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Enviroeconomic and Exergoeconomic Based Analytical Study of Double Slope Solar Distiller Unit Using Al_2O_3 Nanoparticles

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Abstract: ***Present study represents the environeconomic and exergoeconomic analysis of a double slope solar desalination unit (DSDU) coupled with N identical compound parabolic concentrator collector (N-CPC) with helically coiled heat exchanger using Al_2O_3 nanoparticles. The analysis is observed for a yearly based for the atmospheric situation of New Delhi with the help of analytical program fed in MATLAB. The input data required for the mathematically calculation has been taken from Indian Metrological Department, Pune, India. The average value of annual energy output will be computed based on the energy outputs of summer and winter seasons followed by the evaluation of economic, enviroeconomic and exergoeconomic for the system and compared with previous system. Furthermore, based on annual as well as life of 15 and 20 years it is found 8.5% greater yield, annual exergy 7.31% greater, CO_2 mitigation/ton energy 3.9% and 2.85% less, annual productivity 5.17% greater, and exergoeconomic parameter 4% greater respectively. It will be concluded that the proposed system is better than other system based on energy enviroeconomic and exergoeconomic parameters.***

Keywords: Economic, Environ-economic, Exergoeconomic, productivity, nanoparticles

I. INTRODUCTION

As all of us known water is one of the most important thing on our planet because it is required for or biotic or abiotic reaction living and nonliving things and for all industrial and domestic use our Earth is full of water on which 97% of the total surface area is covered with water but very small amount it is available as in form of freshwater.

As 97% water on earth if we assume it 100% percent then 97.2 percent water is sea water and 2.1 5% water is glacier water that are not usable only 0.65% water is available for drinking purpose and for industrial for industrial use so it is required to develop such type of technologies or methods. Which purify the water without or with minimum use of conventional power self sustainable system like non-conventional power sources like solar power. As we know that by the consumption of dirty water or polluted water many types of the disease are developed in human body is due different type of virus and bacteria that are is transmitted through the agriculture fishery industries food industries and let to different types of ailments disease and led to death. Lawrence and Tiwari [1] developed the empirical relations for the inside coefficients of heat transfer from the natural flow with a heat exchanger in a solar distiller unit. Popiel and Wojtkowiak [2] studied the thermo-physical properties of the base fluid. Pak and Cho [3] evaluated various correlations for different properties. G. N. Tiwari [4] studied the fundamental design of solar still. Hwang et al. [5] analyzed the heat transfer coefficient for Al_2O_3 nanofluids. Barden [6] improved the thermo-physical properties of base fluid; the heat transfer coefficients can also be improved. The nanoparticles (1-100) nm are suspended simply in base fluid (ethylene glycol, thermal oil, water, etc.) due to their better thermo-physical properties. The nanofluids are embryonic fluids with ultrafast heat transfer capabilities. Further, by tailoring the size and shape, the properties can be improved in the base fluid. Tiwari and Tiwari [7] expressed few merits of solar distillers over other distillation technologies such as filters, membranes, batteries, no definitive resource of energy, and primarily low investment. Ho et al. [8] numerically analyzed nanofluids for natural convection in a square enclosure: effects due to uncertainties of viscosity and thermal conductivity. Otanicar and Golden [9] analyzed the enviroeconomic aspect of solar collectors using nanofluid and found it neutralizes 74 kg for the life span of 15 years. Patel et al. [10] found the thermal conductivity of nanofluids. Singh et al. [11] theoretically investigated entropy generation for nanofluids. Elzen et al. [12] analyzed emission reductions, abatement costs, and carbon price. Khanafer and Vafai [13] this work presented thermophysical properties of nanofluids. Khullar and Tyagi [14] analyzed and reported emissions of 103 kg approx./household/year reduced for a solar heating device for nanofluids. Faizel et al. [15] analyzed based on the cost of flat plate collector (FPC) using tin oxide, copper

