchers.

The majority of research in the literature examined how flat plate collectors and heat exchangers function when solar energy is still being used. On the Nth partially covered solar thermal power hybrid desalination unit employing nanoparticles, no researchers have examined Energy matrices, Life cycle costs, or Energy payback times. Table 1 provides a summary of earlier research on solar distiller units that use water-loaded nanofluids. The current literature survey indicates that both passive and active solar stills have been the subject of several studies. The examination of active solar systems that are still filled with water-based nanofluids is, however, not well covered in the literature. Dharamveer et al. [23] were used CuO nanoparticles to study active double slope solar still. Exergoeconomic and Environmental ramifications based on Energy matrices have not been researched by any academic. Additionally, no studies have been conducted on water-based nanofluid-filled compound parabolic concentrator collectors or evacuated tube collectors for basin-style solar stills.

The proposed study would combine Active Solar Desalination unit that are filled with Water-based Nanofluids to better understand these impacts. In the current study, Productivity, Environmental Economics, are evaluated. The efficiency of the proposed strategy will also be assessed in light of the results of earlier research. (1) Nth partially covered (PVT) Solar Active Double Slope Desalination system (CPC) using a water based Nanoparticles with a helically coiled heat exchanger (system-A). (2) An active double slope Nth partially covered PVT system with flat plate (FPC) collector using a heat exchanger of helically coiled (system-B). The suggested system examined the mass of base fluid and the optimal nanoparticle concentration. Table 1, below provides an overview of earlier research.

2. Material and Methods

2.1 System description

Figure 1, depicts the PVT module and focusing parabolic collector when solar energy is falling on them. As soon as the concentrating collector receives heat, it starts to raise the temperature of the nanofluid passing through the heat exchanger tube. How does the fluid gain energy as it travels from first PVT-CPC collector to the second PVT-CPC collector, given that the same fluid is travelling through both of them and a solar energyapprox.1367W/m^2. The fluid has gains some heat again through the other PVT-CPC collectors. After absorbing the most heat possible, fluid is poured into a high-quality copper helical coil heat exchanger. The open to the sun portion of this heat exchanger is situated inside a water tank. The temperature of the water in the water tank is raised to roughly 100°C during this process of water evaporation as solar radiation strikes and travels through the inside of the water tank. Sensible heating occurs when the fluid enters the heat exchanger and begins to lose heat as it comes into contact with the surrounding water in the tank. The difference between inner and outer glass cover, water vapor that has started to flow upward condenses. The glass cover is sloping on both sides. The working fluid is now removed from the heat exchanger's outlet and returned for the following cycle. To create a constant forced flow of working fluid, a DC motor is used. This DC motor's energy needs are met by solar panels, each of which has a capacity of 25 watts.

Table 1. Prior research on water based nanofluids solar distiller unit.

References	Adaptation in passive and active solar distiller	Conclusions
Kabeel et al. [14]	Providing single slope passive distiller, Al_2O_3 NPs and external condenser	Al_2O_3 with vacuum116 %
Elango et al. [15]	Single slope basin type with Fe_2O_3, ZnO, Al_2O_3 NPs	29.95% with Al_2O_3, 18.63% Fe_2O_3, ZnO with 12.67%
Sahota and Tiwari[16]	Investigated passive double slope desalination unit	45.23% Al_2O_3, 42.72% CuO, 39.74% T_iO_2
Shashir et al. [17]	Passive slope distiller CuO, and graphite with cooling rate over glass cover	47.8% with CuO, graphite 57.6%
Saleha et al. [18]	Solar distiller	Recommended ZnO
Chen et al. [19]	Solar distiller	Recommended SiC
Mahian et al. [20]	Heat exchanger operated using CuO, Al_2O_3, and TiO_2 NPs	9.86% with CuO
Sahota et al. [21]	Helically coiled heat exchanger using flat plate collectors operated using CuO, Al_2O_3, and TiO_2 NPs	With CuO with Al_2O_3 than TiO_2 system
Dharamveer et al. [22]	Active and passive operated Matrices, EPT, and LCCE.	C_uO nanoparticles
Dharamveer et al. [23]	Performed active double slope desalination unit (N-PVT-HE-DS)	Using CuO nanoparticles
Dharamveer et al. [24]	Performed active single slope desalination unit (N-PVT-HE-DS)	UsingCuO nanoparticles
Present study	**Analyses of Enviro-economic to a helically coiled heat exchanger hybrid solar desalination unit Nth PVT-CPC-DS-HE.**	Using **Al_2O_3 nanoparticles**

