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EFFECT OF DISSIMILARITY OF N ON ENERGY PAYBACK TIME OF N EQUAL PARTLY COVERED COMPOUND PARABOLIC CONCENTRATING COLLECTORS COUPLED TO SINGLE SLOPE TYPE SOLAR ENERGY BASED WATER PURIFIER

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ABSTRACT

In the present article, the outcome of sum total of solar concentrating devices on the energy payback time (EPBT) of a single slope solar desalting plant (SSSDP) incorporated by number of indistinguishable partially wrapped photovoltaic thermal compound parabolic concentrator collectors (PVTCPCs) has been investigated. The examination has been implemented for a standard 24 hours time of month of July and December in the aerosphere site of capital by the assistance of inquisitive code written via tools of MATLAB. The median value of energy yield with respect to a typical meteorological circumstances is chosen to calculate yearly energy yield. The incoming details necessary for the computational analysis being withdrew from Indian Meteorological Deapartment , Pune, India. A conclusion being perceived that the *amount of energy payback time (EPBT) expands with the rise in the sum total of number of solar collectors.*

Key words: Series of Single slope solar still (SSSS), PVTCPC, energy payback time (EPBT).

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1. INTRODUCTION

The utilization of solar thermal mechanism build appliance that have need of sun radiation for the absolution of water is the utmost requirement for time as we all know that a very little quantity of clean water present all over the planet. The implication of contaminated water by civilization beings may out-turn in the occurrence of several ailment in the physique and occasionally, the ailment are so grave that they may even become fatal. The peoples living on planet earth have a quite limited access of pure water for various purposes . Hence a appalling requirement of production of self sustainable system with competitive yield is needed. The ready for use systems that are employed did not operate independently since they demand electricity for operation and making of electricity by utilizing traditional ways of power produce several harmful gases and solvents which contaminates our ecosystem. Hence, absolution of brackish and impure water by utilizing inexhaustible source is a remarkable method of solution of the current complication of clean water undersupply.

Each solar desalting system operated either in direct or indirect modes. The solar desalting plant which work in unassertive way are self reliant besides that they offer outstanding solution for remote locations where abundant amount of solar energy is accessible. But, these types of systems have very less outcome almost about 1-3 litres in a day of freshwater. The shortcoming of inassertive way of functioning of desalting plant might be control with acknowledge the solar desalting system to operate in assertive way inside a supplementary part connected in the bottom liner for providing extra thermal energy. So, assertive way of functioning of solar desalting system utilizes thermal energy by any outer resource in place of heat resource. The assertive solar desalting system arises in the year 1983 [1-2] by utilizing flat plate collector (FPC) and they were connected to the bottom liner of SS system. The conclusion was deduced about everyday yield of clean water enhanced in comparison with traditional SS system of identical base area. After that, a handful of assertive solar desalting plants being identified from investigations throughout the world.

The investigational monitoring of incorporation ETC to the bottom liner of SS by Sampathkumar et al. [3] and deduced about potable water outcome of the underlined system was 129% enhanced in comparison to fresh water unassertive unit of exact basin area due to the addition of energy by concentrator to bottom liner of SS. Singh et al. [4] concluded that the solar desalting unit incorporated via ETCs in routine stream revealed about exergy value connected to plant have the scale of 0.15% to 8%. Kumar et al. [5] revealed that idea proposed by Singh et al. in unnatural course way by incorporating the external device in the middle of ETC and bottom liner and proposed that the potable water yield in enforced way was greater in amount in comparison to the clean water outcome from the plant in established way due to enhanced water circulation in unnatural method.

Mishra et al. [6] give out the heated imitation of N indistinguishable sequentially attached evacuated tubes. Their outcome was put forward by the work performed by Singh et al. [7-9]. They conferred heat prototype of dish type SS integrated in the company of N evacuated collectors after that relative energy, exergy and cost amount of dish category assertive SS. Issa and Chang [10] explored some findings on SSSS integrated via ETC in variegated manner interrelation and deduced about the output that, it soars than the identical plant worked in unassertive way. Moreover, Singh along with Al-Helal [11] and Singh [12] described about pronouncement established over energy scale or metrics for SS.