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oxide, titanium oxide, and aluminum oxide) nanofluids. It is found that the performance of CuO nanofluid is better credited to its high density, low specific heat, and thermal conductivity. Liu et al. [16] have evaluated the economic analysis of the integrated solar distiller unit of the evacuated tube. Kabeel et al. [17] analyzed the sole inclined solar distiller unit with vacuum as water-based nanofluid. Elango et al. [18] analyzed practically single slope solar distiller as thermal energy, exergy, and productivity using different nanofluids. Omara et al. [19] analyzed the performance of corrugated wick type and simple solar distiller unit using nanofluids. Tiwari et al. [20] analyzed experimentally on active solar distiller the exergoeconomic and environeconomic using water-based nanofluid the photovoltaic thermal flat plate collector is met potable water requirements daily. It has been observed that the environmental cost of 6.29 dollars annually. Sharon and reddy [21] analyzed the annual economic performance of an active solar distiller loaded with saline water. Sahota et al. [22, 24] analyzed the passive double slope solar distiller unit performance using nanofluids and concluded that the aluminum oxide-based nanofluid gives better performance than others. Singh et al. [23] analyzed the energy matrix and existence cycle conversion efficiency for conventional single and double slope distiller units and found 0.144. and 0.137 per unit cost, respectively, and exergoeconomic parameters. Singh and Tiwari [25] analyzed the energy matrices and life cycle cost of an active partly PVT-CPC solar distiller. Shashir et al. [26] analyzed the performance of nanoparticles like copper oxide and graphite micro-flakes on solar distiller units with different cooling on the cover of toughened glass. It is concluded that 47.8% and 57.6% solar distiller yield increased with graphite and copper oxide micro-flakes. Sahota et al. [27] studied the performance of PVT-FPC double slope solar distiller unit with or without helical coil heat exchanger using nanofluid and found water-based nanofluid performance was better with a heat exchanger. Saleha et al. [28] analyzed the effect of solvent and found it effective in solar distiller units. Chen et al. [29] analyzed that experimentally found stability of weak luminous was very good with nanofluid in solar distiller unit and the effect of brackish water's constancy, ocular and thermal properties using nanofluid feasible. Mahian et al. [30] investigated experimentally and found that the heat exchanger was not significant at a temperature lower than 50 °C, and the amount of water was two times greater than without a heat exchanger. Furthermore, nanoparticles with water give better evaporation at low temperatures. It is vital to evaluate its cost-effective viability in design, construction, life cycle cost, net present value, annual cost, and payback time of renewable energy systems. Sahota et al. [31] analyzed environeconomic and exergoeconomic for passive double slope solar distiller with water-loaded nanofluid (CuO, Al_2O_3, TiO_2) and found payback time of energy of the system is low and the cost of environmental per annum is higher on mitigation with nanofluid. Singh and Tiwari [32] analyzed the augmentation in energy matrices of N-PVT-FPC partly double slope solar distiller. Joshi and Tiwari [33] analyzed a single slope N identical PVT-CPC single slope solar distiller. Dharamveer et al. [34] reviewed nanofluid-loaded desalination. Kumar and Singh [35] analyzed Energy and exergy of active solar stills using compound parabolic concentrator. Shanker, et al. [36] analyzed performance of C.I. engine using biodiesel fuel by modifying injection timing and injection pressure. Anup et al. [37] analyzed using FEA of refrigerator compartment for optimizing thermal efficiency. Kumar and Singh [38] Optimized thermal behavior of compact heat exchanger. Zhang et al. [39] presented in the area of sustainable energies focuses on utilizing green and clean technologies. Dhivagar et al. [40] analyzed grate crude shrewd heat storage single slope solar still energy, exergy, and economic assessment. Dharamveer and Samsher [41] studied the active and passive solar still behavior on energy matrices and enviroeconomics. Arora et al. [42] studied incorporating with carbon nanotubes using N-PVT-CPC double slope solar still. Dharamveer et al. [43] analytical studied N^{th} identical photovoltaic thermal (PVT) compound parabolic concentrator (CPC) active double slope solar distiller with helical coiled heat exchanger using C_uO Nanoparticles. Dharamveer et al. [44] analyzed performance of N-identical PVT-CPC collectors an active single slope solar distiller with a helically coiled heat exchanger using CuO nanoparticles. Kumar and Singh [45] comparative analyzed of single phase microchannel for heat flow Experimental and using CFD. Subrit and Singh [46] performed thermal analysis of coal and waste cotton oil liquid obtained by pyrolysis fuel in diesel engine. Till date many researcher have research on integrated solar stills which produce pure water. The extant literature survey shows that many works have been done on passive and active solar stills. However, not much literature is available on the analysis of active solar still loaded with nanofluids based water. Dharamveer et al. analyzed only Compound parabolic concentrator collector integrated double slope solar still based on energy and exergy. Analysis of double slope solar still integrated with compound parabolic collector having different nanofluids based water, energy matrices, exergoeconomic and environeconomic effects have not been reported by any researchers. Further, basin type solar stills incorporating compound parabolic concentrator collectors/evacuated tubular collectors loaded with nanofluid based water have not been analyzed by any researchers. Hence, the proposed research will analyze exergoeconomic and environeconomic effects of double slope solar stills integrated with compound parabolic concentrator collector and loaded with nanofluid based water. Solar desalination systems will be through analyze in terms of energy metrics, exergoeconomic parameter, enviroeconomic parameters, various efficiencies and productivity. The performance of the proposed system will also be compared with results of earlier researchers.

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II. SYSTEM DESCRIPTION

Fig. 1 shows, when solar radiation is fall on the PV module and concentrating parabolic collector. After receiving the heat PV module generate electricity and concentrating collector start increasing the temperature of nanofluid which is flow through the heat exchanger tube. As fluid passes from the first PV module and CPC collector it gain some heat and enter in the second PV module and CPC collector then it gain again some heat here a simple question is arise same fluid is passes through first and second CPC collector and a constant solar constant 1367 what how flute gain the energy. The reason behind for gaining the energy in second CPC collector because fluid have some heat storage capacity in first module the capacity is not fulfilled so it gain again some amount of heat through second third and fourth PV module CPC collector. After gaining the maximum amount of heat fluid is enter into helical coil heat exchanger which is made of high quality copper. This heat exchanger is placed in the water tank and open to Sun portion is covered by glass plate which is inclined to both directions. When fluid enter in the heat exchanger start losing their heat because of contact by surrounding water in the tank by the process of sensible heating as solar radiation is incident on the glass cover passes through the inside the water tank they also increase the temperature of water in water tank approx 100°C temperature is achieved in this process for evaporation of the water. Vapor from the water start move in upper direction and reaching the glass cover is condense due to temperature difference inside and outside of glass cover. As glass cover is sloped on both sides proper arrangement should be make to collect these drop in a external container by sliding these drop on the glass cover in both direction. Now the working fluid is exit from the outlet of the heat exchanger and re-circulated through for next cycle. A DC motor is used to make the continuous forced flow of working fluid. The energy required for running to this DC motor is obtained from PV module which is individually have capacity of 250 watt and extra energy is stored in battery that is used for other purposes. The schematic is shown in figure-1