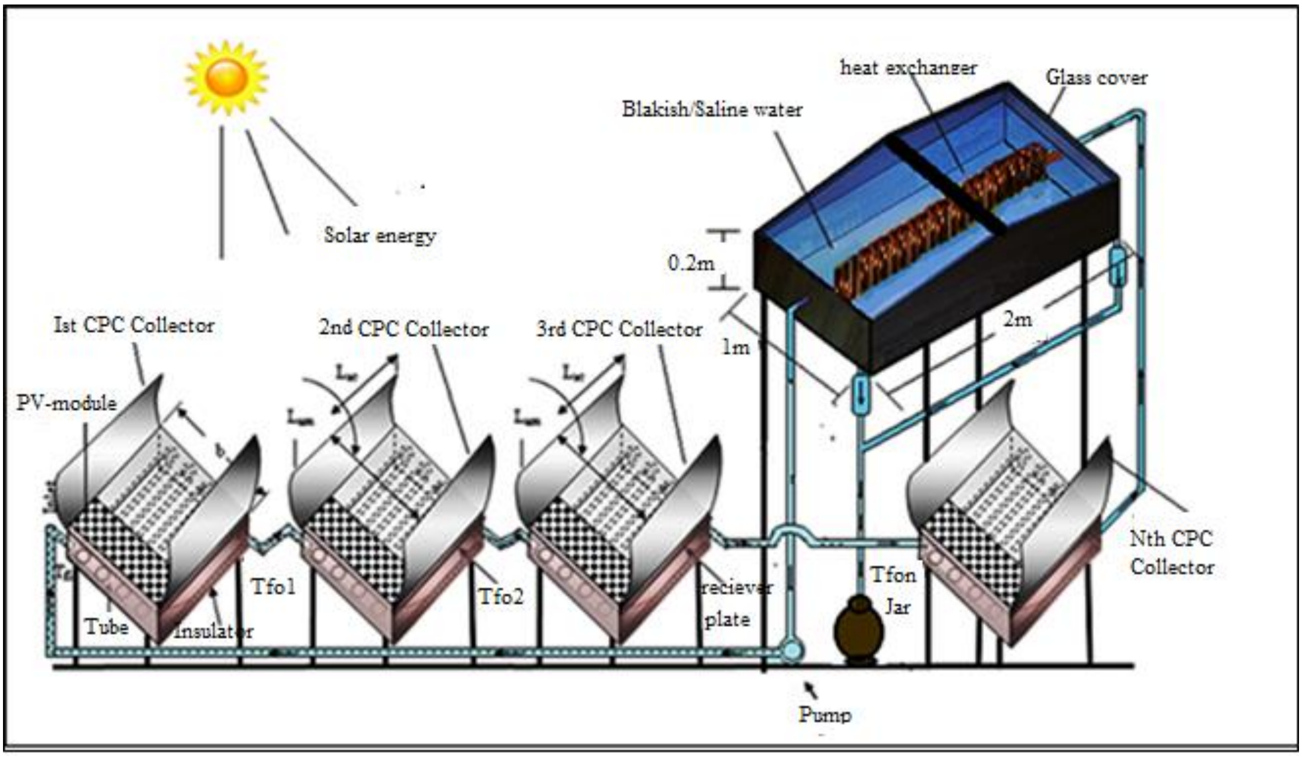

Figure 1. Representation of active double slope hybrid desalination unit.