Atheaya et al. [13] evolved working relation about partially enveloped PVTCPC for one collector. By utilizing work done by Atheaya et al., Tripathi et al. [14] expanded the same work for N indistinguishable PVTCPCs. Additionally, Singh and Tiwari [15-17] explained dish class assertive SS and deduced about assertive DSSS indicated great execution in comparison with identical single slope (SS) set-up at 14 cm height of water ascribed to stronger dissemination of sun radiation all over the period in menifestation of DS experimental plant. Singh [18] revealed exergoeconomic description about DSSS incorporated via PVTCPC and differentiate outcome in comparison to DSSS integrated with photo voltaic thermal FPC (PVTFPC) and revealed that DSSS incorporated with PVTFPC attained more than good output in possible enhanced circumstances caused by the existence of large quantity of FPCs. Gupta et al. [19] ascribed thermal prototype of completely enveloped PVTCPC coupled with SSSS. Singh et al. [20] explained about consequences of mass of water about attainment of SSSS integrated via PVTFPCs.

2. FUNCTION OF SSSS INCORPORATED IN THE COMPANY OF N INDISTINGUISHABLE PVTCPCS

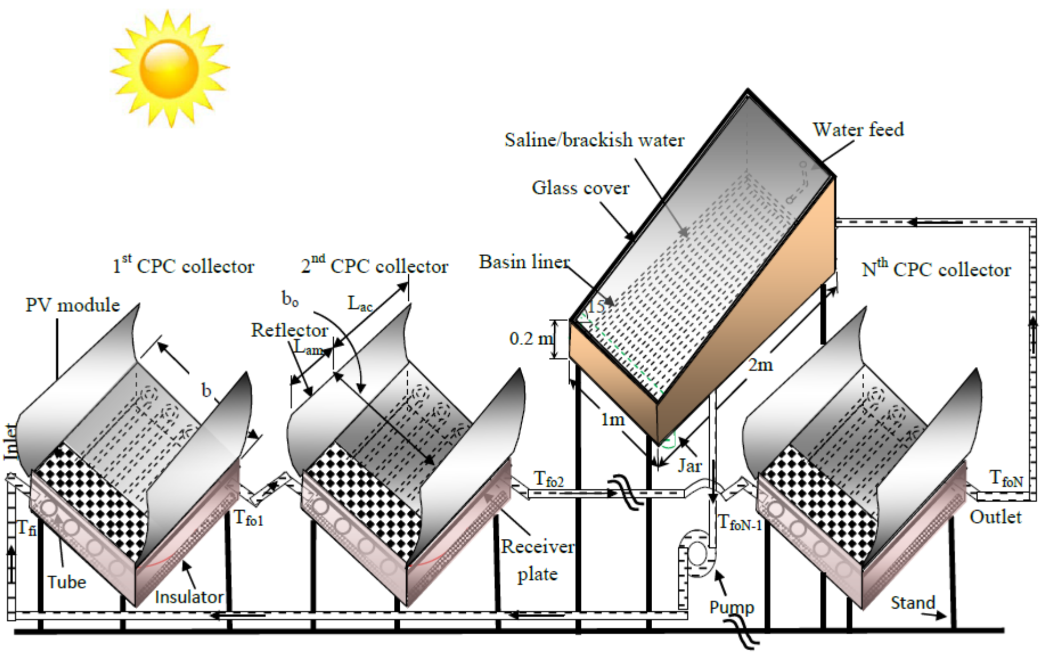

Figure 1 Depiction of SSS desalting plant incorporated via N partially covered PVTCPCs

By the present available study of existing resources, this is quite evident that the consequences of liquid mass flowing per unit time on energy payback time of SSS desalting system connected via N-partly enveloped PVTCPCs is never been investigated by no active scientist. The present investigational task is the expansion of the description reported by Singh and Tiwari [16]. The suggested study is quite distinct in comparison to past studies in the perception about the consequences of liquid flowing mass per unit time on life cycle conversion efficiency (LCCE) is being investigated whereas Singh and Tiwari [16] computed mathematically the energy metrics for selected scales of water flowing rate and concentrator quantities and differentiates observations via outcome from identical systems on the ground of energy metrics.