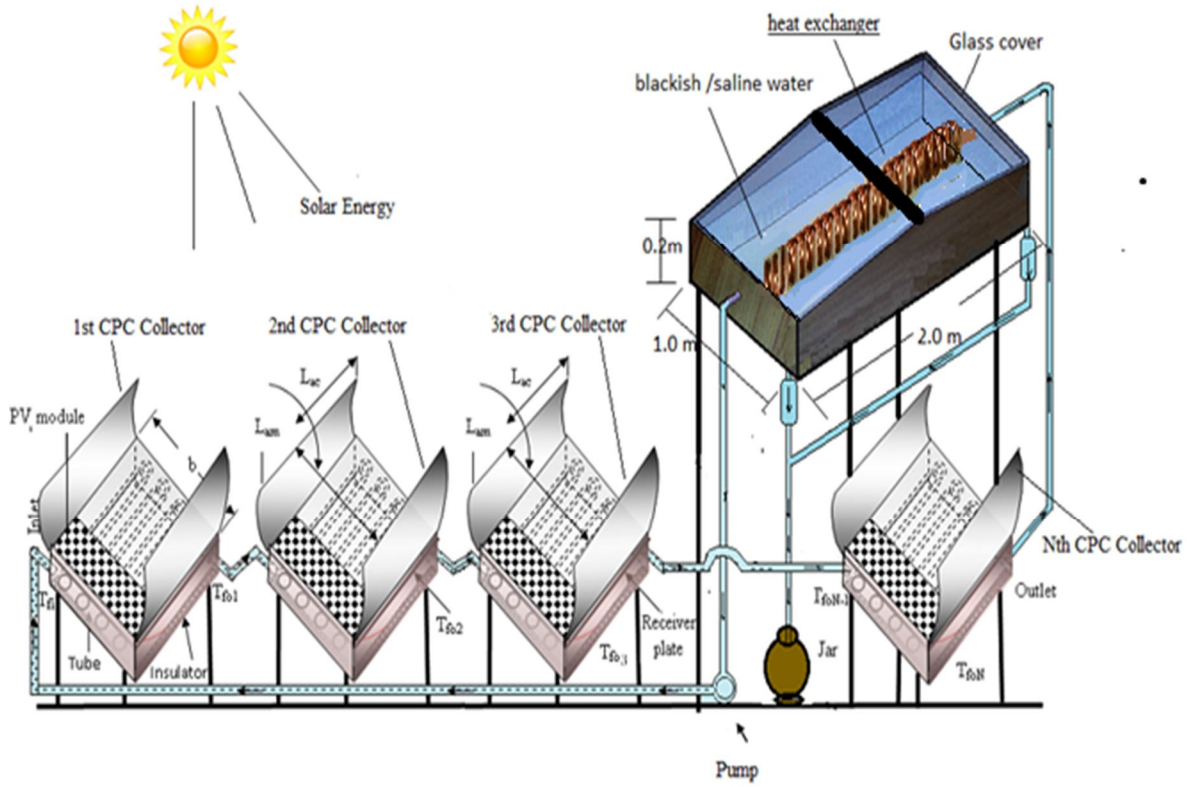


Fig. 1 double slope active solar still 25% N-PVT-CPC-DS-HE

Table 1
Thermophysical properties of Al_2O_3 nanoparticles [43]

Nanoparticles (NPs)	Density k_g/m^3	Thermal conductivity k_p (W/mK)	Specific heat C_p $(j/k_g K)$
Al_2O_3	$6.3*10^3$	17.6	550

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Table 2
Different parameters used in calculations [43]

Parameters	Numerical values	Parameters	Numerical values
α_g	0.050	A_{am}	0.5
α_b	0.5861	A_{ac}	1.5
α_{bf}	0.82	L_p	0.0020
α_c	0.90	K_m	64 W/m K
α_p	0.80	K_p	64 W/m K
β_c	0.89	L_i	0.1m
K_g	0.8160 W/m K	h_i	5.7 W/m^2 K
K_b	0.035 W/m K	h_0	9.5 W/m^2 K
K_p	0.166 W/m K	U_{tcp}	5.5451 W/m^2 K
L_g	0.004	U_{tca}	15.03 W/m^2 K
L_c	0.005	U_{tpa}	5.56 $W/m^2 - K$
L_i	0.1	U_{Lm}	9.03 $W/m^2 - K$
β_0	0.0045/K	U_{LC}	5.43 W/m^2 K
x	0.33m	PF_1	0.2695
σ	$5.67*10^{-8}$ $(W/m^2\ K^4)$	PF_2	0.9398
τ_g	0.95	PF_c	0.977
$F^/$	0.968	ϵ_g	0.95
η_0	0.15	ϵ_{bf}	0.95

Table 3
Specifications of double slope PVT-CPC-DS active solar distillation system [43]

Active double slope solar distiller unit			
components		Specifications	
Length of basin		2.0 m	
Width of basin		1.0 m	
glass cover inclination		15°	
basin height (smaller side)		0.2 m	
Material of body		GRP	
material of stand		GI	
Cover material		Glass	
Orientation		south	
glass cover thickness		0.004 m	
K_g		0.816 W/mK	
Thickness of insulation		0.1 m	
Insulating material thermal conductivity		0.166 W/mK	
PVT-FPC-DS-HE and PVT-CPC-DS-HE collector			
Name of component	Specifications	Name of component	Specifications
Type of collector	Tube type	aperture area	2 m^2
solar water collector receiver area	1.0 m^2	aperture area of module	1.0 m^2
Collector plate thickness	0.0020 m	Receiver aperture area	1.5 m^2
Cu tube thickness	0.00056 m	receiver module area	0.25 m^2
Cu tube length	1.0 m	receiver area of collector	0.75 m^2
Fill factor	0.8	No of collectors	N=4
D.C. motor	12V, 40 Watt	Pipe dia.	0.0125 m
angle of CPC with Horizontal	30°	angle of FPC with Horizontal	30°
Below glass effective collector area	0.75 m^2	Below PV module effective collector area	0.660 m^2
No of solar cells	36	Area single solar cell	0.007 m^2
Basin area	2 m^2	m_f	0.02 kg/s
Helical coiled heat exchanger (copper)			
Number of turns	12	Dia of the coil tube	0.0125 m
Length of heat exchanger	1.937 m	Coil diameter	0.045 m