2.2 Thermal modeling

2.2.1 Economic analysis

It is economically feasible for System-A and System-B total yearly cost, factor of shrinking fund, factor of recovery for both systems [10].

a. Capital cost

The capital investment of different components involve in system-A are given in Table 2, provide the system's fabrication cost.

b. System's lifespan

It is considered for 15 years.

c. Salvage value (S)

Salvage value (s) = 0.2 × Principal capital (PCC) (1)

PCC stands for principal capital cost

Cost of annual salvaging (ASC)

Annually salvage = S × shrinkage in fund (SFF) (2)

SFF is factor used for shrinkage

d. Yearly maintenance (YM)

Yearly maintenance (YM) =0.15×FYC (3)

FYC stands for first yearly cost.

e. Factor for capital recovered (CR).

At a fixed rate of interest, it shows the present cost as a constant annual cost across time.

$$\mathrm{CR} = \frac{i(1+i)^n}{(1+i)^n-1} \tag{4}$$

f. Factor of shrinking fund

$$\mathrm{SFF} = \frac{i}{(1+i)^n-1} \tag{5}$$

g. Cost of first annually gained

$$\mathrm{FYC} = \mathrm{PCC} \times \mathrm{CR} \tag{6}$$

h. Total cost gained annually

$$\mathrm{TAC} = \mathrm{FYC} + \mathrm{YM} - \mathrm{ASC} \tag{7}$$

i. distillate cost/kg

$$\mathrm{Cost/kg} = \frac{\mathrm{TAC}}{\text{yield in life}} \tag{8}$$

2.2.2 Enviro-economic analysis

The following are examples of mathematical expressions for environmental costs like carbon credits and CO_2mitigation annually [10]:

a. CO_2 Emission

The mean CO_2 intensity, which is about 0.98, and the electrical generation intensity are similar kg of CO_2/kWh

$$CO_2\ \text{emission/year} = \frac{\text{Embodied energy} \times 0.98}{\text{life time}} \tag{9}$$

For Indian conditions

$$CO_2\text{ emission/year} = \frac{\text{Embodied energy} \times 1.58}{\text{life time}} \quad (10)$$

b. CO_2 mitigation

Equation can be used to determine it per kWh

$$CO_2\text{mitigation/year} = (E_{out} \times n) \times 1.58 \quad (11)$$

Equation calculates total CO_2 mitigation

$$\text{Mitigation net over life} = (E_{out} \times n) \times 1.58/1000 \quad (12)$$

c. Earned carbon credit

$$\text{Carbon credit} = \text{Mitigation (during life span)} \times D \quad (13)$$

D is the shift from \$5 to \$20 per tones of CO_2 mitigation Embodied energy of different component involve in fabrication of proposed system are given below in Table 3.

2.3 Methodology

The following steps are included in the approach used to study the suggested system:

Step-I

First, proposed systems for the annual are calculated using the Lui and Jordan equations.

Step-II

Calculate daily solar radiation by through number of days in a month by as clear, hazy, hazy, cloudy, and cloudy days.

Step-III

Maximize the collector output using all parameters. Environmental and energy economic characteristics have been assessed Economic and Environmental and energy economic characteristics have been assessed.

Step-IV

Proposed systems are contrasted with the prior system using numerically computed values.

Figure 2, represents the flow chart for the steps involve in computing the performance of proposed system on the basis of yield, economic, and enviro-economic.

Table 2. Capital investment previous and proposed system.

Parameters	System- B [21] Cost		System-A Cost	
	₹	\$	₹	\$
FRP body	10200	139.135	10200	139.135
Glass cover 2.05	1600	21.825	1600	21.825
MS stand	1000	13.641	1000	13.641
Nozzle (input/output)	200	2.728	200	2.728
MS clamp	250	3.410	250	3.410
Gaskets	200	2.728	200	2.728
Silicon gel	200	2.728	200	2.728
PVT-FPC (N=4) 8500	34000	463.784		0.000
PVT-CPC (N=4) 9000		0.000	36000	491.06
Pump & Motor	1200	16.369	1200	16.369
Heat exchanger (helical coiled)	466.25	6.360	466.25	6.360
Fabrication and other cost	6000	81.844	6000	81.844
100 gmsAl_2O_3nanoparticles	7425	101.282	7425	101.282
Total cost of	62741.25	855.83	64741.25	883.11

Table 3. Illustrates embodied energy of different components of previous and proposed system.