The solar desalting system represented in Fig. 1 operates by the working concept of greenhouse effect. The numerous parameters of SSSS are depicted in Table number 1. The concatenated N partly enveloped PVTCPCs is being integrated in bottom vessel of solar desalting constituent having an objective to dispense thermal energy into bottom liner. The radiation obtained from sun at the uppermost portion of solar still (SS) is fed to impure water in the bottom surface of still after multiple optical phenomenon of reflection and absorption through the plane surface . Some part of radiation is again reflect by water surface, remaining part of intensity is collected through the liquid portion besides this remanant is propagated in bottom liner there optimum amount of thermal energy is perceived. By this operation of radiation absorption the heated effect of still bottom base upgrades that imparts thermal energy to impure fluid into the bottom liner of SS. The polluted water present inside the bottom liner of SS as well encounter thermal energy coming from solar collectors. In such manner, impure water become thermally heated and dissipated. The water haze outstretch into the interiormost film of condensation film cover where film by film precipitation happens and extract spill to the way connected in underneath side. The filter water is therefore drain out towards the container.

3. ENERGY BALANCE EQUATIONS OF THE SYSTEM

The mathematical statement representing the proposed idea can be written as :

$$T_{foN} = \frac{I_b(t)(A\,F_R(\alpha\tau))_1}{\dot{m}_f C_f}\frac{(1-K_k{}^N)}{(1-K_k)} + \frac{T_a(A\,F_R U_L)_1}{\dot{m}_f C_f}\frac{(1-K_k{}^N)}{(1-K_k)} + T_{fi}K_k^N \quad (1)$$

Where, T_{foN} is the mass thermal gradient at the way out of Nth solar collector, $I_b(t)$ is the solar strength imparted on the upper surface of solar collectors, $\dot{m}_f$ is the mass of flowing fluid per unit time, C_f is the specific heating capacity of water, T_a is the temperature of neighbourhood, T_{fi} is the temperature of fluid entering in the first solar collector. Also, $T_{fi} = T_{wo}$ in which T_{wo} is the impure water temperature before the thermal energy fed to the system.

The equations for impure water temperature available inside interior of SS (T_w) and temperature on the interior face of condensation glass cover are given below:

$$T_w = \frac{\bar{f}(t)}{a}(1 - e^{-at}) + T_{w0}e^{-at} \quad (2)$$

$$T_{gi} = \frac{\alpha'_g I_s(t)A_g + h_{1w}T_w A_b + U_{c,ga}T_a A_g}{U_{c,ga}A_g + h_{1w}A_b} \quad (3)$$

Where, $\bar{f}(t)$ depicts centre value of $f(t)$ for 0 - t scale. We can evaluate the quantity of clean water manufacturing from the plant by solving equation (4) after calculating numbers of T_w, and T_{gi} given by equations (2) and (3) separately.

$$\dot{m}_{ew} = \frac{h_{e,wg}\,A_b(T_w - T_{gi})}{L} \times 3600 \quad (4)$$

Mean while, per hour electrical power ($\dot{E}x_e$) may be calculated by the relation 5.

$$\dot{E}x_e = A_m I_b(t)\sum_1^N(\alpha\tau_g\eta_{cN}) \quad (5)$$

Where, L is known as latent vaporization heat capacity.