Table 4
Thermophysical properties of Al_2O_3 nanoparticles [43]

Density	$\rho_{nf} = \emptyset_p\rho_p + (1-\emptyset_p)\rho_{bf}$
Thermal expansion coefficient	$\beta_{nf} = \emptyset_p\beta_p + (1-\emptyset_p)\beta_{bf}$
Thermal conductivity	$k_{nf} = k_{bf}[0.9843 + (0.398)(\emptyset_p)^{0.467}(\frac{\mu_{nf}}{\mu_{bf}})^{0.0235}(\frac{1}{d_p(nm)})^{0.2246} - (3.951)(\frac{\emptyset_p}{T_{nf}}) + (34.034)(\frac{\emptyset_p^2}{T_{nf}}) + 32.51(\frac{\emptyset_p}{T_{nf}})$
	$0 < \emptyset_p < 10\%; 20 < T_{nf} < 70°C; 11 < d_p < 150nm \quad (CuO-water)$
Viscosity	$\mu_{nf} = (2.414 * 10^{-5})10^{\frac{247.8}{(T_{nf}-140)}}$
	$0 \leq \emptyset_p \leq 10;\ 11 \leq d_p \leq 150nm;\ 20 \leq T_{nf} \leq 70°C$ (CuO – water) [38]
Specific heat	$C_{nf} = 0.8429\left(1+\frac{T_{nf}}{50}\right)^{-0.3037}\left(1+\frac{\emptyset_p}{100}\right)^{2.272}\left(1+\frac{d_p}{50}\right)^{0.4167}]$
	$15 < d_p < 50\,nm; 0 < \emptyset_p < 4\%; 20 < T_{nf} < 50°C$ CuO-Water

III. METHODOLOGY

The methodology is adopted to carry out the study of the proposed system follow the following steps:

A. Step-I

Firstly Lui and Jordon formulae for beam solar radiation (I_b) and global irradiation (I_s) is used to calculate proposed systems for the annual. Further calculate per day solar radiation with number of days according to clear, hazy, hazy and cloudy and cloudy days given in a month.

B. Step-II

All the parameters are optimized to maximize the collector's output temperature, basin water temperature computed based on hourly, monthly and annually.

C. Step-III

Enviroeconomic and exergoeconomic parameters have been evaluated.

D. Step-IV

Proposed systems are compared based on numerically computed values with previous system.

In this unit the methodology has been adopted to find the objectives. Detailed discussion enviroeconomic and exergoeconomic analysis of N-PVT-CPC-HE of active solar distiller using Al_2O_3 nanofluid (double slope). The analysis based on economic, environ-economic, exergoeconomic study of various systems i.e. double slope active solar distiller N-identical photovoltaic thermal (PVT) compound parabolic concentrator (CPC) with a helically coiled heat exchanger using Al_2O_3 nanoparticles have been computed, and results have been compared with previous system an active double slope N-identical photovoltaic thermal (PVT) flat plate collector (FPC) with a helically coiled heat exchanger using nanofluid.

IV. THERMAL MODELING

Analysis N-PVT-CPC collector active solar distiller with helically coiled heat exchanger using Al_2O_3 nanoparticles

A. Economic analysis N-PVT-CPC collector active solar distiller with helically coiled heat exchanger using Al2O3 nanoparticles - Economic analysis is necessary for the economic feasibility of the system. The total annual cost, shrinking fund factor, and capital recovery factor for system-A (N-PVT-CPC-DS-HE) and system-B (N-PVT-FPC-DS-HE)

1) Capital cost

The fabrication cost of the system is given in Table 3.1 and 3.2

2) Lifetime of the system

The lifetime of the system are taken 15 and 20 years.

3) Salvage value (S)

$$S = 0.2*PCC \quad (24)$$

Where PCC is primary capital cost

4) Annual salvage cost (ASC)

$$ASC = S*SFF \quad (25)$$

Where SFF is a factor of shrinking fund

5) Maintenance cost annually (AMC)

$$AMC = 0.15*FAC \quad (26)$$

Where FAC is first annual cost

6) Capital recovery factor (CRF)

It represents present cost in uniform annual cost over life at a fixed rate of interest.

$$CRF = \frac{i(1+i)^n}{(1+i)^n-1} \quad (27)$$

7) Shrinking fund factor

$$SFF = \frac{i}{(1+i)^n-1} \quad (28)$$

8) First annually cost is obtained

$$FAC = PCC*CRF \quad (29)$$

9) The total annual cost obtained

$$TAC = FAC+AMC-ASC \quad (30)$$

10) Cost of distillate per kg obtained

$$Cost/kg = \frac{TAC}{\text{yield in life}} \quad (31)$$

B. Environ-economic analysis N-PVT-CPC collector active double slope solar distiller with helically coiled heat exchanger using Al_2O_3 nanoparticles – Mathematical expression of the environmental cost like carbon credits, Co_2 mitigated per annum are given as follows:

1) CO_2 Emission

The electrical generation intensity is equivalent to average CO_2 which is approximately 0.98 kg of CO_2/kWh.

2) CO_2 emission per year $= \frac{\text{Embodied energy}*0.98}{\text{life time}}$ (32)

For Indian conditions

$$CO_2 \text{ emission per year} = \frac{\text{Embodied energy}*1.58}{\text{life time}} \quad (33)$$

3) CO_2 mitigation

It can be calculated per kWh and represented by equation

$$CO_2 \text{ mitigation per year} = (E_{out}*n)*1.58 \quad (34)$$

Total CO_2 mitigation is computed by equation

$$\text{Total mitigation over life} = (E_{out}*n)*1.58/1000 \quad (35)$$

4) Carbon credit earned

The carbon credit earned = Net mitigation of over life * D (36)

Where D is change from 5$ to 20$/ton of CO_2 mitigation

C. Exergoeconomic analyses of N-PVT-CPC collector active double slope solar distiller with helically coiled heat exchanger using Al_2O_3 nanoparticles - The concept of the second law of thermodynamics is used with a combination of cost analysis. Many authors have been researched exergoeconomic analysis loss of energy per unit cost with the motto of exergy loss have to minimize.