Name of component	Embodied energy (kWh)	
	System-B [10]	System-A
RFP body	755.61	755.61
MS angle	416.4	416.4
Cover (glass)	180.5	180.5
FPC (N=4)	2209.92	-
CPC (N=4)	-	3279.41
PV (glass-glass)	980	980
Copper heat exchanger	25.83	25.83
Nanoparticles (Al_2O_3)	17.82	17.82
Others	20	20
Total EE of system	4606.08	5675.57

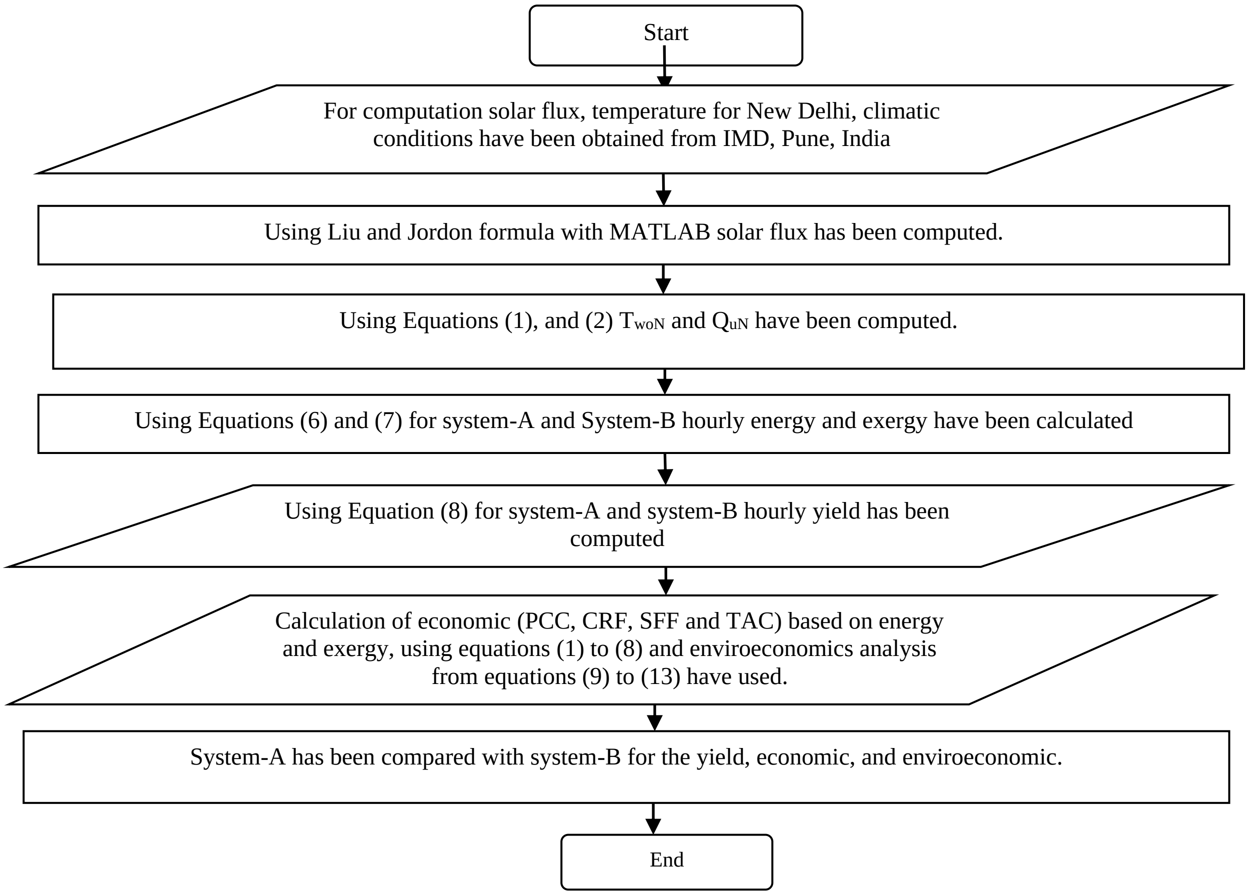

Figure 2. Flow chart of methodology adopted.

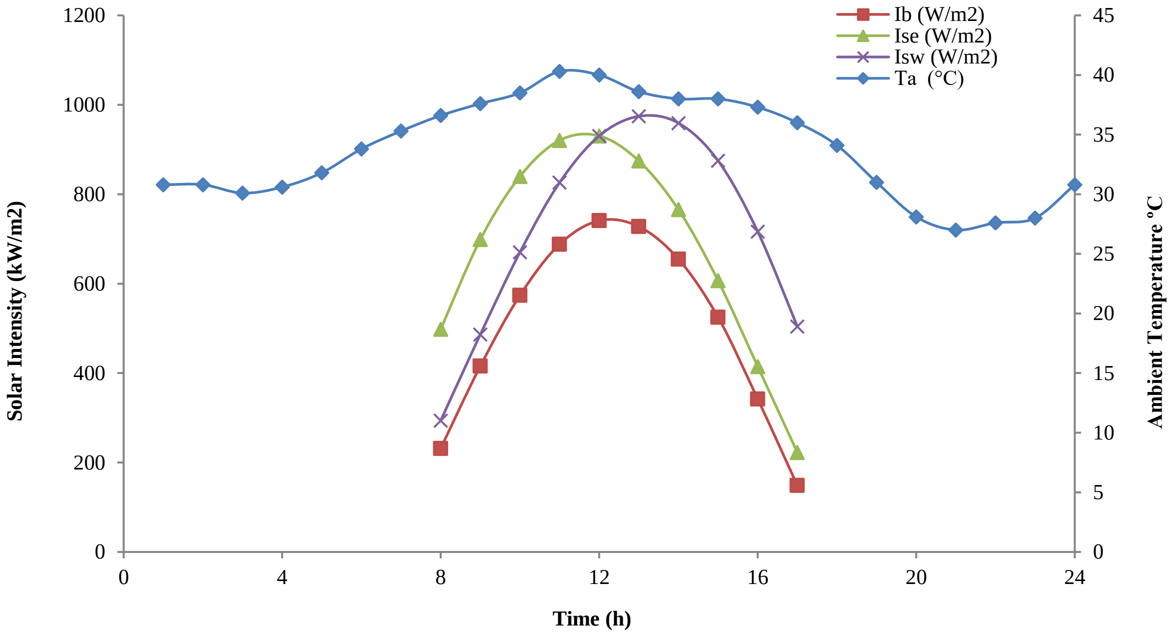

Figure 3. Shows per hour variation and the surrounding temperature in ºC on May a-type days.

3. Result and Discussion

MATLAB has been used to calculate pertinent data and equations for the climate in New Delhi in terms of solar radiation and ambient temperature. The hourly changes of the beam radiation is shown in Figure 3. Using Lui Jordan Formula [23]

$$F = 1 - 0.0335 \sin 360°(n_d - 94)/365 \quad (14)$$

Where n_d is the day of the year (on 1 January $n_d = 1$; on 31 December $n_d = 365$); the argument of the sine function is in degrees.

3.1 Analysis of the economics of employing Al_2O_3 nanoparticles in an active solar distiller with an NPVT-CPC collector and heat exchanger (helically coiled) -

For the system to be economically viable, economic analysis is required. Economic analysis of system-A and system-B are found that distillate cost in (₹/kg) of system-A is less to system-B for interest rate of 1%, 3%, and 5%

respectively and total annual cost of system-A in ($) for interest rate of 1%, 3%, and 5% is less for system-B as represent in Table 4. It is obvious the system-A better to system-B.