Table 1 Amount and specifications of various constituents of the system

Single slope solar (SSS) desalting system			
Constituent	Specification	Constituent	Specification
Length	2 m	K_g	0.816 W/m-K
Breadth	1m	K of insulating material	0.166 W/m-K
Angle of condensing cover with horizontal	15°	Insulation thickness	0.1 m
Altitude of smaller side	0.2 m	Condensing cover thickness	0.004 m
Body material	GRP	Direction	South
Spport material	GI	Material of cover	Glass
PVTCPC			
Constituent	Description	Constituent	Description
Type and amount of collectors	plate type ,N	Aperture area	2 m^2
Receiver area of PVTCPC	1 m^2	Aperture area of module	0.5 m ×2.0 m
Thickness of absorber plate	0.002 m	Aperture area of receiver	0.75 m ×2.0 m
Tube thickness (material-copper)	0.00056 m	Receiver area of module	0.25 m ×1.0 m
Tube length of each PVTCPC	1.0 m	Receiver area of collector	0.75 m ×1.0 m
$K_i\ (Wm^{-1}K^{-1})$	0.166	F'	0.968
FF	0.8	ρ	0.84
Insulating material thickness	0.1 m	τ_g	0.95
Inclination of PVTCPC	30°	α_c	0.9
Glass thickness used on CPC	0.004 m	β_c	0.89
Area of collector inside glass	0.75 m^2	α_p	0.8
Diameter of pipe	0.0125 m	Calculative area of concentrator inside PV sheet	0.25 m^2
Rating of DC motor	12 V, 24 W		

The particular explanation of equations (1) to (5) and related terms mentioned in those relations might be observed in Singh and Tiwari [16]. Once we evaluate the amount of per hour outcome of clean and potable fluid by the plant, per day manufacturing of clean water might be computed by combining per hour fresh water amount obtained in plant for 24 h. After that, the amount of yearly pure water outcome of solar still (M_{ew}) can be evaluated by multiplying per day fresh water manufacturing by total number of clear days in a year. In same manner, yearly electrical power output might be computed. The related whole yearly energy outcome from the system might be computed as

$$E_{out} = (M_{ew} \times L) + \frac{(P_m - P_u)}{0.38} \quad (6)$$

Where, P_m stands for yearly electrical energy output manufcatured by photovoltaic (PV) module, P_u refers to yearly electrical energy consumed by external pump.

The life cycle conversion efficiency (LCCE) [16] might be written as

$$Life\ cycle\ conversion\ efficiency = \frac{Annual\ energy\ outputn \times life\ of\ system - Embodied\ energy}{Annual\ solar\ enegy \times life\ of\ system} \quad (7)$$

The explanation of equation (7) might be referred in Singh and Tiwari work [16].

4. PROCEDURE

The amount of solar intensity over the flat face and the temperature of environvent have been obtained from Indian Meteorological Department , Pune ,India. The amount of sun radiation over tilted surface of SS being evaluted from Liu and Jordan formula by substituting the corresponding details in program written in MATLAB. After that amount of T_w and T_{gi} can be evaluated by utilizing equations (2) - (3) one by one and go behind by the evaluation of $\dot{m}_{ew}$ from relation (4). The electricity manufactured and total yearly power outputs can be evaluated by utilizing relations (5) - (6). The amount of incorporated energy and yearly solar energy has been withdraw by the work of Singh and Tiwari [11]. Finally, amount of LCCE has been computed by utilizing equation (7) for several data of fluid flow mass/ unit time.