The following parameter (R_{ex}) is expressed the exergoeconomic Tiwari et al. [ref-20]

$$R_{ex} = \frac{L_{ex,annm}}{TAC} \quad (37)$$

V. RESULT AND DISCUSSION

Relevant data and equations for climatic conditions of New Delhi for solar radiation and ambient temperature have been computed using MATLAB. Fig. 5 represents the hourly variation in beam radiation, solar radiation intensity in Eastside and Westside in kW/m^2 and ambient temperature in °C.

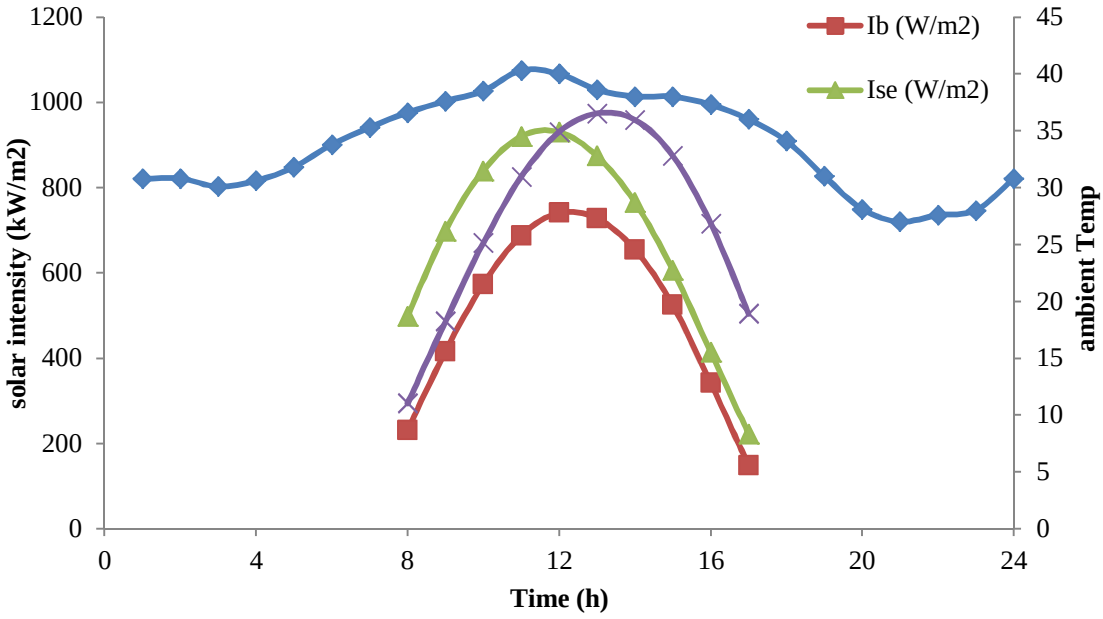


Fig. 5 hourly variation in solar intensity and ambient temperature in °C of typical day of May

As per previous study the systems have been tested for 30 years but practically it is not feasible. Therefore in present study the environeconomic and exergoeconomic analysis have been computed for 15, 20, and 30 years.

A. Economic analysis N-PVT-CPC collector active solar distiller with helically coiled heat exchanger using Al_2O_3 nanoparticles - Economic analysis is necessary for the economic feasibility of the system. The total annual cost, shrinking fund factor, and capital recovery factor for system-A (N-PVT-CPC-DS-HE) and system-B (N-PVT-FPC-DS-HE)

Table 5
The total annual cost, fixed annual cost, annual maintenance cost, annual yield for system-A (N-PVT-CPC-DS-HE) for 15 years at interest rate of 1%, 3%, and 5% respectively.

	NPVT-CPC-DS-HE		
i	0.01	0.03	0.05
n	15.00	15.00	15.00
(1+i)^n	1.16	1.56	2.08
CRF	0.07	0.08	0.10
PCC	883.11	883.11	883.11
FAC	63.69	73.98	85.08
AMC	9.55	11.10	12.76
AMC life	143.31	166.44	191.43
S	176.62	176.62	176.62
SFF	0.06	0.05	0.05
ASC	10.97	9.50	8.19
ASC life	164.59	142.45	122.78
TAC	62.27	75.58	89.66
TAC life ($)	42.42	97.97	153.74
TAC life (₹)	3109.56	7182.45	11270.44
yield in annual	3666.39	3666.39	3666.39
yield in life	54995.85	54995.85	54995.85
Cost ($)/kg annual	0.02	0.02	0.02
Cost(₹)/kg annual	1.25	1.51	1.79
Cost($)/l life	0.001	0.002	0.003
Cost in life(₹)	0.06	0.13	0.20

As results are shown for 15years in Table 5, it is found that the cost of distillate depends on rate of interest. Interest rate increases will increase price of distillate per annum while life of system increases will decrease the cost of distillate. For 15 years system-A and system-B at interest rate of 1%, 3%, and 5% the cost of distillate are 1.25, 1.51, and 1.79 (₹/kg), and 1.31, 1.59, and 1.89 (₹/kg). It is found that the system-A performance is better than system-B as per cost of distillate.

Table 6
The total annual cost, shrinking fund factor, and capital recovery factor, and cost of distillate per annum in ($/kg and ₹/kg) for system-A (N-PVT-CPC-DS-HE), and system-B (N-PVT-FPC-DS-HE) [Sahota] have been shown.