3.2 Enviro-economic analysis of active double slope still for proposed system-A using Al_2O_3 nanoparticles-

The environmental costs like carbon credits and CO_2 has reduced annually: The Enviro-economic analysis of the proposed and previous systems are illustrate in Figure 4. It is discovered that the proposed system's CO_2 energy-based mitigation/ton and carbon credit gains ($) are 3.97% less than those of the previous approach for 15 years. The CO_2 mitigation per ton is 40.85kg, respectively.

The proposed and previous systems enviro-economic analysis is shown in Figure 5. It is observed that the proposed system-A PCC, is all 3.18 % higher than those of the preceding system. It is found that over a 15-year lifespan, are for embodied energy, yield, PCC all based on the suggested system's energy, which costs $883.11 ($). As the embodied energy is high while CO_2 mitigation and carbon credit earns in ($) are better to previous system enviroeconomic analysis for 15, 20 and 30 years on the basis of CO_2 mitigation/ton, carbon credit earned in USD($) represents Table 5. It is obvious from data system-A is more economical to system-B.

4. Conclusion and Future Scope

4.1Conclusions

Based on annual examination of the proposed system-A, energy, exergy, and yield with Al_2O_3 nanoparticles revealed the following final observations.

1. Based on distillate cost, System-A performs better than System-B. System-A for 15, 20, and 30 years at rate of interest 1%, 3%, and 5% the cost of distillate 1.25, 1.51, and 1.79 ₹/ kg respectively and system-B, for 15, 20, and 30 years at rate of interest 1%, 3%, and 5% the cost of distillate 1.31, 1.59, and 1.89 ₹/ kg respectively.
2. Based on yield system-A is 8.5% greater, annual energy 3.9% greater to system-B.
3. System-A is more environmentally friendly than System-B, based on carbon credit earnings ($) based on energy. System-A for 15, 20, and 30 years, $204.26, $287.30, and $453.36 respectively and system-B, for 15, 20, and 30 years, $212.71, $295.75 and $461.81respectively.
4. Based on CO_2 mitigation/ton based on energy system-A for 15, 20, and 30 years, 40.85, 57.46, and 90.67 respectively and system-B, for 15, 20, and 30 years, 42.54, 59.15, and 461.81respectively.it is obvious system-A is better to system-B.

The active solar still using Al_2O_3 nanoparticles is thought to be the best design overall because of its annual performance based on economic, environmental, and energy-related aspects.

4.2Future scope

1. To operate the system at night extra supporting electrical appliances and partially covered FPC need to be increased over 25%. The mass water temperature could be raised even more by the CPC profile, which the PCM could also make use of at night. It may be another factor contributing to the improvement in system performance, and more study is required to determine its magnitude.
2. Use of various nanoparticles to study of energy matrices, environmental economics, and energy economics is conceivable. Investigations on the impact of size, shape, and mass flow rate are to be needed to examine.

Table 4. Economic analysis for proposed system (system-A) and previous system (system-B).

	Years (n)	**I (%)**	**S ($)**	**CRF**	**SFF**	**Cost of water (inkg)/annum (₹/kg)**	**TAC ($)**
System (A)		1	176.6	0.07	0.06	1.25	45.42
N-PVT-CPC-DS-HE	15	3	176.6	0.08	0.05	1.51	97.97
(Proposed system)		5	176.6	0.1	0.05	1.79	153.74
System (B)		1	171.1	0.07	0.06	1.31	41.11
N-PVT-FPC-DS-HE	15	3	171.1	0.08	0.05	1.59	94.95
(Previous system)[21]		5	171.1	0.1	0.05	1.89	148.99

Table 5. Enviroeconomic analysis of system-A and system-B for 15, 20, and 30 years.