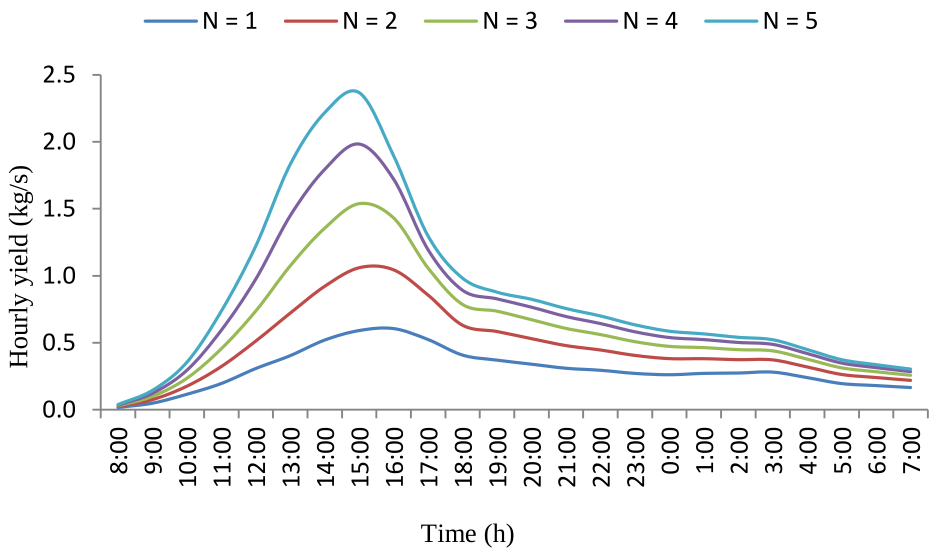

Figure 2 Distribution of per hour yield with flow of fluid mass per unit time at flow of fluid mass = 40 g/s and water depth = 14 cm for a standard day of July

5. RESULTS AND DISCUSSION

The mathematical code of statement has been compiled in MATLAB by bearing in mind all energy balance relations and all required incoming amounts and specifications . The outcome acquired has been depicted in figure 2-5. Fig. 2 represents the change of per hour potable water manufacturing by the plant for various numbers of N for provided liquid flow mass/ unit time and height of impure water for a typical standard day of July month. Fig. 3 demonstrates the identical change for the month of December. This is perceived from those below graphs that the amount of per hour manufacturing of pure water by the plant expands as the amount of N is enhanced. It occurs on account of a large amount of thermal energy is provided to the bottom liner due to enhanced solar rdiation collection area at bigger amount of N. Also, little heat is wasted due to bigger dimensions chiefly due to enhancement in the dimension of the plant. The identical change will be perceived for various amount of liquid mass flow per unit time.

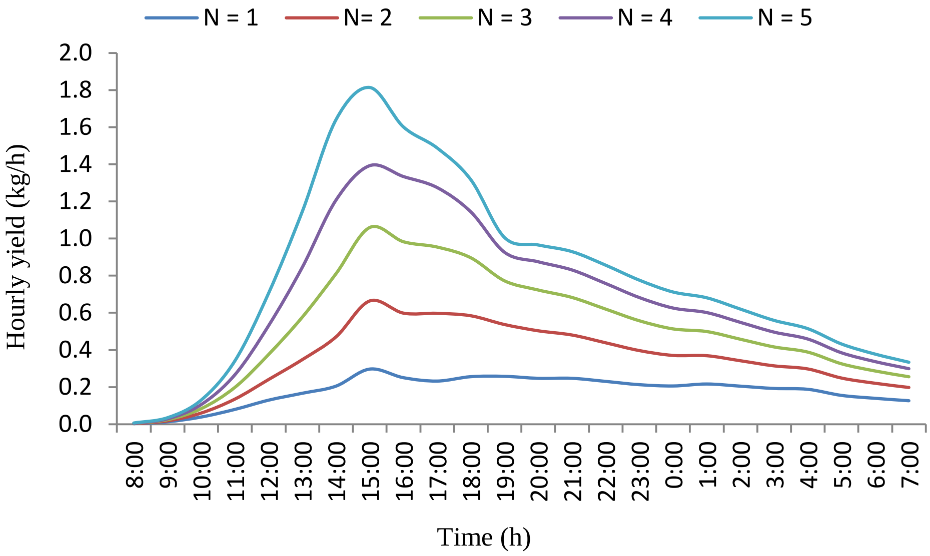

Figure 3 Change in per hour production with flow of fluid mass per unit time at flow of fluid mass = 40 g/s and water depth = 14cm for a standard day of December month

Fig. 4 depicts the change in per hour electrical power outcome for several amount of N for provided value of flow of liquid mass per unit time and water depth of 14 cm for a standard day of July. This was evident from graph about the amount of electrical energy enhanced by the enhancement in amount of N for providing amount of flow of liquid mass per / time and water depth or height in the container. Electrical energy first expands and then contracts due to identical change in intensity of sun radiation. As value of N is rises, electrical energy rises due to rise in solar intensity assembly surface.