	Years (n)	I (%)	S ($)	CRF	SFF	Cost of water (in kg)/annum		TAC
						($/kg)	(₹/ kg)	($)
System (A)	15	1	176.62	0.07	0.06	0.02	1.25	45.42
N-PVT-CPC-DS-HE		3	176.62	0.08	0.05	0.02	1.51	97.97
(Proposed system)		5	176.62	0.1	0.05	0.02	1.79	153.74
System (B)	15	1	171.17	0.07	0.06	0.02	1.31	41.11
N-PVT-FPC-DS-HE		3	171.17	0.08	0.05	0.02	1.59	94.95
(Previous system)		5	171.17	0.1	0.05	0.03	1.89	148.99

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B. Environ-economic analysis N-PVT-CPC collector active double slope solar distiller with helically coiled heat exchanger using Al_2O_3 nanoparticles – Mathematical expression of the environmental cost like carbon credits, Co_2 mitigated per annum are given as follows: Fig.6, represents the environeconomic analysis of proposed and previous system. It found that the CO_2 mitigation/ton and carbon credit earned ($) based on energy of proposed system are 3.97 lower than previous system. The system has been studied for life span of 15, years life span the CO_2 mitigation/ton based on energy of proposed system 40.85, and carbon credit earned ($) based on energy of proposed system 204.26 respectively.

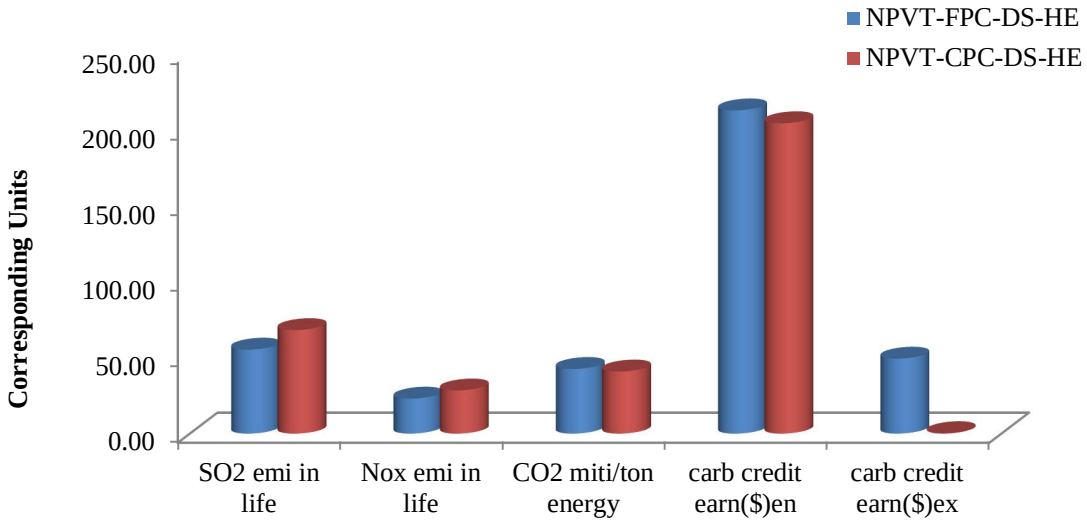


Fig. 6 environ-economic analysis for 15 years

Fig.7, represents the environeconomic analysis of proposed and previous system. It found that the based on energy of proposed system PCC, yield, and embodied energy are 3.18 % greater than previous system. The system has been studied for life span

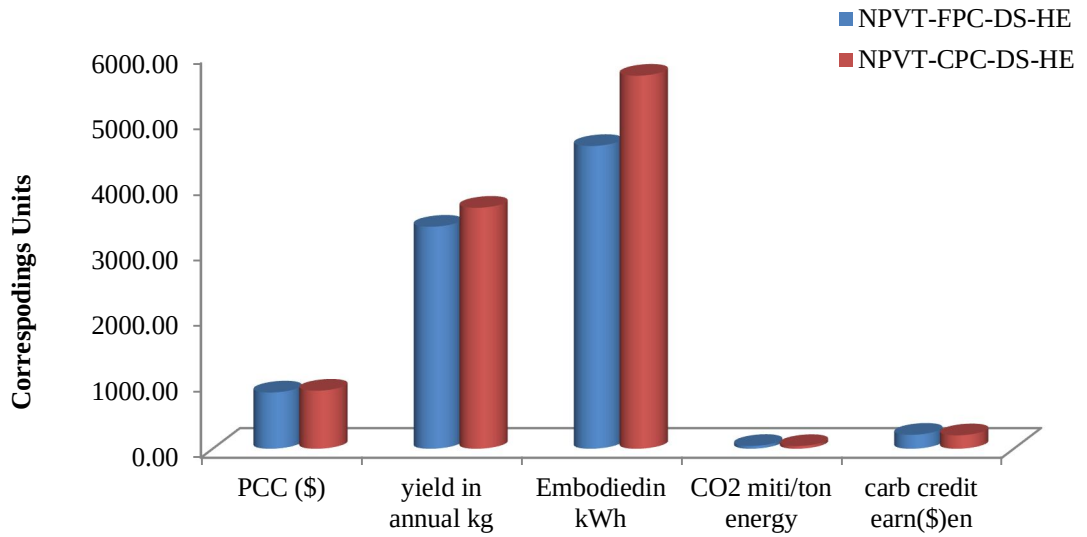


Fig. 7 environ-economic analysis for 15 years

of 15years. It is found that for 15 years life span the PCC, yield, and embodied energy are based on energy of proposed system 883.11 ($) respectively.

C. Exergoeconomic analyses of N-PVT-CPC collector active double slope solar distiller with helically coiled heat exchanger using Al_2O_3 nanoparticles- The concept of the second law of thermodynamics is used with a combination of cost analysis. Many authors have been researched exergoeconomic analysis loss of energy per unit cost with the motto of exergy loss have to minimize.