		System-A NPVT-CPC-DS-HE	**System-B [21] NPVT-FPC-DS-HE**
15 Years	CO_2miti/ton	40.85	42.54
	Carbon credit earn($)	204.26	212.71
20 Years	CO_2miti/ton	57.46	59.15
	Carbon credit earn($)	287.30	295.75
30 Years	CO_2 miti/ton energy	90.67	92.36
	Carbon credit earn($)	453.36	461.81

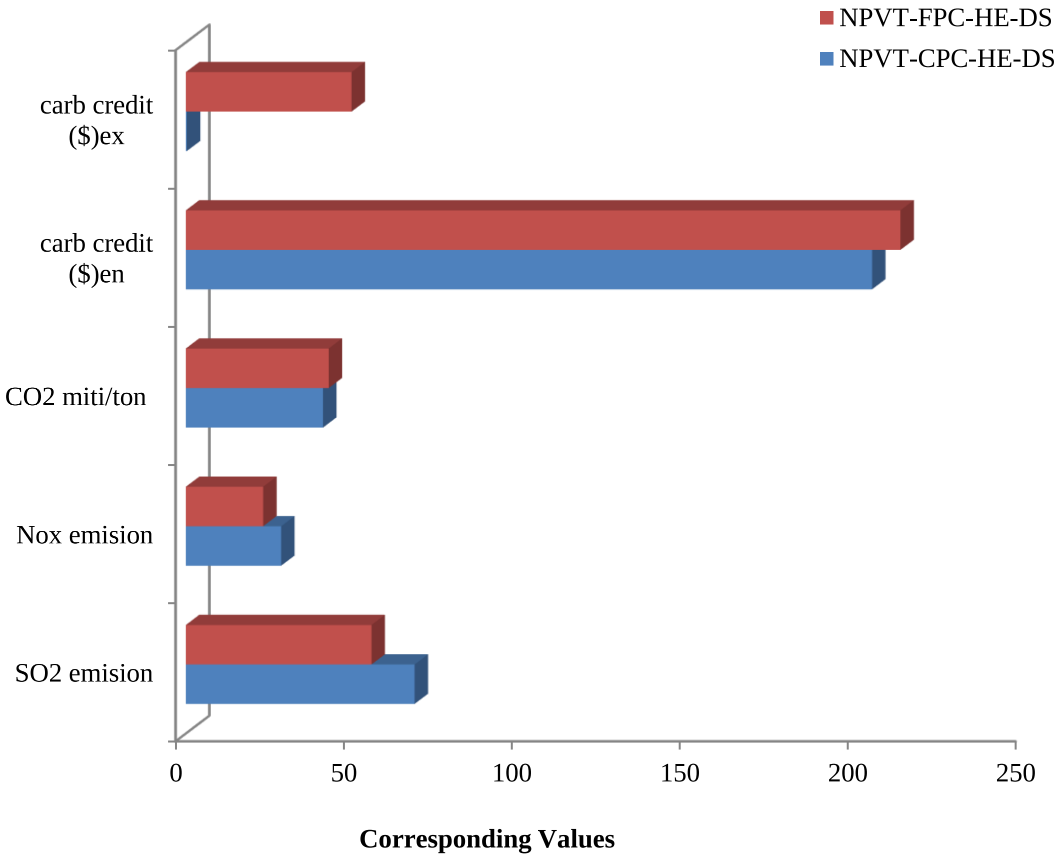

Figure 4. Enviro-economic analysis based on SO_2, CO_2 and NO_x for 15 years.