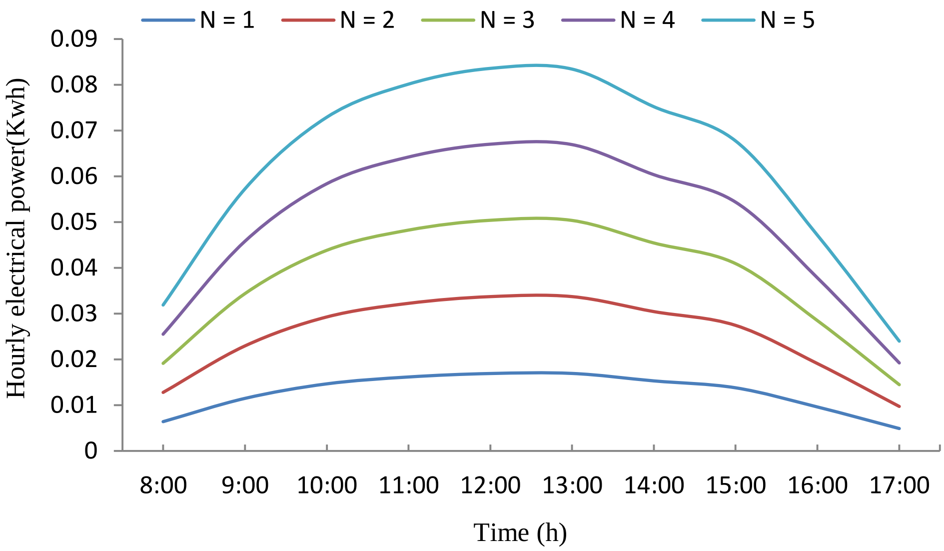

Figure 4 Change in per hour electrical power outcome at flow of fluid mass / unit time 40 g/s and water depth = 14 cm for a standard day of July month

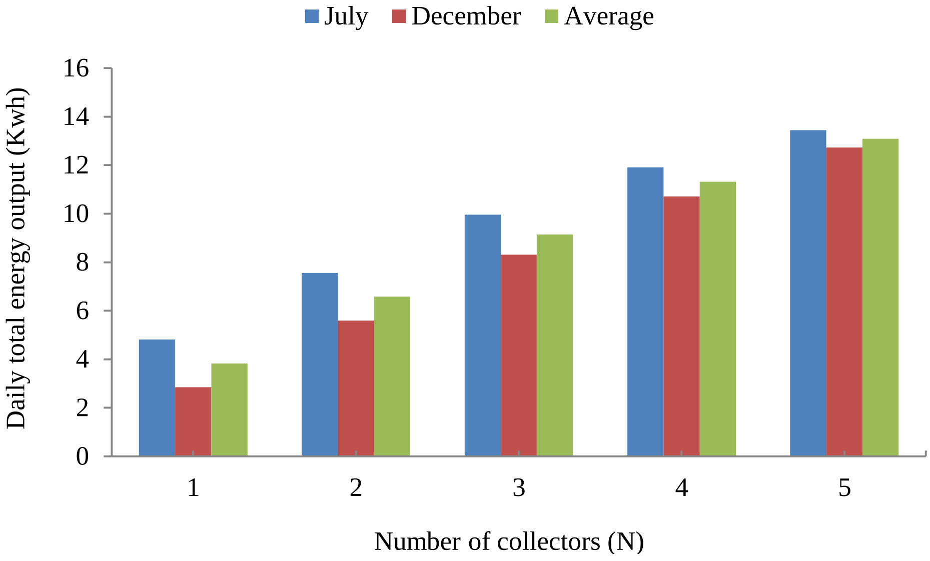

Figure 5 Variation of per day total energy outcome with flow of liquid mass per unit time