Table 7
Exergoeconomic analyses of N-PVT-CPC collector active double slope solar distiller with helically coiled heat exchanger using Al_2O_3 nanoparticles for 15 years

Rate of Interest	0.01	0.03	0.05
Annual Exergy	378.65	378.65	378.65
Rex in kWh/₹	6.08	5.01	4.22
USD ($)	73.31	73.31	73.31
Rex in kWh/₹	0.08	0.07	0.06
Mw	3666.39	3666.39	3666.39
Sell price (₹)	5.00	5.00	5.00
Annual productivity (np)	401.54	330.88	278.91
Present value	152.13	113.37	84.96

Fig 8 Exergoeconomic analyses of N-PVT-CPC using Al_2O_3 nanoparticles and N-PVT-FPC using CuO nanoparticles collector active double slope solar distiller with helically coiled heat exchanger at rate of interest 1% for 15 years are shown below.

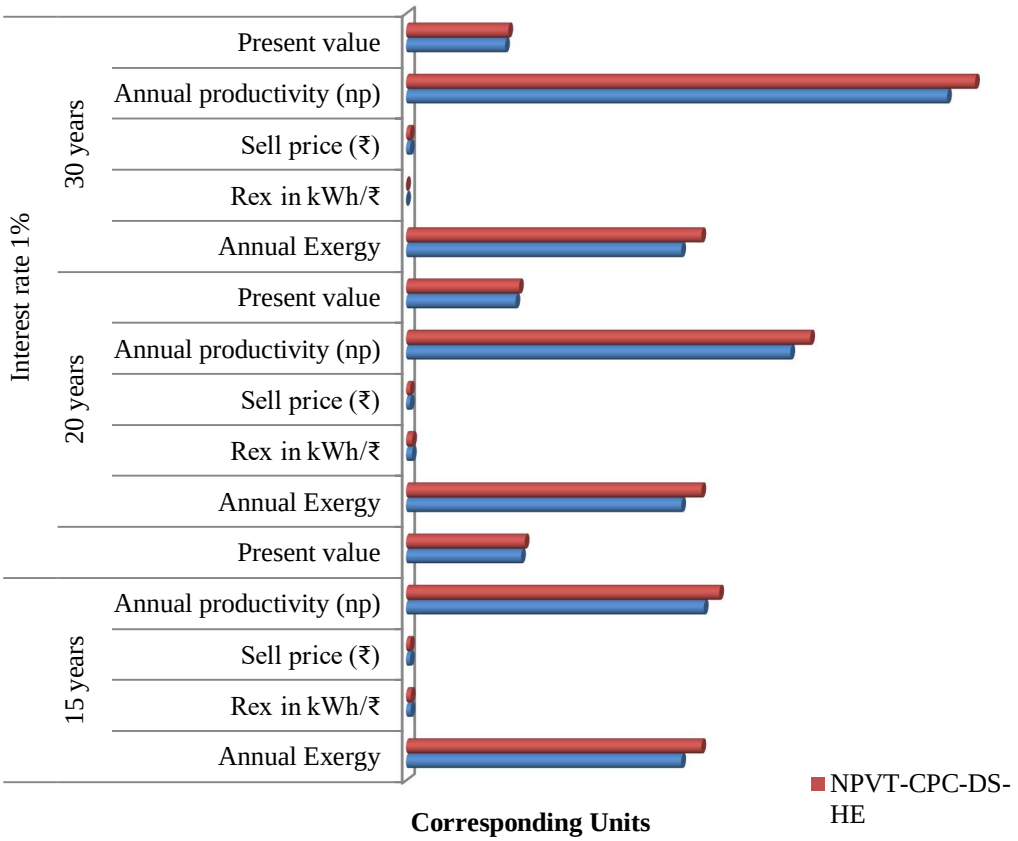


Fig. 8a shows various exergoeconomic parameters

The exergoeconomic analysis based on exergoeconomic parameter (Rex) kWh/₹ for 15 years at rate of interest 1, 3, and 5% for the system-A are 0.082, 0.068, and 0.057, system-B are 0.0789, 0.0650, and 0.0548 respectively. Analysis based on exergoeconomic parameter (Rex) kWh/₹ for 20 years at rate of interest 1, 3, and 5% for the system-A are 0.106, 0.083, and 0.067, system-B are 0.102 0.080, and 0.065 respectively. Similarly the exergoeconomic analysis based on exergoeconomic parameter (Rex) kWh/₹ for 30 years at rate of interest 1, 3, and 5% for the system-A are 0.149, 0.106, and 0.080, system-B are 0.143, 0.102, and 0.077 respectively. Show that the system-A is more economic than system-B. Therefore the system-A is better than system-B.
The analysis based on exergoeconomic parameters, present value on selling price (₹) 5 show that the system-A is better than system-B. Therefore it is found that the system-A is better than system-B.

VI. CONCLUDING REMARKS AND FUTURE SCOPE

A. *Conclusions*

The proposed systems have been studied based on the temperature of the basin, collector outlet temperature, thermal energy, exergy, electrical exergy, and yield to be higher using CuO nanoparticles in the order followed as CuO > Al_2O_3 > T_iO_2 > water. Moreover, the proposed system is better than the previous system. The temperature differences are also better than in the previous study.
The following concluding remarks are observed by annual analysis of the proposed systems energy, exergy, and yield with CuO nanoparticles.