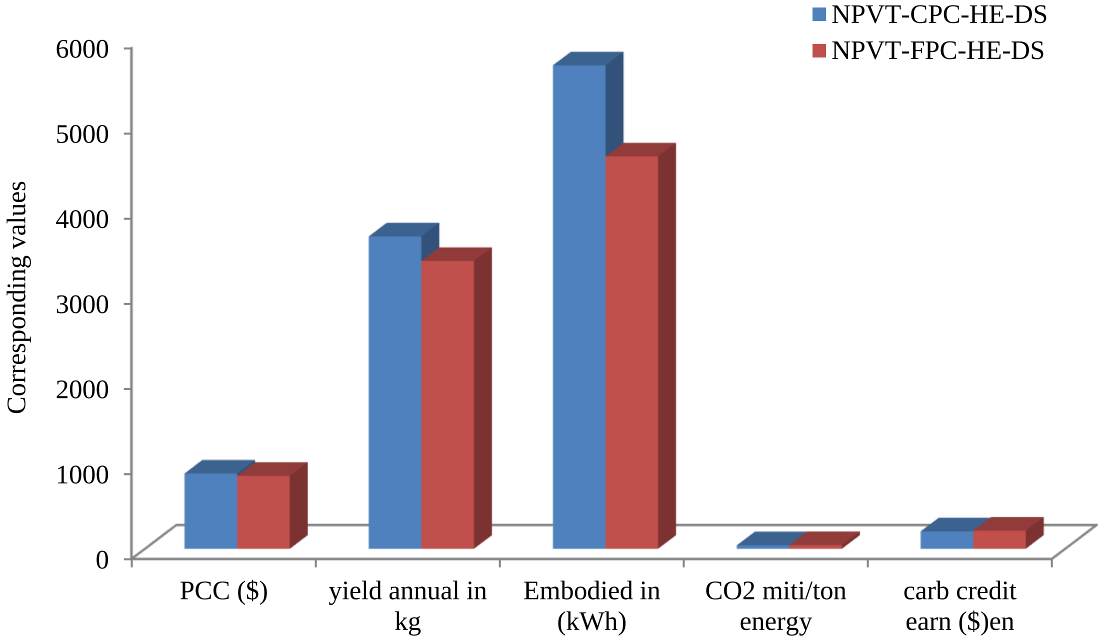

Figure 5. Enviro-economic analysis based on yield for 15 years.

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Nomenclature

Symbol	***Variable***
A_{ba}	basin surface, in (m^2)
A_{ca}	flat plate collector area under glazing, in (m^2)
A_{gE}	eastside glass cover area, in (m^2)
A_{gW}	westside glass cover area, in (m^2)
A_m	photovoltaic area in (m^2)
D_i	tube area under FPC, in (m^2)
d_p	Nps dia., in (nm)
h_{HE}	in heat exchanger convective heat transfer coefficient, in (W/m^2K)
I_b	on the collector solar irradiation, in (W/m^2)
I_{SE}	eastside over glass cover solar irradiation, in (W/m^2)

I_{SW}	westside over glass cover solar irradiation, in (W/m^2)
M_w	water mass, in kg
Q_{uN}	N identical 25% PVT-CPC linked in series, the rate of heat transfer, in (kWh)
T_a	surrounding temperature in (˚C)
T_{wi}	fluid inlet temperature in (˚C)
T_{bf}	in collector basefluid temperature, in (˚C)
T_{woN}	water temperature at the Nth collector outlet, in (˚C)
T_w	temperature of basin water in (˚C)
T_{wo}	temperature of water at t=0, in (˚C)
ΔT_{HE}	temperature between nanofluid to basefluid at heat exchanger, in (˚C)
ΔT	temperature between T_w and $\frac{T_{giE}}{T_{giW}}$ for time(t), in (h)

Subscripts

e_n	energy
e_x	exergy
E_{in}	input of embodied energy
E_{out}	outputembodied energy
E_{sol}	annual solar energy
i	interest rate
n	life time period
p	particle

Abbreviation

YM	maintenance cost annually
ASC	salvage cost annually
CR	capital recovery factor
CM	carbon dioxide mitigation
FYC	fixed annual cost
FPC	flat plate, collector
HE	heat exchanger
PCC	primary capital cost
SFF	shrinking fund factor
S	value of future salvage
TAC	total annual cost
CPC	compound parabolic concentrator

N-PVT-DS-CPC-HE, incorporating PVT-CPC double slope with N^th collector using heat exchanger (helically coiled)

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