Figure 5 represents the change of per day actual energy outcome obtained in plant with N at given liquid flow mass/ unit time and fluid height. It is perceived by this graph that amount of per day total energy outcome enhanced by the enhancement in the amount of N for providing liquid flow mass/ unit time and water height. It occurs on account of per day total energy outcome rely opon per hour pure water manufacturing besides per day electrical energy production. A larger amount of electrical energy is consumed to operate the external pump. So, elctrical power output does not put up more to total energy outcome. So, actually, per day manufacturing of pure water production put up to total energy outcome and per day water manufacturing rises with the enhancement in the amount of N. The per day water manufacturing enhances with the rise in N for providing given liquid mass flow per unit time and water height because a big part of thermal energy is provided to bottom liner of SS due to big concentrating surface of solar intensity.

In the mean time, identical changes will be perceived for cumbersome amount of solar collectors. But, related amount of per day manufacturing of pure water for a providing amount of liquid flow mass/ unit time is greater for more number of solar collectors on account of more degree of thermal energy besides to the bottom liner due to heat concentrating surface enlarges on account of the enlargement in values of solar concentrators.

Table 2 Computation of energy payback time due to several values of N

Number of collectors	**Daily mean energy**	**No. of standard days**	**Yearly energy**	**Embodied energy [16]**	**energy payback time**
(N)	(kWh)		(kWh)	(kWh)	(year)
1	3.83	47	180.01	3873.27	21.52
2	6.58	47	309.26	3873.27	12.52
3	9.14	47	429.58	3873.27	9.02
4	11.31	47	531.57	3873.27	7.29
5	13.08	47	614.76	3873.27	6.30

Table 2 represents the computation of energy payback time (EPBT) for various values of N for providing liquid flow mass/ unit time and water height. It has been perceived from this table that the amount of energy payback time (EPBT) enhances as the amount of N is enhanced. It occurs due to total yearly energy outcome enhances with the enhancement in the amount of N for providing liquid flow mass per unit time as depicted in Fig. 5. Also, dropping of energy decline as the dimensions increases due to the enhancement in dimensions of plant. So, EPBT enhances with enhancement in N.

6. CONCLUSIONS

The EPBT for several numbers of N has been computed after employing mathematical statement in MATLAB software. The statistical specifications of weather for the theoretical description has been taken from Indian Meteorological Department, Pune. Over the basis of current investigation, it has been perceived that the amount of EPBT enhances as the enhancement in the amount of N for providing amount for liquid flow mass per unit time and water height. This was being perceived about the identical outcomes for predicted for several data of liquid flow mass / unit time.

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NOMENCLATURE

PVTCPC	photovoltaic thermal compound parabolic concentrator collector
SSSDU	single slope solar desalination unit
N	number of collectors
INR	Indian rupee
IMD	Indian meteorological department
SD	solar distillation
FPC	flat plate collector
PVT	photovoltaic thermal
T_{foN}	temperature of fluid at the outlet of Nth collector, ^oC
$I_b(t)$	beam radiation falling on the surface of collector, W/m^2
$\dot{m}_f$	mass flow rate, kg/s
C_f	specific heat capacity of fluid, J/kg-K
T_a	ambient air temperature/temperature of surrounding
T_{fi}	temperature of fluid at the inlet of first collector, ^oC
T_{wo}	temperature of water at t=0, ^oC
T_w	temperature of water, ^oC
t	time, s
T_{gi}	temperature at inside surface of glass, ^oC
h_{1w}	overall heat transfer coefficient between water surface and inside surface of glass, W/m-K
A_b	area of basin, m^2
$U_{c,ga}$	net heat transfer coefficient from cell to ambient through glass, W/m-K
$h_{e,wg}$	evaporative heat transfer coefficient between water plane and inside plane of glass, W/m-K

L	latent heat, J/kg
$\dot{E}x_e$	hourly electrical energy output, kWh
A_m	area of module, m^2
η_{cN}	cell efficiency, %