1) System-A performance is better than system-B, and as per cost of distillate. The distillate cost on an annual basis and life span of 30 years at rate of interest 5% for system-A is 1.27₹/kg, and system-B is 1.33 ₹/kg.
2) System-A is environ-economic than system-B, on an annual basis and life span of 30 years at rate of interest 5% CO_2 mitigation per ton for 30 years system-A 90.67, and system-B 92.36.
3) According to carbon credit earned ($) based on energy, system-B is more environeconomic than system-A, and system-B is more environ-economic than system-A, respectively. For 30 years, system-A 453.36, and system-B 461.81.
4) Exergoeconomic analysis based on exergoeconomic parameter (R_{ex}) kWh/₹, for 30 years at rate of interest 1%, 3%, and 5% for system-A is more economic than system-B. Therefore system-A is better than system-B.
5) System-A productivity is greater than system-B for 30 years at rate of interest 5%. system-A is 394.37%, and system-B 374.98 %. Therefore system-A is better than system-B.
6) System-A present value is greater than system-A for 30 years at rate of interest 5% for system-A is 40.86 ($), and system-B 39.6 ($). Therefore system-A is better than system-B.
7) System performance on 0.02 kg/s flow rate, which is less than prior system 0.03 kg/s flow rate shows that reducing the pump work correspondingly reduces motor power to drive the pump hence reducing the requirement for electricity.

The overall best design is active N-PVT-CPC double slope solar distiller incorporating a helically coiled heat exchanger using Al_2O_3 nanoparticles because of its annual performance based on economic, enviroeconomic and exergoeconomic.

B. *Future Scope*

1) The present work can be further expanded by doing intensive research in CPC-PVT-PCM utilizations up to their optimum level. The partly covered FPC can be increased beyond 25% to run the system at night with additional supportive electrical subsystems. The profile of CPC may further increase the mass water temperature and can be further utilized by the PCM at night. It can be another cause for the system performance enhancement, and to quantify that, further research is needed.
2) The energy matrices, environeconomic and exergoeconomic assisted with different nanoparticles, and nanofluids can be studied. The effect of mass flow rate, size, and shape of nanoparticles can be investigated. PCM materials can also be used to store energy in the daytime when the sun is shining, which can further utilize when the sun is absent.

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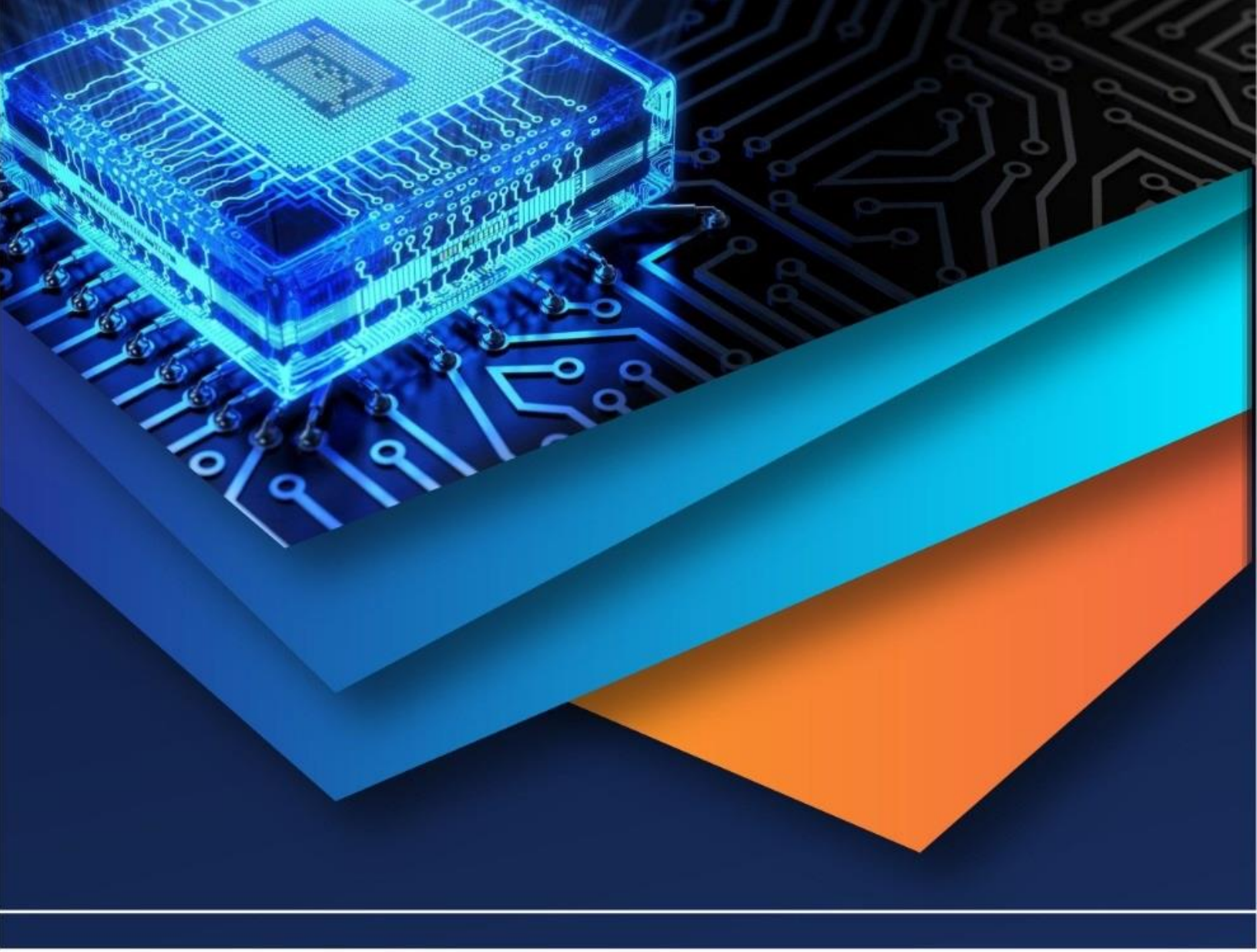
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